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Reduction in inpatient and severe condition visits for respiratory diseases during the COVID-19 pandemic in Wuhan, China

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A B S T R A C T

Background: In Wuhan, China, a stringent lockdown was implemented to contain the spread of COVID-19, transitioning later to normalised prevention and control strategy. This study examines the trends in hospital visits for acute and chronic respiratory diseases, with a focus on outpatient, inpatient, and severe condition visits.
Methods: The study used administrative health insurance data spanning from January 2018 to August 2021, an interrupted time series analysis was conducted to assess the trend in hospital visits per million population for respiratory diseases. To confirm whether the change was exclusive to respiratory diseases, neoplasms and intracerebral haemorrhage were used as controls. The impact of the pandemic was estimated by comparing by weekly admissions to pre-pandemic levels. Subgroup analyses dissected variations by disease and visit types.
Results: Hospital visits for respiratory diseases declined significantly during the lockdown and exhibited a slower recovery in the later normalised prevention and control period compared to the control conditions. As of August 2021, outpatient visits increased by over 22.2% above the pre-pandemic level, while inpatient and severe condition visits witnessed significant reductions, falling to 46.7% and 80.6% of pre-pandemic levels, respectively. Compared to three other subgroups, visits for acute lower respiratory infections experienced the most significant decline, with inpatient and severe visits dropping to 23.9% and 25.7% of pre-pandemic levels.
Interpretation: Our study revealed a persistent reduction in inpatient and severe case visits for respiratory diseases throughout the ongoing pandemic. These findings suggested the possible role of non-pharmaceutical interventions in mitigating acute and chronic non-COVID respiratory diseases.
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1. Introduction

In response to the abrupt onset of the COVID-19 pandemic, numerous countries and regions have adopted a diverse range of non-pharmaceutical interventions (NPIs) to curb the transmission. In China, a strict 76-day lockdown was imposed in Wuhan, Hubei Province, with measures including halting transport, closing business and public spaces, and enforcing home quarantine. These concerted efforts contained the virus within three months. Subsequent to the lifting of the lockdown, a series of measures were put in place to ensure public health, such as enhanced community management, healthy lifestyle promotion, self-monitoring, and vaccination campaigns [1]. These measures have also been found to influence individual's risk perceptions and adherence to protective behaviours [2–4].

Considering the shared transmission route through the respiratory tract, NPIs such as mask-wearing, social distancing, and personal hygiene have been linked to reduced transmission of respiratory pathogens other than SARS-CoV-2. This effect has been observed for seasonal influenza [5–11], respiratory syncytial virus

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[12,13], mycobacterium tuberculosis and pneumococcus [14,15]. Respiratory pathogens play a critical role in both acute infections and the exacerbations of chronic respiratory diseases, often leading to hospitalisation [15,16]. While previous studies have primarily focused on specific respiratory acute or chronic conditions in developed countries [17–38], there have been less investigation into the broader spectrum of respiratory diseases in underdeveloped countries. Acute and chronic respiratory diseases have emerged as major causes of health burden in low- and middle-income countries [39–41]. The lockdown and subsequent NPIs in Wuhan, China have provided a natural experiment to study the immediate and extended effects of the pandemic and associated NPIs on hospital visits related to respiratory diseases. In this study, we aimed to explore the temporal trends of acute and chronic respiratory diseases from 2018 to 2021 in Wuhan.

2. Data and methodology

2.1. Health insurance data

This study used retrospective national health insurance data from Wuhan City, spanning the period from January 2018 to July 2021. It was estimated that the medical insurance database covered over 96.7% of the resident population in Hubei Province in 2020 [42], hence providing a broad representation of the population. The database comprises comprehensive individual medical records, including admission and discharge dates, diagnoses, and utilised healthcare services. Annual population estimates were sourced from the Public Security Bureau's household registration system. The catchment population of Wuhan increased from 10.893 million at the end of 2017 to 13.649 million at the end of 2021 [42]. This study was approved by the Institutional Review Board of Tsinghua University (Ref: 20220231).

