Zhu et al. BMC Public Health (2025) 25:951
https://doi.org/10.1186/s12889-025-22140-5

BMC Public Health

RESEARCH

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Investigating the relationship between social deprivation and health outcomes in China: using spatial regression analysis approach

Introduction

Health inequality is a topical topic of international concern [1, 2]. China is the largest developing country, and health inequality still exists. Despite significant breakthroughs in China's level of medical services, the level of health welfare among residents still diverges between urban and rural areas, with urban dwellers taking the lead [3]. To reduce this health welfare gap, the *Healthy China Initiative (2019–2030)* was launched by the Chinese government in 2019, which explicitly proposes to achieve basic health equality.

The main factors affecting health equity can be summarized into two aspects. First is income inequality. Economic status is positively correlated with health levels in both developed countries and developing countries [4, 5]. Second, social inequality must be considered [6]. Some potential social determinants, such as housing environment, immigration [7], education [8], and health literacy, impact the health level of the population. Therefore, the concept of "social deprivation" has been introduced in recent years academically to assess how social factors affect health outcomes.

"Social deprivation" describes the condition where individuals or groups entirely lack, or do not possess sufficient living conditions due to unfair treatment [9]. Empirical research has recognized that social deprivation has a crucial impact on health outcomes [10, 11]. Chinese scholars have also explored the relationship between social deprivation and health outcomes. In China, research has shown a close correlation between social deprivation and non-communicable chronic diseases [12]. Researchers found spatial association between type 2 diabetes prevalence and neighbourhood deprivation in Zhejiang, China [13]. Scholars further propose that social deprivation in rural areas of China in 2010 may impact public health, and this impact exhibits spatial dependence [14].

However, research on the relationship between social deprivation and health outcomes is inadequate in China. On the one hand, compared with foreign scholar's research on the relationship between social deprivation and health, recent studies on social deprivation in China are mostly limited to specific provinces or cities, and nationwide studies are relatively scarce. On the other hand, previous studies may be inapplicable to explain the current relationship between social deprivation and health outcomes in China. It is worth noting that with the improvement of urbanization levels in China, by 2020, the permanent urbanization rate reached 63.89%. Accompanied by large-scale urbanization, a large number of rural residents migrated to cities, enjoying many advantages brought about by urbanization [15], such as more opportunities to access education, work, and healthcare, which gradually narrows the living standard gap between urban and rural areas. And it has been shown that the level of urbanization can have a significant negative impact on public health outcomes [16]. Consequently, it is necessary to provide evidence of whether social deprivation is changing in China and whether the association between social deprivation and public health outcomes has changed.

The study puts the following questions: more than a decade has passed, compared to studies mainly concentrated in rural areas ten years ago, have nationwide social deprivation situations, including cities and rural areas, changed? Has its impact on health intensified? Does the relationship with health still exhibit spatial dependence? Is there mutual influence between adjacent areas?

Based on these questions, this paper aims to conduct a deep analysis of the relationship between the health status of populations in 31 provinces and autonomous regions in China and social deprivation using the latest census data. Firstly, it will assess the state of social deprivation in China and explore the spatial distribution of social deprivation in 31 provinces. Secondly, through the spatial regression model, quantify the relationship between social deprivation and the health of the population in each province, and analyze the impact of social deprivation on population health.

Literature review

Concept of social deprivation

"Social deprivation" is defined as the obstacles and limitations individuals encounter in achieving a high-quality life when they fall into disadvantageous positions in domains such as material resources, living environment, educational opportunities, employment prospects, and community services [17]. This concept can be divided into two categories: absolute deprivation and relative deprivation.

Absolute deprivation refers to the deprivation individuals experience due to lack or loss of certain resource(s) necessary for basic survival needs (such as food, clothing, and shelter). Absolute social deprivation reveals the multiple disadvantages of material resources and quality of life, which are significant factors leading to poverty. Poverty is inherently connected to the concept of deprivation. Poverty caused by lack of material resources is unidimensional, but deprivation is multidimensional and a reflection of poverty [18]. With the deepening of poverty governance research, it has been a dominant trend to shift the poverty perspective from a single dimension of income poverty to a multi-dimensional deprivation perspective. The approach of using multidimensional social deprivation to identify relative poverty has been widely used.

