



Original Contribution

PANDEMIC PRESSURES AND CHRONIC DISEASE OUTCOMES: CARDIOVASCULAR MORTALITY IN BULGARIA DURING COVID-19

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ABSTRACT

Purpose: Cardiovascular disease (CVD) is Bulgaria's leading cause of death. The Covid-19 pandemic disrupted global health services, likely worsening CVD mortality. This study examined CVD mortality trends in Bulgaria during 2020–2022 versus pre-pandemic years and assessed the pandemic's impact.

Material and Methods: CVD mortality data (ICD-10: I00–I99) came from the National Center of Public Health and Analyses. An ARIMA model forecast expected rates for 2020–2022 using 2000–2019 trends. Observed rates were compared to predictions. Regional disparities across Bulgaria's six planning regions were analyzed via one-way ANOVA with Tukey post-hoc tests.

Results: Observed CVD mortality exceeded ARIMA forecasts throughout the pandemic. In 2020, it was 8.8% above expected; 2021 peaked at 1,163.2 per 100,000—the highest in two decades. Rates dipped slightly in 2022 but stayed elevated. Significant regional differences emerged ($F = 12.826$, $p < 0.001$), with the North West Region highest.

Conclusions: Covid-19 substantially increased CVD mortality in Bulgaria, exceeding trends and predictions, with northern regions hardest hit. Findings highlight needs for resilient systems, chronic care continuity, and targeted regional planning in crises.

Keywords: cardiovascular diseases, mortality, Covid-19, Bulgaria, health services accessibility, pandemics, regional health planning

INTRODUCTION

Mortality from cardiovascular disease (CVD) has long been a leading cause of death both in Bulgaria and internationally. The Covid-19 pandemic has caused unprecedented limitations to access, continuity, and timeliness of medical care for patients with CVD worldwide.

During 2020, access and continuity to health services for chronic non-communicable diseases (NCDs) was severely limited across 155 countries, with hypertension treatment services partially or completely interrupted in 53% of surveyed countries (1). Einstein et al. (2021) reported a 64% reduction in both invasive and non-invasive cardiac diagnostic testing worldwide during the first two months

of the Covid-19 pandemic compared with the same period in 2019 (2). Benjamin et al. (2021) found that European countries experienced a more substantial decline in cardiac imaging and more extensive alterations in medical practices than the other regions (3). During the initial phase of the Covid-19 pandemic, studies observed marked declines in hospital admissions for acute coronary syndromes (4-6) alongside a global rise in out-of-hospital cardiac arrests, accompanied by increased cardiovascular mortality (7, 8).

Restrictions imposed by countries during the pandemic, as well as fear of infection, were the leading causes of disruption to the continuity and timeliness of medical care for CVD. The disruption impacted on the appropriate secondary prevention treatment (9). Moreover, increased social isolation may have reduced opportunities for friends and family to recognize symptoms of stroke (9) or heart failure, delaying emergency care.

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The findings from prior studies underscore the substantial indirect impact of the Covid-19 pandemic on cardiovascular emergency care and clinical outcomes worldwide, driven by significant disruptions to healthcare access, reductions in diagnostic procedures, changes in medical practice, and delays in seeking urgent treatment.

Bulgaria was heavily affected by the Covid-19 pandemic. By the end of August 2021, Bulgaria's Covid-19 mortality rate was approximately 65% higher than the EU average (10). At the onset of the pandemic, the proportion of Bulgarian patients undergoing invasive diagnostic procedures for CVD dropped by 33.3% compared to the same period the previous year (11). The same study reported similar declines in invasive cardiology treatment procedures. Additionally, there was a 21.2% decrease in hospitalized stroke patients during the pandemic, and the number of emergency thrombolysis procedures for ischemic stroke cases fell by nearly 10% in the first three months of 2020 compared to the previous year. A comparison between 2019 and 2021 showed a 20% reduction in hospitalized stroke cases in Bulgaria (12). The high burden of COVID-19 cases and deaths led to various national and regional restrictive measures in 2021. In addition, fear of infection further impaired access to and continuity of care in Bulgaria during this period.

The pandemic and the health system reaction to it likely contributed to increased cardiovascular morbidity and mortality in Bulgaria during the pandemic. Understanding the extent and nature of COVID-19's impact on cardiovascular mortality is essential for informing healthcare policies and improving care delivery during ongoing and future public health crises. The study aimed to examine how mortality from cardiovascular diseases developed in Bulgaria during the pandemic years 2020-2022 compared to trends in the preceding years and to describe the effect of the Covid-19 pandemic on CVD mortality.

