Reductions in mortality resulting from COVID-19 quarantine measures in China

Junjie Shen[1,2,†], Congju Wang[3,†], Chen Dong[1,2], Zaixiang Tang[1,2], Hongpeng Sun[1,2]

[1]Department of Epidemiology and Biostatistics, School of Public Health, Medical College of Soochow University, Suzhou 215123, China
[2]Jiangsu Key Laboratory of Preventive and Translational Medicine for Geriatric Diseases, Medical College of Soochow University, Suzhou 215123, China
[3]Centers for Disease Control and Prevention of Suzhou High-tech Zone, Suzhou 215123, China
Address correspondence to Hongpeng Sun, E-mail: hpsun@suda.edu.cn; Zaixiang Tang, E-mail: tangzx@suda.edu.cn
[†]Junjie Shen and Congju Wang have contributed equally to this work.

ABSTRACT

Background To explore the impact of quarantine measures on the cause of death.

Methods We use time series analysis with the data from death cause surveillance database of Suzhou from January 2017 to December 2019 to estimate the expected deaths from January to June 2020 and compare these expected deaths with the reported numbers of deaths.

Results After the implementation of epidemic prevention measures in Suzhou in the first 3 months, overall number of all-cause deaths declined for 5.36, 7.54 and 7.02% compared with predicted numbers. The number of deaths from respiratory causes and traffic accidents declined shapely by 30.1 and 26.9%, totally. When quarantine measures were released (April–June), however, the observed numbers of total deaths exceeded the predicted deaths. People aged over 70 accounted for 91.6% of declined death number in respiratory causes and people aged over 60 accounted for 68.0% of declined death number in traffic accidents. Women over the age of 80 benefited the most from respiratory prevention (accounts for 41% of all reductions), whereas women aged over 60 benefited the most from traffic control (44%).

Conclusions Overall, the whole population benefited from the epidemic prevention measures especially elderly females. This study is a useful supplement to encourage the government to develop regular preventive measures under the era of normalized epidemic.

Keywords COVID-19, deaths, quarantine measures, time series analysis

Introduction

Cases of viral pneumonia of unknown cause were firstly reported in December 2019 in Wuhan, China, and spread rapidly across the country and over the world.[1,2] On 11 February 2020, the World Health Organization officially named the virus COVID-19.[3] This novel severe acute respiratory syndrome corona-virus is mainly transmitted through respiratory tract and people of any ages are vulnerable.[4,5] The elderly and the infirm seem to be more susceptible to the infection of this virus and die of secondary severe respiratory problems or other diseases.[6] The global epidemic has caused great losses and challenges to human beings.[7,8]

Powerful measures have been implemented by the Chinese government to contain the outbreak.[9,10] Since 23 January 2020, the bus and subway ferry long-distance passenger service of Wuhan city had been suspended; the airport railway station was temporarily closed and citizens were not allowed to leave Wuhan without special reasons.[11] In addition, the media have been following the progress of the epidemic on a daily basis, and the government has publicized the knowledge of disease prevention nationwide to enhance the people's awareness of self-protection, including less out-going, keeping a social distance and wearing mask when you go out. People throughout the country responded positively to the government's epidemic prevention measures.[12,13]

In the assessment of the evolution and impact of the pandemic, death is one of the clearest and worst outcomes. A national study in the USA estimated the number of excess

Junjie Shen, Doctor of Public Health [DSc (PH)]
Congju Wang, Research Assistant
Chen Dong, Professor
Zaixiang Tang, Professor
Hongpeng Sun, Associate professor

deaths attributable to COVID-19 of its country from March to May 2020.[14] The results show that the number of all-cause deaths is 28% higher than the number of officially reported deaths caused from COVID-19. In contrast, studies have shown that, with the exception of areas with severe outbreaks, such as Wuhan in China, both air pollution reduction and mortality benefit from the quarantine measures.[15,16] The number of lives that were saved due to the decrease in air pollution potentially outnumbered the number of deaths directly due to COVID-19.[17] Nevertheless, the extent to which the major causes of deaths are affected by epidemic prevention measures remains to be explored.

