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Age-related diseases through the lens of health economics, volume II

Edited by
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Age-related diseases through the lens of health economics, volume II

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Spatial Analysis and Comparison of the Economic Burden of Common Diseases: An Investigation of 5.7 Million Rural Elderly Inpatients in Southeast China, 2010–2016

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Background: As China embraced an aging society, the burden of age-related diseases had increased dramatically. Knowledge about spatial distribution characteristics of disease burden and the influencing factors of medical expenditure is of great significance to the formulation of health policies. However, related research in rural China is still insufficient.

Methods: A total of 5,744,717 records of hospitalized rural elderly in southeast China were collected from 2010 to 2016. We described the temporal trends of hospitalization medical expenditure and the prevalence of catastrophic health expenses (CHE) in the rural elderly by common diseases. Then, geographical information tools were used for visualization of geographic distribution patterns of CHE, the ordinary least squares methods (OLS) and geographically weighted regression (GWR) were employed to examine the influencing factors of medical expenditure.

Results: The number of CHE hospitalizations and the total number of hospitalizations for the rural elderly people increased by 2.1 times and 2.2 times, respectively, from 2010 to 2016. Counties with a high prevalence of CHE were clustered in the eastern coastal area (Moran's $I = 0.620$, $P < 0.001$, General $G < 0.001$, $P < 0.001$). Unspecified transport accidents, cardiovascular disease, and essential hypertension were the top causes of CHE in the rural elderly. Adequate hospital beds ($P < 0.05$) and reasonable utilization and distribution of town-level ($P < 0.001$) and county-level hospitals ($P < 0.001$) may help reduce medical expenditures.

Conclusions: In the context of an aging society, the disease burden for the elderly in rural areas should arouse more attention. These findings highlight the importance of age-related disease prevention and the rational allocation of medical resources in rural areas.

Keywords: rural China, older adults, catastrophic health expenses, geographically weighted regression, age-related diseases

INTRODUCTION

China is the country with the largest population and the largest number of older adults in the world, who began to embrace an aging society in 1999, is one of the first developing countries to enter an aging society. The population of China aged 65 years and over is about 150 million, accounting for 11.9% in 2018. Compared with the national census in 2010, the population aged 65 years and over increased by 33.7% (1). As the population is growing and aging, the age-related disease burden is rising rapidly. For instance, in the past two decades, the causes of disease burden in China have changed dramatically. Stroke and ischemic heart disease were the leading causes of death and disability-adjusted life-years (DALYs). Stroke, ischemic heart disease, lung cancer, chronic obstructive pulmonary disease, and liver cancer were the five leading causes of (years of life lost) YLLs. Musculoskeletal disorders, mental health disorders, and sense organ diseases were the three leading causes of years lived with disability (YLDs) (2). Besides, past research indicates that the aging problem was worse, and the burden of disease was higher in rural China (3, 4). A recent study found that residents in rural areas suffered a greater financial burden from health expenditures, with the percentage 2.4 times higher than that of urban residents in 2013 (5). Therefore, to cope with the challenge of aging to the health care system in rural areas, it is necessary to formulate disease-focused health policies. Taking corresponding preventive measures for common diseases of the elderly is an excellent way to reduce the burden of diseases. However, in China, less research has been done to compare common disease burden for the rural elderly.

Catastrophic health expenditures (CHE) mean that medical expenditures account for disposable income unreasonably, which is an important indicator to measure the economic burden of disease (6, 7). Previous studies have reported that rural areas have a higher incidence of CHE than urban areas, although China had made progress in reducing CHE (8), and related research also found that the elderly are a high-risk group of CHE in China (9, 10). Therefore, research on pointing out the causes of CHE in the elderly in rural areas is of great significance for taking measures to reduce CHE incidence. However, there exists a knowledge gap on CHE in common diseases for the rural elderly. Besides, to provide a reference for the formulation of health policies or disease prevention measures in different regions, spatial analysis has been widely used in epidemiology and health economics. For example, previous research applied spatial analysis to the description of geographic distribution characteristics of health resources such as hospitals, hospital beds, and medical experts, and diseases such as COVID-19 (11–13). However, there are few spatial analysis studies on the medical economic burden for the elderly in rural China, which is worthy of further exploration.

Accordingly, to provide references for health policymaking, our research investigated the rural elderly inpatients in southeast China from 2010 to 2016 and described the number of hospitalizations and the medical expenditures of common diseases of the elderly. In addition, the geographic spatial distribution characteristics of the prevalence of CHE in the rural elderly and the influencing factors of medical expenses were explored through spatial analysis.

METHODS

Data Sources

The data of inpatients was extracted from the New Rural Cooperative Medical Scheme (NRCMS) in the Fujian province, a representative coastal province with about a population of 39 million and a land area of 121,400 km^2 in southeast China. The NRCMS was guided, organized, and supported by the government, and rural residents participated voluntarily. The previous study indicated that China had accomplished nearly universal insurance coverage, the enrolment rate of NRCMS among rural residents had reached 96.6% in 2010 (14). Taking into account the privacy issues of inpatients, the data manager removed the names and phone numbers and Chinese ID numbers of inpatients, and the addresses of inpatients were reserved at the county level. The subjects of this study were rural residents, 60 years or older, and who participated in the NRCMS. Finally, 5,744,717 inpatient records were enrolled in the study. Variables included gender, age, residential county, low-income or not (low-income patients were defined as patients whose household per capita income was below the local minimum living standard), admitted hospital level (town, county, municipal, and provincial), year of admission, length of stays, discharge diagnoses according to the International Classification of Diseases Tenth Revision (ICD-10 code), surgery or not, year of admission, total medical fee, and medical insurance reimbursement amount. The demography, economics, traffic conditions, and health resources data of the counties in the study regions were extracted from the Statistics Yearbook (15). Variables include rural population (RP), total population, per capita income (PCI), per capita consumer expenditure (PCCE), per capita GDP (PGDP), total road length, land area, number of hospitals beds, and number of health technicians.

Variables of Interest

The out-of-pocket (OOP) expenditure is defined as the differences between total medical fee and medical insurance reimbursement amount, and in spatial analysis, defined as the mean value of inpatients in the county. CHE is defined as OOP medical expenditure equal to or exceeded 40% of a household's capacity to pay (16). The capacity of inpatients to pay was estimated by the rural PCI and rural PCCE of the county where he lived when he was admitted. Road density (RD) is defined as the total length of roads in the county (km) divided by the land area of the county (km^2). Hospital beds per thousand population (HB) is defined as the number of hospital beds in the county divided by whose total population. Health technicians per thousand population (HT) is defined as the number of health technicians in the county divided by whose total population. The proportion of town-level hospitals inpatients (PTH) is defined as the proportion of patients hospitalized in town-level hospitals to all inpatients in the county. The proportion of county-level hospitals inpatients (PCH) is

defined as the proportion of patients hospitalized in county-level hospitals to all inpatients in the county. The measurements of our dependent and explanatory variables are presented in **Supplementary Table 1**.

Data Analysis

Numbers (percentages) of inpatients were calculated for categorical variables. The numbers of inpatients with CHE, the prevalence of CHE, and the means of OOP expenditures by the top 50 discharged diagnose in each year were calculated and then visualized by heatmap and treemap. Global Moran's I was used to assess the spatial autocorrelation of the prevalence of CHE (17). Evidence of local clusters characteristics was evaluated using Anselin local Moran's I statistic (17). Clustering for the prevalence of CHE density was assessed by the Getis–Ord General G statistic (18). Hot spot analysis for the prevalence of CHE was piloted using Getis–Ord Gi* (19, 20). Ordinary least square (OLS) regression was employed to examine the relationships between variables and OOP expenditure and perform the multiple co-linear diagnoses. To explore the spatial variability between the OOP expenditure and variables, geographically weighted regression (GWR) was adopted (21, 22). The data analysis was done using SPSS and Excel. Spatial analysis was done using ArcMap. Statistical significance was based on two-sided tests and was set to 5%.

TABLE 1 | Demographic characteristics of rural elderly inpatients, from 2010 to 2016, *n* (%).

Variable		Inpatients (n = 5,744,717)	CHE inpatients (n = 3,151,087)
Age (years)	60–63	1,244,209 (21.7)	712,556 (22.6)
	64–69	1,478,095 (25.7)	828,964 (26.3)
	70–76	1,513,536 (26.3)	807,918 (25.6)
	≥77	1508,877 (26.3)	801,649 (25.4)
Gender	Female	2,824,879 (49.2)	1,494,135 (47.4)
	Male	2,915,970 (50.8)	1,655,260 (52.5)
Low-income households	No	5,605,879 (97.6)	3,084,230 (97.9)
	Yes	138,838 (2.4)	66,857 (2.1)
Hospital level	Town	2,230,231 (38.8)	185,808 (5.9)
	County	2,074,820 (36.1)	1563540 (49.6)
	Municipal	1,057,237 (18.4)	1,024,168 (32.5)
	Provincial	382,393 (6.7)	377,537 (12.0)
Length of stays (days)	0–6	2,897,462 (50.4)	1,160,531 (36.8)
	≥ 7	2,847,175 (49.6)	1,990,515 (63.2)
Surgery	No	4,910,987 (85.5)	2,417,970 (76.7)
	Yes	833,730 (14.5)	733,117 (23.3)

RESULTS

Demographic Characteristics

Table 1 shows the demographic characteristics of rural elderly inpatients in southeast China from 2010 to 2016. In total, there were 5,744,717 hospitalizations; 52.6% of inpatients aged older than 70 years, 49.6% were admitted for more than 1 week, and 14.6% of the patients underwent surgery. The number of inpatients in the town, county, municipal, and provincial hospitals accounted for 38.8, 36.1, 18.4, and 6.7% of the total, respectively. Besides, ∼3 million (54.9% of all inpatients) may suffer CHE. Among all inpatients with CHE, there were 51% aged over 70 years, town, county, city, and provincial hospitals accounted for 36.8, 63.2, 76.7, and 23.3% respectively. **Figures 1A,B** illustrates that the number of inpatients and CHE inpatients had increased by 2.2 and 2.1 times, hospitalization expenses had increased by ∼1.4 times, and OOP medical expenses had increased by ∼1.3 times in the rural elderly from 2010 to 2016.

CHE in Top 50 Discharge Diagnoses

The number and prevalence of CHE and the average OOP medical expenditure caused by the top 50 discharge diagnoses from 2010 to 2016 are shown in **Figures 1C–E**, in which the differences in the number of inpatients, prevalence rates of CHE, average OOP expenditure between years, and discharge diagnoses are visualized by colors. Exactly, during the study period, unspecified transport accidents, senile and other cataracts, cerebral infarction, and chronic ischemic heart disease were the discharge diagnoses with the most significant increase in the actual number of inpatients with CHE, among the top 50 discharge diagnoses (**Figure 1C**). Meanwhile, other medical care, other cataracts, fracture of the femur, intracerebral hemorrhage, senile cataract, and unspecified transport accidents accompanied the highest prevalence of CHE among the top 50 discharge diagnoses (**Figure 1D**). Besides, fracture of the femur, other medical care, intracerebral hemorrhage, unspecified transport accident, and cancers were the discharge diagnosis with the heaviest OOP expenditure in the top 50 (**Figure 1E**). In total, unspecified transport accidents, cerebral infarction, essential (primary) hypertension, chronic ischemic heart disease, and others such as chronic obstructive pulmonary disease were the top discharge diagnoses for CHE (**Figure 2**).

Geographic Variation of CHE

Figure 3A depicts the prevalence of CHE in southeast China during the study period at the county level. The results of the spatial analysis of the prevalence of CHE are shown in **Table 2**, in which the result of the spatial analysis of Global Moran's I was 0.620, the $Z = 8.329$, and the $P < 0.001$, indicating significant spatial autocorrelation for the prevalence of CHE in the study area. Furthermore, the observed value of General G < 0.001, $Z = 4.598$, $P < 0.001$, indicates that there were hot or cold spot areas of CHE prevalence within the scope of the study (**Table 2**). In addition, **Figure 3B** displays the local clusters of the prevalence of CHE by using the local Moran's I, which showed that the high–high cluster regions were located in east coast county, and on the contrary, the low–low cluster regions located in western Inland county. Likewise, Getis–Ord Gi* analysis results show that hot spot regions (99% confidence) of the prevalence of CHE were

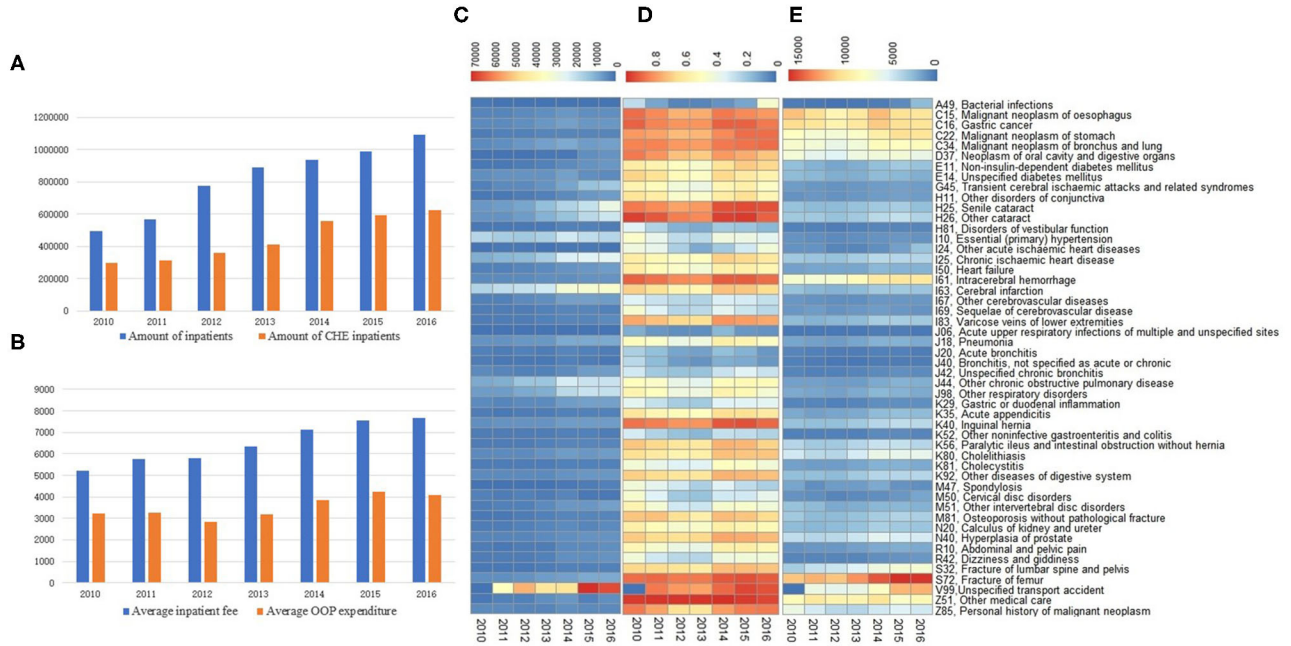

FIGURE 1 | Medical expenditures and prevalence of catastrophic health expenses (CHE) of rural elderly inpatients, from 2010 to 2016. **(A)** Amounts of inpatients and inpatients with CHE. **(B)** Average inpatient fee and out-of-pocket (OOP) expenditure of inpatients, unit Yuan. **(C)** Amounts of inpatients with CHE in the top 50 discharge diagnoses. **(D)** The prevalence of CHE in the top 50 discharge diagnoses. **(E)** Average OOP expenditure in the top 50 discharge diagnoses, unit Yuan.

gathered in the east coast, and cold spot regions (99% confidence) gathered in the east (**Figure 3C**).

