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Effect of COVID-19 on hospital visits in Ningbo, China: an interrupted time-series analysis

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Abstract

Objective: Unprecedented rigorous public health measures were implemented during the coronavirus disease 2019 (COVID-19) epidemic, but it is still unclear how the intervention influenced hospital visits for different types of diseases. We aimed to evaluate the impact of the intervention on hospital visits in Yinzhou District, Ningbo, Zhejiang province, China.

Methods: We conducted an interrupted time-series analysis from 1 January 2017 to 6 September 2020 based on the Yinzhou Health Information System in Ningbo, Zhejiang province. The beginning of the intervention was on 23 January 2020, and thus, there were 160 weeks before the intervention and 32 weeks after the implementation of the intervention. Level changes between expected and observed hospital visits in the post-intervention period were estimated using quasi-Poisson regression models.

Results: Compared with the expected level, there was an estimated decrease of −22.60% (95% confidence interval (CI): −27.53%, −17.36%) in the observed total hospital visits following the intervention. Observed hospital visits for diseases of the respiratory system were found to be decreased dramatically (−62.25%; 95% CI: −65.62%, −58.60%). However, observed hospital visits for certain diseases were estimated to be increased, including diseases of the nervous system (+11.17%; 95% CI: +3.21%, +19.74%); diseases of pregnancy, childbirth and the puerperium (+27.01%; 95% CI: +17.89%, +36.85%); certain conditions originating in the perinatal period (+45.05%; 95% CI: +30.24%, +61.56%); and congenital malformation deformations and chromosomal abnormalities (+35.50%; 95% CI: +21.24%, +51.45%).

Conclusions: Our findings provided scientific evidence that cause-specific hospital visits evolve differently following the intervention during the COVID-19 epidemic.

Key words: COVID-19, hospital visits, interrupted time-series analysis

Introduction

In late December 2019, patients with unknown causes of pneumonia broke out in Wuhan, China [1]. The novel coronavirus disease, later known to be coronavirus disease 2019 (COVID-19), spread across China although proactive public measures were taken to combat the disease. The first case of COVID-19 in Zhejiang province was diagnosed on 17 January 2020 [2], and the first-level public health emergency response was officially activated on 23 January 2020. Subsequently, unprecedented rigorous public health interventions were implemented, including quarantines, stay-at-home orders and travel restrictions [3]. People practiced social distancing, self-isolation, cleaning hands frequently and wearing masks under the circumstances [4].

The intervention caused significant disruptions in daily life and also affected the number of hospital visits. A series of studies [5–7] reported sharp drops in the number of persons seeking emergency medical care during the COVID-19 outbreak. For instance, a nationwide study in the USA found that emergency department visits during the early pandemic period (29 March to 25 April 2020) were 42% lower than that during the same period a year earlier [7]. An interrupted time-series (ITS) analysis in France indicated that the number of pediatric emergency department visits and related hospital admissions decreased by 68% and 45%, respectively, after the lockdown [8]. A Chinese study showed that dental urgency visits decreased by 38% at the beginning of the COVID-19 epidemic than earlier [9].

Given the altered behavioral patterns and evolution of hospital visits during the COVID-19 epidemic, we hypothesized that the intervention could have an impact on the supply of medical service, people's willingness to seek medical help and the incidence of certain diseases and, thus, affect hospital visits for different types of diseases. However, to date, limited studies can be available to systematically evaluate the impact of the intervention during the COVID-19 epidemic on total and cause-specific hospital visits in China.

Herein, we conducted an ITS analysis to quantify the effect of the intervention on hospital visits in Yinzhou District, Ningbo, Zhejiang province, China. Our findings could not only reveal change patterns of hospital visits during the COVID-19 epidemic period but also provide evidence-based references for future disease control and prevention.

