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Widening rural–urban gap in life expectancy in China since COVID-19

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ABSTRACT

Introduction Disparities in life expectancy between rural and urban populations are well established but how it varies with epidemics and pandemics remains poorly understood. We aimed to quantify the rural–urban differences in the mortality burden of COVID-19 and to contribute to understanding the disparity trends in life expectancy between 1987 and 2021 in China.

Methods We used monthly death counts from death registration systems. Rural–urban gap estimation and decomposition were carried out using period life tables to calculate life expectancy, the Arriaga decomposition technique to break down into age-specific and cause-specific mortality, and the Lee-Carter forecasts to estimate the expected gap.

Results The rural–urban gap increased to 22.7 months (95% credible interval (CI) 19.6 to 25.8) in 2020 and further to 23.7 months (95% CI 19.6 to 26.7) in 2021, and was larger than expected under the continuation of the prepandemic trends. Compared with that in the recent 2003 SARS-CoV-2 epidemic and the 2009 influenza epidemic, excess rural–urban gaps in the COVID-19 pandemic changed from urban disadvantage to rural disadvantage, and the contributions shifted toward old age groups and circulatory diseases. Variations in the rural–urban gap since 1987 were positively correlated with the rural–urban disparity in public health expenditures, especially among ages <60 (p values <0.005).

Conclusions Our findings identified a widening rural–urban gap in life expectancy since COVID-19, and a shifting trend towards old ages and circulatory diseases, disrupting the diminishing trend of the gap over 35 years. The findings highlight the unequal impact of the pandemic on different communities in terms of mortality burdens.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Disparities in life expectancy between rural and urban populations are well established.
⇒ Little is known about the influence of the COVID-19 pandemic on the difference, especially when compared with other epidemics.

WHAT THIS STUDY ADDS

⇒ Compared with the counterfactual scenario would the prepandemic trends continue, the rural–urban gap increased considerably during the pandemic.
⇒ Excess rural–urban gaps have changed from urban disadvantage in SARS-CoV-2 and influenza epidemics to rural disadvantage during the COVID-19 pandemic, and the death toll shifted to older ages and circulatory diseases.
⇒ Variations in the rural–urban gap over 35 years were positively correlated with the rural–urban disparity in public health expenditures, especially among ages <60.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The pandemic has unequally affected different communities in terms of life expectancies, especially the elderly.
⇒ Tailored epidemic response plans are needed to address vulnerabilities specific to local areas and to reduce the differences in the impact of epidemics between rural and urban areas.

INTRODUCTION

Disparities in life expectancy between rural and urban populations are well established but how it varies with epidemics and pandemics remains poorly understood.[1 2] Epidemics could disproportionally affect the populations of urban and rural areas, with urban populations having high population density and interconnection that facilitate the transmission of diseases,[3 4] and rural areas having minimal pandemic preparedness, persisting healthcare challenges in health infrastructure and literacy, and high prevalence of pre-existing comorbidities that may amplify the effect of the disease.[5–8] Evidence from population-based studies suggests that rural populations experienced more severe negative impacts of the COVID-19 pandemic on unemployment, economic outlook, life satisfaction and mental health.[9] However, many of these differences correlate with the differences in age structure between rural and urban populations. Little is known about the influence of the COVID-19 pandemic on age-standardised life expectancy between the two populations, especially when compared with other epidemics.

Not only does this lack limit a fuller understanding of the impact of the pandemic itself, but also obscures the need for more accurate and evidenced-based progress towards eliminating health disparities and increasing longevity for all.[10 11] Health disparity between rural and urban populations is widespread in China and is particularly prominent in years before poverty alleviation campaigns and national health reforms.[12–15] In China, rural populations tend to have higher levels of poverty,[16] far more limited access to healthcare[17] and a larger medical financial burden relative to urban populations.[18] High dependence on out-of-pocket payments, which is the direct medical costs borne by households,[15] had exacerbated inequity.[19] Although the percentage of out-of-pocket payments in total health expenditure declined from 60.0% in 2001 to 27.6% in 2021,[20] the figures fail to show vast differences between rural and urban groups.[21] More importantly, it remains unknown how these variations in health expenditures among geographical groups are related to changes in life expectancy trends over time.

We examine the rural–urban gap in life expectancy in China since the COVID-19 pandemic, using data on cause-specific mortality from China's National Health Commission (CNHC) death registration systems.[22] We estimate the observed and the counterfactual rural–urban gap in life expectancy, with the former showing the observed difference and the latter indicating the difference in the counterfactual scenario had prepandemic trends remained. We compare the magnitude of the excess rural–urban gap, defined as the difference between observed and counterfactual gaps, with those during the recent SARS epidemic in 2003 and the influenza epidemic in 2009. Using decomposition techniques, we describe which age group and to what extent different chronic diseases contributed to trends in the rural–urban gap across these epidemics. We further investigate associations between the rural–urban gap in public health expenditure since 1987. We report all the results for females, males and the total population. Our results quantify the differences in the mortality burden of COVID-19 between rural and urban populations and contribute to understanding the disparity trends in life expectancy over the past 35 years in China.