Factors Related to OOP Expenditure

Table 3 and **Supplementary Figure 1** show the results of the OLS model in 2011, 2013, and 2015. The R-squared of the model were 0.87, 0.81, and 0.81, and the standard deviation of most counties is controlled within 1.5 times, except two counties in 2013, which represented a good model fit to OOP expenditure of the rural elderly in each county of the study area. Results reveal that the lower OOP expenditure of each county was related to more HB (coefficient = −281.38, $P = 0.024$, in 2011; coefficient = −378.25, $P = 0.004$, in 2013; coefficient = −339.82, $P = 0.013$, in 2015), the county with more HT suggest higher OOP expenditure (coefficient = 324.23, $P = 0.001$, in 2011; coefficient = 263.02, $P = 0.023$, in 2013), and the county with a higher PTH prompt lower OOP expenditure (coefficient = −53.54, $P < 0.001$, in 2011; coefficient = −74.11, $P < 0.001$, in 2013; coefficient = −84.69, $P < 0.001$, in 2015). County with a higher PCH prompt lower OOP expenditure (coefficient = −27.85, $P < 0.001$, in 2011; coefficient = −40.72, $P < 0.001$, in 2013; coefficient = −44.04, $P < 0.001$, in 2015).

To eliminate the influence of collinearity, the variables with variance inflation factors (VIF) less than 7.5 and whose coefficients were statistically significant ($P < 0.05$) were included in the GWR model. Results for the GWR model can be seen in **Table 3**. To analyze the influence of each variable on OOP expenditures in each county, the coefficient distribution map for the influencing factors was shown in **Supplementary Figure 2**. Regression coefficient of PTH exhibited a characteristic of being "high in the southwest, low in the northeast" (coefficient ranged from −58.952 to −58.723 in 2011; from −90.687 to −56.239 in 2013; and from −87.971 to −84.131 in 2015) suggesting that the OOP medical expenditure of counties in the northeast are more sensitive to changes in PTH. Similarly, the coefficient of HB increased from southwest to northeast (coefficient ranged from −420.421 to 60.037 in 2013 and from −242.811 to −185.599 in 2015) suggesting that increasing the HB of counties in the northwest region may have higher effectiveness for reducing OOP medical expenditure. Besides, there was a rather unexpected outcome that the region with the lowest regression coefficient of PCH gradually shifted from the southwest to the northeast during the study period. Specifically, counties in the southwest region had the lowest PCH regression coefficient in 2011 (range from −33.658 to −33.420), counties in the northeast of the central region had the lowest in 2013 (range from −57.715 to −30.667), and in 2015 the northeast region had the lowest (range from −45.220 to −44.392). These outcomes suggest that in the future, increasing the PCH of counties in the northeastern region may have good benefits in reducing the OOP medical expenditure.

DISCUSSION

Findings from the research indicate that the hospitalization expenses of the rural elderly in southeast China showed a rapid growth trend during the study period. At the same time, the number of hospitalizations for the rural elderly and the number of hospitalizations for the rural elderly who suffered

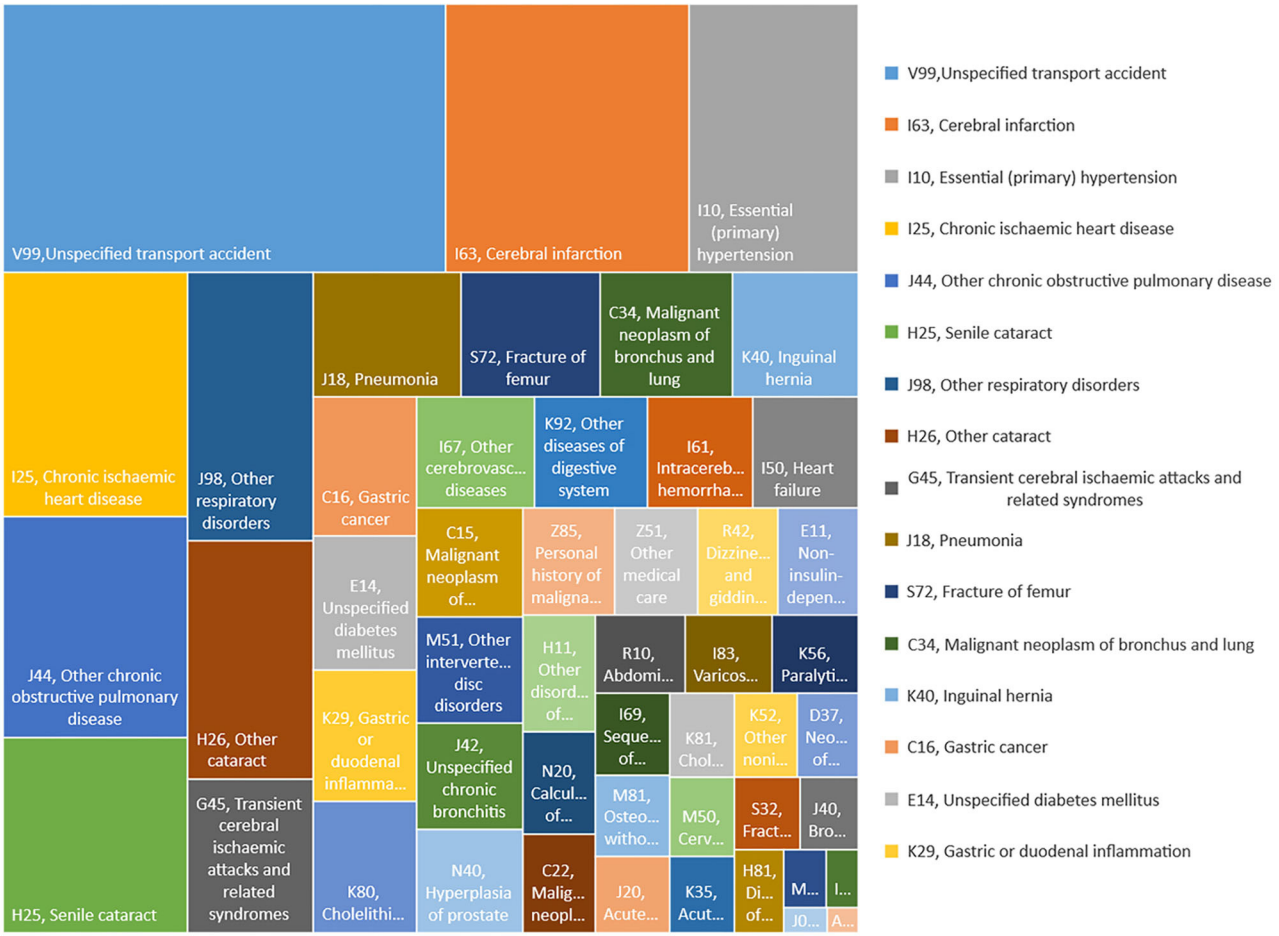

FIGURE 2 | The proportion of rural elderly inpatients with CHE by discharge diagnoses from 2010 to 2016.

CHE also increased significantly. Counties with a high prevalence of CHE are clustered in the eastern part of the study area. Besides, we found that unspecified transport accidents, cerebral infarction, essential (primary) hypertension, chronic ischemic heart disease were the leading cause of CHE. Other medical care, other cataracts, and fracture of the femur were the discharge diagnoses with the highest prevalence of CHE for rural elderly inpatients. In addition, our research suggests that the OOP medical expenditures decreased with increasing HB, PTH, and PCH, which was more dramatic in the northeast region.

The finding of the study shows that the number of inpatients for rural elderly had increased by 2.2 times from 2010 to 2016. It is a particularly shocking result which means that the demand of the rural elderly for medical services had significantly increased. The observed increase in the number of inpatients could be attributed to the rise in the proportion of the elderly population in rural areas and the advance of the primary health system in China. The aging problem will pose a huge challenge to China's health care system. Prior studies have noted that with aging in China in the twenty first Century, the prevalence and incidence of age-related diseases have increased sharply. At the same time, a large number of young rural laborers have migrated to urban areas, resulting in an increase in the proportion of the rural elderly population and further aggravating the burden of the current rural health care system (3). Another possible explanation for increasing inpatients is that China's long-term health care reforms have achieved certain results. China launched 125 billion US dollars in 2009 to establish a national essential medicines system covering 90% of China's population by 2020, enabling more rural elderly to receive medical services and thus increasing the number of hospitalizations (14, 23). However, the current health care system faces the problems of waste of resources, low efficiency, poor quality, and the scarcity and unequal distribution of qualified labor (24). Therefore, the rational use and distribution of medical or health resources and the improvement of health care service quality are the primary goals of Chinese policymakers.

Another important finding is that the number of elderly who were hospitalized in the study area who suffered from CHE increased by 2.1 times during the study period. Counties with a high CHE prevalence were clustered in the eastern coastal region. These spatial distribution characteristics of CHE may partly be explained by the unequal distribution of medical

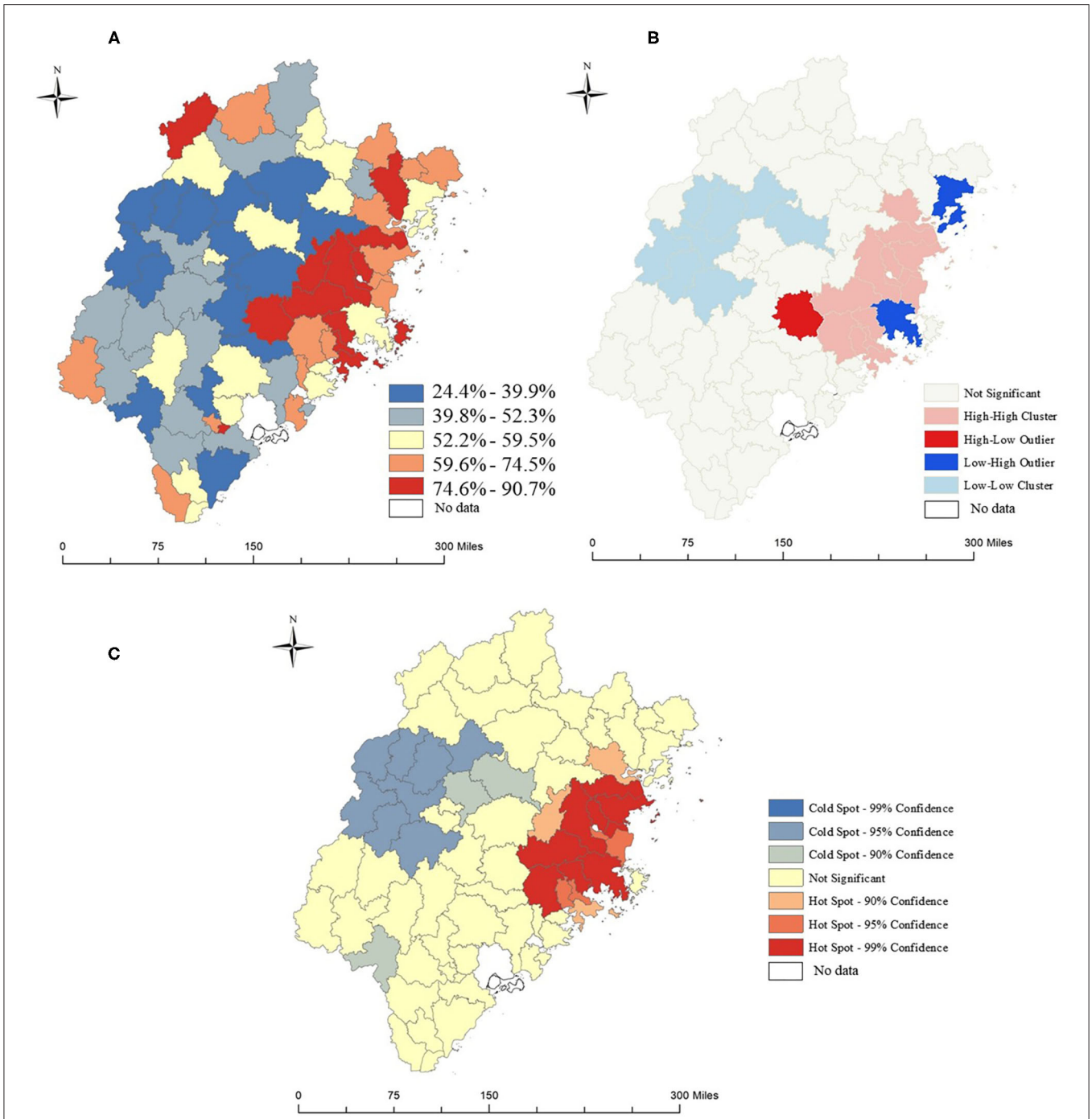

FIGURE 3 | Spatial analysis of CHE prevalence among rural elderly inpatients in southeast China, from 2010 to 2016. **(A)** The prevalence of rural elderly inpatients with CHE. **(B)** Anselin local Moran's I analysis of the prevalence of rural elderly inpatients with CHE. **(C)** Hot spots analysis of the prevalence of rural elderly inpatients with CHE.

and health resources. High-quality medical institutions, such as provincial and municipal hospitals, are mainly located in relatively developed coastal areas, which has caused residents in the eastern region to bear higher medical costs. Another possible explanation for this was that the local health system does not make full use of primary hospitals such as town-level hospitals and county-level hospitals, leading to a large number of patients with mild symptoms who choose high-level hospitals, which exacerbates the occurrence of CHE in the eastern regions. It is worth noting that among the 50 most diagnosed diseases,

TABLE 2 | Summary of Global Moran's I and Getis–Ord General G results.

Global Moran's I		Getis–Ord General G	
Parameter	**Estimated value**	**Parameter**	**Estimated value**
Expected index	−0.002	General G observed value	<0.001
Moran's I	0.620	General G expected value	<0.001
Variance	0.006	Variance	<0.001
Z	8.329	*Z*	4.598
P	<0.001	*P*	<0.001

unspecified transport accidents, cerebral infarction, essential (primary) hypertension, and chronic ischemic heart disease were the leading causes of CHE.

Although traffic accidents are a major global public safety and health issue, what shocked us was that transport accidents, as a kind of injury accident, caused the most CHE for the elderly in rural areas, surpassing all diseases. Related research had found that China is in the most rapid development stage of road transportation. The number of vehicles, the number of motor vehicle drivers and car drivers, and the density of roads are increasing rapidly, leading to a significant increase in road accidents and deaths (25). Another study had shown that elderly people and rural area were the main factors associated with prehospital cardiopulmonary arrest due to a traffic crash (26). Therefore, road safety risk prevention and control, road safety legislation, road safety supervision, and road safety publicity and education should be taken seriously, especially in rural areas. Besides, as mentioned above, with the rise in aging population in China, the prevalence and incidence of these diseases had significantly increased.