Methods

Design and source of data

We conducted an ITS analysis from 1 January 2017 to 6 September 2020 based on the Yinzhou Health Information System (YHIS) [10] in Ningbo, Zhejiang province. YHIS was composed of residents' health-care records, Chronic Diseases Recording System and Hospital Information System, making it possible to obtain comprehensive and timely health information for each resident. Hospital Information System, including date of hospital visits, diagnosis of disease and International Classification of Diseases, Revision 10 (ICD-10), was used for our analysis. Diagnosis of disease was classified according to ICD-10, and the number of hospital visits was grouped by calendar weeks for each year. This study was approved by the Institutional Review Board of the Zhejiang University School of Medicine. Informed consent was not required because anonymous and de-identified information was used for our analysis.

Outcome

The main outcome was the evolution of the number of total and cause-specific hospital visits before and after the implementation of the intervention in response to the COVID-19 epidemic in Zhejiang, China.

Statistical analysis

ITS analysis with a quasi-Poisson regression model was used to estimate changes in hospital visits following the intervention during the COVID-19 epidemic. Several variables were entered into the model [11]: (i) the time elapsed since the start of the study (T, ranged from 1 to 192, representing a total of 192 weeks during the study period); (ii) a dummy variable indicating the intervention owing to the COVID-19 epidemic (X_t, Code 0 indicated the pre-intervention period and 1 indicated the post-intervention period); (iii) Fourier terms modeling seasonality patterns (Fourier) [12] and (iv) 1-week lagged residuals fitting the autocorrelation of time series (ε). In our study, we only considered the short-term changes in level (not the long-term changes in trend) and used the following segmented regression model:

$$\mathrm{Log}\,(\mathrm{Y_t}) = \beta_0 + \beta_1 \mathrm{T} + \beta_2 \mathrm{X_t} + \mathrm{Fourier} + \varepsilon$$

where Y_t is the total or cause-specific hospital visits, β_0 is the intercept, exp (β_1) is the change in hospital visits with a time unit change and exp (β_2) is the change in levels following the intervention. Fourier terms were determined by auto Arima models, and ε was determined by the models without residuals. In our analysis, the beginning of the intervention was defined as a time point on 23 January 2020, when Zhejiang province officially activated the first-level public health emergency response. Thus, the pre-intervention period was from 1 January 2017 to 22 January 2020 ($T = 1$ to $T = 160$), and the post-intervention period was from 23 January 2020 to 6 September 2020 ($T = 161$ to $T = 192$) (i.e. there were 160 weeks before the intervention and 32 weeks after the implementation of the intervention).

The validity of our regression model was checked by plotting residuals, autocorrelation functions and partial autocorrelation functions. All statistical tests were two-sided, and P-value <0.05 was considered statistically significant. All statistical analyses were performed using R v4.0.1 (http://www.R-project.org). All data analyses were conducted in 2020.

Results

A total of 48 574 128 hospital visits (42 113 607 for pre-intervention period and 6 460 521 for post-intervention period) were identified from the YHIS (Table 1). Overall, decreased total hospital visits per week were observed during the post-intervention period. For cause-specific classification, diseases of the respiratory system (ICD-10: J00–J99), the circulatory system (I00–I99) and the digestive system (K00–K93) were the top three hospital visits in total during the pre-intervention period, whereas diseases of the circulatory system (I00–I99), the digestive system (K00–K93) and the musculoskeletal system and connective tissue (M00–M99) accounted for the top three during the post-intervention period.

Regression analysis of weekly data indicated a sharp decrease between expected and observed values for total hospital visits after the implementation of the intervention (−22.60%; 95% confidence interval (CI): −27.53%, −17.36%) (Table 2, Figure 1). Similar results were observed for most of the cause-specific hospital visits (Table 2, Figure 2). The diseases of the respiratory system (J00–J99); certain infectious and parasitic diseases (A00–B99); and symptoms, signs, and abnormal clinical and laboratory findings, not elsewhere classified (R00–R99), ranking as the top three decreased

Table 1 Description of total and cause-specific hospital visits during pre- and post-intervention periods

