

Original Article

Association between country-level diabetes prevalence and COVID-19 mortality across 38 OECD member states in the first year of the pandemic

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Abstract

Objective. In December 2019, an outbreak of unprecedented spread, later known as COVID-19, has taken the world by storm. Pre-existing metabolic disorders have been reported to be high-risk factors for severe COVID-19. We explored associations between severe COVID-19 outcomes and diabetes across 38 countries of the Organization for Economic Cooperation and Development (OECD). **Methods.** This was an ecological study that used freely accessible data from OECD and the World Health Organization databases. Outcome variables were case-fatality rate (CFR) and number of years of healthy life lost due to COVID-19 per 100,000 (YLLs/100,000). CFR was calculated based on cumulative COVID-19 cases and deaths as of 31 December 2020. Pearson's correlation analysis was carried out to determine the correlates of COVID-19 CFR and YLLs; thereafter, ecological regression analysis was performed to identify the predictors of COVID-19 CFR and YLLs. **Results.** Mean population was 35,875,100 ($\pm 9,641,900$) inhabitants. There were 1,559,488 ($\pm 699,285$) COVID-19 cases reported and 43,579.5 ($\pm 19,055$) deaths, for a COVID-19 CFR of 2.1 (0.2)% and COVID-19 YLLs of 566.8 (± 91.5)/100,000 population. Overweight and obese population rate was 60.1 (± 3.7)%, and overall diabetes prevalence rate was 6.9 (± 0.4)%. Pearson correlation analysis showed that COVID-19 CFR was inversely correlated with country's "high education completion rate" ($\rho = -0.41$; $p < 0.009$), GDP *per capita* ($\rho = -0.47$; $p = 0.013$), the ratio nurses/10,000 ($\rho = -0.36$; $p = 0.045$), and positively correlated with diabetes prevalence ($\rho = 0.48$; $p = 0.003$). On the other hand, COVID-19 YLLs were inversely correlated with elderly population rate ($\rho = 0.47$; $p = 0.003$), and positively with diabetes prevalence rate ($\rho = -0.51$; $p = 0.011$). Furthermore, the bivariate regression analysis showed that diabetes prevalence was positively associated with both COVID-19 CFR ($\beta = 1.01(0.3)$, 95%CI: 0.38–1.63; $p = 0.002$) and COVID-19 YLLs ($\beta = 8.28(3.5)$, 95%CI: 2.07–14.40; $p = 0.010$). **Conclusion.** Findings from this study tend to confirm that diabetes is a high-risk factor for severe COVID-19 outcomes at country level, disease mortality in particular.

Keywords: coronavirus disease 2019, diabetes, ecological study, fatality

Introduction

Since early 2020, the rapid spread of COVID-19 outbreak that originated in China has caused a global health crisis, affecting over 200 countries¹. Metabolic disorders, particularly diabetes and its associated disorders, are reported to be strong determinants of COVID-19 morbidity and mortality². There have been approximately 463,000,000 individuals with diabetes worldwide in 2019^{2,3}. With the spread of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and the high prevalence of obesity and diabetes, there is a possibility for increased incidence of COVID-19-related severe outcomes in most affected countries. Considering the negative influence of metabolic health impairment, efficient strategies should be implemented for the prevention and management of obesity and related metabolic disorders in countries where the COVID-19 pandemic remains one of major health problems⁴.

Since the beginning the pandemic, obesity has caused concerns given its high prevalence in SARS-CoV-2-infected patients⁴. Studies conducted in China have shown higher incidence rates of severe pneumonia in patients infected by SARS-CoV-2-infected patients with overweight and obesity as compared with individuals with normal weight. Additionally, the coexistence of obesity and diabetes is reported to increase the risk of severe COVID-19 outcomes^{5,6}. In the present study, we searched to explore the associations between country-level COVID-19 epidemiological indicators, and the prevalence of metabolic disorders (rate of overweight/obese population, diabetes prevalence) for the first year of COVID-19 pandemic, across 38 member states of the Organization for Economic Cooperation and Development (OECD).