Research results also suggest that circulatory system diseases, such as cerebral infarction, essential hypertension, and chronic ischemic heart disease are also the leading causes of CHE for rural residents. This finding could have been generated by the increased cardiovascular disease (CVD) treatment and informal caregiving costs. A similar situation has been found in the United States. In the United States, people over the age of 65 years spend the most on CVD, and the total cost of CVD increased to $616 billion in 2015 and is expected to increase to $1.2 trillion by 2035 (27).

We found that the diagnosis with the highest prevalence of CHE was other medical care, other cataracts, and fracture of the femur. According to ICD-10, other medical terms include radiotherapy session, chemotherapy session for neoplasm, maintenance chemotherapy, blood transfusion, preparatory care for subsequent treatment, palliative care, desensitization to allergens, preparatory care for subsequent treatment, and palliative care. Those treatments are mainly applied to advanced tumors or other diseases with very high mortality, low incidence, and require high costs. Affected by the age factor, the elderly are more prone to fracture injuries. Fractures need to be treated for a long time, which brings a huge burden to individuals and the society. Recent studies in China suggest that the total number of hip fractures aged 55 years and older increased by about 4 times. The total hospitalization cost per patient increased by about 1.59 times between 2012 and 2016 (28). Research on the medical expenditure of cataracts was less reported. A cataract is an age-related disease and requires surgical treatment, and the medical insurance compensation rate being low, may cause a higher economic burden on the elderly.

In general, to reduce the prevalence of CHE among the elderly in rural areas, the health care system should be further improved, such as making full use of primary health institutions to improve the efficiency of medical services, especially in the eastern regions where CHE is more serious. Second, take measures for the top diseases that cause CHE and the diseases with a high prevalence of CHE noted by the research. For example, by improving the living environment and focusing on health education, guiding the rural elderly to learn a healthy lifestyle reduces the prevalence of CHE-related diseases. On the other hand, the public medical insurance management department can flexibly adjust the hospital reimbursement rate based on economic conditions. For example, it is necessary to increase the compensation rate of medical insurance for areas or diseases with high prevalence of CHE.

The research results also manifest that the average OOP medical expenditures for the rural elderly inpatients in each county were associated with HB, PTH, and PCH. And there was a spatial difference in this relationship, which suggests that a reasonable allocation of medical resources in a specific area may be more efficient in reducing medical costs.

Hospital beds per thousand population is an indicator that can directly reflect the abundance of medical resources. The results demonstrated that increasing HB could help reduce local OOP medical expenditure for inpatients. This phenomenon was even more pronounced in the northeast. This phenomenon can be explained as follows. In China, there is an unequal distribution of medical resources. Health resources are mainly concentrated in economically developed areas. Affected by the level of consumption, medical expenses in financially developed areas are usually higher. Those have been reported in previous studies (24, 29). At the same time, residents in the northeast areas with insufficient medical resources have to visit other counties or cities with abundant medical resources to seek medical services that meet their needs and bear the high medical expenses that do not match their income.

The proportion of town- and county-level hospitals inpatients reflects the willingness of residents to seek medical services from local primary medical institutions, which may be affected by the quantity, quality, and efficiency of local primary medical institutions. The results also suggest that increasing PTH and PCT could help reduce local OOP medical expenditure, especially in the northwest region. Although compared with provincial and municipal medical institutions, the service quality of primary medical institutions is slightly inferior, and primary hospitals used to be characterized by high efficiency and low prices, which can meet the needs of health care for the most elderly. Therefore, prioritizing the development of primary medical institutions has shown superior benefits in reducing medical expenses.

TABLE 3 | Summary of ordinary least squares methods and geographically weighted regression results.

Year	Variable	OLS				GWR	
		Coefficient[a]	P[b]	VIF[c]	R-squared[d]	Coefficient, mean (min, max)	R-squared[d]
2011	Intercept	3,912.96	0.000**	–	0.87	4,275.198 (4,211.795, 4,291.947)	0.84
	RP	13.84	0.009*	2.32		7.708 (7.608, 7.818)	
	PCI	0.18	0.019*	4.15		0.220 (0.216, 0.223)	
	PCCE	−0.01	0.93	4.64		–	
	PGDP	−57.67	0.456	3.68		–	
	RD	578.68	0.008*	2.28		418.646 (412.420, 424.743)	
	HB	−281.38	0.024*	7.77		–	
	HT	324.23	0.001*	8.95		–	
	PTH	−53.54	0.000**	2.1		−58.821 (−58.952, −58.723)	
	PCH	−27.85	0.000**	2.22		−33.545 (−33.658, −33.420)	
2013	Intercept	6,566.93	0.000**	–	0.81	8,770.820 (5,924.285, 10,610.617)	0.89
	RP	11.63	0.081	1.77		–	
	PCI	0.08	0.277	3.24		–	
	PCCE	0.08	0.384	4.89		–	
	PGDP	−47.01	0.509	3.03		–	
	RD	−182.07	0.458	1.85		–	
	HB	−378.25	0.004*	7.43		−162.626 (−420.421, 60.037)	
	HT	263.02	0.023*	8.22		–	
	PTH	−74.11	0.000**	2.64		−80.781 (−90.687,−56.239)	
	PCH	−40.72	0.000**	2.2		−49.103 (−57.715, −30.667)	
2015	Intercept	6,585.25	0.000**	–	0.81	6,781.457 (6,436.422, 7,129.868)	0.80
	RP	4.28	0.628	3.28		–	
	PCI	−0.02	0.897	6.15		–	
	PCCE	0.33	0.018*	6.46		0.276 (0.264, 0.286)	
	PGDP	−79.21	0.316	3.01		–	
	RD	−34.69	0.83	2.66		–	
	HB	−339.82	0.013*	6.33		−215.472 (−242.811, −185.599)	
	HT	160.65	0.952	7.11		–	
	PTH	−84.69	0.000**	1.72		−86.238 (−87.971, −84.131)	
	PCH	−44.04	0.000**	1.74		−44.835 (−45.220, −44.392)	

Coefficient[a]: represents the strength and type of relationship between each explanatory variable and the dependent variable.
Probability[b]: the asterisk (*) or (**) indicates a coefficient is statistically significant ($p < 0.05$) or ($p < 0.001$).
Variance inflation factor[c] (VIF): large VIF values (>7.5) indicate redundancy among explanatory variables.
The R-squared[d]: the fraction of the variance in the data that is explained by the model.
OLS, ordinary least squares methods; GWR, geographically weighted regression; RP, rural population; PCI, per capita income; PCCE, per capita consumer expenditure; PGDP, per capita GDP; RD, road density; HB, hospital beds per thousand population; HT, health technicians per thousand population; PTH, proportion of town-level hospitals inpatients; PCH, proportion of county-level hospitals inpatients.

LIMITATIONS

There are some limitations to our study. First, we used rural per capita income and rural per capita consumer expenditure of each county to estimate the individual disposable income, which may bias the estimation of the prevalence of CHE. Because medical treatment may be affected by personal disposable income, wealthy people may be more willing to receive treatment. Second, under the influence of policies, some counties did not participate in NRCMS or withdrew halfway through, resulting in missing data, which may reduce the model fitting of OLS and GWR. Third, only the main diagnosis of the patient was recorded in the database, but in fact, many patients often suffer from multiple diseases at the same time. Therefore, the number of hospitalizations and the prevalence of CHE may be underestimated.

CONCLUSIONS

In the context of aging, the number of hospitalizations, the number of hospitalizations with CHE, and the economic burden of the elderly in rural areas had increased. To reduce the economic burden of diseases for the elderly in rural areas, policymakers should pay attention to the prevention of traffic accidents, cardiovascular diseases, tumors,

fractures, and cataracts, reasonably adjust the proportion of medical insurance compensation rate for the above diseases, and equitably allocate medical resources, especially in rural areas.

DATA AVAILABILITY STATEMENT

The datasets used in this study are available from the corresponding author on reasonable request.

AUTHOR CONTRIBUTIONS

ZH and XX conceptualized and led the study. XT and XX designed the study. Data collection was done by XT and ZZ. XT and ZR contributed to data analysis. The first draft of the article was written by XT. ZH, XX, CH, and SL reviewed the manuscript and provided critical inputs. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2021.774342/full#supplementary-material

Supplementary Figure 1 | Spatial distribution of the standard deviation of the OLS model.

Supplementary Figure 2 | Spatial distribution of the coefficient of explanatory variables.

Supplementary Table 1 | Definition and measurements of variables.

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How Do Intergenerational Economic Support, Emotional Support and Multimorbidity Affect the Catastrophic Health Expenditures of Middle-Aged and Elderly Families?–Evidence From CHARLS2018

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Objectives: The elderly face multiple vulnerabilities such as health, economy and society, and are prone to catastrophic health expenditures. This study aims to analyze the impact of children's intergenerational economic support, emotional support, and illness on the catastrophic health expenditures of middle-aged and elderly families.

Methods: Using China Health and Retirement Longitudinal Study (CHARLS 2018) data to calculate the catastrophic health expenditure of Chinese households as the dependent variable. Taking children's intergenerational economic support, emotional support and multimorbidity as core independent variables, gender, age, marital status, medical insurance and other variables as control variables, and perform logistic regression analysis. According to the heterogeneity analysis of age and gender, the impact of intergenerational economic support, emotional support and multimorbidity on the catastrophic health expenditure of middle-aged and elderly families is explored.

Results: When catastrophic health expenditures occur in middle-aged and elderly families, the children's intergenerational economic support will increase significantly, especially in families with members aged 60–74. Children's emotional support can effectively reduce the risk of catastrophic health expenditures for middle-aged and elderly families. Compared with children's intergenerational economic support and emotional support, the impact of multimorbidity on the catastrophic health expenditures of middle-aged and elderly families is the most significant. Suffering from multimorbidity can increase the risk of catastrophic health expenditures for middle-aged and elderly families, especially families with male members suffering from multiple diseases.

Conclusions: It is recommended that we should do a good job in popularizing the knowledge of chronic diseases to minimize the occurrence of multimorbidity. The government should establish group medical insurance related to chronic disease

diagnosis. According to the severity of the disease or the special circumstances of the patient, the level of medical insurance reimbursement is divided in detail, especially for chronic disease clinics and drug reimbursement. Children should be encouraged to strengthen the emotional connection and effective care of the elderly, focusing on the elderly 60–74 years old, in order to reduce their care pressure and maintain the physical and mental health of the elderly.

Keywords: intergenerational economic support, emotional support, multimorbidity, catastrophic health expenditure, middle-aged, elderly family

INTRODUCTION

Chronic Diseases and Catastrophic Health Expenditure (CHE)

At present, chronic diseases have become one of the major public health problems affecting human health. According to statistics from the World Health Organization (WHO), chronic diseases such as heart disease, stroke, cancer, chronic respiratory diseases and diabetes are by far the world's leading cause of death, accounting for 63% of all deaths. With the rapid development of China's economy, industrialization, accelerated urbanization, and changes in the disease spectrum, chronic diseases have become a major health problem for Chinese residents. Incurable chronic diseases such as high blood pressure, diabetes, stroke and coronary heart disease not only lead to a decline in human health, but also cause catastrophic health expenditures for the family, leading to poverty and return to poverty due to illness (1, 2). Among them, the same individual suffering from two or more chronic diseases at the same time can be called multimorbidity.

Scholars have launched a lot of research on chronic diseases and catastrophic health expenditures. Somkotra et al. (3) found that families with a high proportion of elderly members, families with chronic diseases or disabilities among members, and families with hospitalized members are more likely to have catastrophic medical expenditures. Wang et al. (4) found that the economic burden of chronic diseases in rural Malawi is very high, causing severe and catastrophic expenditures and exacerbating poverty. In addition, Jiang et al. (5) evaluated the catastrophic health expenditures of families with chronic diseases in different types of insurance in China. The results showed that 10.53% of families with chronic diseases fell into poverty due to medical expenditures, which was more than twice the proportion of families without chronic diseases. Xu et al. (6) studied the impact of China's new medical reform on their catastrophic health expenditures by taking the families of patients with chronic diseases as the research object. They found that the implementation of the new medical reform did not effectively reduce their catastrophic medical expenditures. In addition, Dugee et al. (7) found that compared with other families, families with members suffering from chronic diseases and multimorbidities are more likely to experience catastrophic expenditure and medical poverty. Although Mongolia's population has a high health insurance coverage rate, health expenditures still have a significant impact on poverty, especially for families with chronic disease patients. Fu et al. (8) compared the differences in catastrophic health expenditures (CHE) between urban and rural families with chronic diseases in China. They found that compared with urban households with chronic diseases, the risk of catastrophic health expenditures (CHE)in rural Chinese households with chronic diseases is higher, and the economic burden of disease is heavier. Brinda et al. (9), Si et al. (10), and Hailemichael et al. (11) specifically studied the family disasters of patients with chronic non-communicable diseases such as diabetes, respiratory diseases, gastrointestinal diseases, dementia, hypertension and depression. It is found that these families bear a higher risk of catastrophic health expenditure. Zhou et al. (12) found that members suffering from chronic non-communicable diseases are one of the important factors for catastrophic health expenditures in the family. Kien et al. (13) assessed the socioeconomic inequality of catastrophic health expenditures and poverty related to non-communicable diseases in northern Vietnam. They found that family self-reported diagnosis of noncommunicable diseases had the greatest correlation with catastrophic health expenditures and poverty.

We found that scholars have proved through a large number of empirical studies that chronic diseases can significantly increase the possibility of catastrophic health expenditures for families. Secondly, scholars take the families of patients with chronic diseases as specific research objects and directly study the catastrophic health expenditures of the families of patients with chronic diseases. Some scholars have carried out comparative studies to compare the catastrophic health expenditures of different regions and families of patients with chronic diseases and those with non-chronic diseases. Some scholars study chronic diseases as an influencing factor of catastrophic health expenditures. Some scholars have carried out research on the types of chronic diseases. In summary, the current research on chronic diseases and single chronic diseases has been in-depth. However, due to work pressure, living habits and other factors, modern people, especially the elderly, are increasingly susceptible to many chronic diseases (14). Therefore, it is of great significance to further study the catastrophic health expenditure of the multimorbidity, especially the elderly for multimorbidity.

Abbreviations: CHE, Catastrophic Health Expenditure; EcoSup, Economic Support; lnEcoSup, ln(Economic Support); EmoSup, Emotional Support; ADL, Katz Index Scale of Activities of Daily Life; GC, Grandchild Care; SRH, Self-Rated Health.