2.2. Outcomes

The primary outcome of interest was the number of weekly hospital visits per million population related to respiratory diseases. The respiratory diseases were identified using discarge diagnosis codes, including J00-J06, J09-J18, J20-J22, and J40-J47, as recorded using the International Classification of Diseases 10th Revision (ICD-10). COVID-19 cases, identified by discharge diagnosis (code of U07 or diagnosis name of COVID-19), were excluded from our analysis. Weekly visit counts were considered as outliers if they deviated by more than eight standard deviations from the meantime trend. These outliers were then adjusted using kernel-weighted local polynomial smoothing [43]. Respiratory diseases were categorised into four subgroups, namely, acute upper respiratory infections (J00-J06), influenza and pneumonia (J09-J18), acute lower respiratory infections (J20-J22), and chronic lower respiratory diseases (J40-J47). The overall respiratory disease visits and disease subgroup visits were further divided into outpatient, inpatient, and severe condition visits (defined as those necessitating ventilation, intubation, or admission to an intensive care unit). To determine whether the impact extended beyond respiratory diseases to affect a broader spectrum of medical conditions, we also examined hospital visits related to neoplasms (C00-D36) and intracerebral haemorrhage (I61 and I62).

2.3. Model specification

To examine trends in respiratory diseases and quantify the changes associated with the pandemic, we employed interrupted time series analyses (ITSA), a widely used method to assess the effects of policy interventions over time [44,45]. This method was based on the assumption that the outcome variable would remain stable in the absence of the interruption and relied on segmented regression to analyse the impact of the interruption [46]. In alignment with the policy context in Wuhan, we segmented the time series into three periods: the pre-pandemic period (Week 1, 2018 to Week 3, 2020), the lockdown period (Week 4 to Week 16, 2020), and normalised prevention and control period (Week 17, 2020 to Week 31, 2021). This segmentation was further supported by data on COVID-19 confirmed cases in Hubei Province, where 99.12% of the cases were identified during the lockdown period within the observation period[42]. Considering the seasonal patterns exhibited in respiratory disease incidence, the model incorporated calendar month indicators as covariates:

$$Y_t = \beta_0 + \beta_1 T_t + \beta_2 Period1_t + \beta_3 Period1_t \times T_t + \beta_4 Period2_t + \beta_5 Period2_t \times T_t + \beta_6 Month_t + \varepsilon_t$$

where Y_t represents the dependent variable, indicating the weekly admissions of patients with respiratory diseases per million population in week *t*. T_t is a continuous variable, representing the number of weeks elapsed since week 1, 2018. $Period1_t$ is a binary indicator coded as one for the lockdown weeks and zero for all other weeks. The first interaction term, $Period1_t \times T_t$, takes the value of zero during the pre-pandemic weeks and increments by one for each subsequent lockdown week. $Period2_t$ indicates the normalised prevention and control weeks and takes the value of one during these weeks. The second interaction term, $Period2_t \times T_t$, takes the value of zero before the normalised prevention and control period and increments by one in each subsequent week. $Month_t$ represents the calendar month indicator. β_0 stands for the intercept. β_1, β_3 and β_5 represent the observational period trend, the difference between the trend during the observational and lockdown period, and the difference between the trend during the observational and normalised prevention and control period, respectively. β_2 and β_4 are the intercepts at the time of lockdown and normalised prevention and control period, respectively. To account for autocorrelation, the error term ε_t was adjusted using the Newey-West standard error with three lags. The regression was performed separately for different visit types and disease types to explore potential heterogeneities.