METHODS

Data

Monthly death counts for the years 1987–2021 were sourced from CNHC death registration systems. These monthly counts were aggregated into annual counts and categorised into five-age groups from 0 to 85+ (online supplemental eFigure 2). Separate tables of annual counts were created for males, females and the total population in rural and urban residences. Annual mortality estimates by age and rural–urban residence were calculated as the annual death account divided by the mid-year population estimates, sourced from the CNHC population registration system. To attribute changes in life expectancy to changes in mortality from deaths registered as due to different causes (including infection and parasitic diseases, respiratory diseases, circulatory diseases and other diseases), we sourced age-specific, sex-specific and residence-specific death counts due to different causes using the codes of the international classification disease, with 9th and 10th versions before and after 2002, respectively.

Rural–urban gap estimation and decomposition

We calculated life expectancy from 1987 to 2021 using annual period life tables via standard demographic techniques[23] for rural and urban residences separately. All-age rural and urban gaps were estimated as the life expectancies of the urban population minus those of the rural population. Using the Arriaga decomposition technique,[24] we attributed annual changes in the gaps to changes in age-specific mortality, and attributed annual gaps to all-cause mortality. Additionally, we calculated excess rural–urban gaps for 2003, 2010, 2020 and 2021 defined as observed gap minus expected gap based on a continuation of outbreak trends. We estimated the expected rural–urban gap using the Lee-Carter forecasts[25] of age-specific and sex-specific mortality over the 5 years before the start of the outbreaks. We performed an Arriaga decomposition of the rural–urban gaps in these years (ie, 2003, 2010, 2020 and 2021) into age-specific and cause-specific contributions for four causes, infection and parasitic diseases, respiratory diseases, circulatory diseases, and other diseases. In addition, we conducted a formal cause-specific decomposition of the change in the rural–urban life expectancy gap since 1987. As a sensitivity analysis, we recalculated the decomposition using the contour method.[26] 95% credible intervals (CIs) around our gap estimates, gap changes, excess gap and gap decompositions were derived from 100 Poisson simulations of the annual death counts.

Association of rural–urban gap with medical expenses

Data on medical expenses were collected from China Health Statistics Yearbook.[20] The public expenditure on health as a percentage of total expenditure shows the weight of public spending on health within the total spending. It was calculated as public spending (including government and collective spending) in health divided by the total spending in health, for rural and urban populations respectively. For each year, we calculated the public percentages separately for four age groups 0–19, 20–59, 60–79 and 80+. Annual rural–urban gaps were regressed on the public percentages and year for ages <60 and ages 60+ separately.

Data on health expenditure were missing in the years 1987–1989 and 2020–2021. Data on total health expenditure were missing in the years 1987–1989 and 2016–2021. Missing values were imputed using the predicted values from polynormal regression with year as the dependent variable. The regression was conducted separately for rural and urban populations, public spending and total spending. The best model was selected based on the methods of analysis of variance.

Table 1 Rural–urban gap during the pandemic

Year	Age group	Observed mean	Observed 95% CI	Counterfactual mean	Counterfactual 95% CI
2020	0–19	+0.8	(+0.7 to +0.9)	+1.1	(+1.0 to +1.4)
2020	20–59	+7.2	(+6.7 to +7.5)	+6.7	(+5.9 to +7.4)
2020	60–79	+8.9	(+7.8 to +10.1)	+5.9	(+4.6 to +7.4)
2020	80+	+5.8	(+2.8 to +8.6)	−6.5	(−9.2 to 2.9)
2020	Total	+22.7	(+19.6 to +25.8)	+7.2	(+3.2 to +11.5)
2021	0–19	+1.2	(+1.1 to +1.3)	+1.4	(+1.2 to +1.6)
2021	20–59	+8.9	(+8.4 to +9.3)	+6.2	(+5.3 to +7.1)
2021	60–79	+9.3	(+7.8 to +10.7)	+5.6	(+4.0 to +7.4)
2021	80+	+4.2	(+0.5 to +7.4)	−6.2	(−9.4 to 2.1)
2021	Total	+23.7	(+19.6 to +26.7)	+6.9	(+2.2 to +12.1)

Rural–urban gap is defined as the life expectancies of the urban population minus those of the rural population. + indicates the rural population has shorter life expectancies, − indicates the urban population has shorter life expectancies.
CI, credible interval.

Patient and public involvement

Our study involved the analysis of anonymised secondary data from the death registration systems maintained by CNHC. The data were analysed in an aggregate manner. As a result, it was not appropriate or possible to involve patients or the public in the design, or conduct, or reporting, or dissemination plans of our research.