To estimate the mortality burden of a new infectious agent in the context of relatively strict quarantine measures, it is common to assess changes in rates of death. Time series analysis is a statistical method of dynamic data processing, which is based on random process theory and mathematical statistics method to study statistical laws followed by random data sequence, so as to solve practical problems.[18] Exponential smoothing method and autoregressive integrated moving average (ARIMA) model concern relatively simple theory and do not contain much mathematics or statistics that are commonly used in time series analysis and prediction methods.[19,20] Time series analysis has been successfully used in the field of medicine and public health for time series prediction of epidemic diseases[21,22] and has been widely applied to predict trends in COVID-19 prevalence and deaths over the world.[23]

In this study, we estimated the expected deaths due to any cause in each month from January to June 2020 about Suzhou, China—a city affected by a mild COVID-19 outbreak if the pathogen had not circulated. We compare these estimates of expected deaths with the reported numbers of deaths to assess the impact of quarantine measures on all-cause mortality. These analyses may enhance our understanding of the importance of quarantine measures to some deaths and serve as useful evidence for formulating health protection guidelines.

Materials and methods

Data resource
All data in this study were obtained from the death cause surveillance database of Suzhou. The objects of the death registration report are all-cause deaths occurring in the area under the jurisdiction of Suzhou carried out by the district health service institutions and secondary or above hospitals. Basic information includes name, sex, date of birth, nationality, marriage, education, occupation, etc. Death information includes cause of death, date of death, place of death, etc.

These data included the total number of all-cause deaths in Suzhou from January 2017 to June 2020 and were stratified by month. Descriptive statistics are given in supplementary materials. In this study, a time series containing 3 years, i.e. 36-month data were used to predict the deaths' numbers in the next 6 months with 95% relative confidence intervals (CIs).

Prediction model
The prediction method of time series assumes that the change of the predicted object is only related to time, which is a simplification of the complex effect of external factors. According to its changing characteristics, time series analysis can be used to predict its future state based on the principle of inertia.

Exponential smoothing method is a kind of time series analysis and prediction method developed on the basis of moving average method. It is to predict the future of phenomena by calculating exponential smoothing value and combining with a certain time series prediction model. The principle is that the exponential smoothing value of any period is the weighted average of the actual observed value of the period and the exponential smoothing value of the previous period.[24]

ARIMA model refers to the model established by converting non-stationary time series into stationary time series. The dependent variable is only regressed to its hysteresis value and the present value and hysteresis value of the random error term. ARIMA model contains three parameters: p, d and q. 'd' represents the number of order differentiation required for the sequential data to be stable, also known as I. The general formula of AR (p) and MA (q) models can be expressed in equations.[25] In addition, ARIMA model can be divided into seasonal model part and non-seasonal model part. Whether there is obvious seasonality can be judged according to the time series diagram.

The prediction model was selected in exponential smoothing method and ARIMA model using the Statistical Product and Service Solutions (SPSS) for Windows software package (ver.22.0, IBM) expert modeling method. The model choice is based on the stationary R^2.

Results

We simulated the number of all-cause deaths and the number of deaths from each major cause over the past 36 months (from January 2017 to December 2019) in Suzhou city using a time series model and predict the deaths' numbers in the next 6 months (January–June 2020). The time series modeler module of SPSS was used to establish the prediction model by using

exponential smoothing method, and ARIMA model, respectively, the recommended model of each cause by SPSS, is a 'simple seasonal' model of an exponential smoothing method. The fitting effect of each model is shown in Supplementary Table 1. The outcome of these predictions is presented in Fig. 1. It can be seen from Fig. 1 that models have a good fitting effect expect 'Tumor'. The distribution of deaths from each cause was generally seasonal, with no significant upward or downward trend.

