Factors determining different death rates because of the COVID-19 outbreak among countries

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ABSTRACT

Background During the coronavirus disease 2019 (COVID-19) pandemic, all European countries were hit, but mortality rates were heterogenous. The aim of the current paper was to identify factors responsible for this heterogeneity.

Methods Data concerning 40 countries were gathered, concerning demographics, vulnerability factors and characteristics of the national response. These variables were tested against the rate of deaths per million in each country. The statistical analysis included Person correlation coefficient and Forward Stepwise Linear Regression Analysis (FSLRA).

Results The FSLRA results suggested that 'days since first national death for the implementation of ban of all public events' was the only variable significantly contributing to the final model, explaining 44% of observed variability.

Discussion The current study suggests that the crucial factor for the different death rates because of COVID-19 outbreak was the fast implementation of public events ban. This does not necessarily mean that the other measures were useless, especially since most countries implemented all of them as a 'package'. However, it does imply that this is a possibility and focused research is needed to clarify it, and is in accord with a model of spreading where only a few superspreaders infect large numbers through prolonged exposure.

Keywords COVID-19, death rate, measures, public events ban

Introduction

During the coronavirus disease 2019 (COVID-19) pandemic, all European countries were hit, but mortality rates were heterogenous, with some countries like Italy being hit very hard (1), whereas others like Latvia, Greece or Bulgaria had much lower death rate. It is important to understand why such differences exist, in order to learn how to best prepare for future pandemics and how to plan for optimal actions. A number of factors have been proposed as determining the outcome, including the age composition in combination with background disease in the population (especially asthma), smoking habits, hosting of big public events, socializing habits or the capacity of the health care system. A significant number of deaths seem to have occurred in elderly nursing homes, and the number of these beds in a country might also constitute a risk factor.

Some authors suggest that social inequality and social determinants of health can have a considerable effect on COVID-19 outcomes (2, 3). These include poverty, race or ethnicity, homelessness (4), malnutrition, health-related habits and behaviors (including smoking (5)) and others. Additionally, socially vulnerable populations might find it much more difficult to follow prophylactic and hygiene measures (2).

However, although the above have been extensively discussed, there is no empirical verification of these claims. The aim of the current paper was to identify which of these factors

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Table 1 Correlation and forward stepwise linear regression analysis in steps with death rate as dependent variable and the listed variables as predictors

	Pearson correlation coefficient	*Stepwise regression analyses (A)*			*Stepwise regression analysis (B)*		
Variable	*R*	*beta*	*R^2*	*P-level*	*beta*	*R^2*	*P-level*
Demographics							
Population density per km^2	0.15						
Urban population (%)	***0.42***						
Urban population density per km^2 of urban space	0.08						
Males in total population (%)	0.16						
Females in total population (%)	−0.16						
Males >65 in male population (%)	***0.37***						
Females >65 in female population (%)	0.12						
Males <30 male population (%)	−0.14						
Females <30 in female population (%)	−0.01						
Rate of nursing beds per 1000 of elderly population	***0.48***						
Male life expectancy at 65	***0.51***	0.44					
Female life expectancy at 65	***0.50***						
			0.32	0.001			
General health vulnerability factors							
Male smoking (%)	***−0.47***						
Female smoking (%)	−0.03						
Obesity rate (%)	−0.09						
Doctor-diagnosed asthma (%)	***0.55***						
Clinical asthma (%)	***0.54***						
Wheezing symptoms (%)	***0.56***	0.56					
			0.28	0.033			
International connectivity							
No. of tourists arrivals (in 2018)	***0.53***						
Chinese population in country	***0.50***						
Number of Chinese visitors	0.31						
The Air Connectivity Index (%)	***0.57***	0.47					
Air transport, number of passengers carried	***0.44***						
			0.31	0.024			
Social–economic vulnerability factors							
Poverty rate	−0.02						
GINI index	0.02						
Outbreak characteristics and national response							
Days of first death in country since first death in Europe	***−0.59***	−0.59*					
School closure—days since first national death	0.07*/0.56**						
Workplace closure—days since first national death	0.05*/0.26**						
Public events ban—days since first national death	0.09*/0.59**	0.76***			0.45**		
Gathering ban—days since first national death	−0.06*/0.32**						
Public transport closure—days since first national death	0.14*/0.70**						
Lockdown implementation—days since first national death	−0.14*/0.39**						
Domestic travel ban—days since first national death	0.14*/0.27**						
International travel ban—days since first national death	0.23*/0.33**						
School closure—days since first European death	−0.08*/−0.19**						
Workplace closure—days since first European death	−0.11*/−0.14**						
Public events ban—days since first European death	−0.05*/−0.03**						
Gathering ban—days since first European death	−0.18*/−0.28**						