RESULTS

The rural–urban gap in life expectancy during the pandemic

Unlike the USA and most European countries,[27 28] China saw increased life expectancy during the pandemic, but the gap between rural and urban populations has grown. Between 2019 and 2020, the life expectancy of rural populations of China increased by 10.5 months (95% CI 7.8 to 13.6), and that of urban populations increased by 14.8 months (95% CI 11.3 to 17.8) (online supplemental extended data table 1), leading to a wider rural–urban gap of 22.7 months (95% CI 19.6 to 25.8) in 2020 (table 1). This rural disadvantage multiplied in 2019 when the SARS-CoV-2 viruses started circulating. Compounding the 2020 fall behinds, the life expectancy of rural populations climbed further throughout 2021. Still, the increase was slower than that of urban populations (rural, 8.4 months, 95% CI 5.6 to 11.9 vs urban, 9.7 months, 95% CI 6.1 to 12.8), leading to an even wider gap of 23.7 months (95% CI 19.6 to 26.7) in 2021.

All age groups of rural populations experienced a disadvantage in life expectancy compared with their urban partners in 2020 (figure 1), indicating a relatively worsening mortality across all rural age groups. In 2021, the increasing gap trend shifted towards younger age groups. Rural people aged below 80 had aggravating disadvantages in life expectancy compared with their urban partners, whereas those above 80 bounced back from falling behind. Of these rural age groups that experienced magnified gaps in 2021, people aged 60–79 contributed most to the increase in the gap (9.3 months, 95% CI 7.8 to 10.7).

The rural–urban gaps were more prominent than expected under the continuation of the prepandemic trends (figure 1). Rural people above 80 suffered substantially larger life expectancy loss during the pandemic than their urban partners (5.8 months in 2020, 95% CI 2.8 to 8.6; and 4.2 months in 2021, 95% CI 0.5 to 7.4, table 1). They could instead have a considerable advantage compared with their urban partners would the pandemic not occur (−6.5 months in 2020, 95% CI −9.2 to −2.9; and −6.2 months, 95% CI −9.4 to −2.1 in 2021). Only rural infants and children (aged 0–19) would experience a slightly larger disadvantage under the counterfactual scenario. In a sensitivity analysis with the rural–urban gap in mortality rates investigated, we also observed that the rural–urban gap in mortality improvement rates was larger than expected in each age group, similar to the rural–urban gap in life expectancy (online supplemental eFigure 1).

Comparison with recent epidemics

Insights gleaned from previous epidemics that rural populations had a relatively lower burden of epidemics than urban populations[29 30] were changed by the COVID-19 pandemic. The excess rural–urban gap during the pandemic, defined as the observed gap minus the expected gap under the counterfactual scenarios without epidemics, differed greatly from that during the previous epidemics.

Compared with the counterfactual scenarios without epidemics, rural populations showed lower life expectancy loss or even increased life expectancy during the SARS and influenza epidemics (online supplemental extended data table 2). In contrast, urban populations showed substantial life expectancy loss, adding to negative rural–urban gaps after the two epidemics (figure 2). The excess rural–urban gaps were −47.7 months (95% CI