Intergenerational Support and Catastrophic Health Expenditure (CHE)

Intergenerational relationship refers to the relationship between two adjacent generations, the core of which is the parent-child relationship (15). Children's intergenerational support refers to the help provided by adult children to older parents, such as emotional support, financial assistance, and informal care. Scholars have also conducted a series of studies on intergenerational support. Merz et al. (16) studied whether the quality of intergenerational relations regulates the happiness between parents and adult children. They found that the well-being of parents benefited from the support of their children. Chen et al. (17) investigated the differences between children's intergenerational support and life satisfaction of the elderly in different Chinese elderly groups. The results show that there is an age difference between children's intergenerational support and life satisfaction of the elderly, whether it is exchange mode or different types of support. Schwarz et al. (18) compared samples from rural and urban areas in China, Indonesia and Germany. It is found that under different cultural backgrounds, the happiness of elderly mothers is differently related to the help they give to their adult daughters. Yang et al. (19) used 78 Asian female college students as samples to explore the relationship between intergenerational cultural conflicts, parental social support and subjective well-being. In addition, Wu et al. (20) studied 153 elderly people in Taiwan Province of China and found that depressive symptoms are significantly related to social media use, social support, and intergenerational relationships. Choi et al. (21) investigated the relationship between intergenerational support patterns and depressive symptoms of elderly men and women in South Korea and found that lack of mutual financial support significantly increased the risk of depressive symptoms. Gierveld et al. (22) used the data of the intergenerational and gender surveys in three countries in Eastern Europe and two countries in Western Europe to study the relationship between intergenerational support and loneliness. Some scholars have focused on the differences in intergenerational support. For example, Chen et al. (23) studied the gender differences in intergenerational support between Chinese only-child families and multi-child families. Song et al. (24) used a random effects model to explore the gender differences in intergenerational support for the elderly in rural Chinese families. Bordone et al. (25) compared the intergenerational support between international immigrants and non-immigrant populations in northern, central and southern Europe. Moore et al. (26) explored the difference in intergenerational support between divorced adults and their parents. Santarelli et al. (27) analyzed the similarities and differences between parent-child relationship, closeness and support in four selected Italian regions (Liguria, Umbria, Sicily, and Sardinia). Zhou et al. (28) examined the impact of taking care of grandchildren on the health of grandparents and the role of intergenerational support for adult children.

Combining the existing literature, we found that scholars mainly studied the relationship between intergenerational support and satisfaction, happiness or intergenerational support and loneliness and depression. Some scholars have carried out research on the differences in intergenerational support between different regions and roles. Only a few scholars pay attention to the relationship between intergenerational support and health, and the research conclusions have not yet reached a consensus (29). Intergenerational support is an important link between parents and adult children. In some countries, most elderly people rely on their adult children for financial and instrumental support. At the same time, older parents are also an important source of family help and child's care for adult children. This enables adult children to better participate in the labor market. These intergenerational relationships are the cornerstone of the family's economic welfare and also protect each generation from age-related health threats (30). Therefore, the introduction of intergenerational support into the study of health or catastrophic health expenditure is of great significance to further clarify the relationship between the two. This paper innovatively explores the impact of intergenerational economic support, intergenerational emotional support and multimorbidity on the catastrophic health expenditures of middle-aged and elderly families, which not only provides new ideas for research in this field, but also provides new methods for alleviating catastrophic health expenditures.

METHODS

Data Source

The data used in this article comes from the 2018 China Health and Retirement Longitudinal Study (CHARLS). CHARLS is a large-scale national follow-up survey designed and implemented by the Social Science Investigation Center of Peking University specifically for middle-aged and elderly people. The main target of the CHARLS survey is the elderly in China. The survey aims to establish a high-quality micro-database representing the families and individuals of middle-aged and elderly people aged 45 and above in China. The content of the survey includes information from the macro-social and economic conditions to the micro-level personal health conditions. CHARLS adopted a multi-stage sampling method with probability proportional to scale. The survey samples covered middle-aged and elderly populations in 28 provinces, municipalities, and autonomous regions across the country. Since 2011, CHARLS has officially launched a national survey. The survey followed the baseline survey sample in 2013. The CHARLS follow-up survey covered 450 villages in 150 counties and districts across the country. A total of 23,000 respondents from approximately 12,400 households successfully accepted the interview. On the whole, the sample can represent the middle-aged and elderly population in China and has excellent representation. This article first matched the household codes and obtained a total of 9,110 household samples to calculate catastrophic health expenditures. After excluding the missing values of key variables and control variables, 4,184 effective samples were obtained.

Dependent Variable

The explanatory variable in this article is whether the household has catastrophic health expenditures. Due to the strong rigidity of food expenditures, in order to avoid deviations

in the measurement of catastrophic health expenditures of low-income families, this paper uses non-food expenditures as the denominator to measure catastrophic health service expenditures, and household health expenditures as the numerator to examine family health Expenditure accounts for the remaining proportion of household effective income after deducting basic consumption expenditure (31). Use E_i to indicate whether catastrophic health expenditures occur, and the calculation formula is as follows:

$$E_i = \begin{cases} 0 \ \ if \ \ T_i/(x_i - f(x)) < z \\ 1 \ \ if \ \ T_i/(x_i - f(x)) \geq z \end{cases} \quad (1)$$

In the formula, T_i is the family's annual health expenditure. x_i is the annual household consumption expenditure. $f(x)$ is the household food consumption expenditure. z is the threshold. With reference to the WHO definition criteria, this article assumes that $z = 40\%$ (32). The incidence of catastrophic health expenditure refers to the percentage of households with catastrophic health expenditures in all households. According to E_i, the incidence of family catastrophic health expenditure can be calculated. This article uses the three questions CE010_6, GE000_W4 and GE006_W4 in the CHARLS2018 questionnaire to calculate the incidence of catastrophic health expenditures. CE010_6 is the direct or indirect medical expenditures of your family in the past year. Indirect medical expenditures refer to transportation expenses, nutrition expenses, family care expenses, etc. incurred due to medical treatment. It does not include the part already paid by medical insurance. GE000_W4 is how much money your family spends a month on average (rent, food, clothing, communications, utilities, fuel, service expenses, entertainment expenses, daily necessities and medical expenses are included). GE006_W4 is how much your family spent on food in the last week (wine display, banquets, dining out, buying cigarettes, drinks, etc. are not included). Use "0" to indicate that the family has not incurred catastrophic health expenditures, and "1" indicates that the family has incurred catastrophic health expenditures.

Independent Variables

The core independent variables of this article are intergenerational economic support, intergenerational emotional support and multimorbidity. The intergenerational economic support and emotional support in this article refer to the support provided by adult children to their parents. Many scholars have discussed the main content of intergenerational support provided by offspring (33–35). Existing literature and theories generally summarize the intergenerational support provided by children to the elderly into three aspects: economic support, emotional support and life care (36). This article only specifically studies two aspects of intergenerational economic support and emotional support. The data of intergenerational economic support comes from CE002_1 in the CHARLS 2018 questionnaire. CE002_1 is how much economic support you or your spouse have received from your children in the past year. This paper uniformly adds 1 to the economic support in the empirical process and then takes the logarithm to avoid the influence of extreme values, missing values and zero values. The emotional support data comes from DD006_W4 in the CHARLS2018 questionnaire. DD006_W4 is how often you and your children saw each other in the past year. Assign a value of "1" to see almost once a day. Assign a value of "2" to see almost once a week. Assign a value of "3" to see almost once a month. Assign a value of "4" to meet infrequently and a value of "5" to almost never meet.

The chronic disease data in the CHARLS2018 questionnaire includes hypertension, dyslipidemia, diabetes (abnormal blood sugar), malignant tumors, chronic lung disease, liver disease, heart disease, kidney disease, stomach or digestive system disease, arthritis, asthma, etc. 14 Kind of chronic disease. The multimorbidity referred to in this article refers to the group suffering from 2 or more chronic diseases in the questionnaire. "0" means not suffering from multimorbidity. "1" means suffering from multimorbidity.

Covariates

Considering the influence of other factors on intergenerational economic support, intergenerational emotional support and multimorbidity, this paper incorporates variables such as age, gender, marital status, education level, medical insurance, ADL, intergenerational care, and self-rated health (SRH) into the regression model as covariates to reduce endogeneity and heteroscedasticity (29). Among them, age is a numeric variable. The data comes from the respondents' answers to the question "What is your true date of birth?" in the CHARLS2018 questionnaire. The gender is derived from the interviewer's record. "1" means male and "2" means female. Marital status comes from the question "What is your current marital status?". "1" means married and living with your spouse, "2" means married, but has not lived with your spouse temporarily due to work and other reasons, "3" means separation (no longer living together as a spouse), "4" means Divorced, "5" means widowed and "6" means never married. The level of education comes from the question "Your highest degree?". The items are in the order of 7 levels from illiterate to doctoral degree. Since the samples are mainly middle-aged and elderly, and the generally accepted education level is not high, this article sets "illiterate, not graduated from elementary school" as "beginner" with a value of 1, and "graduated from elementary school" as "intermediate" with a value of 2. And finally, set "junior high school and above" to "advanced" and assign a value of 3 (37). The medical insurance data comes from the question "Are you currently participating in the following medical insurance?".

There are 12 options from urban employee medical insurance to no insurance. Due to the small participation in public medical care and medical aid, this paper assigns urban employee medical insurance to 1, urban and rural resident medical insurance to 2, urban resident medical insurance to 3, new rural cooperative medical insurance to 4, and public medical insurance to medical aid, etc., are assigned a value of 5 as other insurances. The most widely used measures of self-care ability are the Katz Index Scale of Activities of Daily Life (ADL) and the Lawton Instrumental Activities of Daily Life (IADL) (38, 39). This article uses the ADL scale to measure the self-care ability of the elderly as one of the

TABLE 1 | Description of variables.

Variable name	Definition	Obs
CHE	0 = No 1 = Yes	4,184
Economic support	Numerical variable	4,184
Emotional support	1 = Almost every day 2 = Almost every week 3 = Almost every month 4 = Seldom 5 = Hardly	4,184
Multimorbidity	0 = No 1 = Yes	4,184
Age	Numerical variable	4,184
Gender	1 = Male 2 = Female	4,184
Marital status	1 = Married with spouse present 2 = Married but not living with spouse 3 = Separated 4 = Divorced 5 = Widowed 6 = Never married	4,184
Education	1 = Primary school or below 2 = Primary-school graduated 3 = Middle school and above	4,184
Insurance	1 = Urban employee medical insurance 2 = Urban and rural resident medical insurance 3 = Urban resident medical insurance 4 = New rural cooperative medical insurance 5 = other	4,184
ADL	0 = No difficulty 1 = Have difficulty with any of them	4,184
Grandchild Care (GC)	0 = No 1 = Yes	4,184
SRH	1 = Very good 2 = Good 3 = Fair 4 = Poor 5 = Very poor	3,918

covariates. ADL includes the ability to dress, bathe, eat, get in and out of bed, get up/squat while going to the toilet, and control the bowel movement (40). If any of them is difficult, assign a value of "1". If there is no difficulty in all 6 items, the value is "0". The ADL data comes from question DB010 to question DB015. Intergenerational care refers to the elderly taking care of their grandchildren. The data comes from the question "Did you or your spouse spend time looking after your grandchildren and grandchildren in the past year?", "1" means yes, and "2" means no. Self-rated health (SRH) comes from the question "What do you think of your health?". There are five options from "very good" to "very bad", with values of 1–5 in turn. The detailed description of all variables is shown in **Table 1**.

Methodology

In this study, the dependent variable catastrophic health expenditure and the independent variable multimorbidity are binary variables, and the independent variable intergenerational economic support is an ordered multi-categorical variable. Therefore, this paper chooses Logit model for empirical analysis.

$$Logit(Y_i) = Logit(\frac{P}{1-P}) = \alpha_0 + \alpha_1 IES_i + \alpha_2 IAS_i + \alpha_3 Mul_i + \alpha_4 X_i + \varepsilon \quad (2)$$

Among them, Y_i represents the possibility of catastrophic health expenditure in household I; IES_i is intergenerational economic support for children; Mul_i is whether any member of the family i suffers from multiple diseases; X_i is the control variable; ε is a random disturbance item.

RESULTS

Descriptive Statistics Results

Table 2 shows the basic characteristics of the surveyed objects in this article, and they are divided by region. Physically, women account for the majority of the surveyed population, accounting for 60% of the total population. Nearly half of the population is 60–74 years old. People aged 75 and above account for about 20% of the total population. The married population accounts for more than half of the total population. Due to the low level of education in China before the 1980s, more than 50% of the elderly had an education level lower than that of elementary school. It is worth noting that the proportion of people with a junior high school education level and above in the western region is significantly lower than that in the eastern and central regions, indicating that there is a certain degree of educational inequity in China. From the perspective of residence, most of the respondents are located in rural areas, which is more than 70% of the total population. Although most of the investigators have medical insurance, most of them are new rural cooperative medical insurance. Nearly 30% of middle-aged and elderly people have difficulties with ADL. Nearly 80% of people with SRH are average and below. Nearly 30% of middle-aged and elderly people have taken on the task of inter-generational care. More than 30% of the population is suffering from catastrophic health expenditures, and the western region has the highest proportion of catastrophic health expenditures. More than 20% of the population suffers from a variety of chronic diseases, and the central region has the highest prevalence of disease in the population. Less than 30% of middle-aged and elderly people have emotional connection with their children almost every day. The level of economic support for the elderly is also relatively low, with an overall average value of only 4820.36 RMB. Per capita economic support is the highest in the eastern region, at 5649.46 RMB. There is a big difference between the central region, western region and the eastern region, with only 4793.74 RMB and 3975.71 RMB. The differences in economic support for elderly patients with chronic diseases in the three places also reflect the regional differences in China's economic development.

It can be seen from **Figure 1** that among variables such as multimorbidity, intergenerational emotional support, and ADL, the occurrence of family catastrophic health expenditures is more obvious. In variables such as education level and medical

TABLE 2 | Descriptive statistics.