(Continued)

Table 1 Continued

Variable	Pearson correlation coefficient R	Stepwise regression analyses (A) beta	R^2	P-level	Stepwise regression analysis (B) beta	R^2	P-level
Public transport closure—days since first European death	0.04*/0.10**						
Lockdown implementation—days since first European death	−0.27*/−0.29**						
Domestic travel ban—days since first European death	0.02*/−0.27**						
International travel ban—days since first European death	0.11*/0.02**						
			0.33*	<0.001		0.44**	<0.001
			0.55***	<0.001			
Sensitivity analysis							
School closure–days since 10th national death	0.11*/***0.58*****	−1.5					
Workplace closure—days since 10th national death	0.09*/***0.64*****						
Public events ban—days since 10th national death	0.13*/***0.72*****	1.87			0.53		
Gathering ban—days since 10th national death	−0.03*/0.34**						
Public transport closure—days since 10th national death	0.15*/***0.72*****						
Lockdown implementation—days since 10th national death	−0.12*/0.52**						
Domestic travel ban—days since 10th national death	0.15*/0.43**						
International travel ban—days since 10th national death	0.27*/0.33**						
			0.63	0.009		0.51	<0.001

*Calculations with imputation of values of 100 latency days for measures not taken by countries.

**Calculations without imputation of values of 100 latency days for measures not taken by countries.

***Calculations without imputation of values of 100 latency days for measures not taken by countries and without the variable 'Days of first death in country since first death in Europe' in the model.

Significant values at $p < 0.05$ are in bold italics underlined characters.

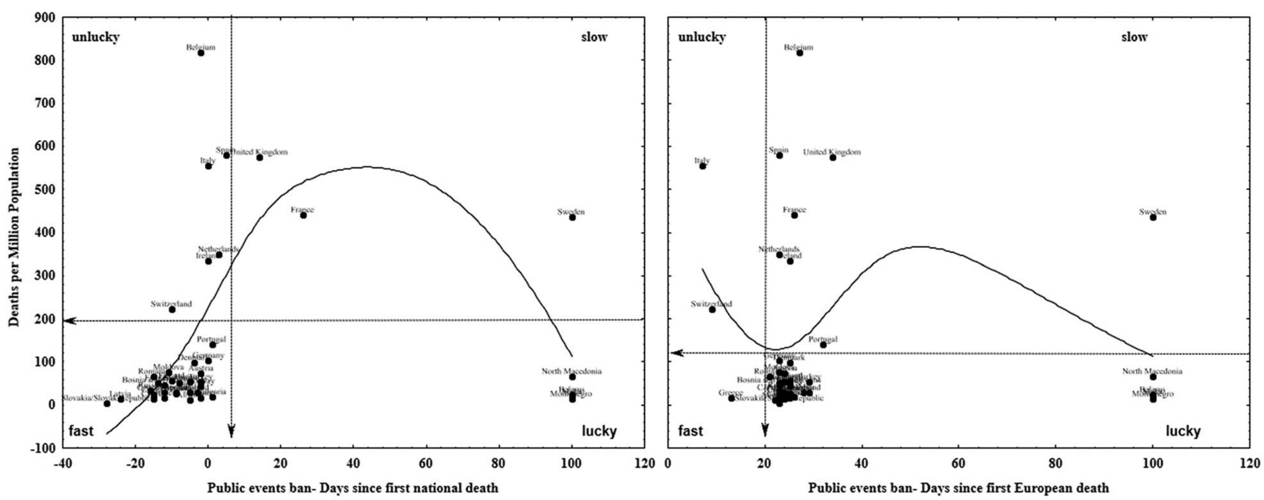

Fig. 1 Deaths per million population (vertical axis) versus latency days for the implementation of public events ban since first national (left) and first European (right) death. The place of each country is pointed in the scatterplot and four groups of countries emerge (lucky versus unlucky and fast versus slow). Unlucky are the countries first stricken by the outbreak (e.g. Italy) whereas lucky those stricken last (e.g. Latvia). Fast were the countries implementing measures early (e.g. Greece) whereas slow where those implementing measures later or not at all (e.g. Sweden).