Disease classification	ICD-10	Pre-intervention		Post-intervention	
		Overall visits (*n*, %)	Visits per week	Overall visits (*n*, %)	Visits per week
Total visits	Not applicable	42 113 607 (100)	263 210	6 460 521 (100)	201 891
Certain infectious and parasitic diseases	A00–B99	1 424 634 (3.38)	8904	218 795 (3.39)	6837
Neoplasms	C00–D48	218 993 (0.52)	1369	65 292 (1.01)	2040
Diseases of the blood and blood-forming organs and certain disorders involving the immune mechanism	D50–D89	127 367 (0.30)	796	32 754 (0.51)	1024
Endocrine, nutritional and metabolic diseases	E00–E90	2 089 803 (4.96)	13 061	456 020 (7.06)	14 251
Mental and behavioral disorders	F00–F99	323 203 (0.77)	2020	83 648 (1.29)	2614
Diseases of the nervous system	G00–G99	639 482 (1.52)	3997	154 474 (2.39)	4827
Diseases of the eye and adnexa	H00–H59	2 318 530 (5.51)	14 491	419 608 (6.49)	13 113
Diseases of the ear and mastoid process	H60–H95	326 355 (0.77)	2040	56 999 (0.88)	1781
Diseases of the circulatory system	I00–I99	5 204 902 (12.36)	32 531	904 133 (13.99)	28 254
Diseases of the respiratory system	J00–J99	6 506 252 (15.45)	40 664	436 494 (6.76)	13 640
Diseases of the digestive system	K00–K93	3 428 444 (8.14)	21 428	641 807 (9.93)	20 056
Diseases of the skin and subcutaneous tissue	L00–L99	1 704 263 (4.05)	10 652	322 254 (4.99)	10 070
Diseases of the musculoskeletal system and connective tissue	M00–M99	2 689 785 (6.39)	16 811	522 245 (8.08)	16 320
Diseases of the genitourinary system	N00–N99	1 951 104 (4.63)	12 194	385 625 (5.97)	12 051
Pregnancy, childbirth and the puerperium	O00–O99	136 683 (0.32)	854	31 954 (0.49)	999
Certain conditions originating in the perinatal period	P00–P96	21 126 (0.05)	132	5267 (0.08)	165
Congenital malformation deformations and chromosomal abnormalities	Q00–Q99	22 119 (0.05)	138	6180 (0.10)	193
Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified	R00–R99	1 600 897 (3.80)	10 006	268 926 (4.16)	8404
Injury, poisoning and certain other consequences of external causes	S00–T98	2 018 005 (4.79)	12 613	364 358 (5.64)	11 386
Factors influencing health status and contact with health services	Z00–Z99	2 424 535 (5.76)	15 153	496 625 (7.69)	15 520
Not classified	Not applicable	6 937 125 (16.47)	43 357	587 063 (9.09)	18 346

cause-specific hospital visits, remarkably decreased over 60%, 29% and 18% compared with the expected values, respectively. However, hospital visits for several diseases were found to be significantly increased, including +11.17% (95% CI: +3.21%, +19.74%) for diseases of the nervous system (G00–G99); +27.01% (95% CI: +17.89%, +36.85%) for diseases of pregnancy, childbirth and the puerperium (O00–O99); +45.05% (95% CI: +30.24%, +61.56%) for certain conditions originating in the perinatal period (P00—-P96) and +35.50% (95% CI: +21.24%, +51.45%) for congenital malformation deformations and chromosomal abnormalities (Q00–Q99) (Table 2, Figure 3). No significant changes were observed for endocrine, nutritional and metabolic diseases (E00–E90); mental

Table 2 Changes in total and cause-specific hospital visits during pre- and post-intervention periods