For each disease type and visit type, we constructed pre-pandemic levels based on the average number of hospital visits per million population at the corresponding time between 2018 and 2019. If the factual estimates consistently exceed the pre-pandemic levels for three consecutive months, we consider the visits to have returned to pre-pandemic levels. We estimated the pandemic's influence on hospital visits by comparing the sum of weekly visits per million population from the factual estimates with the pre-pandemic levels during the lockdown period, normalised prevention and control period, and until hospital visits return to pre-pandemic levels. To quantify the pandemic's impact in 2021, we computed the ratio of the factual estimated total number of visits per million population in 2021 to the corresponding weeks in the pre-pandemic period. Additionally, we included counterfactual scenarios as a sensitivity check, where we rerun the linear model assuming no pandemic and extrapolate the pre-pandemic trend to assess the recovery of hospital visits.

3. Results

3.1. ITSA estimation and temporal trends in respiratory disease visits

Table 1 presents the estimations for the ITSA specification, adjusted for autocorrelation and seasonal trends. In 2018, there

Table 1
ITSA estimation on hospital visits per million population for respiratory diseases.

Time	Variables	Coefficient	95% conf. interval	P > |t|
Week 0, 2018	The initial level of weekly hospital visits (β_0)	1589	(1280, 1897)	0.000
Week 1, 2018 to Week 31, 2021	Weekly change rate during the observational period (β_1)	22	(17, 27)	0.000
Week 4, 2020	The intercept for the lockdown (β_2)	−904	(−1946, 138)	0.089
Week 4–16, 2020	Weekly change rate during the lockdown period ($\beta_1 + \beta_3$)	−188	(−307, −69)	0.001
Week 17, 2020	The intercept for the normalised control and prevention period (β_4)	−2422	(−2884,-1960)	0.000
Week 17, 2020 to Week 31, 2021	Weekly change rate during the normalised prevention and control period ($\beta_1 + \beta_5$)	18	(9, 26)	0.417

Notes: Parenthesis contains Newey-West-corrected confident interval. Controlled for month dummies and autocorrelation.

were 1589 weekly hospital visits related to respiratory diseases. Over the observational period, a weekly increase of 22 visits was observed. Upon initiating the lockdown, there was an immediate reduction of 904 visits. This decrease continued at a rate of 188 weekly visits during the lockdown. After the lockdown ended, there was an additional decrease of 2422 visits. In the subsequent normalised prevention and control phase, a gradual recovery was noted, characterised by a weekly increase of 18 visits.

To ascertain whether the impact of the pandemic was specific to respiratory diseases, we compared the weekly hospital visits for respiratory diseases, neoplasms, and intracranial haemorrhage from 2018 to 2021 (Fig. 1A–C). By employing the pre-pandemic level as a control, visits for both neoplasms and intracranial haemorrhage had returned to pre-pandemic levels by week 4 of 2021 (Table 2). However, respiratory diseases visits did not revert to pre-pandemic levels until week 12 of 2021 and consistently stayed below the thresholds set by the counterfactual scenario throughout the normalised prevention and control period. These findings suggest that while hospital visits for other diseases have normalised, respiratory diseases may still be experiencing the effects of the pandemic.

3.2. Trends and changes in respiratory disease visits categorised by visit type

To examine the trends in hospital visits for respiratory diseases, we further analysed the data by visit type (Fig. 2A–C). Prior to the pandemic, outpatient visits were increasing steadily, while inpatient and severe condition visits remained at relatively stable levels. The lockdown led to a substantial decrease in visits, with reductions of 7766 outpatient, 3531 inpatient, and 86 severe condition visits per million population (Table 3). In the subsequent normalised prevention and control period, outpatient visits returned back to pre-pandemic levels by week 3 of 2021, whereas inpatient and severe condition visits remained below pre-pandemic figures throughout the study period. In 2021, inpatient and severe condition visits stood at 46.7% and 80.6% of pre-pandemic levels, respectively. In contrast, outpatient visits in the same year rose to 22.2% above the pre-pandemic levels. These patterns, especially the drop in inpatient and severe condition visits during the prevention and control period, align with counterfactual scenarios, underscoring a persistent reduction in hosptial visits for respiratory diseases during the pandemic.