Then, we compared these estimates of expected deaths with the reported numbers of deaths and the results are shown in Table 1. From January to March of 2020, the observed numbers of deaths from all causes and each major cause were relatively lower than that of the predicted death numbers. The observed deaths from January to March were 5.36, 7.54 and 7.02% lower than predicted data, respectively. The observed numbers of deaths from respiratory causes and traffic accidents were significantly lower than the predicted numbers statistically (the actual numbers of deaths were outside the 95% CI of the predicted number of deaths). In the first 3 months after quarantine measures (January to March) were implemented, the number of deaths from respiratory causes and traffic accidents declined by 30.1 and 26.9%, respectively. In the following 3 months (April–June), however, the observed numbers of deaths (except respiratory causes and traffic accidents) generally exceeded the predicted numbers. More intuitive difference could be seen in Fig. 2. As seen in Fig. 2, the predicted trend of total death is intersected with the actual observed value with poor consistency. From January to June, there is a 'U' trend of first decline and then rise.

Table 2 shows the comparison of 2020 and 2017–2019 deaths from respiratory causes and traffic accidents in Suzhou in the first 3 months by gender and age. As shown in Table 2, the deaths' numbers from respiratory causes and traffic accidents in the first 3 months of 2020 were lower than that of the average deaths' numbers of 2017–2019 in both genders and ages. The decline death in respiratory (−39.66% versus −31.16%) and traffic fatalities (−41.18% versus −22.45%) for women was higher than that for men. Among deaths from respiratory diseases, the absolute number over 70 years of age declined for 219 people, accounted for 91.6% of declined death number, and aged over 60 accounted for 68.0% of declined death number in traffic accidents. And women over the age of 80 benefited the most from the respiratory prevention (accounts for 41% of all reductions), whereas women aged over 60 benefited the most from traffic control (44%).

Discussion

In this study, the simple seasonal exponential smoothing method was used to predict the death data in January–June 2020, which was regarded as the expected death value without the influence of external factors. By comparing with the actual observed death value, the trend change of the death data in January–June 2020 and the difference between the two were analyzed. The results showed that the predicted trend of total death was intersected with the actual observed value with poor consistency. From January to March, the observed number of total deaths was lower than the predicted total deaths, which was mainly caused by respiratory and traffic accidents death decline. From April to June, the observed numbers of total deaths exceeded the predicted deaths.

The global pneumonia pandemic caused by the COVID-19 virus has brought great impact and huge lose on human society. Nevertheless, there is still experience that the epidemic has brought to us. This virus was first reported in Wuhan, China, and quickly spread across the country taking the Spring Festival express. In the face of this highly contagious epidemic, the Chinese people have fought with one heart and one mind. The epidemic has also been brought under effective control by the government's strong prevention and control measures (such as timely treatment of patients, strict isolation of the infected and contacts, protection of the vulnerable, and so on).[26] Reducing travel, limiting congregational activities and wearing masks are key measures to stopping the spread of the disease.[27] By the end of June 2020, China had recorded more than 80 000 confirmed cases and more than 4000 deaths, and most provinces have no local additions. This achievement is worthy of recognition (https://voice.baidu.com/act/newpneumonia/newpneumonia).