Table 2 Comparison of Greece versus Sweden in risk factors and death rate because of COVID-19

	Greece	*Sweden*	*Ratio GR/SW*
Urban population (%)	79.00	87.00	0.91
Population density per sq km	79.00	22.00	3.59
Urban Population Density per sq km of urban space	457.57	284.18	1.61
Males in total population (%)	48.52	50.25	0.97
Females in total population (%)	51.48	49.75	1.03
Males >65 in male population (%)	19.58	18.61	1.05
Females >65 in female population (%)	23.65	21.58	1.10
Females <30 in female population (%)	27.94	35.19	0.79
Males <30 in male population (%)	30.90	36.99	0.84
N tourists arrivals in 2018	30 123 000	7 440 000	4.05
Rate of nursing beds per elderly population/1000	8.60	60.59	0.14
Male life expectancy at 65	18.56	18.85	0.98
Female life expectancy at 65	21.38	21.50	0.99
Number of Chinese visitors	200 000	94 987	2.11
Chinese population in country	Unknown[a]	37 800	
Days of first death in country since first death in Europe	25.00	29.00	0.86
International travel ban—d ays since first European death	27.00	32.00	0.84
Male smoking (%)	52.60	20.40	2.58
Female smoking (%)	32.70	20.80	1.57
Obesity (%)	24.90	20.60	1.21
Doctor-diagnosed asthma	6.60	20.09	0.33
Clinical asthma	6.84	20.18	0.34
Wheezing symptoms	10.14	21.60	0.47
Poverty rate	0.13	0.09	1.35
GINI Index	34.40	28.80	1.19
The Air Connectivity Index (ACI)%	6.13	7.20	0.85
Air transport, number of passengers carried	15 125 930	11 623 920	1.30
Deaths per million population	17	436	0.04

[a]Probably equal or higher than Sweden.

exerted an effect on the mortality rate because of the COVID-19 outbreak and its difference among countries, with data at the population (country) level.

Material and methods

Material

Data concerning 40 European countries were gathered. The variables utilized, concerned demographics with emphasis on population density and aging, general health vulnerability factors including smoking, obesity and asthma-related conditions, international connectivity of the country in terms of flights, tourists and local Chinese community, social and economic vulnerability factors (poverty rate and GINI index) as well as characteristics of the outbreak and of the national response to it. The Gini index, is a measure of statistical dispersion intended to represent the income inequality or wealth inequality within a nation or any other group of people. It was developed by the Italian statistician and sociologist Corrado Gini. The national response was assessed on the basis of the time latency in days since the first death in Europe (in France on February 16) and since the first death in the specific country and the implementation of specific measures. Sensitivity analysis included the use of the time latency since 10th death in the specific country. For Malta and Montenegro the time since ninth death was calculated. The time since 100th death was also considered but almost half of countries had >100 deaths at the time of the current study. These variables were tested against the rate of deaths per million in each country, which were obtained from https://www.worldometers.info/coronavirus/#countries at 1 June 2020, at 23.59, Coordinated Universal Time.

The complete list of variables is shown in Table 1 and the complete dataset along with sources of data are shown in the appendix.