Disease classification	ICD-10	Changes (%, 95% CI)	*P*
Total visits	Not applicable	−22.60 (−27.53, −17.36)	<0.001
Certain infectious and parasitic diseases	A00–B99	−29.81 (−34.01, −25.36)	<0.001
Neoplasms	C00–D48	−14.20 (−21.23, −6.55)	0.001
Diseases of the blood and blood-forming organs and certain disorders involving the immune mechanism	D50–D89	−7.90 (−14.65, −0.63)	0.035
Endocrine, nutritional and metabolic diseases	E00–E90	+0.10 (−7.59, +8.42)	0.980
Mental and behavioral disorders	F00–F99	−4.90 (−11.37, +2.04)	0.164
Diseases of the nervous system	G00–G99	+11.17 (+3.21, +19.74)	0.006
Diseases of the eye and adnexa	H00–H59	−18.31 (−24.99, −11.06)	<0.001
Diseases of the ear and mastoid process	H60–H95	−17.29 (−22.75, −11.46)	<0.001
Diseases of the circulatory system	I00–I99	−1.36 (−9.53, +7.52)	0.756
Diseases of the respiratory system	J00–J99	−62.25 (−65.62, −58.60)	<0.001
Diseases of the digestive system	K00–K93	+1.58 (−5.32, +8.97)	0.662
Diseases of the skin and subcutaneous tissue	L00–L99	−7.21 (−12.76, −1.33)	0.018
Diseases of the musculoskeletal system and connective tissue	M00–M99	−10.01 (−15.84, −3.80)	0.002
Diseases of the genitourinary system	N00–N99	−6.15 (−12.35, +0.47)	0.070
Pregnancy, childbirth and the puerperium	O00–O99	+27.01 (+17.89, +36.85)	<0.001
Certain conditions originating in the perinatal period	P00–P96	+45.05 (+30.24, +61.56)	<0.001
Congenital malformation deformations and chromosomal abnormalities	Q00–Q99	+35.50 (+21.24, +51.45)	<0.001
Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified	R00–R99	−18.39 (−23.27, −13.22)	<0.001
Injury, poisoning and certain other consequences of external causes	S00–T98	−0.61 (−5.98, +5.05)	0.828
Factors influencing health status and contact with health services	Z00–Z99	−0.98 (−9.88, +8.79)	0.839

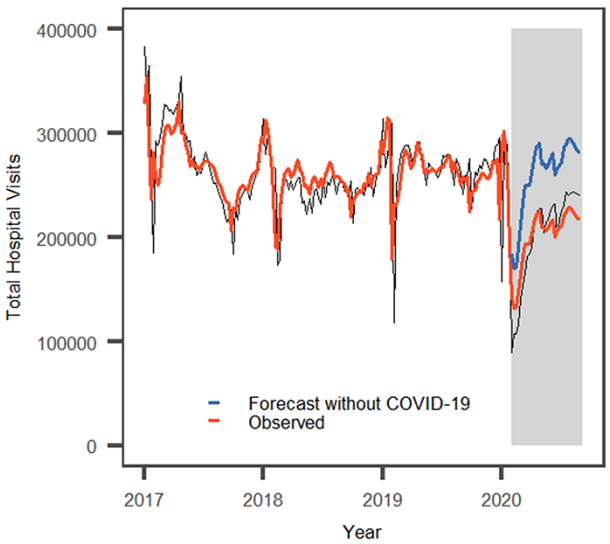

Figure 1 Impact of intervention to COVID-19 on weekly total hospital visits from 1 January 2017 to 6 September 2020 (gray background: post-intervention period).

and behavioral disorders (F00–F99); diseases of the circulatory (I00–I99), digestive (K00–K93) and genitourinary (N00–N99) system; injury, poisoning and certain other consequences of external causes (S00–T98); and factors influencing health status and contact with health services (Z00–Z99) (Table 2, **Supplementary Figure S1**).

Discussion

Statement of principal findings

In this ITS study of 48 574 128 hospital visits, we observed a significant decrease between observed and expected values in total hospital visits during the post-intervention period. Hospital visits for the diseases of the respiratory system (J00–J99) were found to be decreased dramatically, while four kinds of diseases were observed to be increased. Our results provided strong evidence that there was a significant impact of intervention during the COVID-19 epidemic on hospital visits.