METHODS AND MATERIALS

Statistical analysis

Two statistical analyses were conducted to examine the impact of the pandemic and its scope on CVD mortality. The first statistical model produced estimates of death rates from

CVD for the pandemic years 2020, 2021, 2022, based on historical mortality data and compared observed and predicted death rates. The second statistical analysis investigated whether there was a significant difference in death rates between regions in Bulgaria.

The first analysis used Auto Regressive Integrated Moving Average (ARIMA) model to capture temporal trends in mortality from cardiovascular diseases – ICD, IX Diseases of the circulatory system (I00-I99) - from 2000 to 2019 to forecast expected mortality in 2020-2022. We refer to 2020-2022 as the “pandemic period” and before 2019 as the “pre-pandemic period”. We used annual data for mortality from cardiovascular diseases per 100 000 people from annual reports of National Center of Public Health and Analyses (13).

In the comparative analysis, a one-factor analysis of variance (one-way ANOVA) was conducted to test the hypothesis that the arithmetic means of cardiovascular mortality during the pandemic were equal among the six regions – North Central Region, North East Region, North West Region, South East Region, South West Region and South Central Region. Bulgaria is divided into twenty-eight districts, which are grouped into the six regions represented. Statistical analyses were performed using IBM SPSS 30.

RESULTS

Identification, parameter estimates, diagnostic checking and forecasting are four operations for the implementation of ARIMA model (14, 15). Augmented Dickey-Fuller (ADF) test was applied to check whether the natural log-transformed series is stationary or non-stationary. The results of the ADF test showed that the original series is non-stationary. To transform data into stationary, a first-order difference was applied. The time series stabilized after the first difference ($p = 0.026$), hence the ARIMA model's value of d equals one.

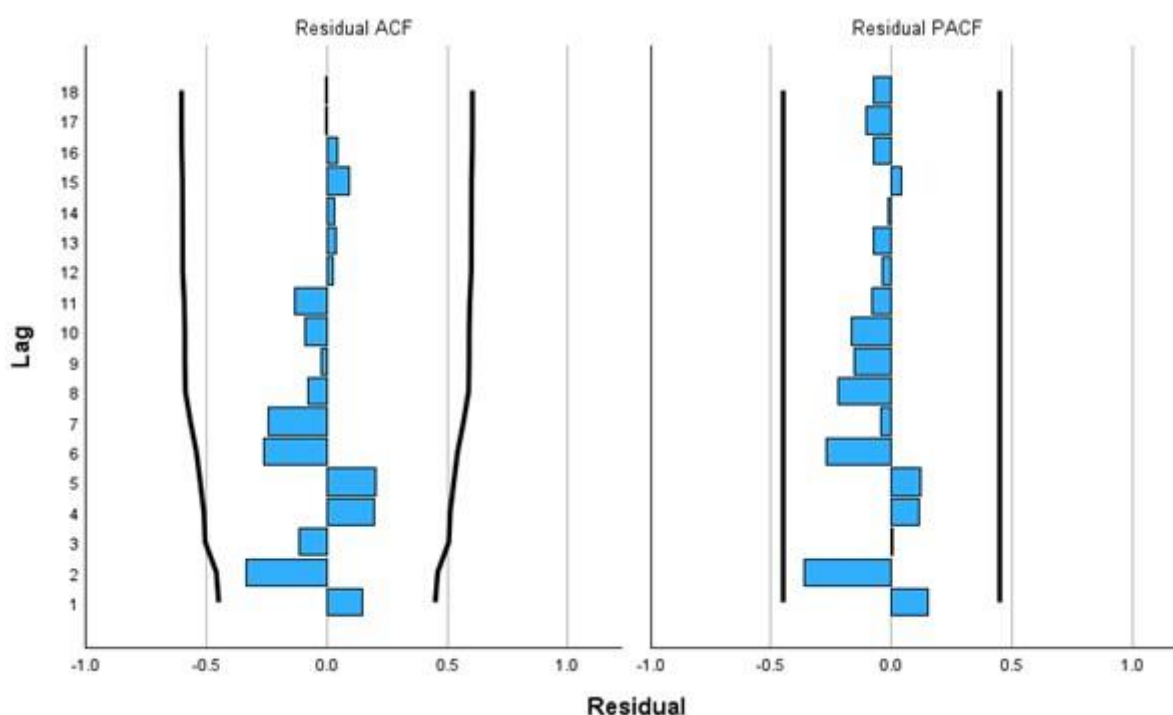
The results of candidate ARIMA models are given in **Table 1**. The ARIMA model with the smallest Akaike's Information Criterion (AIC) score was chosen as the most suitable for the prediction of the rate of mortality in the “pandemic period”. The smallest AIC scores indicate the most suitable ARIMA model [16].