Suzhou is a large Chinese city located in East China with a population of about 7 million which has a stable population, developed economy and high medical level. During the virus outbreak, we found a declined trend in the number of all-cause deaths in the first few months in Suzhou after the implementation of the national epidemic prevention measures. In February and March, when preventive measures were fully implemented, the number of observed deaths was 7% lower than expected. The number of deaths from respiratory causes and traffic accidents had declined by 30.1 and 26.9% in the first 3 months. During the special period, Suzhou residents reduced their visits to relatives and friends, and hospitals took strict measures of disinfection and epidemic prevention and mask protection. People's travel was strictly regulated by the government. The very stringent lock-downs
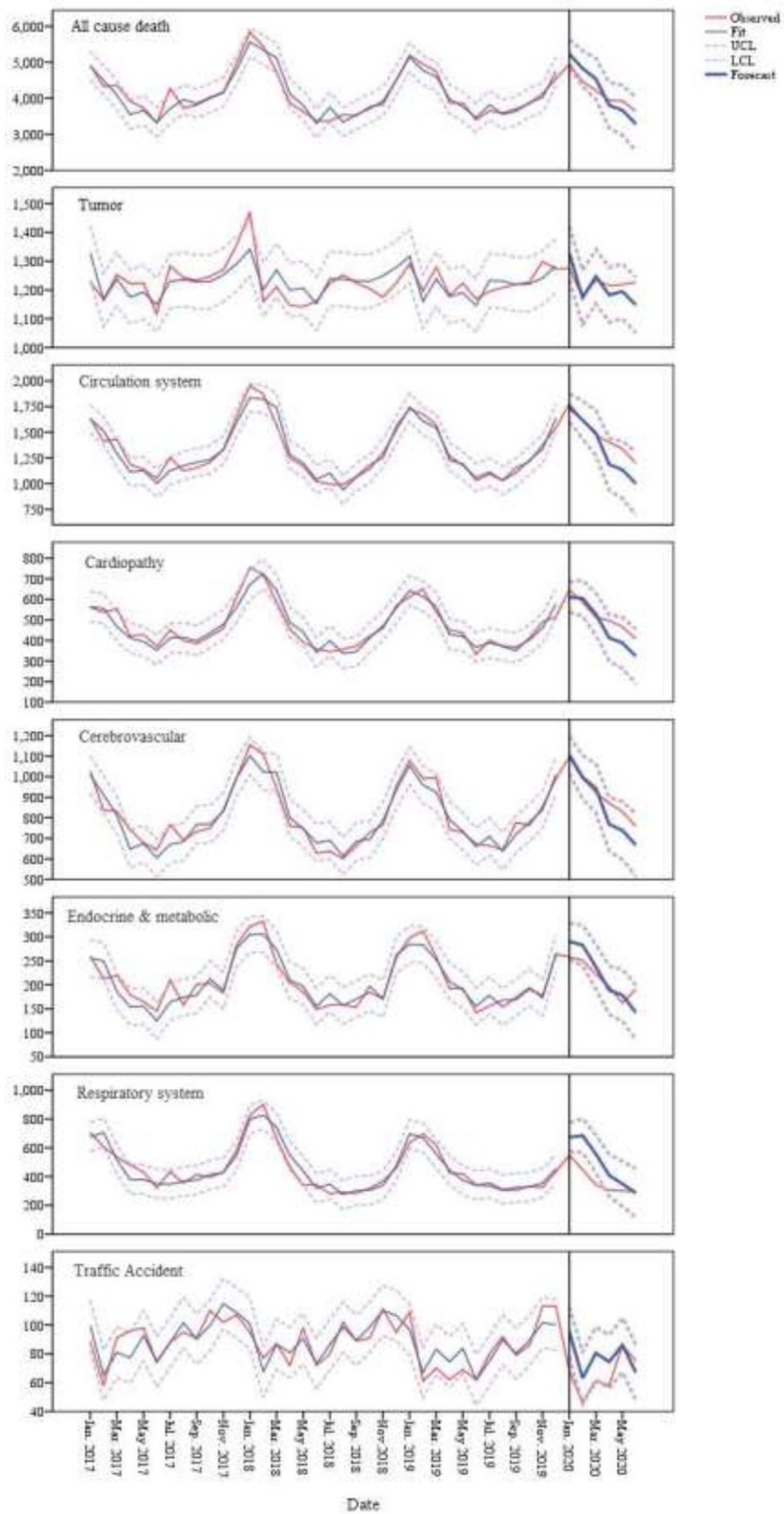
Fig. 1 Trend fitting and prediction of all causes of death in Suzhou from January to June 2020.