In China's academic environment, the application of absolute social deprivation is widespread. It plays a key role in discussing socially concerned issues like land loss of farmers [19], medical security for the poor [20], and human resource allocation in healthcare institutions [21]. Now, Chinese scholars pay more attention to the study of relative poverty based on multidimensional deprivation, such as the identification of relative poverty and the factors affecting poverty [22, 23], the study of the effect of medical insurance in reducing poverty [24], and the mechanism and path of social factors on poverty reduction [25, 26].

In contrast, relative deprivation focuses more on revealing the psychological gap and resulting sense of deprivation generated when comparing oneself with those who are socio-economically superior [27]. It can be observed that while absolute deprivation emphasizes the objective degree of deprivation of material and resources, relative deprivation highlights individuals' sense of dissatisfaction and deprivation on an emotional level.

In this paper, absolute deprivation is chosen as the research tool to deeply explore how the deprivation of material conditions and social resources impacts public health.

Measurement of social deprivation

Currently, there is no standardized indicator for measuring social deprivation, as well as no widely accepted and used evaluation system exists. These indicators usually present different characteristics influenced by the characteristics of the research area itself. For instance, Thompson's social deprivation index includes family activities, social support and integration, social creation, and education [9]. In 2000, British scholars constructed a more comprehensive social deprivation index, including income, employment, health deprivation, education, housing, and service barriers [28]. In Boston, a social deprivation index was established that includes neighborhood deprivation level, income, education, ethnicity, marital status, age, and fertility conditions [29]. Similarly, the multiple social deprivation index of Auckland, New Zealand, has achieved notable success. This index covers employment, income, crime, housing, health, education, and geographic access [30]. China also borrows foreign methods of measuring social deprivation and, based on its national conditions, carries out in-depth exploration of domestic social deprivation evaluation. In Chinese cities, the social deprivation index is measured from five areas: income, education, employment, housing, and population structure [15]. Shenzhen's social deprivation index includes income, employment, education, population structure, and housing [31]. It can be seen that although the domains of indicator measurement in different environments and situations are not exactly the same, they basically all include the five core aspects of income, education, employment, housing, and population structure.

Application of social deprivation in the health field

The concept of social deprivation is widely applied in the health field. Originating from sociology, the initial research focus was on social poverty issues [32], social satisfaction, and social fairness [33]. Subsequently, scholars found a significant correlation between poverty and health conditions. For example, poor levels of social deprivation leads to differences in regional health and welfare levels [34]. Therefore, social deprivation is also used to study issues in the health sector. On the one hand, the risk of disease occurrence is concerned. For instance, Japanese scholars found that levels of economic and social deprivation increased the risk of viral hepatitis B and C infection [35]. Socioeconomic deprivation is recognized as an independent risk factor for kidney disease [36]. Deprivation is associated with an increased risk of developing chronic diseases [37]. On the other hand, the effects on health damage have been widely studied. German scholars have concluded that there is a significant association between regional deprivation and mortality and morbidity [38]. The social deprivation index explains changes in life expectancy at birth [39]. People who were materially deprived and socially deprived have a higher risk of dying from diseases such as cancer, heart attack and stroke [40].

Chinese scholars have also introduced the concept of absolute social deprivation to study health issues. On the one hand, scholars have focused on the relationship between social deprivation and physical health. For example, a higher risk of death exists among highly deprived populations [41]. Populations with lower neighborhood deprivation levels are less likely to suffer from

However, compared to foreign studies on the relationship between social deprivation and health, there is less research on the relationship between absolute social deprivation and public health outcomes in China, and such studies still lack strong evidence. Recent studies on social deprivation in China are mostly limited to specific provinces or cities, and nationwide studies are relatively scarce. Moreover, the few existing studies mainly used rural data from 14 years ago. Therefore, it is of great significance to explore the impact of social deprivation on health at the national level. This can not only supplement research data at the national level but also update research data in recent years.