3.3. Trends and changes in respiratory disease visits by disease and visit types

To further understand the impact of the pandemic on specific respiratory diseases and visit types, we analysed weekly hospital visits, categorising them by disease and visit types (Fig. 2D–O). Prior to the pandemic, all subgroups exhibited seasonal fluctuations, with higher visits in winter. In the winter of 2020, there was only a modest increase in visits compared to previous years. Fig. 2G indicates a large increase in outpatient visits related to influenza and pneumonia during the lockdown period. Afterwards, all types of outpatient visits have returned to the pre-pandemic level no later than week 18 of 2021. Except for severe visits associated with influenza and pneumonia, inpatient and severe condition visits consistently remained below the pre-pandemic level and comparisons projected by the counterfactual scenarios. Among these subgroups, acute lower respiratory infections experienced the most substantial decrease in 2021, with inpatient and severe condition visits dropping to 76.1% and 74.3% of pre-pandemic levels, respectively (Table 4).

4. Discussion

This retrospective observational study has shed light on substantial changes in hospital visits for respiratory diseases per million population during the pandemic in Wuhan, China. Following a plunge for all the investigated diseases during the lockdown period, visits for control conditions rebounded to pre-pandemic levels in the later normalised prevention and control period, with visits for respiratory disease exhibiting a more sustained impact from the pandemic. Subgroup analyses revealed that inpatient and severe condition visits for respiratory disease remained reduced even after the lockdown was lifted. These findings hold implications for future outbreak preparedness, healthcare resource allocation, and respiratory disease prevention and management.

Our findings are in concordance with previous research, which has reported a significant decline in acute respiratory viral infections during the pandemic in various regions, including China [6,49–52], other Asian countries [8,11,34–36], North America [47,48], and Oceania [12,49–51]. Likewise, reductions in asthma and chronic obstructive pulmonary disease cases have been documented in China [17,25], Europe [46–56], the US [19,24,38] and other Asian countries [21,31,32,35–37] during the pandemic. The decrease in cases and hospitalisations has translated into decreased clinical burden and reduced mortality associated with non-COVID respiratory infections [52].

During the normal prevention and control period, life activities in Wuhan returned to pre-pandemic levels in various aspects, including traffic density [53], city temperature [54], tourism [55], and hospital visits for control conditions and respiratory outpatient visits as identified in our study. The decrease in inpatient and severe condition visits for respiratory diseases upon the return to normal daily life is likely a result of the wide and consistent mask-wearing, social distancing, and personal hygiene improvement [38,52,56]. These personal-level NPIs have effectively reduced the incidence of severe respiratory diseases. Although reductions in inpatient visits may be affected by hospital resouce allocation, this finding sheds light on the significance of public health campaigns stressing the importance of individual NPIs in reducing pathogen exposure and managing acute and chronic respiratory diseases. Furthermore, the reduction in inpatient and severe condition