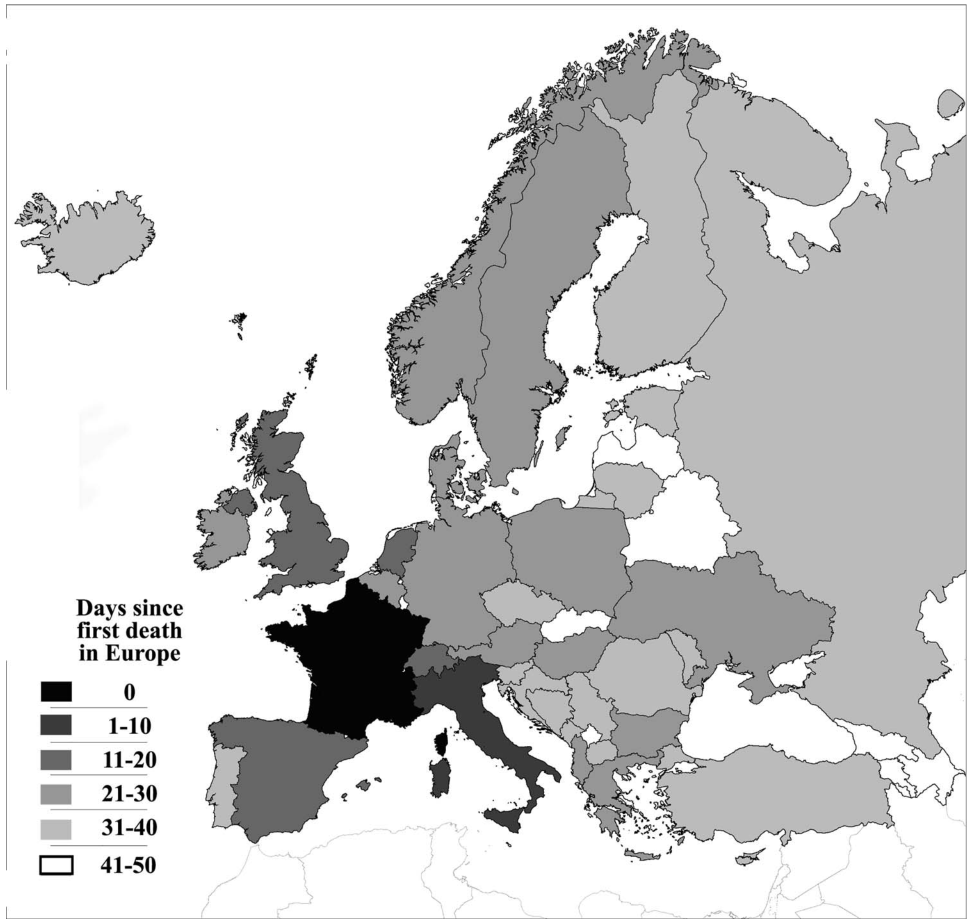

Fig. 2 Timeline map of first death occurrence in the various countries of Europe.

Methods

Not all data were available for all countries. Specifically concerning the measures, the response of countries was heterogenous. Thus, the analysis was made twice, first with the original dataset and then with the imputation of a latency time of 100 days for those countries they did not implement a specific measure. This is as if their latency time to adopt the specific measure was 100 days after the first death in the specific country or in Europe.

The analysis included two stages for continuous variables.

At the first screening stage, Pearson correlation coefficients were calculated for all variables with rates of death per million population.

At the second stage, which was also screening, Forward Stepwise Linear Regression Analysis (FSLRA) was performed with deaths per million as the dependent variable and all the variables with significant correlations at the first stage as independent variables (predictors). At this stage separate FSLRA were performed for each group of variables.

At the third and final stage, a single FSLRA was performed with deaths per million as the dependent variable and all the variables which were selected during the previous stage as predictors.

At each stage sensitivity analysis was performed on the basis of including or excluding the variable 'Days of first death in country since first death in Europe' and imputed data.

Results

The complete dataset concerning the current paper is based on, together with the sources, are shown in the web appendix.

In terms of measures taken, 30 countries implemented a ban for public gatherings, 25 for use of public transportation, 28 a full lockdown, 29 banned domestic travel and 35 banned international travel. Data were not available in a uniform way from all countries and from a minority they were completely missing.

The correlation analysis suggested that Pearson coefficients between the death rate and the various variables were significant in a number of variables at $P < 0.05$ (Table 1).

The use of these significant variables only, in the second step in FSLRA is separately for groups of variables suggested that from the demographic variables only male life expectancy at the age of 65 was predicting the death rates, and explained 32% of the observed variance. From the somatic vulnerability variables, only wheezing symptoms had a significant contribution and explained 28% of the observed variance. The Air Connectivity Index (ACI %) was the only variable significantly contributing from the cluster reflecting international connectivity and explained 31% of observed variance. Interestingly none of the social vulnerability factors was significant.

The national response and outbreak characteristics were entered in two separate FSLRA. In the first, only those countries that implemented these measures were utilized, since the cells concerning latency time from the other countries were empty. In the second analysis, imputation values were also utilized. Depending on the analysis, two variables contributed significantly, that is 'Days of first death in country since first death in Europe' and 'Public events ban—Days since first national death'.