Methods and data

Formulating a social deprivation index for China

The steps to construct a social deprivation index include: (1) selecting indices for measuring social deprivation; (2) normalizing data; (3) using entropy weighting method, variation coefficient method, and Criteria Importance Through Intercrieria Correlation (CRITIC method) to calculate the weight of each index and derive the overall index based on the social deprivation index formula. Additionally, the principal component analysis method is used to construct the social deprivation index. The specific steps are as follows.

Based on previous studies and considering data accessibility, this paper selects 20 indices from five aspects: income, education, employment, housing, and population structure. A panel composed of four experts in social science or public health judged the applicability of each index based on four criteria: scale appropriateness, scientific validity, usability, and recognizability. They rated them into four levels: Level 1 (very unsuitable), Level 2 (unsuitable), Level 3 (suitable), and Level 4 (very suitable). Finally, the average scores of these indices were calculated, retaining those with higher scores. Based on the experts' recommendations, 14 social deprivation indices were finally retained (Table 1). The original data of these indices come from the 7th National Census of China in 2020. Considering data accessibility, only data from 31 provincial administrative regions in China were analyzed.

This study uses factor analysis to reduce the dimensions of social deprivation. As income, employment, and population structure fields only contain one or two indices, no dimension reduction is carried out for these fields. However, education and housing fields undergo dimension reduction through factor analysis. Firstly, in the education field, one reliable main component that explains 75.058% of the total variance was extracted based on the criterion of eigenvalues greater than 1, correlating most with IR, NFE, and BEC. Secondly, in the housing field, two reliable main components were

Table 1 Indicators of Social Deprivation in China

Domain	Indicators	Unit	Definition

extracted, where the first explains 62.166% of the variance, correlating most with WOK, WOW, WOB, WOT, and the second explains 22.479% of the variance, correlating most with HCA. Consequently, the original housing field is split into two fields: housing condition and housing area.

To further enhance the accuracy of the social deprivation index and avoid subjectivity, this paper adopts three objective weight determination methods—the entropy where α_j is the loading factor of index j; X_j is the standardized value of index j; n is the total number of observations.

$$SD_j = \sum_{k=1}^{p} \alpha_k \times F_i \quad (9)$$

where α_k is the variance percentage of the k_{th} component, p is the number of main components, and F_i is the score of the i_{th} main component of deprivation. e social deprivation scores can refer to Table 4.

Index selection for public health outcomes

To reflect the health status of the Chinese population comprehensively, this research selected the incidence rate of Class A and B infectious diseases, mortality rate of Class A and Class B infectious diseases, prevalence rate of low weight children under 5 years old, maternal mortality rate, average life expectancy, and proportion of healthy elderly (Table 2). e corresponding data come from the *China Health Statistics Yearbook* published in 2021.

Infectious diseases, due to their characteristics, can potentially harm public health on a large scale once they break out. In China, according to di erent transmission methods, transmission speeds, and harms to humans of each disease, 35 acute and chronic communicable diseases with high national incidence rates, large epidemic areas, and serious damages are classified into classes A, B, and C, and are included in legal management. e incidence rate and mortality rate of Class A and Class B infectious diseases reflect the national attention to people's health safety and also show China's ability to prevent and control these diseases.

e prevalence rate of low-weight children reflects the survival status of children. Malnutrition is the main cause of low weight in children, and about 45% of deaths among children under 5 years worldwide are related to malnutrition, mainly occurring in low- and middle-income countries and regions [52]. Lack of nutrition will reduce children's immunity, increase morbidity, and further increase economic burdens on families and societies.

Maternal mortality rate can reflect the state of a country's healthcare system. Improving public health service capabilities and medical service levels and quality can help lower maternal mortality rates. Average life expectancy is an important index that measures a society's economic development level and healthcare service level, and it is also one of the three core indices of the UN Human Development Index. e proportion of healthy elderly reflects the quality of life of the elderly and the social security for the elderly group. Statistical descriptions can be seen in Table 3.