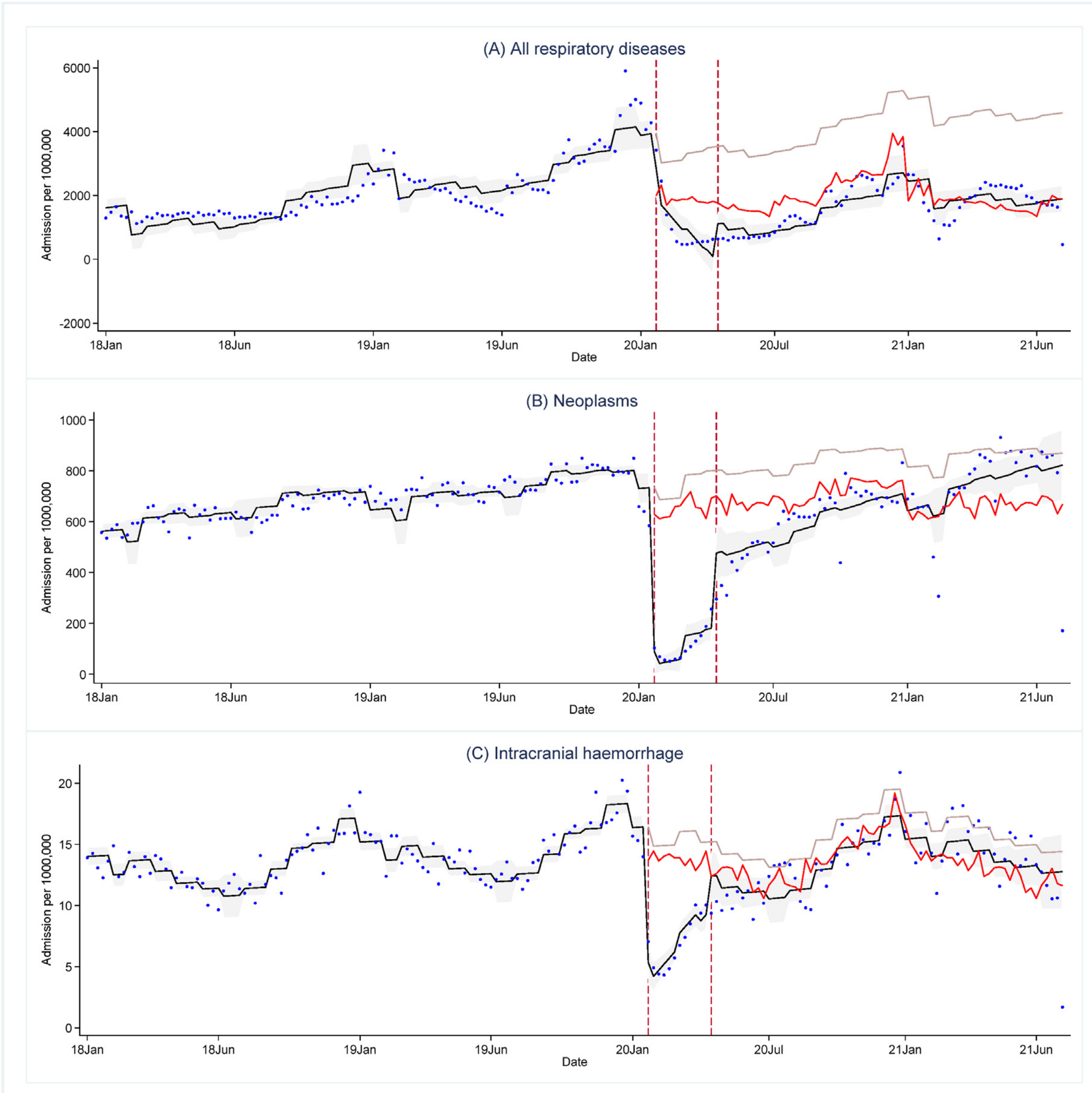

Fig. 1. Weekly hospital visits per million population in Wuhan between 2018 and 2021. *Notes:* Blue dots represent the observed values. Black lines represent the fitted values from the interrupted time series analysis model. Grey shades denote the 95% confidence interval of the fitted values. Red lines are the average number of hospital visits per million population at the corresponding time from 2018 to 2020. Sandy lines indicate the counterfactual scenarios assuming no COVID-19 pandemic. (A) represents the trend for hospital visits related to all respiratory diseases. (B) represents the trend for hospital visits related to neoplasms. (C) represents the trend for hospital visits related to intracranial haemorrhage.

Table 2
Model-based estimation for changes, recovery time, and impact.