Strengths and limitations

In this quasi-experiment study, we evaluated the impact of the intervention during the COVID-19 epidemic on all types of hospital visits, which was limited reported in previous studies. However, several limitations of our study should be acknowledged. Firstly, several time-varying confounders that may affect hospital visits, such as air pollution and meteorological factors, were not included in our regression models although Fourier terms were used to fit the seasonality. Secondly, we did not consider the long-term trend in hospital visit changes because our observation period was not long enough. Finally, data on hospital visits were only extracted from one district of Ningbo, and a nationwide study is needed to further confirm our findings.

Interpretation within the context of the wider literature

During the COVID-19 epidemic, unprecedented rigorous public health measures were implemented, which may unintentionally affect established integrated care systems [5]. In China, some departments

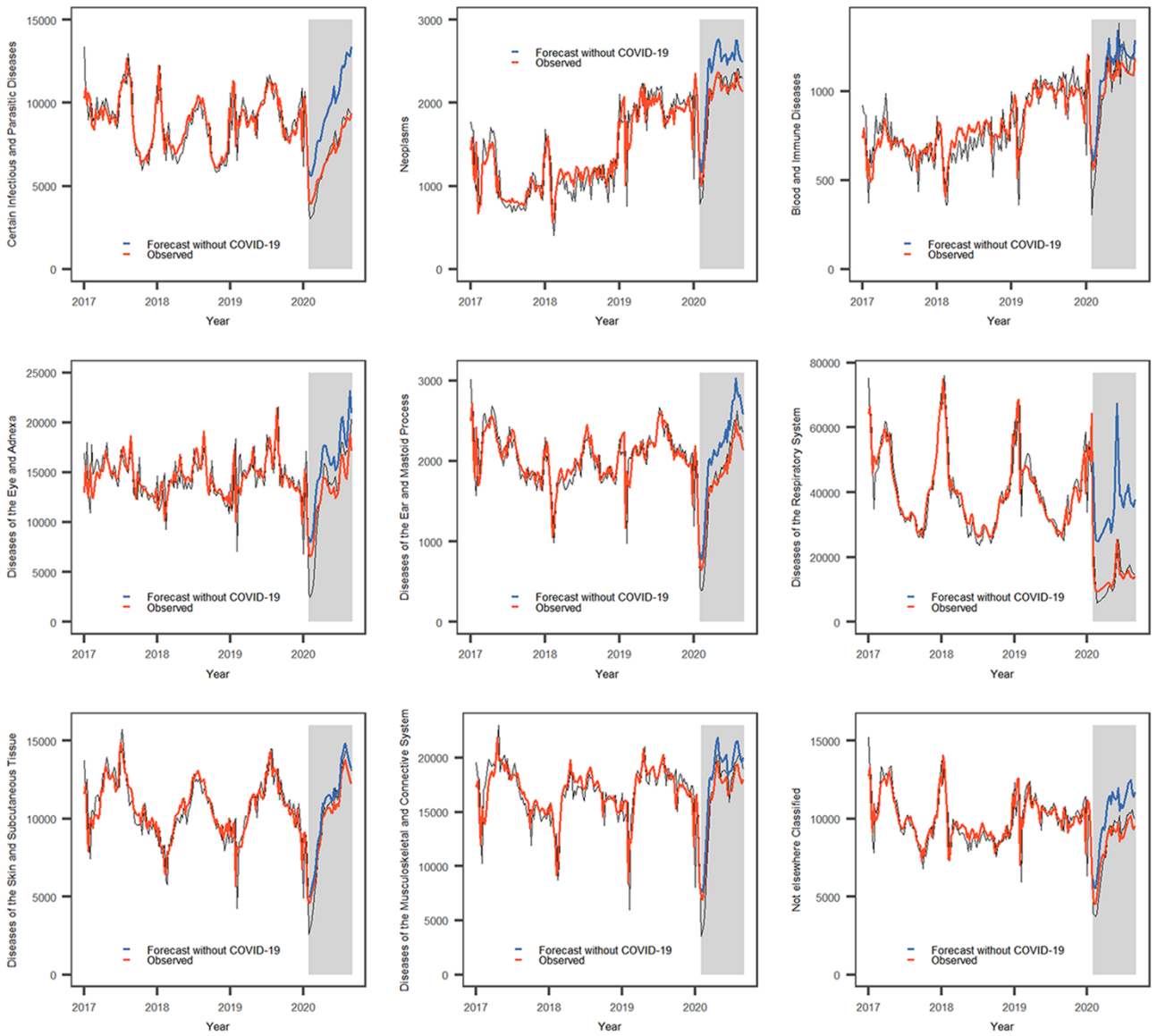

Figure 2 Weekly hospital visits for cause-specific diseases, which were observed to be decreased following the intervention to COVID-19 from 1 January 2017 to 6 September 2020 (gray background: post-intervention period).

in hospitals, such as the dental department and otorhinolaryngology department, were suspended while only emergency services were provided. On the other hand, people's fear of the possible risk of COVID-19 infection might contribute to discouraged hospital access [13]. The decrease in total and certain cause-specific hospital visits could be partly explained by the above reasons. However, the dramatic decrease in hospital visits for certain infectious and