Model selection for social deprivation and health outcomes

Previous research has already found that health outcomes often show spatial autocorrelation at geographical scales. In this context, traditional OLS might be limwhere y is the dependent variable, x is the independent variable, β is the coefficient of the independent variable, W is the spatial weight, λ is the spatial lag coefficient, and ρ is the spatial error coefficient.

Several spatial correlation test methods have been adopted to evaluate the spatial correlation and relevance of spatial regression models in observations, including Moran's I-Error, LM-Error, robust LM-Error, LM-Lag, and robust LM-Lag. Moran's I-Error is a method to test the spatial correlation of residuals in OLS models. The LM test is used to test model residuals and spatial autoregressive effects. Specifically, LM-Error and robust LM-Error statistics are used to verify the spatial association of model residuals, while LM-Lag and robust LM-Lag statistics are used to verify the spatial autoregressive effect of models.

Firstly, Moran's I test is performed on the dependent variable to determine whether there are spatial distribution states such as aggregation, discrete or random distribution. Then the spatial lag model needs to be judged based on the Lagrange Multiplier (LM) test. Secondly, the LM test is performed. If both LM-Error and LM-Lag are insignificant, OLS is retained. If LM-Error is significant but LM-Lag is not, the spatial error model is selected. If LM-Lag is significant but LM-Error is not, the spatial lag model is selected. If both the robust LM-Lag and robust LM-Error of the model are significant ($p < 0.1$), the model with the larger test value is selected [53]. A model with larger R^2 and log likelihood values and smaller Akaike info criterion (AIC) implies better performance is more applicable for subsequent analysis. Model judgment (including SEM, SLM, OLS), health outcomes Moran's I, and spatial weight matrix were performed in GeoDa1.16. The model selection process can be seen in Fig. 1.

Results

Social deprivation in China

Depending on the different methods used to determine the social deprivation index, four approaches—$SD_{Entropy}$, SD

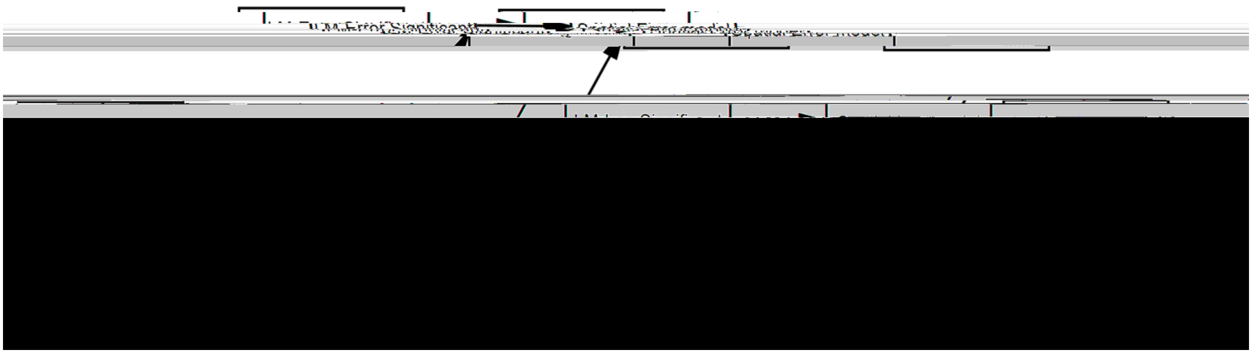

Fig. 1 Spatial regression decision process

Table 4 Corresponding values of social deprivation

District	$SD_{Entropy}$	SD_{CV}	SD_{CRITIC}	SD_{PCA}
Beijing	0.170	0.179	0.268	5.195
Tianjin	0.145	0.181	0.334	7.499
Hebei	0.195	0.234	0.389	11.791
Shanxi	0.347	0.364	0.477	16.205
Inner Mongolia	0.396	0.418	0.542	18.098
Liaoning	0.317	0.360	0.578	0.195