	Lockdown period	Normalised prevention and control period			
	Estimated change in the number of hospital visits	Estimated change in the number of hospital visits	When returned to the pre-pandemic level	Estimated changes before returning to the pre-pandemic level	Pandemic's impact in 2021
All respiratory diseases	−11324	−21428	2021w12	−24941	1.079
Neoplasms	−6915	−1315	2021w4	−3909	1.131
Intracranial haemorrhage	−82	3	2021w4	−26	1.075

Notes: Changes in hospital visits are estimated by comparing the sum of weekly visits per million population from the factual estimates with the pre-pandemic levels during the lockdown period, the period of normalised prevention and control, and until hospital visits return to pre-pandemic levels. The pandemic's impact in 2021 is imputed by the ratio of the factual estimated total number of visits per million population in 2021 to the corresponding weeks in the pre-pandemic period. Severe is defined as visits requiring ventilation, intubation, or admission to an intensive care unit.

Notes: Blue dots represent the observed values. Black lines represent fitted values in the interrupted time series analysis model. Blue shades denote the 95% confidence interval of the fitted values. The red lines are the average hospital visits between 2018 and 2020. Sandy lines indicate the counterfactual scenarios assuming no COVID-19 pandemic. (A)-(C) represent the trend for respiratory disease-related hospital visits by visit type. (D)-(O) represent the trend for respiratory disease-related hospital visits by visit type and discharge diagnosis. Severe condition is defined as visits requiring ventilation, intubation, or admission to an intensive care unit

Fig. 2. Weekly hospital visits per million population in Wuhan between 2018 and 2021 across visit types and discharge diagnoses.

Table 3
Model-based estimation for changes, recovery time, and impact of respiratory diseases, categorised by visit types.

	Lockdown period	Normalised prevention and control period			
	Estimated change in the number of hospital visits	Estimated change in the number of hospital visits	When returned to the pre-pandemic level	Estimated changes before returning to the pre-pandemic level	Pandemic's impact in 2021
Outpatient	−7766	−8488	2021w3	−16817	1.222
Inpatient	−3531	−12799	n/a	n/a	0.467
Severe	−86	−253	n/a	n/a	0.806

Notes: Changes in hospital visits are estimated by comparing the sum of weekly visits per million population from the factual estimates with the pre-pandemic levels during the lockdown period, the period of normalised prevention and control, and until hospital visits return to pre-pandemic levels. The pandemic's impact in 2021 is imputed by the ratio of the factual estimated total number of visits per million population in 2021 to the corresponding weeks in the pre-pandemic period. Severe is defined as visits requiring ventilation, intubation, or admission to an intensive care unit. "n/a" indicates that the factual estimates did not exceed pre-pandemic levels for three consecutive months within the observational period.

Table 4
Model-based estimation for changes, recovery time, and impact characterised by disease and visit types.

	Lockdown period	Normalised prevention and control period			
	Estimated change in the number of hospital visits	Estimated change in the number of hospital visits	When returned to the pre-pandemic level	Estimated changes before returning to the pre-pandemic level	Pandemic's impact in 2021
Acute upper respiratory infections					
Outpatient	−6610	−17228	2021w18	−16426	0.953
Inpatient	−455	1396	n/a	n/a	0.379
Severe	−5	−16	n/a	n/a	0.452
Influenza and pneumonia					
Outpatient	1092	1574	2020w42	−116	2.626
Inpatient	−658	3575	n/a	n/a	0.584
Severe	−11	−107	2021w16	−98.085	0.919
Acute lower respiratory infections					
Outpatient	−1017	2721	2021w3	−1656	1.745
Inpatient	−1166	2431	n/a	n/a	0.239
Severe	−5	−16	n/a	n/a	0.257
Chronic lower respiratory diseases					
Outpatient	−1222	4229	2020w42	−395	1.673
Inpatient	−1217	2862	n/a	n/a	0.56
Severe	−64	−104	n/a	n/a	0.739