Table 1. Candidate ARIMA models

Candidate model	AIC	Selected model
ARIMA (0,1,0)	177514	ARIMA (0,1,1)
ARIMA (0,1,1)	171674	
ARIMA (0,1,2)	172707	
ARIMA (1,1,1)	173818	
ARIMA (1,1,2)	173834	
ARIMA (1,1,0)	178734	
ARIMA (2,1,0)	175968	
ARIMA (2,1,1)	172598	
ARIMA (2,1,2)	174726	

The next step of analysis is a diagnostic check of the selected ARIMA model. The Ljung-Box Q was used to test the absence of autocorrelations in the selected ARIMA model. The Ljung-Box Q is statistically nonsignificant (Ljung-Box Q = 12.567, $p = 0.765$), indicating the absence of autocorrelations. The ACF (Autocorrelation Function) and PACF (Partial Autocorrelation Function) graphs of the

residuals of selected ARIMA model are presented in **Figure 1**. The ACF determines whether the previous value in the series is related to the following value. The PACF shows the level of correlation between a variable and its own lag. The bars of the PACF and ACF plots are within the 95% confidence limits, indicating the absence of autocorrelations.

**Figure 1.** Residuals of ARIMA model

In the “pre-pandemic period” the death rate from CVD increased each subsequent year with periodic peaks and drops (**Figure 2**). In the first year of the Covid-19 pandemic, observed death rates (1,090.1) exceeded the ARIMA-predicted rates (1,002.1), including the upper confidence limit (UCL, 1,044.3). This indicates a statistically significant deviation likely due to the pandemic. The observed death rate in 2021

(1,163.2) was even higher, far exceeding both the predicted rate (1,004.9) and UCL (1,047.1). In 2022, the observed death rate decreased compared with the previous two years but remained above the UCL (1,049.8). The death rates far above the UCL indicate that the pandemic had a catastrophic impact on mortality rates from CVD.