Table 1 Comparison of observed and predicted deaths in Suzhou from January to June 2020

	Observed death						Predicted death (95% CI)					
	January	February	March	April	May	June	January	February	March	April	May	June
All-cause death	4958	4464	4222	3940	3928	3636	5239 (4835, 5642)	4828 (4335, 5320)	4541 (3973, 5108)	3807 (3173, 4441)	3669 (2975, 4363)	3284 (2535, 4033)
Circulation system	1780	1616	1475	1402	1340	1200	1742 (1606, 1878)	1621 (1483, 1804)	1494 (1274, 1714)	1189 (937, 1440)	1136 (856, 1416)	1002 (696, 1308)
Cerebrovascular	1094	991	923	871	829	759	1107 (1016, 1197)	998 (892, 1104)	944 (824, 1063)	768 (637, 899)	739 (597, 881)	668 (516, 820)
Cardiopathy	647	587	512	497	466	408	611 (539, 648)	606 (517, 694)	529 (427, 631)	412 (299, 526)	389 (264, 513)	323 (189, 457)
Respiratory system	549	452	347	303	301	293	673 (573, 774)	685 (568, 802)	557 (425, 689)	408 (263, 553)	349 (192, 505)	286 (118, 454)
Traffic accident	68	46	61	58	86	75	95 (78, 113)	63 (45, 81)	80 (62, 99)	74 (56, 93)	86 (67, 105)	67 (48, 86)
Endocrine & metabolic	258	251	222	196	162	191	290 (252, 328)	283 (240, 325)	237 (191, 284)	189 (138, 239)	178 (125, 232)	142 (85, 199)
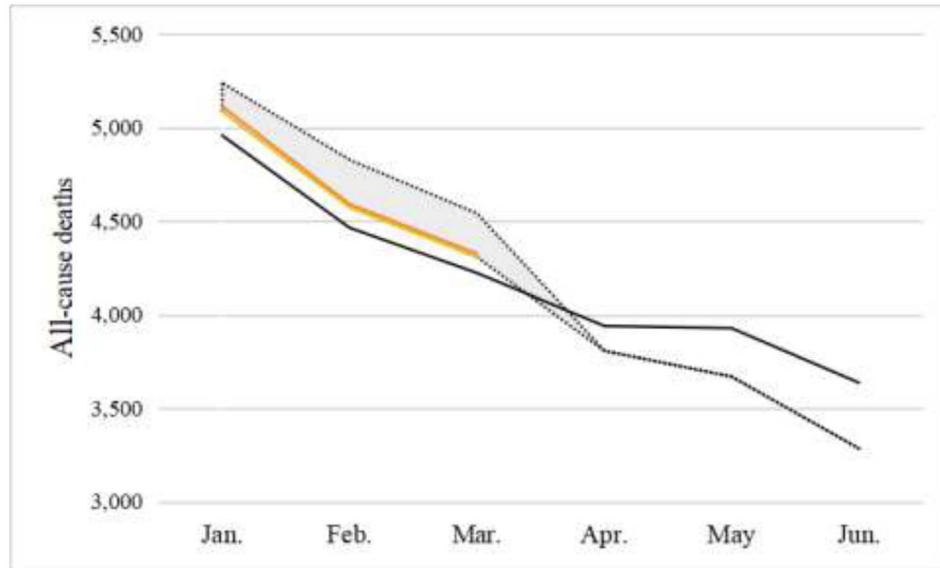
Fig. 2 Observed deaths and predicted deaths in Suzhou from January to June 2020.
The observed number of deaths is indicated by the solid line, and the expected number of deaths is indicated by the dashed line. The shaded area represents a reduction of deaths due to respiratory causes and traffic deaths in the first 3 months.

were placed in China, leading to significant decrease in air pollution levels, and one study reported that the number of lives that were saved due to the decrease in air pollution potentially outnumbered the number of deaths directly due to COVID-19.[17] Another research also found that during and in the months after the 2008 Beijing Olympics, the health status of populations in areas where air pollution levels fell appeared to improve.[28]