Proportion (%)	All (*N* = 4,184)	East (*N* = 1,305)	Central (*N* = 1,650)	West (*N* = 1,229)
CHE				
No	67.76	67.36	68.42	67.29
Yes	32.24	32.64	31.58	32.71
Multimorbidity				
No	77.75	80.46	75.33	78.11
Yes	22.25	19.54	24.67	21.89
Emotional support (EmoSup)				
Almost every day	24.78	28.74	24.24	21.32
Almost every week	22.23	27.82	20.61	18.47
Almost every month	23.16	22.91	22.00	24.98
Seldom	27.08	18.77	30.12	31.81
Hardly	2.75	1.76	3.03	3.42
Gender				
Male	38.10	37.62	38.36	38.24
Female	61.90	62.38	61.64	61.76
Age				
45–59	28.75	25.36	32.12	27.83
60–74	47.63	49.81	46.12	47.36
75 and above	23.61	24.83	21.76	24.82
Marital status				
Married	59.27	60.07	61.58	55.33
Separated/divorced/windowed/never married	40.73	39.93	38.42	44.67
Education				
Primary school or below	52.63	51.80	48.36	59.24
Primary-school graduated	21.85	21.30	21.70	22.62
Middle school and above	25.53	26.90	29.94	18.14
Place of residence				
City or town central areas	18.40	16.02	23.39	14.24
Town or semi-rural areas	6.88	5.52	9.09	5.37
Rural areas	74.71	78.47	67.52	80.39
Medical insurance				
Urban employee medical insurance	12.36	13.56	14.18	8.62
Urban and rural resident medical insurance	12.19	18.77	7.94	10.90
Urban resident medical insurance	4.76	2.68	7.70	3.01
New rural cooperative medical insurance	68.67	62.15	68.42	75.92
Other	2.03	2.84	1.76	1.55
ADL				
No difficulty	70.58	73.41	69.94	68.43
Have difficulty with any of them	29.42	26.59	30.06	31.57
Grandchild care (GC)				
No	72.47	75.33	72.42	69.49
Yes	27.53	24.67	27.58	30.51
SRH				
Very good	6.81	9.90	6.56	3.91
Good	9.21	9.32	9.46	8.77
Fair	46.78	49.34	45.95	45.23
Poor	28.36	25.00	28.96	31.08
Very poor	8.83	6.44	9.07	11.02
ln(Economic support) (RMB/year)				
Mean	4820.36	5649.46	4793.74	3975.71

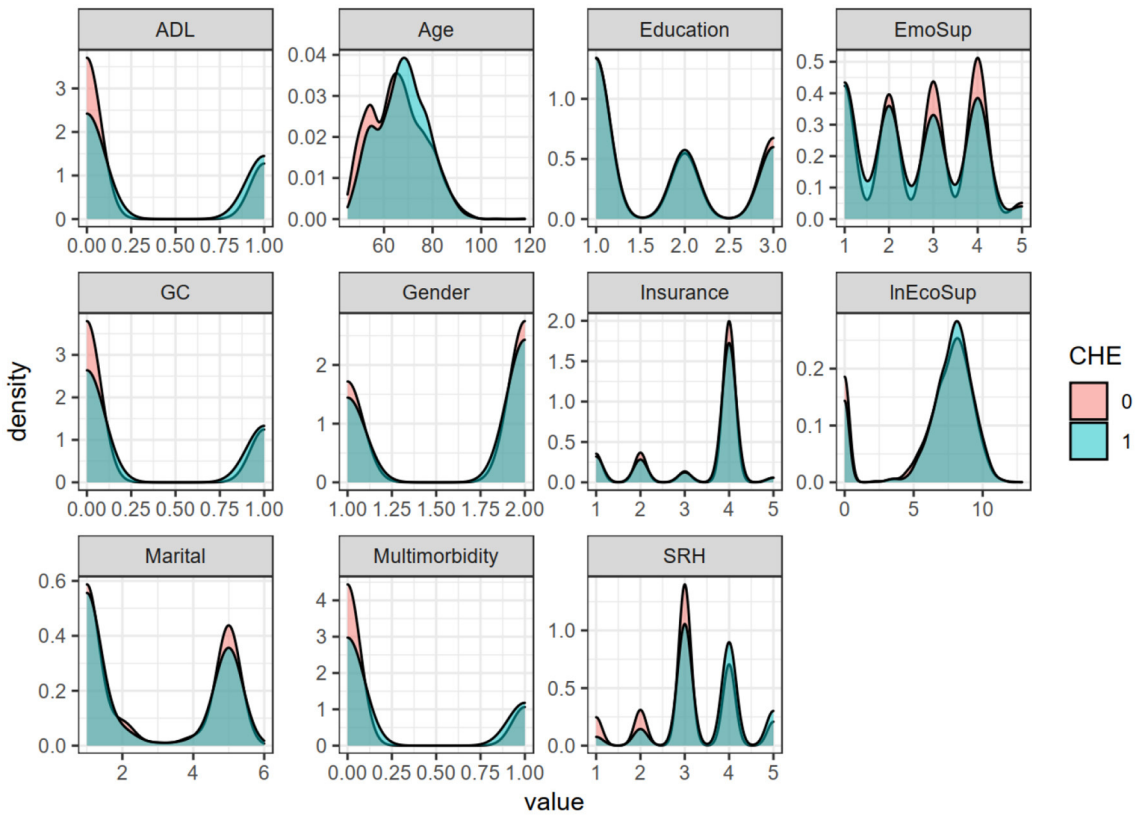

FIGURE 1 | Density curves of respective variables under different catastrophic health expenditures.

insurance, the occurrence of catastrophic health expenditures for households is not very obvious.

Stepwise Regression Results

There are two main parts to the stepwise regression. In the first part, bring the core independent variables and dependent variables into the model (**Table 3**, Model 1–3) and perform marginal effect analysis (**Figure 2**, **Table 2**), excluding the control variables. In the second part, the control variables are gradually included, and the changes in the relationship between the core independent variables and the dependent variables are observed again (**Table 3**, Model 4–8). **Table 3** shows all the results of the stepwise regression. **Table 4** and **Figure 2** show the results of the marginal effect analysis of the core independent variables. In addition, **Figure 3** visualizes the regression coefficients. It can be seen initially from **Figure 3** that the three core independent variables, intergenerational economic support, intergenerational emotional support, and multimorbidity, all have a significant impact on catastrophic health expenditures, and multimorbidity has the most significant impact. The confidence interval for the coefficients of the control variables insurance, education level, and intergenerational care includes 0, so the impact of these variables on catastrophic health expenditures is not statistically significant.

The Influence of Intergenerational Economic Support on Catastrophic Health Expenditure

From the models 1–3 in **Table 3**, we can see that intergenerational economic support has a significant positive impact on the incidence of family catastrophic health expenditures (COA: 0.043, COA = coefficient of action; $P < 0.01$). That is, when intergenerational economic support increases, the incidence of catastrophic health expenditures in the family will increase significantly. After including the control variables, the results remained stable. Through the analysis of marginal effects, it can be seen that under the condition that other influencing factors remain unchanged, increasing intergenerational economic support will increase the incidence of family catastrophic health expenditure by 0.90%; When other influencing factors are averaged, increasing intergenerational economic support will increase the incidence of family catastrophic health expenditure by 0.91% (**Table 4**, **Figure 3**).

The Impact of Intergenerational Emotional Support on Catastrophic Health Expenditures

From the models 1–3 in **Table 3**, it shows that intergenerational emotional support has a significant negative impact on the incidence of family catastrophic health expenditure (COA: −0.096, COA = coefficient of effect; $P < 0.01$). That is, the

TABLE 3 | Stepwise regression results ($z = 0.4$).

Vars	Models							
	1	2	3	4	5	6	7	8
lnEcoSup	0.0470*** (0.0112)	0.0428*** (0.0113)	0.0425*** (0.0113)	0.0342*** (0.0115)	0.0335*** (0.0115)	0.0340*** (0.0116)	0.0342*** (0.0116)	0.0370*** (0.0121)
EmoSup		−0.0951*** (0.0278)	−0.0960*** (0.0280)	−0.0610** (0.0293)	−0.0633** (0.0294)	−0.0671** (0.0296)	−0.0667** (0.0296)	−0.0646** (0.0310)
Multimorbidity			0.496*** (0.0769)	0.504*** (0.0774)	0.509*** (0.0775)	0.455*** (0.0784)	0.444*** (0.0786)	0.314*** (0.0837)
Gender				0.146** (0.0745)	0.149** (0.0745)	0.126* (0.0750)	0.118 (0.0751)	0.163** (0.0785)
Age				0.0194*** (0.0037)	0.0200*** (0.00373)	0.0160*** (0.00379)	0.0147*** (0.00385)	0.0195*** (0.00423)
Marital status				−0.101*** (0.0204)	−0.102*** (0.0205)	−0.107*** (0.0206)	−0.107*** (0.0206)	−0.106*** (0.0214)
Education				−0.0172 (0.0428)	−0.00174 (0.0447)	0.0149 (0.0449)	0.0223 (0.0452)	0.0321 (0.0468)
Insurance					0.0373 (0.0315)	0.0258 (0.0317)	0.0227 (0.0318)	0.00601 (0.0332)
ADL						0.473*** (0.0742)	0.424*** (0.0790)	0.276*** (0.0837)
GC							0.153* (0.0833)	0.0864 (0.0864)
SRH								0.347*** (0.0407)
Obs	4,184	4,184	4,184	4,184	4,184	4,184	4,184	3,918

*Standard errors in parentheses, ***p < 0.01, **p < 0.05, *p < 0.1.*

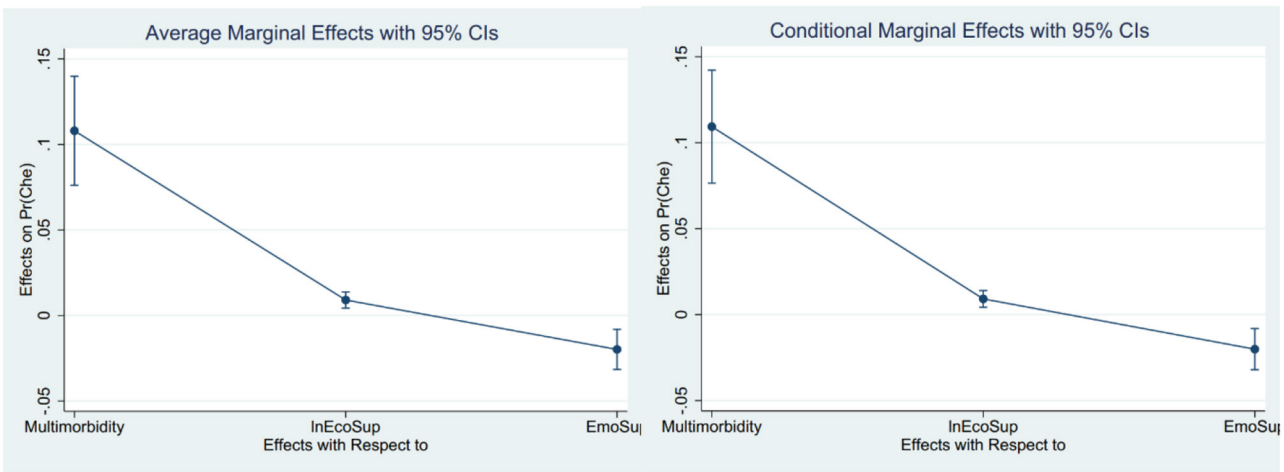

FIGURE 2 | Visualization of the results of the marginal effect analysis of the core independent variables.

more emotionally connected children are, the less likely the family will experience catastrophic health expenditures. After including the control variables, the results remained stable. Through the marginal effect analysis, it can be seen that under the condition that other influencing factors remain unchanged, improving emotional support will reduce the incidence of family catastrophic health expenditure by 1.99%;When other influencing factors are averaged, improving emotional support can reduce the incidence of family catastrophic health expenditure by 2.10% (**Table 4**, **Figure 3**).

The Impact of Multimorbidity on Catastrophic Health Expenditures

From the models 1–3 in **Table 3**, we can see that suffering from multimorbidity has a significant positive impact on the incidence of family catastrophic health expenditures (COA:

TABLE 4 | The results of the analysis of the marginal effects of the core independent variables.

CHE	Margin	Delta-method Std. Err.	z	P > |z|	[95% Conf. interval]	
Multimorbidity	0.1079809	0.0162625	6.64	0.000	0.076107	0.1398548
lnEcoSup	0.0090274	0.0024238	3.72	0.000	0.0042768	0.0137779
EmoSup	−0.0198584	0.0060003	−3.31	0.001	−0.0316189	−0.008098
CHE	**Margin at means**	**Delta-method Std. Err.**	**z**	**P > |z|**	**[95% Conf. interval]**	
Multimorbidity	0.109326	0.0167444	6.53	0.000	0.0765075	0.1421445
lnEcoSup	0.0091398	0.002464	3.71	0.000	0.0043104	0.0139692
EmoSup	−0.0201058	0.0139692	−3.30	0.001	−0.0320559	−0.0081558

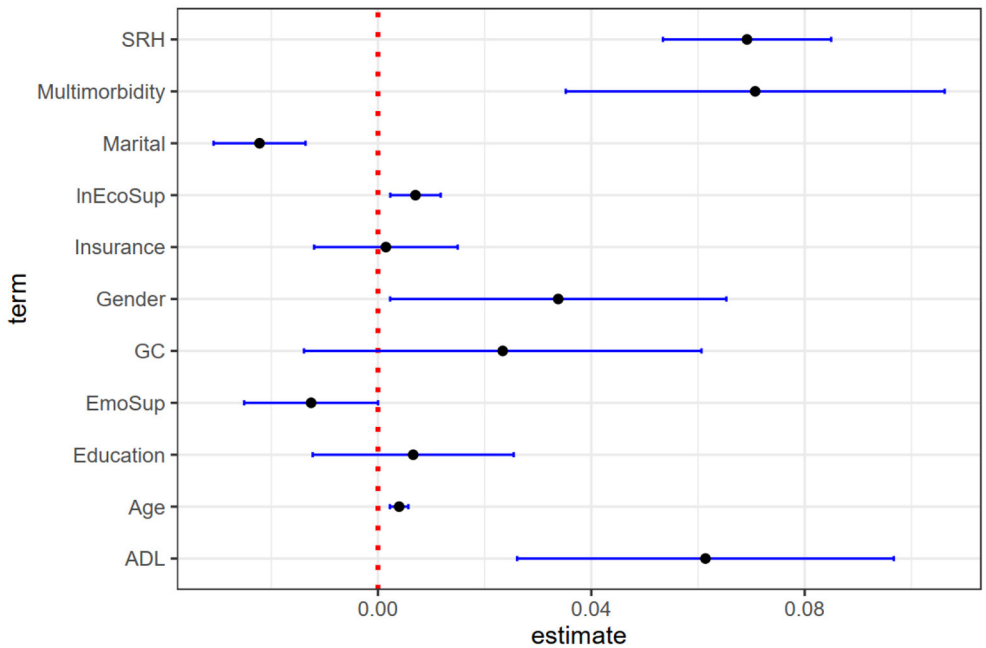

FIGURE 3 | Visualization of logistic regression coefficients.

−0.496, COA = coefficient of action; $P < 0.01$). It shows that families with multimorbidity are more prone to catastrophic health expenditures. After including the control variables, the results remained stable. From the marginal effect analysis, it can be seen that under the condition that other influencing factors remain unchanged, suffering from multimorbidity will increase the incidence of catastrophic health expenditures by 10.64%. When other influencing factors are averaged, suffering from multimorbidity will increase the incidence of catastrophic health expenditures by 10.77%.

The Impact of Covariates on Catastrophic Health Expenditures

From the models 4–8 in **Table 3**, we can see that gender, age, ADL and self-rated health (SRH) have a significant positive impact on family catastrophic health expenditures (COA: 0.163, 0.0195, 0.276, 0,347, COA = coefficient of action; $P < 0.05$, $P < 0.01$, $P < 0.01$, $P < 0.01$). It shows that with age, the incidence of family catastrophic health expenditures gradually increases. Compared with men, women have a higher incidence of catastrophic health expenditures. Respondents who have difficulties in any of the ADL activities in their families have a higher incidence of catastrophic health expenditures. The higher the SRH level (the worse the health status), the higher the incidence of catastrophic health expenditures in the family. Education level, medical insurance and inter-generational care have a positive impact on family catastrophic health expenditures (COA: 0.032, 0.006, 0.086), but the results did not pass the significance test. Marital status has a significant negative impact on family catastrophic health expenditures (COA: −0.106, COA = coefficient of action; $P < 0.01$), indicating that unmarried health expenditures are more likely to lead to catastrophic health expenditures than married ones.