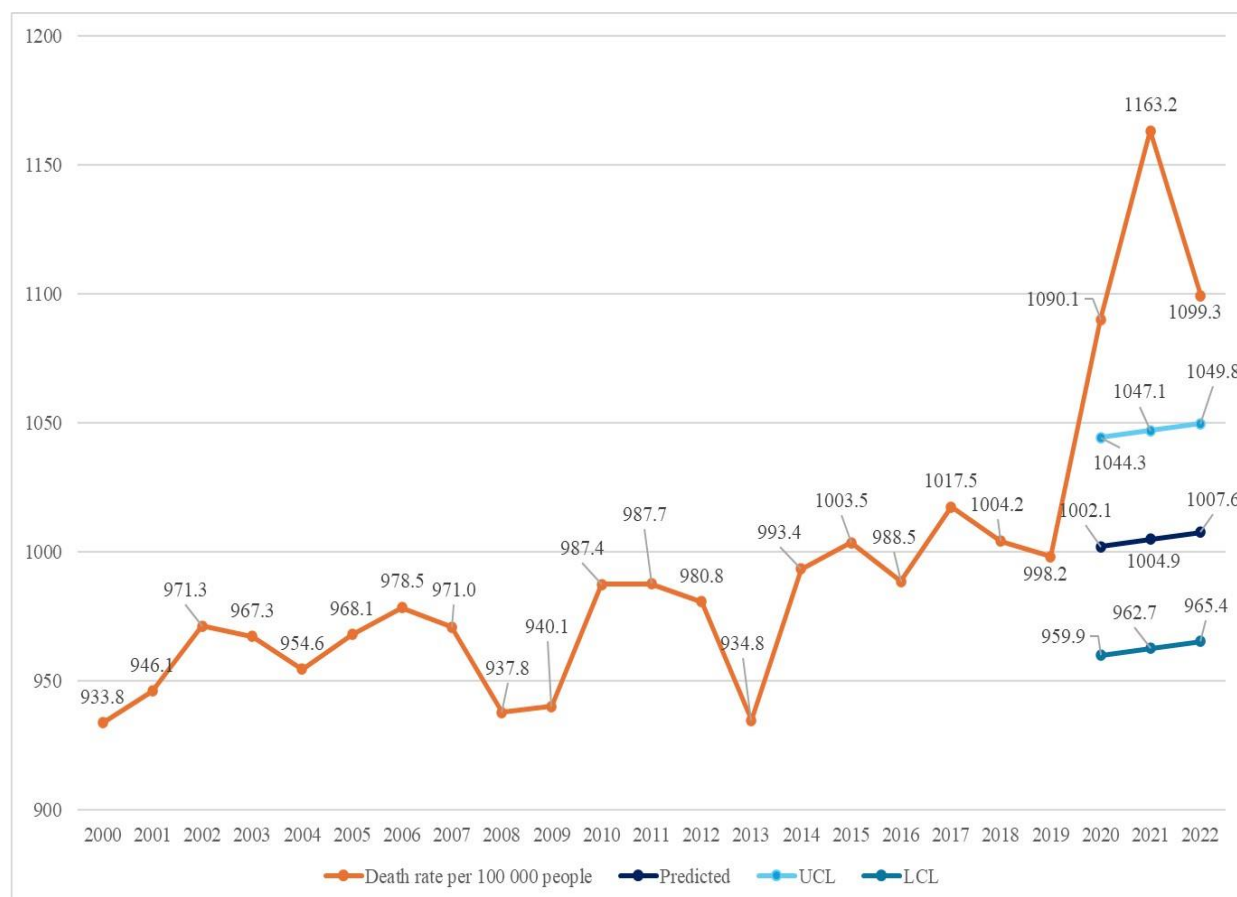


Figure 2. Death rate from cardiovascular diseases

To test the hypothesis whether CVD mortality rates during the pandemic were equal among six regions, a one-way ANOVA analysis was conducted. Results from the one-way ANOVA test shows statistically significant difference, $F(5, 78) = 12.826$, $p < 0.001$ for death rates per 100 000 people between the six regions. The effect size $\eta = 0.451$, which was calculated using the eta coefficient, is much larger than typical using Cohen's interpretation (17). Tukey's post hoc test (Tukey HDS) is a post hoc analysis that pinpoints which specific groups (pairs of regions) differ significantly. We used Tukey HDS to determine where the significant difference is between the six regions. Tukey's post hoc test results showed that the arithmetic means of cardiovascular mortality in:

- The North West Region ($M=1511.35$) is statistically significantly different from the arithmetic means of the North East Region ($M=1047.86$), South East Region ($M=1169.64$), South West Region ($M=1150.64$), and South Central Region ($M=1178.53$). Mortality in the North Central Region was

not statistically significantly different from mortality in the North West Region. It has the highest death rates per 100 000 people compared to other regions.

- The North Central Region's mean ($M=1331.9$) is statistically significantly different from the North East Region mean only ($M=1047.86$).
- The North East Region's mean ($M=1047.86$) is statistically significantly different from the arithmetic means of all but the North West Region and the North Central Region ($M=1331.9$).
- South West Region ($M=1150.64$), South Central Region ($M=1178.53$), South East Region ($M=1169.64$) are statistically significantly different from North West Region only ($M=1511.35$) (**Table 2**).

The Covid-19 pandemic had the greatest impact on death rates from CVD in the northern regions, especially in the North West Region. There is no significant difference in death rates between southern regions, suggesting similar mortality rates between regions.