In addition to the significant decline in deaths from respiratory and traffic accidents, deaths from chronic diseases in other systems such as cardiopathy, cerebrovascular disease, endocrine and metabolic also declined. A study reported that improved air quality during the quarantine period avoided death of which were from cardiovascular diseases.[17] And our study found that being at home may also associate with fewer deaths from endocrine and metabolic diseases. However, after 3 months, the outbreak was brought under control (Wuhan—the core city of COVID-19 in China—reported no new infec-tions for the first time on 18 March. All the new confirmed cases in the Chinese mainland on 18 March were imported cases.), and social activities gradually returned to normal and medical institutions began to function. At the same time, the observed numbers of deaths of most causes exceeded the predicted numbers. We think that this may be the delayed compensatory death. Due to the opening of the hospital, it caused a rush of medical treatment and increased pressure on medical resources.[29]

Besides, this study found that the overall age benefited from the prevention measures. The absolute reduction in deaths was greatest among those over 70 years of age during the period of quarantine measures. The decline deaths in respiratory and traffic fatalities for women were both higher than that for men. And women over the age of 80 benefited the most from the respiratory prevention, whereas women aged 60 benefited the most from traffic control. This was likely because in China usually older women over the age of

Table 2 Comparison of 2020 deaths and 2017–2019 average deaths from respiratory causes and traffic accidents in Suzhou in the first 3 months by age and gender

		January to March 2020	January to March 2017–2019	Difference N (%)	Decline rate (%)
Respiratory system					
Gender	Male	274	398	−124 (51.9)	−31.16
	Female	175	290	−115 (48.1)	−39.66
Age (Male)	<60	5	8	−3 (1.3)	−37.50
	60−	18	25	−7 (2.9)	−28.00
	70−	55	90	−35 (14.6)	−38.89
	80−	196	274	−78 (32.6)	−28.47
Age (Female)	<60	1	4	−3 (1.3)	−75.00
	60−	3	10	−7 (2.9)	−70.00
	70−	22	30	−8 (3.3)	−26.67
	80−	148	246	−98 (41)	−39.84
Traffic accident					
Gender	Male	38	49	−11 (44)	−22.45
	Female	20	34	−14 (56)	−41.18
Age (Male)	<60	10	17	−7 (28)	−41.18
	≥60	28	34	−6 (24)	−17.65
Age (Female)	<60	6	8	−2 (8)	−25.00
	≥60	14	25	−11 (44)	−44.00

60 were more likely to go out and buy food, but they were more confined to their homes during the epidemic, which also reduced their exposure to the outside world. We recommend that people, especially the elderly, wear masks on a regular basis when go out in autumn and winter.

Limitations

There are some limitations in this study. First, death rates are not compared, which can skew the results slightly. However, according to the results of this study, the main population of all-cause deaths is the elderly over 60 years old, and the floating population in Suzhou city is mainly young adults, which has a relatively low contribution to the death of chronic diseases. Second, Suzhou is just one city, and the larger picture still needs to be explored.

Conclusions

This study is based on the number of deaths observed in previous years to predict the number of deaths at baseline this year and to compare the observed and predicted number of deaths. We confirmed that under the quarantine measures, the number of all-cause deaths fell and the number of deaths from respiratory causes and traffic accidents were declined most significantly. The whole population would benefit from the epidemic prevention measures. Overall, our study is a useful supplement to encourage the government to develop regular preventive measures under the era of normalized epidemic.

Supplementary data

Supplementary data are available at the *Journal of Public Health* online.

Data availability

Our data are unidentified participant data. The datasets generated during and/or analyzed during the current study are not publicly available due to cooperation unit needs to be confidential, but are available from the corresponding author on reasonable request.

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Conflict of interest

The authors declare no competing interests.

Authors' contributions

HS and ZT conceptualized and designed the study. CW and CD were involved in data collection and categorization. JS, CW and CD were involved in real data analysis and interpretation. JS and HS led the drafting of the manuscript. All authors reviewed the manuscript.

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