parasitic diseases (A00–B99) and diseases of the respiratory system (J00–J99) may also be attributable to lockdown measures, which could reduce numerous infectious diseases sharing the same transmission routes with COVID-19. A study in France indicated that because of school closure and national lockdown measures, there was a significant decrease in common cold, gastroenteritis, bronchiolitis and acute otitis [8]. Furthermore, individual lifestyles have altered during the COVID-19 epidemic. For instance, people were recommended to wear masks, which were expected to reduce the incidence of airborne transmitted diseases. Patel and his colleagues demonstrated that using surgical masks was an effective measure to prevent the spread of respiratory infection [14], and as a physical barrier, wearing masks could be beneficial to avoid allergens and prevent allergic rhinitis [15].

Not all hospital visits for cause-specific diseases were found to be decreased, and we found a significant increase in hospital visits for four types of diseases. Of note, apart from the diseases of the nervous system (G00–G99, slightly increased), hospital visits for three types of diseases remarkably increased, including diseases of pregnancy, childbirth and the puerperium (O00–O99); certain conditions originating in the perinatal period (P00–P96); and congenital malformation deformations; and chromosomal abnormalities (R00–R99). These findings could be explained by the impact of the intervention on prenatal care during the COVID-19 epidemic. Several studies have shown that pregnant women could not go to the hospital unless in an emergency due to the lockdown in the early COVID-19 pandemic all over the world [16, 17]. In China, a web-based survey indicated that