SDEntropy, SDCV, SDCRITIC and SDPCA are the social deprivation estimated by Entropy method, Coe cient variation method(CV), Criteria importance though intercrieria correlation(CRITIC) and principle component analysis (PCA)

it is found that all Pearson correlation coe cients are significant at the 0.01 level (two-tailed), and all Pearson correlation coe cients exceed 0.7.   e Pearson correlation coe cients between entropy weighting method and variation coe cient method, CRITIC method, principal component analysis method are all significant at the 0.01 level (two-tailed). Among them, the Pearson correlation coe cient between entropy weighting method and variation coe cient method is as high as 0.992, demonstrating a strong correlation. At the same time, there is a strong correlation between entropy weighting method and CRITIC method, entropy weighting method and principal component analysis method, CRITIC method and variation coe cient method, CRITIC method and principal component analysis method, variation coe cient method, and principal component analysis method.

  erefore, despite di erences in the social deprivation values derived from these four methods, their results show consistency. In China, social deprivation exhibits evident heterogeneity (see Fig. 2). Generally, regions with higher degrees of social deprivation in China are mainly concentrated in the west and northeast, while areas with lower degrees of social deprivation are mostly located in the central part and coastal areas in the east.

Model selection for social deprivation and population health

  e Moran's I test statistic of the dependent variable (health outcomes) is significant.   e Moran's I values of incidence rate of Class A and B infectious diseases, mortality rate of Class A and Class B infectious diseases, prevalence rate of low weight children, maternal mortality rate, average life expectancy, and proportion of healthy elderly are 0.487, 0.283, 0.396, 0.325, 0.341, 0.519, respectively.   erefore, the null hypothesis of random distribution of samples in the study area is rejected. Simultaneously, the global Moran's I index being greater than 0 indicates the presence of high-high and low-low

Secondly, social deprivation is positively correlated with the incidence rate of Class A and B infectious diseases, prevalence rate of low weight children, and maternal mortality rate. is implies that regions with high degrees of social deprivation often accompany high incidence rates of infectious diseases, prevalence rates of low weight children, and maternal mortality rates. Meanwhile, there exists a negative correlation between social deprivation and mortality rates of infectious diseases, average life expectancy, proportion of healthy elderly. is finding indicates that in areas with lower degrees of social deprivation, average life expectancy is longer and the proportion of healthy elderly is higher.

In addition, in part of regression models for influence between social deprivation and incidence rate of Class A and B infectious diseases, social deprivation and proportion of healthy elderly, social deprivation and maternal mortality rate, social deprivation and average life expectancy are in the form of spatial lag. It indicates that the values of variables in certain provinces are directly influenced by the corresponding status of these indicators in neighboring provinces. Simultaneously, in part of regression models for impact between social deprivation and prevalence rate of low weight children is in form of spatial error. is implies that social deprivation has a spatial spillover e ect on the prevalence rate of low weight children and mortality rate of Class A and B infectious diseases, meaning that other influencing factors of the prevalence rate of low weight children and mortality rate of Class A and B infectious diseases in certain region can a ect the prevalence rate of low weight children and mortality rate of Class A and B infectious diseases in adjacent areas through spatial transmission mechanisms.

Discussion

Spatial heterogeneity of social deprivation in China

Due to the di erences in the selection of social deprivation indicators, the results of this paper cannot be compared with other countries. Compared with the study on rural social deprivation in China in 2010, the social deprivation situation in most provinces has been alleviated.

Table

paper discusses social deprivation at the national level, encompassing both urban and rural areas. In general, urban areas exhibit better social development than rural regions. However, in the 2010 study, the research was limited to rural areas only.

Social deprivation in China features significant spatial heterogeneity. Regions with higher degrees of social deprivation are primarily concentrated in the west and northeast, whereas those with lower degrees are mainly located in the central regions and coastal areas in the east. is is consistent with the results available [55]. ere could be several reasons behind this phenomenon.