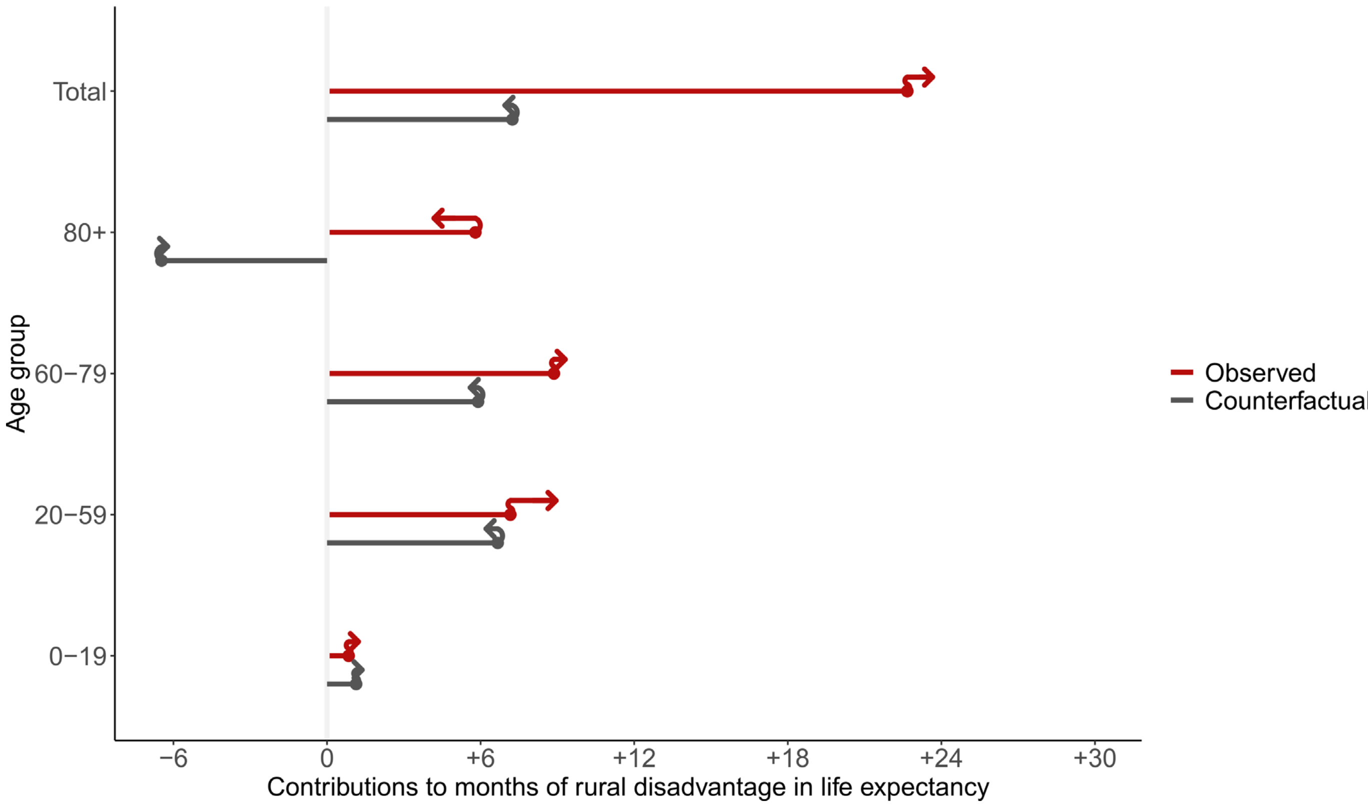

Figure 1 Rural–urban gap during the pandemic. The position of the point indicates the contribution of mortality change in a given age group to the rural–urban gap, defined as the life expectancy of urban populations minus that of rural populations, in 2020. The position of the arrowhead indicates the contributions in 2021. Red lines represent the contributions in the real-world scenario, and the grey lines the contributions in the counterfactual scenarios without pandemics. Negative contributions suggest a diminished rural–urban gap in the age group.

−57.4 to −47.4) and −27.0 months (95% CI −32.4 to −21.6) during the SARS-CoV-2 epidemic and influenza epidemic for females. Compared with those of females, the magnitude of the excess gap for males was smaller (−35.8 months, 95% CI −46.6 to −39.8) during the SARS-CoV-2 epidemic but slightly larger (−32.8 months, 95% CI −36.4 to −28.7) during the influenza epidemic.

However, during the COVID-19 pandemic, the observed rural–urban gaps were larger than expected, and positive excess rural–urban gaps manifested (figure 2). Although rural populations experienced no life loss (0.3 months, 95% CI −3.4 to 4.1) in 2020, the urban populations saw a greater life expectancy gain (16.5 months, 95% CI 12.4 to 20.6). The magnitude of the excess gap thereby was 20.2 months (95% CI 12.9 to 26.3) in 2020 and further increased to 22.1 months (95% CI 15.3 to 29.5) in 2021 for females, and was 13.1 months (95% CI 8.4 to 17.8) in 2020 and increased into 14.0 months (95% CI 8.2 to 18.8) for males (online supplemental extended data table 3), suggesting that the COVID-19 pandemic had magnified the rural–urban gap.

Moreover, from the SARS epidemic to the influenza epidemic and further into the COVID-19 pandemic, the impact of the outbreaks shifted towards old age groups and circulatory diseases (figure 2). In the SARS epidemics, all age groups were affected; in the influenza epidemics, however, people aged below 20 were not significantly affected; and in the COVID-19 pandemic, only people aged above 60 were affected, especially those aged above 80. Also, the impact of the outbreaks shifted from directly related diseases, the infectious and parasite, and respiratory diseases, to circulatory diseases. Deaths due to circulatory and respiratory diseases explained most of the impact of the outbreaks. Deaths due to circulatory diseases had an increasing influence in recent epidemics, whereas deaths due to respiratory and infectious, and parasite diseases had a diminishing role. These conclusions hold for both females and males.

Finally, the extra gap varied more highly for females than males, suggesting that the rural–urban gap for females was more affected by epidemics and the corresponding public health responses.