Materials and Methods

Study design, data sources and outcome variables

We conducted an ecological study using epidemiological databases related to 38 OECD countries. Data on COVID-19 burden statistics for the first year of the pandemic (year 2020), included years of life lost due to COVID-19 (COVID-19 YLLs), demographic and economic indicators, as well as the rates of metabolic disorders. They were extracted from online freely accessible OECD, WHO and World Bank databases. Based on data related to cumulative COVID-19 cases and deaths (as of 31 December 2020), COVID-9 case fatality rate (CFR) was calculated for each country as we reported previously⁷, with the use of the following formula:

$$\text{CFR (\%)} = \frac{\text{Number of COVID-19 deaths} \times 100}{\text{Number of COVID-19}}$$

Ethical considerations and data analysis

Epidemiological data on country's demographics, COVID-19 cumulative cases and deaths, and prevalence of metabolic disorders were anonymous and freely accessible online⁸⁻¹⁰; thus, informed consent was not applicable. Mean (SD) values are used to present data related to continuous variables. For the purpose of statistical analysis of the data, OECD countries also grouped in three regions:

- (1) Asia and Pacific region: Japan, South Korea, Australia, New Zealand.
- (2) Region of the Americas (north, central, south America): Mexico, Costa Rica, Canada, USA, Chile, Colombia.
- (3) Europe and Middle-east: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, England.

To assess the relationship between outcome variables and the covariates, overweight/obese population rate and diabetes prevalence in particular, Pearson's correlation test was conducted. Afterwards, an ecological regression analysis was performed to explore the associations between both severe COVID-19 outcomes (CFR, YLLs) and the explanatory variables. All the statistical analyses were performed with the use of STATA statistical package version 16 (StataCorp, TX, USA).

Results

Sociodemographic characteristics, health system and health indicators of 38 OECD countries

Table 1 shows the distribution of mean values (with minimum and maximum values) of sociodemographic characteristics, health system and COVID-19-related health indicators. Mean population was 35,875.1 (59,436.8) $\times 10^3$, with an elderly population rate of 17.4 (4.3) %, higher education completion rate of 44.9 (1.0)% and a GDP *per capita* of 40,246.5 (23,826.9) USD in the year 2020. Moreover, cumulative COVID-19 cases was 1,559,488 (425,358.5), whereas cumulative COVID-19 deaths was 43,579.5 (91,386) for a CFR of 2.12 (1.3)% and COVID-19 YLLs of 556.8 (556.3) per 1,000.

Correlation between outcome variables and covariates by Pearson correlation analysis

Pearson's correlation analysis showed, on one hand, inverse correlations between COVID-19 CFR and country's "high education completion rate" ($r = -0.41$; $p < 0.009$), as well as GDP *per capita* ($r = -0.47$; $p = 0.013$), and the ratio nurses per 10,000 population ($r = -0.36$; $p = 0.045$); however, it was positively correlated with diabetes prevalence ($r = 0.48$; $p = 0.003$). On the other hand, COVID-19 YLLs were inversely correlated with country's elderly population rate ($r = 0.47$; $p = 0.003$), and positively correlated with diabetes prevalence rate ($r = 0.51$; $p = 0.011$), as shown in **Table 2**. In contrast, when assessing the relationship between overweight/obese population rate and COVID-19 YLLs, the statistical significance was not reached, despite a relatively high r coefficient value. Furthermore, no correlation was observed between country-level full vaccination rate and COVID-19 outcomes (CFR, YLLs) when considering OECD countries all together (**Table 2**).

Fig. 1 shows the two-way graph of the relationship between country-level severe COVID-19 outcomes (CFR, YLLs) and diabetes prevalence. It presents OECD countries' COVID-19 CFR and YLLs values and the corresponding 95% confidence intervals. It was observed that OECD countries with high diabetes prevalence tending to have higher COVID-19 CFR and YLLs in the first year of the pandemic.

Relationship between outcome variables and metabolic disorders (diabetes, overweight and obesity) among OECD countries by bivariate regression analysis

As shown in **Table 3**, of the two metabolic disorders that were entered into the analysis, only diabetes prevalence was revealed to be a predictor of both COVID-19 CFR (beta = 1.01 (0.3), 95%CI: 0.38–1.63; $p = 0.002$) and COVID-19

Table 1. Sociodemographics and health system indicators of 38 OECD countries in 2020

Characteristics/indicators	Mean (SD)	Minimum	Maximum
Sociodemographics			
Total population ($\times 10^3$)	3,5875.1 (59,436.8)	339	329,065
Elderly population rate (65 years or older; %)	17.4 (4.3)	7.2	28.1
Higher education completion rate (%)	44.9 (10)	23.6	69.8
GDP per capita in 2020 (USD)	40,246.5 (23,826.9)	6,428.7	114,705
Health system & COVID-19-related health indicators			
Number of nurses per 10^4	8.6 (4.1)	1.3	17.9
Number of doctors per 10^4	3.4 (0.8)	1.9	5.2
Overweight/obese population rate (%)	60.1 (13.9)	26.7	75.2
Cumulative COVID-19 cases (as of Dec. 2020)	1,559,488 (425,358.5)	2,304	2.60e ⁺⁰⁷
Cumulative COVID-19 deaths (as of Dec. 2020)	43,579.5 (91,386)	577	439,439
Case fatality rate (CFR; %)	2.12 (1.3)	0.48	8.51
Years of life lost due to COVID-19/100,000 (YLLs)	556.8 (556.3)	6	2,055