TABLE 5 | Heterogeneity analysis results.

Vars	Models									
	Age = 1		Age = 2		Age = 3		Gender = 1		Gender = 2	
	1	2	3	4	5	6	7	8	9	10
lnEcoSup	0.0299	0.0285	0.0662***	0.0627***	−0.00959	0.0102	0.0467***	0.0403**	0.0399***	0.0333**
	(0.0184)	(0.0189)	(0.0180)	(0.0187)	(0.0262)	(0.0306)	(0.0179)	(0.0193)	(0.0146)	(0.0156)
EmoSup	0.0660	0.0355	−0.110***	−0.119***	−0.154**	−0.146**	-0.116**	−0.0882*	-0.0826**	−0.0486
	(0.0583)	(0.0605)	(0.0411)	(0.0427)	(0.0615)	(0.0716)	(0.0456)	(0.0505)	(0.0355)	(0.0394)
Multimorbidity	0.133	−0.0760	0.775***	0.598***	0.266*	0.00990	0.605***	0.383***	0.429***	0.271**
	(0.159)	(0.167)	(0.108)	(0.114)	(0.159)	(0.196)	(0.124)	(0.137)	(0.0980)	(0.106)
Gen		0.0638		0.0901		0.429**				
		(0.148)		(0.109)		(0.185)				
Age								0.0165**		0.021***
								(0.00678)		(0.00544)
MS		−0.0856*		−0.0464*		−0.217***		−0.186***		−0.072***
		(0.0507)		(0.0276)		(0.0453)		(0.0384)		(0.0264)
Edu		0.0460		0.0323		0.0141		−0.0291		0.0702
		(0.0836)		(0.0661)		(0.115)		(0.0719)		(0.0618)
Ins		0.115		−0.0123		−0.0765		0.0211		−0.00258
		(0.0722)		(0.0469)		(0.0652)		(0.0505)		(0.0444)
ADL		0.221		0.371***		0.167		0.157		0.337***
		(0.182)		(0.114)		(0.173)		(0.143)		(0.104)
GC		0.264		0.105		0.0543		0.224		0.0284
		(0.200)		(0.123)		(0.172)		(0.154)		(0.109)
SRH		0.331***		0.354***		0.323***		0.371***		0.330***
		(0.0774)		(0.0581)		(0.0874)		(0.0669)		(0.0515)
Obs	1,203	1,187	1,993	1,941	988	790	1,594	1,512	2,590	2,406

*Standard errors in parentheses, ***p < 0.01, **p < 0.05, *p < 0.1.*

Robustness Test

In the previous logistic regression, this article calculated the catastrophic health expenditure with $z = 0.4$. In order to verify the robustness of the results, this paper once again calculates catastrophic health expenditures with $z = 0.2$, $z = 0.3$, and $z = 0.5$, and re-analyses the regression analysis. The specific results are in **Tables 1–3** in the **Appendix** section. The results show that the core independent variables intergenerational economic support and multimorbidity still have a significant positive impact on catastrophic health expenditures, and intergenerational emotional support has a significant negative impact on catastrophic health expenditures. The influence of control variables such as gender and age on catastrophic health expenditure is basically consistent with the original regression results. It can be seen that the regression results of this article are robust.

Heterogeneity Validation

Table 5 reports the difference analysis results of age and gender. Model 1–6 divides the age into three groups according to the middle-aged and old age classification standards (Group 1: $45 \leq age \leq 59$; Group 2: $60 \leq age \leq 74$; Group 3: $age \geq 75$). Then regresses them separately. Models 1, 3, and 5 are the core independent variable regressions, and models 2, 4, and 6 are the results after incorporating the control variables. The results show that intergenerational economic support has a positive impact on family catastrophic health expenditures, and it is more significant in group 2 ($60 \leq age \leq 74$) (COA: 0.0627, COA = coefficient of action, $P < 0.01$). The impact of intergenerational affective support on catastrophic health expenditures in group 1 ($45 \leq age \leq 59$) did not pass the significance test, but it has a significant negative impact on catastrophic health expenditures in group 2 ($60 \leq age \leq 74$) and group 3 ($age \geq 75$) (COA: 0.119,0.146, COA=coefficient of action; $P < 0.01$, $P < 0.05$). Multimorbidity has a positive impact on the catastrophic health expenditures of the three groups, but only the group 2 has a statistically significant result (COA: 0.598, COA = coefficient of action; $P < 0.01$).

Model 7–10 is divided into two groups according to gender (male group: gender = 1; female group: gender = 2), and regression is performed respectively. Model 7 and Model 9 are the core independent variable regressions, and Model 8 and Model 10 are the results after incorporating the control variables. The results show that intergenerational economic support has a positive impact on family catastrophic health expenditures, and it is more significant among male (COA:0.0403, COA = coefficient of action, $P < 0.05$). Intergenerational emotional support has a negative impact on family catastrophic health expenditures, and the impact is also more significant among male (COA:−0.0882, COA=coefficient of action, $P < 0.05$). In the female group, after including the control variables, the impact of intergenerational economic support on family catastrophic health expenditures was not

statistically significant. Multimorbidity have a positive impact on catastrophic health expenditures, and the impact is more significant in male (COA: 0.383, COA = coefficient of action, $P < 0.01$).

DISCUSSION

Through regression analysis and marginal effect analysis, it can be seen that whether or not suffering from multimorbidity has a significant positive impact on family catastrophic health expenditures, and it is more significant than intergenerational economic support and intergenerational emotional support. This means that families with multimorbidity are more likely to fall into catastrophic health expenditures than those without multimorbidity. This result is consistent with previous studies (41, 42). Gao Meng-ting et al. also found that the risk of catastrophic health expenditure in families with chronic patients increased by 1.06 times (43). Chronic diseases have a long course and are generally difficult to cure. Many chronic diseases have resulted in higher drug and medical costs. For example, a study by Agudelo et al. (2) found that in Medellin, Colombia, out-of-pocket expenditures related to high blood pressure accounted for 1.6% of the total annual household basic expenditures on average in terms of purchasing power parity (USD-PPP). In addition, China's medical insurance policy pays less attention to chronic diseases in outpatient clinics, and the coordination mechanism for chronic diseases in outpatient clinics in various regions has not been established and perfected (1, 44). However, the ceiling line for outpatient chronic disease management in each coordinating unit is relatively low. Once a family member has multimorbidity, the outpatient chronic disease co-ordination system cannot effectively alleviate the risk of spillover economic losses, which makes these families more prone to catastrophic health expenditures.

Increases in intergenerational economic support are often accompanied by increases in the incidence of household catastrophic health expenditures. China has always attached importance to filial piety. Affected by traditional concepts such as "bring up children for the purpose of being looked after in old age", the old-age care methods in China, especially in rural areas, are mainly family care and back-feeding. The quality of life and health of the rural elderly directly depend on the intergenerational support provided by their children. The research of Jia et al. and Zhang et al. (45, 46) also proved this view. However, in order to reduce the burden on children, the elderly generally rarely ask for financial support from their children when they have sufficient pension funds or in a timely manner. When catastrophic health expenditures occur in middle-aged and elderly families, children have to increase economic support to ease the pressure on parents. This is manifested as a positive relationship between economic support and catastrophic health expenditure (46). On the contrary, older people are eager to have more emotional connections with their children because of their loneliness. Therefore, the more frequent and close the emotional connection between children and their parents, the better the health of the parents (45). This is often accompanied by a reduction in household medical spending. The risk of households falling into catastrophic health expenditure is also reduced.

Heterogeneity analysis has found that the increase in intergenerational economic support is most likely to lead to catastrophic health expenditures for families with 60–74-year-olds. The study by Zhang et al. (1) also proves that the probability and average intensity of catastrophic health expenditure risk in families with elderly people over 65 are significantly higher. Compared with middle-aged people aged 45–59, the elderly is at higher risk of illness due to reduced (degenerate) physical function, resistance and immunity, and are more likely to have catastrophic health expenditures. However, compared with the elderly over the age of 75, the elderly aged 60–74 still have better activities and working ability, and can provide assistance in housework and child care for adult children. Therefore, should they suffer from catastrophic health expenditures, their children must also provide greater financial support. In addition, families with male members with multiple chronic diseases are more likely to fall into catastrophic health expenditures. The study of Zhai et al. (47) also found that men are more likely to fall into poverty due to illness than women. China's ideology of "Men take charge of the outside, and women take charge of the inside" is deeply rooted, so generally speaking, males are the main labor force in China, especially in rural families (48). When the main labor force in the family is affected by the multimorbidity, and the economic income is greatly reduced or even disappeared, it is very easy to fall into catastrophic health expenditure.

And unexpectedly, enrolling in health insurance can exacerbate household catastrophic health expenditures. This is consistent with the research of Zhao et al. and Huang et al. (44, 49). We believe that the "currency illusion" created by medical insurance makes insured people seek higher-priced medical and health services, leading to increased out-of-pocket medical expenses, which in turn increases the economic burden of disease. On the other hand, there are differences in the socioeconomic characteristics of different types of medical insurance groups. The insured population of Urban resident medical insurance and Urban employee medical insurance is generally the urban population, who receive stable income and a high level of medical reimbursement. However, the new rural cooperative medical insurance participants are rural people with lower income levels and reimbursement levels, which makes them more vulnerable to the economic burden of disease (50).

LIMITATION

This study also has some limitations. First, the intergenerational support studied in this paper only includes two dimensions of economic support and emotional support, and does not include life care, so it is not comprehensive enough. Second, this study only focused on the incidence of catastrophic health expenditures and did not measure their intensity, and the findings may not be

rich enough. It is hoped that it can be further improved in the future research.

CONCLUSION

The findings suggest that intergenerational economic support increases significantly when middle-aged and older households experience catastrophic health expenditure, especially for households with members aged 60–74. Emotional support can mitigate the risk of catastrophic health expenditure. Compared with the former two, multimorbidity has a more prominent exacerbating effect on household catastrophic health expenditure, especially for families with multimorbidty male members. In addition, participation in health insurance may also increase the risk of household catastrophic health expenditures due to the "currency illusion" of health insurance and differences in the socioeconomic characteristics of the insured population. Therefore, it is suggested that we should do a good job in the popularization of chronic disease knowledge to minimize the occurrence of multimorbidity. Secondly, we should set up group medical insurance related to the diagnosis of chronic diseases and divide the medical insurance reimbursement level in detail according to the severity of the disease or the special situation of the patient, especially in terms of chronic disease outpatient clinics and drug reimbursement. In addition, the medical insurance department need to promote the reform of medical insurance and ensure the rational distribution of medical insurance funds among different types of insurance. Also, adult children are encouraged to strengthen their emotional connection and effective care of the elderly. Another important point is that the elderly aged 60–74 should be focused on. The children ought to reduce the pressure of their intergenerational care and maintain the physical and mental health of the elderly.

DATA AVAILABILITY STATEMENT

Publicly available datasets were analyzed in this study. This data can be found here: http://charls.pku.edu.cn/.

AUTHOR CONTRIBUTIONS

ST provided guidance on the thinking the study. LY conceived and wrote the full text. ZL provided us with the full text of the embellishment. TY cleaned data on economic support and intergeneration care. ML painted **Figure 3**. YG, YX, and CY provided suggestions for revisions to the article. All authors read and approved the final manuscript.

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SUPPLEMENTARY MATERIAL

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Real-World Impact of Switching From Insulin Glargine (Lantus®) to Basaglar® and Potential Cost Saving in a Large Public Healthcare System in Saudi Arabia

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Background: The advent of Basaglar®, which is a biosimilar insulin glargine formulation for Lantus® has brought hope that it will result in similar outcomes and lower costs. However, some health practitioners raised some concerns about the therapeutic equivalence of this new biosimilar. Therefore, we aimed to examine the clinical and financial impact of switching from Lantus® to Basaglar®.

Methods: This was a single–center retrospective chart review study of adult patients (e.g., ≥18 years) with diabetes mellitus (DM) who were treated with insulin glargine (Lantus®) for at least 12 months and then switched to Basaglar® for another 12 months. The potential cost savings for the years 2018 to 2021 and the cost avoidance for 2022 were estimated using different conversion ratios between the two insulin glargine products (Basaglar® and Lantus®) and acquisition prices.

Results: One–hundred patients with DM who were previously treated with Lantus® and switched to Basaglar® were retrospectively recruited. About two–thirds of the patients (68%) had type 2 DM, and the male and female patients were equally represented. The mean glycated hemoglobin (A1C) at baseline was 9, and the mean difference in the A1C levels before and after switching to Basaglar® was not significant (0.18, *p*-value = 0.503, 95% CI [−0.36–0.72]). Although the difference in the total daily insulin units between Lantus® and Basaglar® was not significant, the difference was leaning toward statistical significance despite the small sample size (−1.88, *P*-value = 0.25, 95% CI [−5.15–1.38]). Switching from Lantus® to Basaglar® could have led to significant cost savings that would range from approximately 1.77 to 23.7 million United States Dollars (USD) for the years 2018 to 2021 assuming an equal conversion ratio. However, those cost savings might not be realized if the switching to Basaglar® required higher daily

insulin units, and the difference in the public tender acquisition price between Lantus® and Basaglar® is less than 15%.

Conclusion: Basaglar® and potentially other biosimilar insulin glargine products can lead to significant cost savings without compromising the quality of care. However, their acquisition prices should be discounted.

Keywords: diabetes mellitus, insulin glargine, Lantus®, Basaglar®, cost savings, Saudi Arabia

INTRODUCTION

Diabetes mellitus (DM) is a prevalent chronic health condition with serious complications if left untreated, such as stroke, chronic kidney disease, and myocardial infarction (1). DM is characterized by an elevation in the blood glucose levels that require close monitoring and effective control (2). It is believed that more than 476 million people worldwide suffer from either type 1 or type 2 DM, and this number is expected to rise to 570.9 million by 2025 (1). Moreover, the current global incidence of DM is approximately 23 million people annually (1). In Saudi Arabia, the prevalence and incidence of DM are one of the highest in the world (3). It is believed that around 7 million people suffer from DM and 3 million have prediabetes in Saudi Arabia (3, 4).

Although multiple oral and injectable medications have been approved for the management of DM, insulin remains the mainstay therapy, especially for type 1 DM (5, 6). Different insulin types exist today for different indications, such as rapid–acting, short–acting, intermediate–acting, and insulin mixtures. Short–acting regular insulin is administered subcutaneously usually 30 min before the meal with a duration of 5 to 8 h (7, 8). Similarly, the rapid–acting insulin, such as lispro and aspart, are administered subcutaneously before meals, however, they should be administered 15 min before meals due to their faster onset in comparison to regular insulin (8). Moreover, they are associated with a lower incidence of postprandial hypoglycemia and better control of postprandial glucose levels (8). On the other hand, intermediate–acting insulin, such as the Neutral Protamine Hagedorn (NPH), takes approximately 2 h to work and lasts 10–16 h (9). Therefore, it is available in different mixtures with regular and rapid–acting insulins [e.g., NPH/regular (70/30), protamine/lispro (50/50), and protamine/aspart (70/30)] to make its onset of action faster (9). Basal insulins, such as insulin glargine, insulin detemir, and insulin degludec are widely used in the management of both type 1 and type 2 DM (10–13). Their onsets and durations of action are variable and range from 1 to 4 h and 20 to 42 h, respectively (12). Although basal insulins, such as degludec and glargine, were found to have lower rates of hypoglycemic events in comparison to NPH insulin, no significant differences were found between them with regard to common side effects, such as weight gain and local site reactions (10, 14). However, insulin degludec appears to show lower rates of hypoglycemic events in comparison to insulin glargine among patients with type 2 diabetes but not type 1 (14). Nonetheless, insulin glargine has by far the largest market share in comparison to other basal insulins (12, 15).