The rural–urban gap by sex and cause of death since 1987

The recent trend of diminishing rural–urban gaps[2] was disrupted by the pandemic. Rural populations had substantially shorter life expectancies than their urban partners until recent years. The years 2014–2018 were exceptions where the gap was substantially narrowed down, especially for females (figure 3, online supplemental extended data table 4). However, our results show that this recent narrowing down gap stretched during the pandemic. Since 2019, rural females and males again experienced significantly shorter life expectancy than

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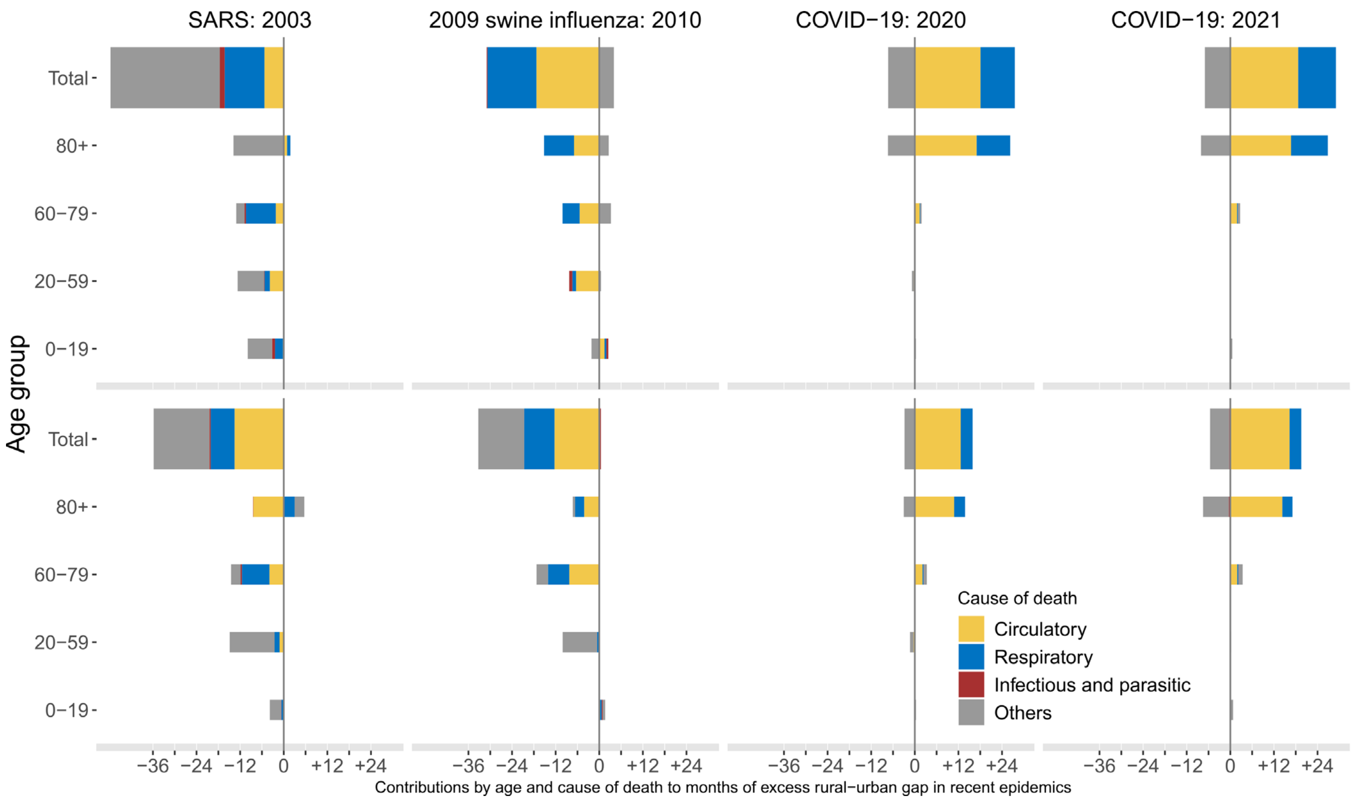

Figure 2 Contributions by age and cause of death to months of the excess rural–urban gap in recent epidemics. The excess rural–urban gap is defined as the gap in the real-world scenario minus that under the counterfactual scenario without pandemics.

their urban partners, with the gap achieving 21.2 months (95% CI 17.4 to 26.1) for females and 24.9 months (95% CI 21.9 to 27.0) for males in 2021 (online supplemental extended data table 4).

Deaths due to respiratory disease explained more than half of the rural–urban gap before 2007 for both females and males (figure 3). After that year, mortality due to circulatory disease played a comparable role as that of respiratory disease and then contributed most to the rural–urban gap since 2009. The years 1987–1999 were exceptions where deaths due to circulatory disease contributed negatively to the rural disadvantage for females and males. Deaths due to respiratory disease have always contributed to compounding the rural disadvantage since 1987; similarly, deaths due to infectious and parasitic diseases mostly contributed positively to the rural–urban gap, although the contribution was much smaller than that due to respiratory disease. The contributions of both diseases have been diminished in recent years but magnified during the pandemic.