Table 2. Relationship between COVID-19 health indicators (CFR, YLLs) and country-level sociodemographic, economic and health system indicators by Spearman correlation test

Covariates	Rho	p-value
(1) Predictors of COVID-19 CFR		
High education completion rate	-0.41	0.009
Elderly population rate	-0.17	0.311
GDP per capita	-0.47	0.013
Full vaccination coverage rate	-0.24	0.166
Nurses per 10 ⁴	-0.36	0.045
Doctors per 10 ⁴	-0.34	0.228
Overweight/obese population rate	0.34	0.228
Diabetes prevalence (%)	0.48	0.003
(2) Predictors of COVID-19 YLLs		
High education completion rate	-0.37	0.063
Elderly population rate	0.47	0.003
GDP per capita	-0.26	0.109
Full COVID-19 vaccination coverage rate	-0.15	0.393
Nurses per 10 ⁴	-0.19	0.267
Doctors per 10 ⁴	-0.21	0.255
Overweight/obese population	0.50	0.074
Diabetes prevalence	0.51	0.011

*Notes: %, percentage; CFR, case fatality rate; COVID-19 YLLs, years of healthy life lost due to COVID-19; GDP, gross domestic product.

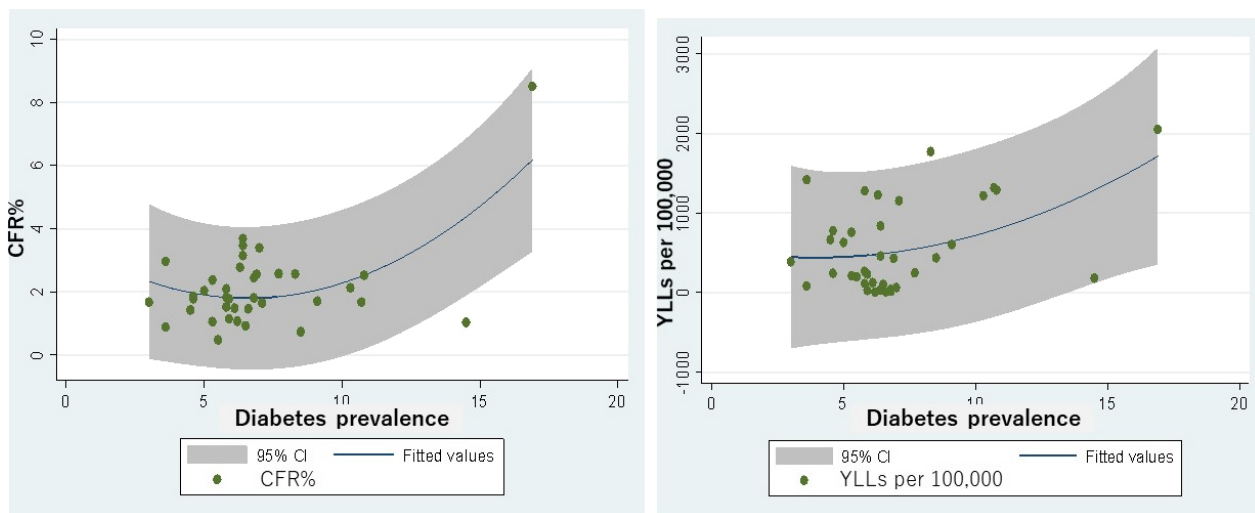


Fig. 1. Two-way graph of the correlation between severe COVID-19 outcomes (case fatality rate, years of healthy life lost due to COVID-19) and country-level diabetes prevalence across OECD member states

YLLs (beta = 8.28 (3.5), 95%CI: 2.07–14.4; $p = 0.010$). Furthermore, higher education completion rate was inversely associated with both COVID-19 CFR (beta = -3.21(1.1), 95%CI: -5.53–(-0.89), $p = 0.008$) and COVID-19 YLLs (beta = -2.28(8.5), 95%CI: -40.13–(-5.43); $p = 0.012$).

Table 3. Association between COVID-19-related health indicators (CFR, YLLs) and metabolic disorders (overweight/obesity, diabetes) across OECD countries in the first year of the pandemic (2020) by ecological regression analysis.