Insulin prices have witnessed a dramatic increase over the past decade putting a huge strain on the budgets of different healthcare systems (16–18). The approval of long–acting biosimilar insulins with comparable safety and efficacy profiles to that of originators has improved the prospects of better affordability and access to those highly essential therapeutic molecules (18, 19). In 2014, Basaglar® (insulin glargine) has been launched by Eli Lilly (Eli Lilly and Company, Indianapolis, IN, USA) and Boehringer Ingelheim (Ingelheim am Rhein, Germany) as the first follow–on biologic or biosimilar insulin to Sanofi's Lantus® (Sanofi Aventis, Paris, France) and was approved by the European Union and tentatively by United States Food and Drug Administration (USFDA) (20, 21). Shortly after that, it was approved by the USFDA in December 2015 (22, 23). Basaglar® has shown comparable safety and efficacy profiles to Lantus® among patients with type 1 and type 2 DM based on two randomized controlled trials (ELEMENT-1 and ELEMENT-2) (24, 25). However, these studies did not provide sufficient evidence to support the interchangeability or substitution between Lantus® and Basaglar® (26). Nonetheless, some observational studies have shown no difference in terms of a change in the glycated hemoglobin levels (A1C) or daily insulin units. Moreover, the switch from Lantus to Basaglar resulted in significant cost savings according to a recently published retrospective observational study that included 225 patients from five different clinics affiliated with three different healthcare systems in the State of Iowa, United States (27).

In Saudi Arabia, the utilization of insulin is one of the highest in the world due to the high prevalence of DM among the local population (3, 4). The most conservative estimate of the direct medical cost of diabetes based on the Saudi Ministry of Health (MoH) data is 17 billion Saudi Riyals (USD 4.53 billion) in 2014, and this figure is expected to rise to USD 7.2 billion if those with undiagnosed diabetes join the treatment pool (28). Therefore, different strategies to minimize the financial burden of DM on the public healthcare sector are explored, and switching to less expensive biosimilar insulins is one of them (19). However, several Saudi public healthcare sectors are reluctant to switch from Lantus® to Basaglar® mainly due to the perceptions among some physicians that Basaglar® is not therapeutically equivalent to Lantus® and may lead to poor glycemic control if patients were switched to it. Thus, we aimed to explore the impact of switching from Lantus® to Basaglar® on the A1C levels and budget of a large military health system in Saudi Arabia.

METHODS

Study Design and Setting

This was a retrospective review of electronic medical records (EMRs) from the National Guard Health Affairs (NG–HA). The NG–HA is one of the largest public health systems in Saudi Arabia that was founded in 1982 and has two large medical cities and multiple hospitals and primary care clinics with more than 3,000–bed capacity. Data from different institutions across the kingdom that are affiliated with the NG–HA were reviewed. The study was approved by the ethics committee of the King Abdullah International Medical Research Center, Riyadh, Saudi Arabia (approval no. RC20/608/R). No consent forms were needed since the study only involved the review of EMRs, and no personal identifiers of patients (e.g., name, phone number, and national identification number) were collected. The study adhered to the ethical principles of the Helsinki declaration and all collected data were anonymized and kept confidential (29).

Population

Adult patients (e.g., ≥18 years) with type 1 or type 2 DM who have been treated with insulin glargine (Lantus®) for at least 12 months before being switched to Basaglar® and treated for at least another 12 months were included in the study. Patients who have not been treated with Lantus® before Basaglar®, those who have not been treated with Lantus® or Basaglar® for at least 12 months, and those who have their treatment plans modified, such as an increase or discontinuation of medication for DM, were excluded. Furthermore, patients with missing observations, such as the A1C, were excluded. Additionally, those who have their DM medications changed during the first 12 months after the switch to Basaglar® were excluded. Demographic patient characteristics, such as age and gender, weight, duration of illness in years, other chronic health conditions (e.g., hypertension, dyslipidemia, cardiovascular disease), glycated hemoglobin (A1C), daily units of rapid–acting insulin (e.g., aspart), and the number of other hypoglycemic medications were collected.

Statistical Analysis

The patients' baseline characteristics were reported using descriptive statistics, such as mean standard deviation, frequencies, and percentages. Daily insulin units, A1C, and weight were compared before and after the switch to Basaglar® using paired Student's *t*-test.

To examine the budget impact of replacing Lantus® with Basaglar®, the total number of procured pre-filled pens of Lantus for the years 2018 to 2022 were retrieved from one of the largest military healthcare systems in Saudi Arabia, and the potential cost savings were estimated based on a scenario of total replacement of the procured number of pre–filled pens of Lantus® with Basaglar®. This method was used due to the lack of accurate statistics (e.g., prevalence and incidence rates) about the number of patients with DM in these institutions. Therefore, examining the budget impact using the real procured quantities for the years 2018 to 2022 should represent the true budget impact. The acquisition prices for both Lantus® and Basaglar® for each unit (pre-filled pen) were retrieved from the Saudi Food and Drug Authority (SFDA) website, which shows the public prices of different registered medications (30). Moreover, sensitivity analyses were conducted by varying the acquisition prices for each unit of Lantus® and Basaglar® based on the opinions of five individuals working in the pharmaceutical planning and purchasing in five different public health sectors in Saudi Arabia. Additionally, the potential procured quantities of Basaglar® were varied based on the 95% confidence limits of the mean difference in total daily insulin units between Lantus® and Basaglar®. Statistical analyses were conducted using SAS® version 9.4 (SAS Institute, Cary, NC, USA), and Microsoft® Excel 2016.

TABLE 1 | Patient baseline characteristics.

Characteristics	Total (*N* = 100)
Age in years, mean ± SD	54.41 ± 21.91
Gender, *N* (%)	
Male	50(50%)
Female	50(50%)
Type of diabetes, *N* (%)	
Type 1 diabetes	32 (32)
Type 2 diabetes	68 (68)
Duration of illness in years, mean ± SD	3.95 ± 0.53
Comorbidities, *N* (%)	
Dyslipidemia	38 (38)
Hypertension	52 (52)
Cardiovascular disease	56 (56)
Number of comorbidities, mean ± SD	2.54 ± 1.97
Weight in KG, mean ± SD	77.15± 20.83
Number of oral antidiabetic medications, mean ± SD	0.522 ± 0.848
Hemoglobin A1C, mean ± SD	9.05± 2.04

RESULTS

Using the EMRs queries, data for 117 patients who were switched from Lantus® to Basaglar® were retrieved. However, 17 patients were excluded due to missing observations resulting in a sample of 100 patients. The female and male patients were equally represented in the sample and the patients' mean age was 54 years. Most of the patients (68%) had type 2 DM, and hypertension and cardiovascular disease were the most commonly encountered comorbidities (e.g., >50%). The mean duration of illness, number of comorbidities, weight, A1C, and number of oral antidiabetic medications are shown in **Table 1**. The mean difference in insulin glargine daily units was −1.88 units (95% CI: −5.1491–1.376) lower for Lantus® in comparison to Basaglar®. With regard to insulin aspart, the mean daily units for Lantus® was 1.93 units (95% CI: −6.22–10.08) higher than Basaglar®. The mean A1C was 0.18% (95% CI: −0.36–0.72) higher with Lantus® in comparison to Basaglar®. The patients' mean weight was 4.19 kg (95% CI: 1.17–7.22) higher with Lantus® than Basaglar®. However, these differences except for weight were not statistically significant as shown in **Table 2**.

TABLE 2 | Number of daily units for the two insulin glargine formulations (Lantus® and Basaglar®) and insulin aspart and the difference between the A1C levels.

Variable	Lantus®, Mean ± SD	Basaglar®,Mean ± SD	Difference (95% CI)	*P*-value
Insulin glargine daily units	28.23 ± 14.94	30.11 ± 15.44	−1.88(−5.1491–1.376)	0.250
Insulin aspart daily units	41.06 ± 24.83	39.14 ± 28.68	1.93(−6.22–10.08)	0.635
A1C	9.05 ± 2.04	8.86 ± 1.72	0.18(−0.36–0.72)	0.5032
Weight in KG	77.15± 20.83	72.95 ± 20.12	4.19(1.17–7.22)	0.007

TABLE 3 | The quantities ordered (e.g., pre-filled pens) of Lantus® for a large public healthcare system in Saudi Arabia for the years 2018–2022 and their costs using different acquisition prices based on expert opinions.

Year	Quantity	Total cost at different actual acquisition prices (AAPs) per Pre-filled pen of Lantus®			
		With an AAP of $5.56	With an AAP of $11.32	With an AAP of $12.65	With an AAP of $15.81
2018	956,295	$5,319,550.64	$10,825,259.40	$12,095,726.00	$15,119,664.67
2019	1,036,086	$5,763,401.40	$11,728,493.52	$13,104,964.85	$16,381,213.84
2020	1,108,612	$6,166,839.39	$12,549,487.84	$14,022,312.14	$17,527,898.49
2021	1,141,870	$6,351,842.57	$12,925,968.40	$14,442,976.95	$18,053,729.75
2022	1,153,289	$6,415,362.66	$13,055,231.48	$14,587,410.52	$18,234,271.79

Table 3 shows the procured quantities of Lantus® and their costs for different selected prices per unit (pre-filled pen) based on expert opinions; while **Table 4** shows the costs of insulin glargine if the same procured quantities of Lantus® were replaced with Basaglar® using different selected prices based on expert opinions as well. **Figure 1** shows the expected cost savings for the years 2018 to 2022 if Lantus® was switched to Basaglar® using a conversion ratio of 1:1 units at different prices. However, the procured quantities can vary depending on the conversion ratio which ranges from 1:0.95 to 1:1.18 insulin units based on the 95% confidence limits for the mean difference in the total daily insulin units. These variable quantities are shown in **Figure 2**. Assuming the cost per unit for Lantus® and Basaglar® are $5.56 (SAR 20.85) and $5.15 (SAR 19.31), respectively, the potential cost reduction or increase based on the aforementioned conversion ratios for the years 2018 to 2022 are shown in **Figure 3**.

DISCUSSION

This study provides an interesting insight into the potential financial impacts if a decision to switch all insulin glargine from Lantus® to Basaglar® in a large military–affiliated healthcare system was taken. In Saudi Arabia, all public hospitals including those affiliated with military institutions have to procure their needs of medicines and medical supplies through a centralized procurement. Therefore, the national unified procurement company for medical supplies (NUPCO) was established back in 2009 and is believed to be the largest procurement company in the Middle East responsible for procuring, warehousing, distribution, and re-exporting of pharmaceuticals, medical equipment, and supplies on behalf of all public hospitals and healthcare facilities (31). The main aim of the centralized procurement is to cut costs and reduce waste in the public healthcare sector to improve the public health sector spending efficiency (32). Basaglar®, which is a biosimilar insulin glargine of the reference biologic (Lantus®), has shown comparable safety and efficacy profiles to Lantus® among patients with type 1 and type 2 diabetes in different industry–sponsored randomized clinical trials (24, 25). Moreover, a recently published study that examined the interchangeability between Basaglar® and Lantus® in real–world settings found no difference in the glycemic outcomes among the 225 adult patients who were retrospectively recruited from five clinics affiliated with three different healthcare systems in the United States (27). Similar findings were observed in this study since no difference in the A1C levels was found between the baseline (e.g., before Basaglar® treatment) and after 12 months of follow–up. However, there were on average about 1.9 incremental daily insulin units among this study's sample even though this difference was not statistically significant.

The use of biosimilar insulin can result in immense cost savings depending on the acquisition prices of both biosimilar insulin and the biological reference products, which is Lantus® in this case (23). However, due to the uncertainty about the conversion ratio between the different insulin glargine products, such as Lantus® and Basaglar®, and the variation in the acquisition prices of biosimilar insulins in comparison to the reference biologic products, the potential cost savings are variable (19). Although substituting generics for brand medications has resulted in significant cost savings, similar cost savings were not always realized with switching from reference biologics to biosimilar formulations. For example, Humira® (adalimumab) has seen its price reduced by more than 80% since its patent expiry and the approval of several biosimilars of adalimumab (33). The inconsistent cost savings when switching from original reference biologics to biosimilars can be attributable to a myriad of factors, such as the higher cost of manufacturing

TABLE 4 | The costs of Basaglar® based on the procured Lantus® quantities (e.g., pre-filled pens) for the years 2018–2022 ordered for a large public healthcare system in Saudi Arabia using different acquisition prices based on expert opinions.

Year	Quantity	Total cost at different actual acquisition prices (AAPs) per pre-filled pen of Basaglar®			
		With an AAP of $5.15	With an AAP of $7.67	With an AAP of $8.38	With an AAP of $10.23
2018	956,295	$4,921,094.07	$7,334,782.65	$8,012,477.04	$9,779,646.45
2019	1,036,086	$5,331,698.56	$7,946,779.62	$8,681,019.23	$10,595,637.09
2020	1,108,612	$5,704,917.35	$8,503,054.04	$9,288,690.41	$11,337,331.48
2021	1,141,870	$5,876,063.02	$8,758,142.90	$9,567,348.11	$11,677,447.74
2022	1,153,289	$5,934,825.19	$8,845,726.63	$9,663,024.10	$11,794,225.29

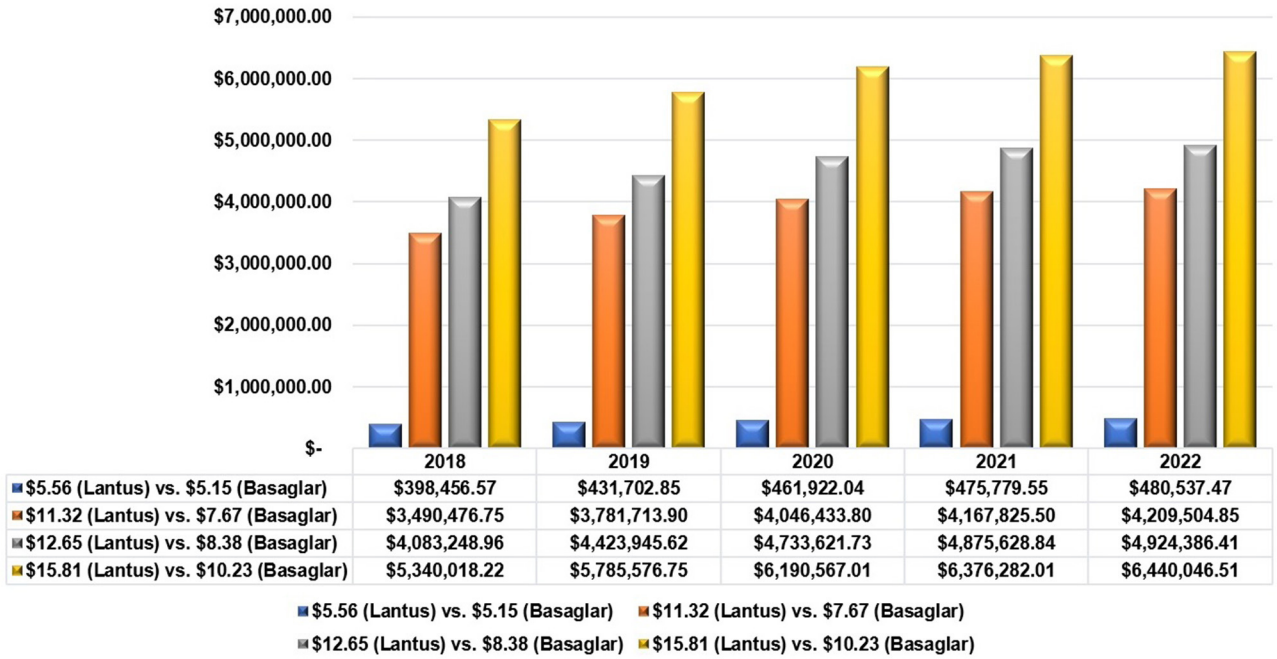

FIGURE 1 | The potential cost savings due to switching from Lantus® to Basaglar® using different prices.

biologics in comparison to small molecules, the regulatory requirements of proving bio-similarity with reference biologic products, and clinical data to support the safety and efficacy of new biosimilars (34). Nonetheless, the competition between biosimilar insulins and their reference biologics can result in significant cost reduction even if their prices are slightly lower (35).