The changes in the rural–urban gap by sex and cause of death during 2019–2020, 2020–2021

During the period 2019–2020, mortality due to circulatory disease contributed most to the changes in the rural–urban gaps, and due to respiratory disease contributed second most. This is true for both females and males (figure 4). However, during the period 2020–2021, deaths due to circulatory and respiratory diseases contributed negatively to the changes in the rural–urban gaps. These findings align with the recent trend of the rural–urban gap shown in figure 3. Our sensitivity analysis using the contour-decomposition method resulted in similar conclusions to the additive decomposition in our main analysis (see online supplemental eFigure 3).

The rural–urban gap in life expectancy by the gap in public health expenditure

Larger rural–urban gaps in public health expenditure were associated with larger gaps in life expectancy among ages <60 (1.55 increase in months of life expectancy by 1 percentage increase in the gap, p values <0.005; 95% CI 0.53 to 2.57) and were not statistically associated with gaps in life expectancy among ages 60+ (0.84 increase in months of life expectancy by 1 percentage increase in the gap, p values=0.711; 95% CI −3.65 to 5.33).

DISCUSSIONS

The COVID-19 pandemic has had wide-reaching impacts on the rural–urban gap in life expectancy. The recent trend of diminishing rural–urban gaps[2] was disrupted by the pandemic. Compared with the counterfactual scenario would the prepandemic trends continue, the rural–urban gap increased considerably during the pandemic, leading to positive excess rural–urban gaps in life expectancy. The direction of excess rural–urban gaps has changed from urban disadvantage in SARS-CoV-2

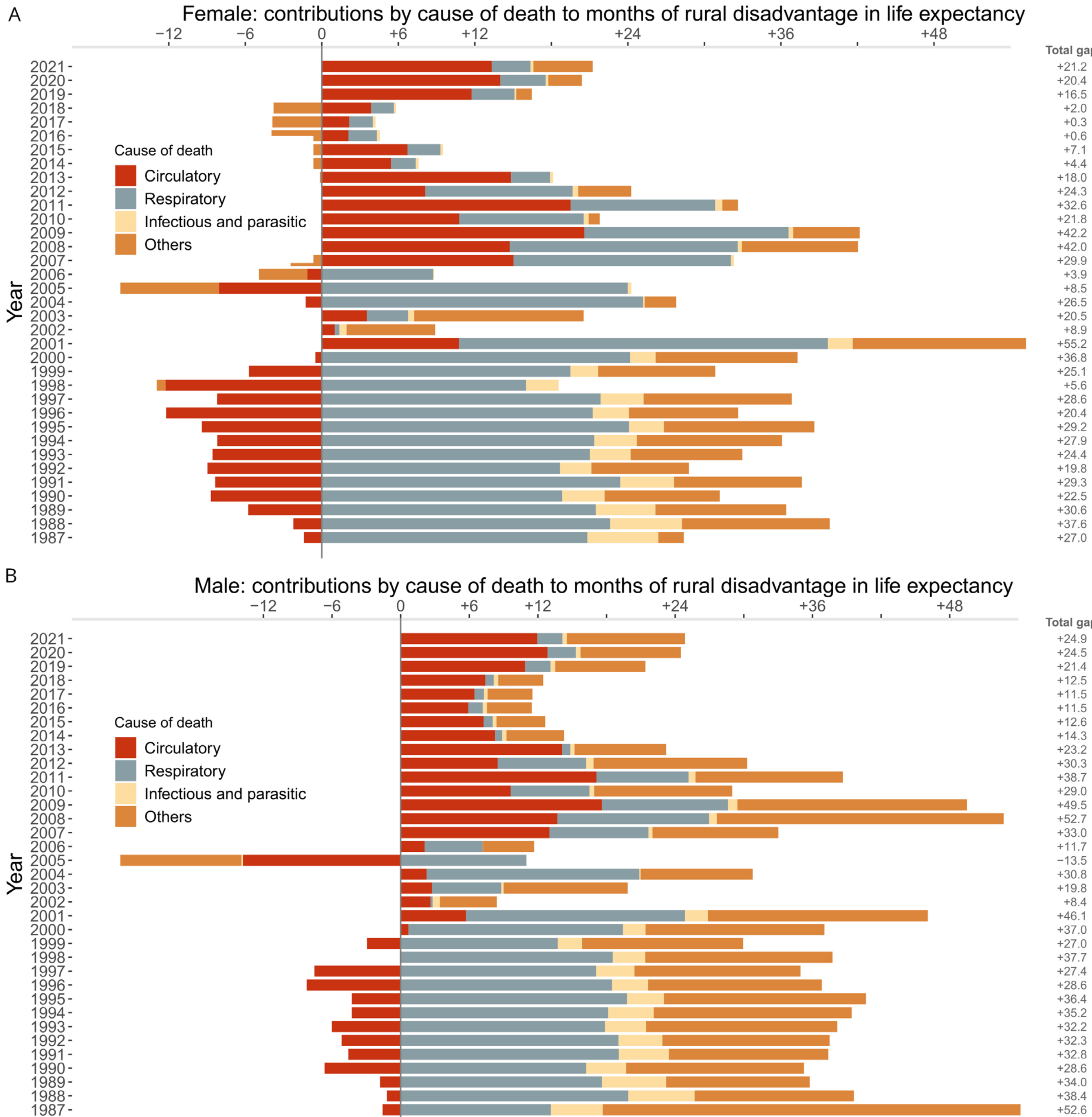

Figure 3 Contributions by cause of death to months of rural–urban gaps in life expectancy since 1987 by sex. A, Female. B, Male. The total gap marks the overall gap across all diseases.