Covariates	CFR (%)			YLLs per 100,000		
	Beta (SE)	95%CI	<i>p</i>	Beta (SE)	95%CI	<i>p</i>
Elderly population rate	-0.06 (0.05)	-0.17–0.04	0.220	-39.6 (20.8)	-81.91–2.76	0.066
Higher education completion rate	-3.21 (1.1)	-5.53–(-0.89)	0.008	-22.8 (8.5)	-40.13–(-5.43)	0.012
Overweight/obese population rate	0.04 (0.0)	-0.03–0.12	0.228	0.01 (0.0)	-0.01(0.0)–0.02	0.074
Diabetes prevalence rate	1.01 (0.3)	0.38–1.63	0.002	8.28 (3.5)	2.07–14.4	0.010

*Notes: OR, odds ratio; %, percentage; CFR, case fatality rate; YLLs, years of healthy life lost due to the disease.

Discussion

The present study explored the relationship between severe COVID-19 outcomes, namely case fatality rate and the number of years of healthy life lost due to SARS-CoV-2 infection on one hand, and metabolic disorders (diabetes, overweight/obesity) across 38 countries that belong to the OECD organization in the first year of the pandemic (2020). We found that countries with low tertiary education rate, low GDP *per capita*, as well those with low ratio of nurses per 10,000 tended to have COVID-19-related fatalities. These findings suggest that country's high education completion rate, the socioeconomic status of the population and the importance of the nursing workforce might have had an influence on the outcomes of COVID-19 among infected populations of OECD member states in the first year of the pandemic. A meta-analysis conducted by Takkavatakarn and colleagues¹¹⁾ that investigated the global incidence and mortality of COVID-19 has also shown an inverse correlation between country's GDP per capita and COVID-19 mortality.

Additionally, another study conducted in Brazil that investigated the impact of socioeconomic inequality on hospital case-fatality among SARS-CoV-2-infected children and adolescents showed that municipalities with lower GDP per capita had worse indicators of hospital-based COVID-19 case fatality rates¹²⁾. In most health crises, nurses have been at the frontline to respond to emergencies; thus, increasing the nursing workforce and the competency with COVID-19 CFR and YLLs. A previous study conducted by Sourij and colleagues¹⁴⁾ that assessed the predictors of in-hospital mortality in COVID-19 patients showed that mortality rate was markedly high in diabetic patients. Furthermore, a systematic review and meta-analysis that included 22 studies and conducted by Saha and colleagues¹⁵⁾ found that, among hospitalized patients with COVID-19, mortality rate was highest in diabetic individuals in Europe, the United States and Asian continent.

Our study did not find any relationship between country-level vaccination coverage rate and the outcome variables in the year 2020. Previous reports have contradictory results in terms of booster vaccine necessity in some categories of the population. For example, a Brazilian study¹⁶⁾ that investigated the relationship between COVID-19 vaccination coverage and the disease mortality among elderly citizens. On the other hand, a meta-analysis conducted by Zhu *et al.*¹⁷⁾ that included seven studies showed that booster vaccine could reduce infection rates, especially against Omicron variant, but it was less effective against Delta variant, suggesting that the efficacy of COVID-19 vaccine booster should be considered when making vaccination plans, especially in young adults and children.

Our study also revealed that old age and diabetes were among high-risk conditions for COVID-19 fatality and other severe outcomes in OECD countries. Both covariates were positively correlated with COVID-19 CFR and COVID-19 YLLs. Moreover, the regression analysis showed that countries with high diabetes prevalence rate in the first year of the pandemic tended to have higher COVID-19 CFR and YLLs.

The present study has some limitation. Country-level data used in this study do not provide the characteristics on individual COVID-19 cases; thus, the findings should be interpreted with caution, and they cannot be applied to

countries other than OECD member states. Additionally, of the metabolic disorders, only obesity and diabetes were taken into account as covariates. Data on other conditions such as hypertension were not included in the analysis.

Conclusions

Findings from this study, which used country-level health system and health indicators and COVID-19-related epidemiologic indicators, suggest that old age and diabetes are major predictors of serious COVID-19 outcomes, disease mortality in particular. An integrated anti-COVID approach that includes tackling prevalent metabolic disorders in the fight against the pandemic is needed to reduce COVID-19-related disability and mortality.

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Author Contributions

Conceptualization: NRN., DKT; SA., AM.; Data curation: KK., YM., SA.; Formal analysis: NRN, AM.; Methodology: KK., AM., YM.; Supervision: NRN.; Writing original draft: NRN., DKT.; Manuscript editing: TH.

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Conflict of Interest

Authors declare no conflict of interest.

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