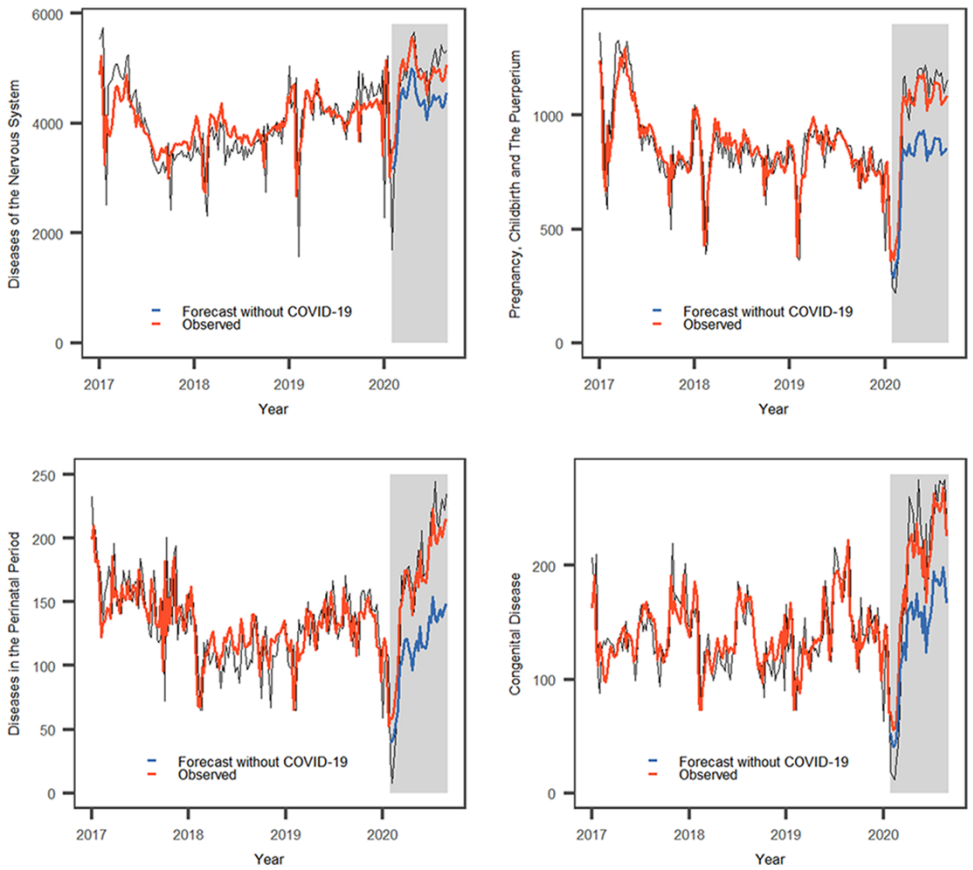

Figure 3 Weekly hospital visits for cause-specific diseases, which were observed to be increased following the intervention to COVID-19 from 1 January 2017 to 6 September 2020 (gray background: post-intervention period).

> 40% of respondents feared in-hospital antenatal visits, and >50% considered or decided to cancel or postpone their appointments [18]. Although online antenatal care programs were proposed, not all pregnant women used the internet and online gestational information needed to be screened. A drive-through prenatal care model was developed in the USA, and thus, pregnant women would remain in their automobiles while being assessed by the health-care professional [19].

Although we observed no effect of the intervention on hospital visits for most of the non-communicable diseases (NCDs), such as endocrine, nutritional and metabolic diseases (E00–E90); mental and behavioral disorders (F00–F99); diseases of the circulatory system (I00–I99) and diseases of the digestive system (K00–K93), we can never ignore the long-term effect of the intervention. Due to the short observation period, we were not able to detect the changes in the long-term trend of hospital visits. As we know, the intervention measures, such as stay-at-home orders and travel restrictions, may increase unhealthy lifestyles like being sedentary and overuse of electronic devices and thus increase the risk of NCDs [20]. Future studies with a longer observation period are needed to further identify the effect.

Conclusions and implications for policy, practice and research

In summary, we provided scientific evidence of the impact of intervention during the COVID-19 epidemic on hospital visits based on this quasi-experiment study. What is more, lessons should be taken from the intervention. Proposing suggestions for wearing masks during the epidemic period of respiratory diseases and mitigating the impact of the COVID-19 on health-care systems are important for future disease control and prevention.

Supplementary material

Supplementary material is available at *International Journal for Quality in Health Care* online.

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Contributorship

ZongMing Yang designed this study and wrote the manuscript; MengYin Wu and JieMing Lu were in charge of the statistical

analysis and interpretation of the results; Peng Shen, MengLing Tang, MingJuan Jin, HongBo Lin and LiMing Shui conducted this study; TieZheng Li collected and processed data; JianBing Wang and Kun Chen designed this study and made critical revisions of the manuscript.

Ethics and other permissions

This study was approved by the Institutional Review Board of the Zhejiang University School of Medicine. Informed consent was not required because anonymous and de-identified information was used for our analysis.

Data availability

No new data were generated or analyzed in support of this review.

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