The final FSLRA included 'male life expectancy at the age of 65', 'Wheezing symptoms', ACI, 'Days of first death in country since first death in Europe' and 'Public events ban- Days since first national death' as predictors. No matter whether there was imputation of data for the 'days since first national death for the implementation of ban of all public events' or not, the results were identical and this later variable was the only significantly contributing to the final model, explaining 44% of observed variability.

Sensitivity analysis produced the same results at the final stage, suggesting also that speed of banning of public events was the important factor (Table 1).

Discussion

Main finding of this study

The results of the current study suggest that the crucial factor was the fast implementation of public events ban (Fig. 1).

What is already known on this topic

It has been discussed widely and especially in the media that different backgrounds and different country reactions to the outbreak have determined the final outcome, but opinions are conflicting as to which factors are important. An interesting comparison would be that of Sweden versus Greece. The two countries are similar in population size but with completely different characteristics, but Greece was the fastest to implement measures (Fig. 1) whereas in contrast Sweden adopted the 'herd immunity' approach. Greece had most of the risk factors against as compared with Sweden, that is, 3.6 times higher population density, 1.6 times higher urban population density, more aged population, 4-times more tourist visits, probably a larger Chinese community, 2-times more Chinese tourists, earlier first death in comparison to first death in Europe, higher smoking and obesity rates and more adverse socioeconomic environment. The only higher risk factors for Sweden were two to three times higher asthma-related conditions. The critical difference was that Greece was one of the fastest countries to implement all measures (Fig. 1) Sweden implemented only a ban on international travel. The result was a 25-times higher mortality rate (Table 2).

What this study adds

The current study is the first to quantify the effect of various risk factors on the different mortality rates across European countries. The findings do not necessarily mean that the other measures were useless, especially since most countries implemented all of them as a 'package'. However, it does imply that this is a possibility and focused research is needed to clarify it. It is in relative contrast with a report suggesting that the lockdown was the strongest measure with 81% or R_0 reduction attributed to it, but the methodology of that study was quite different from ours and based on self-report data (6). That study also suggested that that only multiple measures implemented simultaneously could reduce R_0 below 1. Our results do not preclude such an assumption, they are however in sharp contrast with the analysis by the ICL (only in 11 countries) which suggests that lockdown was the only efficacious measure (7). The results are in accord with a model of spreading where only a few superspreaders infect large numbers through prolonged exposure (superspreading events) (8, 9).

Finally, it is interesting to inspect the map of Europe as it is colored on the basis of first death in each country in relationship to the first death in Europe, which occurred in France (Fig. 2). It is evident that geography played a significant role, with countries neighboring France suffering a heavier burden because of the outbreak. Geography also suggests that COVID-19 spread in Europe probably through Germany and Italy. This is not in contrast with reports of isolated instances of COVID-19 contamination by e.g. Chinese visitors to Germany since the characteristics of the virus demand that the virus should be introduced at least four to five times in the country in order to trigger an outbreak. These suggest that some countries seem to be 'unlucky' since they were struck very early and therefore they were too late in implementing measures. On the other hand, some other countries were too slow in spite of having enough time and information on the outbreak and its consequences (Fig. 1).

Limitations of this study

The data utilized in the current paper are at the population/country level. They are heterogenous in the sense that there are different ways of registering and reporting deaths because of COVID-19 (10) and different ways of practically implementing measures and to different extent (11, 12).

The strength of the current study is that it is the first based on the statistical analysis of quantified data reported by third-parties.

Conclusion

The current study suggests that the crucial factor that determined the difference in the death rates because of COVID-19 among European countries was the latency time in the implementation of public events ban specifically. This does not necessarily mean that the other measures were useless, but it does imply that this is a possibility, superspreader events might be very important rather than a wider way of infecting. Focused research is needed to clarify it.

Supplementary data

Supplementary data mentioned in the text are available to subscribers in *Journal of Public Health* online.

Authors' contribution

All authors contributed equally to the paper. KNF conceived and designed the study. The other authors participated formulating the final protocol, designing and supervising the data collection and creating the final dataset. KNF did the data analysis and wrote the first draft of the paper. All authors participated in interpreting the data and developing further stages and the final version of the paper.

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None.

Conflict of interest

None pertaining to the current paper.

Patient and public involvement

None.

License

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