Table 2. Arithmetic means of cardiovascular mortality during Covid-19

	One-way ANOVA Death rate per 100 000 people	Post-hoc comparison Death rate per 100 000 people	
Regions	M±SD		p
North West Region	1511.35±170.97	North Central Region North East Region South East Region South West Region South Central Region	.060 .001* .001* .001* .001*
North East Region	1047.86±111.86	North Central Region North West Region South East Region South West Region South Central Region	.001* .001* .518 .641 .377
North Central Region	1331.90±108.54	North East Region North West Region South East Region South West Region South Central Region	.001* .060 .160 .056 .158
South West Region	1150.64±246.49	North East Region North West Region North Central Region South East Region South Central Region	.641 .001* .056 1.00 .998
South East Region	1169.64±162.50	North East Region North West Region North Central Region South West Region South Central Region	.518 .001* .160 1.00 1.00
South Central Region	1178.53±183.30	North East Region North West Region North Central Region South West Region South East Region	.377 .001* .158 .998 1.00

DISCUSSION

The Covid-19 pandemic has had significant negative impact on the already high mortality from CVD in Bulgaria. In the pre-pandemic period (2000-2019), the death rates fluctuated but remained within a relatively stable range, with minor peaks and troughs. Our study demonstrates that during the pandemic, CVD mortality rates per 100,000 people reached unprecedentedly high levels compared to the previous two decades (**Figure 2**). Notably, the observed mortality rates during the pandemic exceeded the ARIMA model's predicted values for the same period (**Figure 2**).

During the first year of the pandemic, access to and continuity of medical services for CVD prevention, diagnosis, and treatment declined

markedly both in Bulgaria (11) and globally (1, 2, 18). Specifically, CVD mortality in Bulgaria in 2020 was approximately 9% higher than in 2019 and about 8% above the predicted value (ARIMA) (**Figure 2**).

In particular, the emergence of the Delta and Omicron variants exerted unprecedented strain on Bulgarian hospitals in 2021, contributing to a significant decline in hospitalizations for conditions unrelated to Covid-19 (19). A comparative analysis of hospitalizations for acute myocardial infarction (ICD-10 codes I21, I22) and other ischemic heart diseases (I23–I25) in Bulgaria between 2019 and 2021 reveals a 17.8% reduction in 2021 (13). Similarly, hospital admissions for cerebral infarction (I63) decreased by 24.8% over the same period (13).

Notably, 2021 recorded the highest CVD mortality rate in Bulgaria throughout the pandemic (Figure 2). This elevated mortality is likely attributable to the substantial burden on health facilities imposed by successive Covid-19 waves during that year. Supporting this finding, Rohova and Koeva (2024) report an approximately 50% reduction in the number of patients undergoing clinical pathways for the diagnosis and treatment of both acute and exacerbated chronic heart failure in 2021 compared to 2019 (19).

Our analysis further indicates that mortality rates in 2021 were higher than those in 2020 (Figure 2), exceeding the ARIMA predicted values and surpassing the upper confidence limits (UCL), reflecting a statistically significant increase. Following the lifting of the state of epidemic emergency in Bulgaria on 1 April 2022 (20) (MoH, 2022), restrictions such as mandatory mask-wearing, physical distancing, limits on indoor gatherings, and visitor bans in hospitals and social facilities were removed. However, despite the easing of these measures, treatment rates remained substantially reduced compared to pre-pandemic levels. Specifically, in 2022, there was a 27.5% decline in patients treated under clinical pathways for acute and chronic heart failure, a 36.5% reduction for acute and exacerbated chronic heart failure, and an 18.6% decrease in treatment for ischemic stroke relative to 2019 (19).

CONCLUSION

This study demonstrates that the Covid-19 pandemic significantly exacerbated mortality from cardiovascular diseases in Bulgaria. Using ARIMA modelling and regional statistical analysis, we show that CVD mortality rates during the pandemic period (2020–2022) far exceeded both the pre-pandemic trends and forecasted values.

Our findings indicate that the pandemic led to dramatic reductions in hospitalizations for acute myocardial infarction, other ischemic heart diseases, and cerebral infarction, highlighting severe disruptions in access to diagnosis and treatment for CVD patients. Regional disparities were evident, with the North West Region experiencing the highest CVD death rates. Statistically significant differences in mortality between the northern and southern regions of Bulgaria point to the need for more

targeted and regionally sensitive health policy interventions.

Despite the lifting of restrictive measures in 2022 CVD mortality persisted above pre-pandemic levels and higher than UCL levels of the ARIMA model. These results highlight the enduring impact of the Covid-19 pandemic on chronic disease outcomes and emphasize the importance of restoring and safeguarding continuity of care for patients with cardiovascular diseases during public health emergencies.

Future research and policy efforts should focus on strengthening the resilience of health systems to maintain essential services for non-communicable diseases during global crises, and address regional inequalities to mitigate the long-term public health consequences of disruptions to care.

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