First, the spatiotemporal variations in social deprivation may be closely related to regional resource allocation. e measurement of social deprivation encompasses multiple dimensions, including education, income, population, and housing, which vary significantly among di erent provinces. Furthermore, the developmental resources available in each region also display prominent imbalances. During the initial stages of China's reform, due to accelerated opening up of coastal areas, these regions developed faster, leading to a significant flow of human, physical, and financial resources towards the eastern coastline areas. is resulted in considerable economic development imbalance between eastern and western regions [56]. Subsequently, the Chinese government made strenuous e orts to narrow the economic development gap between the central and eastern regions. For instance, over the past decade, the Chinese government implementing targeted poverty alleviation strategies, transferred a massive amount of talent, funds, and technical resources to 22 provinces in central and western China, while simultaneously accelerating the construction of infrastructures such as transportation and water conservancy [57].

It is noteworthy that although Xinjiang and Ningxia are located in the western region, these two provinces have lower levels of social deprivation, which could be attributed to the implementation of China's "one belt, one road" policy and targeted poverty alleviation policies. ese policies aim to promote the development of the western region in China and narrow the economic gap

Table 7 OLS and Spatial regression analysis results

[a] The best a model performances

* $P < 0.1$, ** $P < 0.05$, *** $P < 0.01$

SD Assessing values of social deprivation, *SLM* Spatial lag model, *SEM* Spatial error model between the eastern and western regions. For example, in Ningxia, due to the implementation of precise poverty alleviation policies and counterpart assistance policies, Ningxia has identified its development advantages, developed characteristic agricultural products, and thus promoted the economic growth of Ningxia [58].

Second, the spatiotemporal variations in social deprivation may be closely related to economic circumstances. Previous research has confirmed that people in areas of worse economic development have higher levels of deprivation [59]. the relatively low level of economic development in the western region may lead to a higher degree of social deprivation. This low level of economic development is primarily due to the constraints of geographical environment, and shortage of educational resources in the western region. The western region is characterized by traditional agriculture and industry as its industrial pillars. However, the geographical environment in this region is usually harsh, with extensive high mountains, deserts, and lack of water resources [60]. These geographical features may limit agricultural production and increase the difficulty of infrastructure construction and transportation.

Impact of social deprivation on population health status

Social deprivation shows a positive correlation with the incidence rate of Class A and B infectious diseases, prevalence rate of low weight children, maternal mortality rate, and a negative correlation with average life expecunhealthy diets, smoking) and infectious diseases also have a potentially negative impact on the health of people living in the surrounding areas [75].

Additionally, there's a spatial error effect between social deprivation and the prevalence rate of low weight children. This might suggest that when evaluating the prevalence rate of low weight children, besides considering local socioeconomic factors, attention should be paid to random errors in the spatial direction. This could come from unobserved spatial factors such as environmental conditions, distribution of medical resources, hygiene policies, and socio-economic interactions across regions.

There are implications for health policy from the result that social deprivation has spatial spillover effects on population health. On the one hand, the spatial spillover effects of social deprivation suggest that health problems

In practical terms, this study reveals the impacts of social deprivation on di erent population health aspects and social deprivation has spatial spillover e ects on population health, further improving the precision of population health policy formulation, advocating for national attention to the impact of unequal regional development on health inequalities, providing reference for the promotion of health equity and the achievement of population-wide health.

Authors' contributions

YZ and YD conceived the idea and design of this study, dealt with data analysis and wrote the manuscript. SQ review and editing the manuscript. All authors read and approved the final manuscript.

Funding

This research was funded by The National Social Science Fund of China (Grant Number: 23BGL286). The financial sponsor played no role in the design of the study and collection, analysis, and interpretation of data and in writing the manuscript.

Data availability

The datasets generated and/or analysed during the current study are public and available in the National Bureau of Statistics of China [https://www.stats.gov.cn/sj/pcsj/rkpc/7rp/indexch.htm], and National Health Commission of China [http://www.nhc.gov.cn/mohwsbwstjxxzx/tjtjnj/202305/304a301bfdb444afbf94b1a6c7f83bca.shtml].

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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Received: 5 December 2024 Accepted: 28 February 2025
Published online: 11 March 2025

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