Notes: Changes in hospital visits are estimated by comparing the sum of weekly visits per million population from the factual estimates with the pre-pandemic levels during the lockdown period, the period of normalised prevention and control, and until hospital visits return to pre-pandemic levels. The pandemic's impact in 2021 is imputed by the ratio of the factual estimated total number of visits per million population in 2021 to the corresponding weeks in the pre-pandemic period. Severe is defined as visits requiring ventilation, intubation, or admission to an intensive care unit. "n/a" indicates that the factual estimates did not exceed pre-pandemic levels for three consecutive months within the observational period.

hospital visits provides an opportunity for healthcare systems to adapt and innovate, allowing for flexible allocation of healthcare resources and personnel in response to evolving healthcare challenges.

During the lockdown, community-level NPIs and government policies, particularly stay-at-home orders and travel restrictions [6,60] have impeded patients' access to healthcare services [57,58], primarily explaining the substantial decrease in hospital visits for all investigated diseases. Alongside the sustained impact of community and individual-level NPIs, the slow recovery during the normal prevention and control period might also be attributed to several factors, such as constrained healthcare resources [59–62], fear of COVID-19 [63–65] and financial constraints [66]. Additionally, it is notable that many individuals increasingly opted for remote consultations [68,69], regardless of primary care availability [67]. The sudden decrease and slow recovery in healthcare services during the pandemic may lead to delays and unresolved patient demand. These findings underscore the importance of proactive preparedness by healthcare sectors to effectively manage outbreak shocks while ensuring the continued provision of essential medical services [60]. Further, healthcare systems should consider bolstering their resilience to ensure rapid adaptability to diverse healthcare needs in the ongoing presence of the pandemics.

Our study has several limitations. Firstly, the data we used, derived from health insurance records, may be subject to errors or omissions. For instance, during the lockdown period, we observed a notable increase in visits related to acute respiratory diseases, after excluding COVID-19-related diagnoses. This could be attributed to the misclassification of other diagnostic terms within this category for suspected, probable or confirmed COVID-19 cases. Moreover, the accuracy of outpatient diagnoses may be compromised, as it is challenging to identify specific pathogens causing respiratory diseases and distinguish between viral and bacterial infections. Secondly, as a retrospective observational study, we cannot rule out alternative explanations for the sustained reduction in respiratory disease-related hospital visits. Future research could assess the causal influence of NPI measures like mask-wearing on respiratory disease incidence and study the effects of dynamic hospital resource allocation on hospital visits.

In conclusion, this research adds to the understanding of the collateral effects of the COVID-19 pandemic on respiratory diseases. This observational study highlights the substantial and lasting reduction in hospital inpatient and severe condition visits related to respiratory diseases in the aftermath of the COVID-19 pandemic. While these reductions cannot be attributed to any single factor, the implementation of NPIs emerges as a crucial contributor in mitigating acute and chronic non-COVID respiratory disease. This study underlines that healthcare systems should consider proactive preparedness to effectively manage outbreak shocks and enhance resilience to adapt to diverse and changing healthcare needs during ongoing pandemics.

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Declaration of interests

Guanqiao Li is an editorial board member, and Wannian Liang is the editor-in-chief for Global Transitions. They were not involved in the editorial review or the decision to publish this article. All authors declare that there are no competing interests.

CRediT authorship contribution statement

Xuemin Zhu: Formal analysis, Investigation, Methodology, Validation, Writing – original draft, Writing – review & editing. **Yuehua Liu:** Conceptualization, Data curation, Investigation, Methodology, Project administration, Resources, Software, Supervision. **Wei Dai:** Data curation, Resources, Supervision. **Wannian Liang:** Conceptualization, Project administration, Resources, Supervision, Writing – review & editing. **Guanqiao Li:** Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Resources, Validation, Writing – review & editing.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used OpenAI in order to improve the language and readability. After using this tool/service, the authors reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.glt.2023.12.001.

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