and influenza epidemics to rural disadvantage during the COVID-19 pandemic, and the death toll shifted to older ages and circulatory diseases. Variations in the rural–urban gap over 35 years were positively correlated with the rural–urban disparity in public health expenditures, especially among ages <60.

Rural communities—which make up 14% of China's 1.4 billion people living outside urban areas[31]—are among the nation's most vulnerable populations and may have low resilience to the effects of large public health shock. The COVID-19 pandemic has considerably increased rural–urban life expectancy gaps across all age groups, with a more significant impact among old adults aged above 80. Previous studies have noted that urban populations have a disadvantage in life expectancy.[32 33] Our study confirms this finding for old adults aged above 80 in counterfactual scenarios without epidemics. One possible reason for this is that the mortality rates for older adults in rural areas may be under-reported.[34 35] While, it is also possible that adults in urban areas are less likely to

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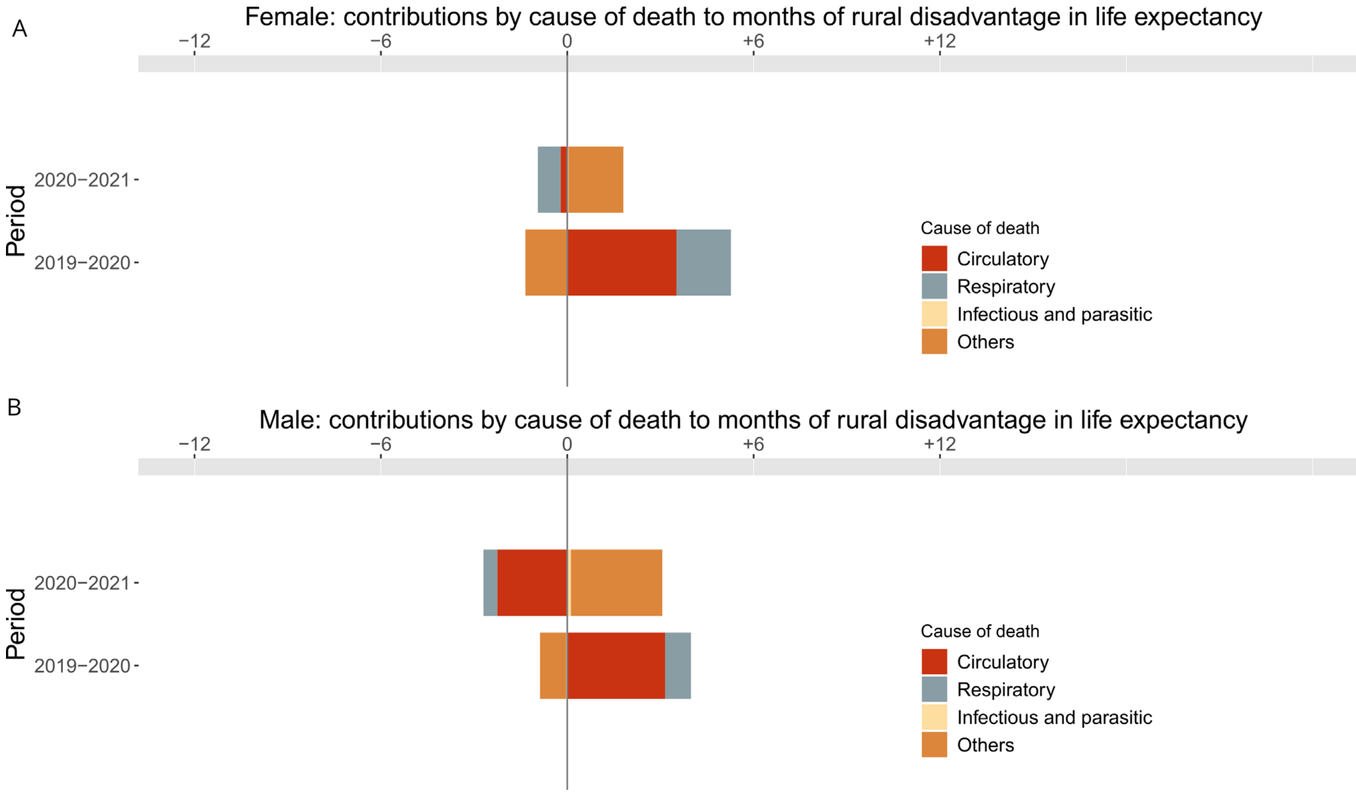

Figure 4 Contributions by cause of death to changes in months of rural–urban gaps in life expectancy since 1987 by sex. A, Female. B, Male.

have healthy lifestyles and meet physical activity recommendations compared with their rural counterparts.[32 33] However, the pandemic has reversed this trend, with rural areas now observing a higher mortality burden than urban areas. This has resulted in a significant increase in the gap between rural and urban life expectancy in 2020 and 2021, especially for old adults. The findings highlight the unequal impact of the pandemic on different communities in terms of mortality burdens, particularly for old adults.

Rural and urban populations had a distinctive pattern of mortality development in the recent epidemics. In the SARS and influenza epidemics, the rural–urban gap shrank, resulting in a negative excess rural–urban gap, defined as the difference between the actual and counterfactual scenarios without the epidemics. However, during the COVID-19 pandemic, the gap widened, resulting in a positive difference. This change could be attributed to the varying risks of health shocks between rural and urban populations. Although the risks of large outbreaks in rural areas could be lower than those of urban areas due to the lower population mobility in rural areas, health accessibility and capacity are inferior in rural areas than those in urban areas.[9 31] In small and moderate health shocks, the health capacity is sufficient and thus the magnitude of population mobility dominates the mortality burdens through affecting sizes of infections; while in larger outbreaks, health access and capacity are likely to be the bottleneck in determining the mortality burdens. In particular, older adults are more likely to be affected by the shortfall in health capacity. Notably, the age pattern of the excess rural–urban gap shifted to older ages in the COVID-19 pandemic. As such, it is critical to understand susceptibilities and vulnerabilities ahead of time to allow policymakers and stakeholders to plan and allocate health resources accordingly. Pandemic response plans need to address vulnerabilities that are tailored to local areas.[36]

Recent years (prior to the COVID-19 pandemic) have seen rapid catch-up life expectancy convergence between rural and urban populations. The diminishing gap could be related to improved living conditions and health insurance coverage in the rural area. However, the COVID-19 pandemic has disrupted the trend. Low engagement in COVID-19-related preventive health behaviours for rural residents may help to exacerbate existing disparities in health access and thus contribute to the mortality for rural Chinese,[37] but further investigation is needed. It remains to be seen whether the rural–urban gap will continue to be increasing, after the release of the COVID-19-related restrictions.

Growing public health expenditure disparities in China across urban and rural areas can intensify health inequalities already thought to exist. But studies that have attempted to quantify these associations are modest in number. Although researchers have reported an urban advantage, they have less frequently studied the mechanisms accounting for this advantage.[35] We have associated the variations in public health expenditure trends among rural and urban groups over time with changes in the magnitude of rural–urban gaps in life expectancy. Of note, China ranked 188th among 191 member states in the equality of financial access to health, according to the WHO.[19] Our findings suggest that this inequality in health access is closely related to mortality and calls for China's implementation of integrated rural and urban public health systems to address the inequalities in healthcare resource allocation and distribution.[15]

To properly interpret our findings, it is important to note that the rural–urban difference need not reflect the causal effects of living in a particular area and may be driven by differences in the characteristics of the residents of each area. Second, death numbers could be under-reported particularly in rural areas,[35 38 39] which might lead to biased estimates of the impact of COVID-19 and other epidemics if the under-reporting varies greatly from what is typically observed without these epidemics. Furthermore, the positive correlation between rural–urban differences in public health expenditure and the rural–urban gap in life expectancy should not be interpreted as causal effects of increased differences in public health expenditure because the public health expenditure is correlated with other attributes (eg, health behaviour) that affect mortality.[9] Although the correlational analysis in this study cannot establish causal mechanisms, it is a step towards determining which theories for disparities in longevity deserve further consideration. In addition, we focused on the rural–urban gap in life expectancy and health expenditure for long-term residents who have lived in local areas for over 6 months, who may be affected by in-immigration and urbanisation's spillover effects.

In sum, our findings identified a widening rural–urban gap in life expectancy since COVID-19, which disrupted the diminishing trend of the gap over 35 years. The age pattern of the excess rural–urban gap has changed notably across recent epidemics. In 2020 and 2021, the gap in the death toll shifted to older ages. Our investigation suggests that the health disparity between rural and urban populations may be contributing to this trend.

Contributors SH and XZ designed research. BS, YZ and CC collected the data. SH performed analysis. SH and BS wrote the manuscript. XZ made critical revisions. All authors approved the final manuscript as submitted. SH serves as the guarantor and accepts full responsibility for the finished work and/or the conduct of the study, had access to the data, and controlled the decision to publish.

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Competing interests None declared.

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Patient consent for publication Not applicable.

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