Based on the findings of this study, switching from Lantus® to Basaglar® could have resulted in cost savings that would range from approximately 1.77 to 23.7 million United States Dollars (USD) for the years 2018 to 2021, and the potential cost avoidance for the year of 2022 could range from about 480 thousand USD to 6.4 million USD depending on the prices of the both Basaglar® and Lantus® and assuming a 1:1 conversion ratio. However, these savings might not be realized if patients with DM needed higher dosages of insulin and if the price difference between Basaglar® and Lantus® is smaller than 15%. Although the price difference between each prefilled pen of Basaglar® and Lantus® is 35.32% ($10.23 vs. $15.81) based on the SFDA public prices (36), this difference in the unit prices (prefilled pen) was not observed in the centralized tender prices based on the expert opinions. The lowest offered prices per a prefilled pen of insulin glargine for the public tenders were 5.56 USD and 5.15 USD for Lantus® and Basaglar®, respectively, which is only 7.37% cheaper. Usually, a price reduction in the range of 20 to 40% for biosimilars should be provided to justify switching from a biological reference product to a biosimilar (19). Therefore, a reduction in the price of Basaglar® by 20% to 40% should be provided for public tenders to make the switching financially worthwhile. By discounting the prices of biosimilars in general and biosimilar insulins in particular in comparison to their original reference biologics, the rates of biosimilar adoption and inclusion in different public healthcare systems' drug formularies will increase leading to more efficient utilization of healthcare

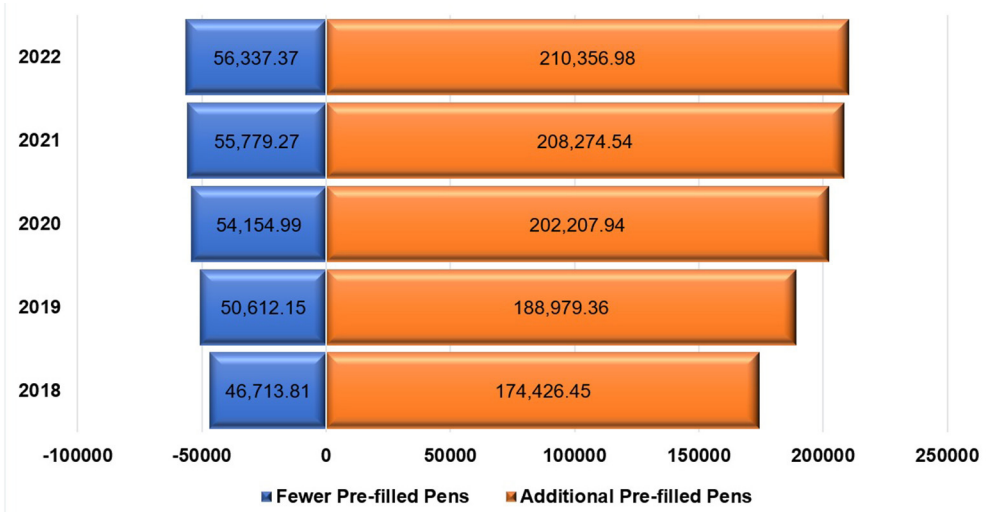

FIGURE 2 | Tornado chart for the number of pre-filled pens of Basaglar® needed to replace Lantus® for the years 2018 to 2022 based on the 95% confidence intervals (95% CI) of mean difference in number of total daily insulin units.

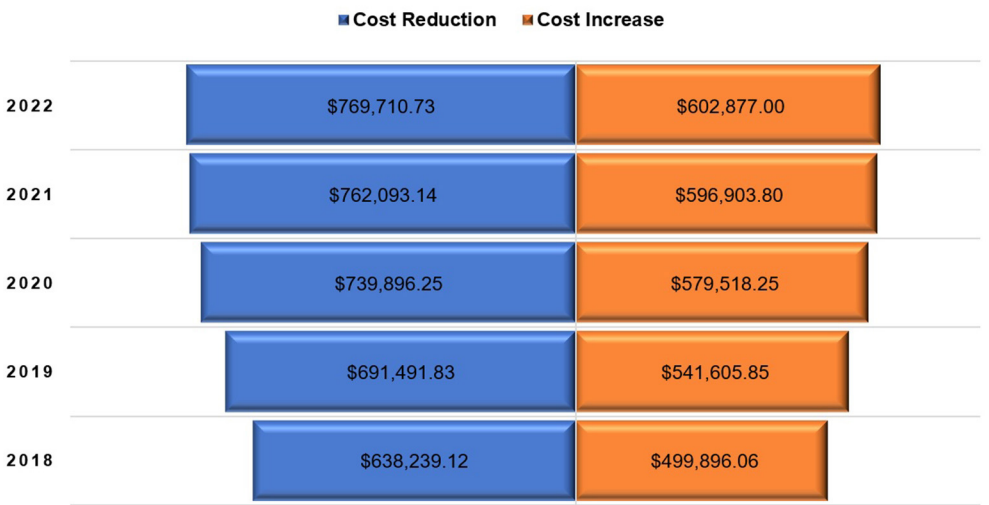

FIGURE 3 | Tornado chart of potential cost reduction or increase due to complete switching from Lantus® to Basaglar® for the years 2018 to 2022 based on the 95% confidence intervals (95% CI) of mean difference in number of total daily insulin units.

resources in the kingdom, and better accessibility to medicine for the public as advocated by the Saudi economic vision 2030 (37).

Although this is the first study to the best of our knowledge that examined the impact of switching from insulin Lantus® to Basaglar® on the glycemic outcomes and budget from the perspective of public healthcare payers in Saudi Arabia using real-world data, multiple limitations must be acknowledged. First, the study included only 100 patients which limit the generalizability of the results and increases the likelihood of selection bias. In addition, information bias cannot be ruled out since the data were retrieved from the EMRs. Moreover, the budget impact was estimated based on the procured quantities rather than the number of patients with DM who are treated with insulin glargine due to the lack of data about the real number of patients with DM in these healthcare institutions. Additionally, the selected prices upon which budget impact was examined were based on expert opinions.

CONCLUSION

The biosimilar insulin glargine (Basaglar®) has shown similar glycemic outcomes to its biological reference product (Lantus®) with insignificant difference in the mean total daily insulin dose. However, these slight differences in the total daily insulin dose could offset any cost savings attributable to the lower acquisition price of Basaglar® in light of the meager difference between

the public tender prices of the two products (Basaglar® and Lantus®). Therefore, an additional discount in the public tender price of Basaglar® in the range of 20% to 40% should be provided to justify the switching from Lantus® to Basaglar®. Future studies should further examine the interchangeability between the two insulin glargine products using a more robust research designs and among a larger sample of patients with DM.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The study was approved by the Ethics Committee of the King Abdullah International Medical Research Center, Riyadh, KSA (approval no. RC20/608/R). Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

YA, HA, and OB: concept and design. YA, HA, OB, MoA, AA, SA, and MaA: acquisition, analysis, and interpretation of data. YA and OB: drafting of the manuscript and statistical analyses. SA, HA, MoA, HA-A, MaA, and AA: administrative, technical, and material support. All authors have read, agreed to the published version of the manuscript, and critical revision of the manuscript for important intellectual content.

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Conflict of Interest: MaA is an employee of the National Unified Procurement Company (NUPCO).

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Inequalities in access to community-based diabetes examination and its impact on healthcare utilization among middle-aged and older adults with diabetes in China

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Globally, diabetes and its complications are becoming one of the leading challenges in health governance. As health inequalities and primary care services related to diabetes are gaining traction, the status of community-based diabetes examination largely remains unclear in the literature. This study aims to investigate inequalities in access to community-based diabetes examination among people with diabetes and to analyze its impact on healthcare utilization. Data from the 2018 China Health and Retirement Longitudinal Study (CHARLS) were applied, and a total of 767 patients with diabetes were included. Inequalities in community-based diabetes examination were illustrated by the concentration curve and normalized concentration index. Propensity score matching (PSM) were used to identify the impact of community-based diabetes examination on outpatient and inpatient care utilization. We found that community-based diabetes examination was accessible to 23.08% of the respondents, of which 76.84% were free, and the highest frequency was 2–6 times per year, accounting for 47.46%. Community-based diabetes examinations were more concentrated among people with poorer-economic condition (95% confidence interval, 95%CI = −0.104, p = 0.0035), lower-education level (95%CI = −0.092, p = 0.0129), and less-developed areas (95%CI = −0.103, p = 0.0007). PSM analyses showed that community-based diabetes examination increased the utilization of outpatient care (odds ratio, OR = 1.989, 95%CI = 1.156–3.974) and decreased the use of inpatient care (OR = 0.544, 95%CI = 0.325–0.909), and the sensitivity analyses confirmed the robustness of the results. This study is the first to examine the status and inequalities of community-based regular diabetes examination and its effect on the likelihood of healthcare utilization among patients with diabetes. The findings suggest that the overall level of community-based diabetes examination is low, and there are pro-socioeconomically disadvantaged inequalities. The value of community-based diabetes examination should be recognized to help person with diabetes face up to their health needs for better disease control and health promotion.

KEYWORDS

inequality, community-based, diabetes, healthcare utilization, propensity score matching

Introduction

Globally, diabetes and its complications are becoming one of the leading challenges in health governance. As reported by the International Diabetes Federation (IDF), approximately 537 million adults were living with diabetes in 2021 and had caused nearly one trillion dollars in health expenditure (1). According to a recent study conducted by the Chinese Center for Disease Control and Prevention, the overall prevalence of diabetes and prediabetes were estimated to be 12.4 and 38.1% (2). In terms of numbers, China is at the epicenter of the world diabetes epidemic. Worst of all, the rates of awareness, treatment, and adequate control are low and even seem to have stagnated (3, 4). In the face of the heavy disease burden, a major call is to strengthen diabetes self-management and glycemic control *via* regular diabetes examination such as blood glucose monitoring (5–7). Going to the hospital for tests is time-consuming and expensive (such as transportation fees), and performing the tests at home requires the acquisition of equipment and certain knowledge; community-based care services have the advantages of convenience and affordability (8, 9) and are an important aid to achieve a more balanced transition from the hospital to the individual, becoming an increasingly advocated mode of care in China. Routine prevention and management of chronic diseases are critical components of community healthcare provision, and their effective implementation contributes to increased knowledge and ability to control disease, improved health status, and cost savings, as evidenced by several previous studies on diabetes (10–13).

However, the fact is that with limited access to diabetes examinations and a general lack of patient education, a considerable proportion of diabetes cases go undiagnosed or are poorly controlled (2). Previous research has established that one significant factor for this is the absence of primary care actions (14). As a priority population for chronic disease management in the community, regular diabetes examination for people with diabetes is pinned on the hope that it will improve these conditions and facilitate the achievement of health system goals.

Compared to specialized services, primary healthcare services are relatively low cost and sometimes provided free of charge; nevertheless, inequalities in community-level healthcare may still exist even for people living in generous welfare states with universal health coverage (15). It is an undisputed fact that communities of different socioeconomic status (SES) have varying levels of access to health-promoting resources and services (16), particularly in developing countries. While health equity is the focus of attention across countries at the moment, the reality is that the balance is becoming increasingly skewed. Many studies have shown not only health inequalities but also disparities in healthcare utilization among different diabetes populations (17–23). Specifically, a lower SES is associated with a higher prevalence, poorer glycemic control, and more complications (17, 18). Disadvantaged people with diabetes lack the ability to acquire diabetes information (19), lack self-management efforts (20), do not have adequate access to diabetes care (21, 22), and may even avoid healthcare (23). Related issues have aroused great attention in light of the growing demand for healthcare caused by diabetes, but there is little research available on community-based diabetes examination, and our understanding of both its status and actual impact on healthcare utilization is extremely limited. The purpose of this study is to address these two questions.

Andersen's model is the most widely used theoretical foundation for forecasting the factors of healthcare utilization and can serve as a solid conceptual framework for this study. The determinants are categorized into four sets, namely contextual factors, individual characteristics, health behaviors, and health outcome (24), of which the proposed community-based diabetes examination is an important contextual factor. Gaps or inequities in access must be addressed before people with diabetes can benefit from larger community-based diabetes examination to meet health needs and enhance health. Increased understanding is of great value for researchers and policymakers to develop targeted initiatives to promote overall health equity and reasonable healthcare utilization. This study may provide some clues to this end.

Materials and methods

Data source and study sample

The data used in this study were from the fourth wave of the China Health and Retirement Longitudinal Study (CHARLS), which is available for free at http://charls.pku.edu.cn. CHARLS is a large and representative national study hosted by Peking University's National School of Development. The baseline survey was conducted in 2011, followed by three subsequent waves in 2013, 2015, and 2018. The database covered the population from 450 communities/villages and 150 counties in 28 provinces of Mainland China. CHARLS data quality has been reported to be satisfactory in previous studies (25–27). Given the CHARLS database contains a wealth of information on individuals' SES, health status, and health service utilization, we employed it to investigate the inequalities of regular diabetes examination in the community and their relationship to healthcare utilization among patients with diabetes aged 45 years and older. As blood tests were not performed in the 2018 survey, diabetes was defined as self-reported diabetes diagnosed by a doctor (the questionnaire did not distinguish between type 1 and type 2 diabetes mellitus, so it was assumed that both types 1 and 2 were included). The procedure of sample inclusion is presented in Figure 1.

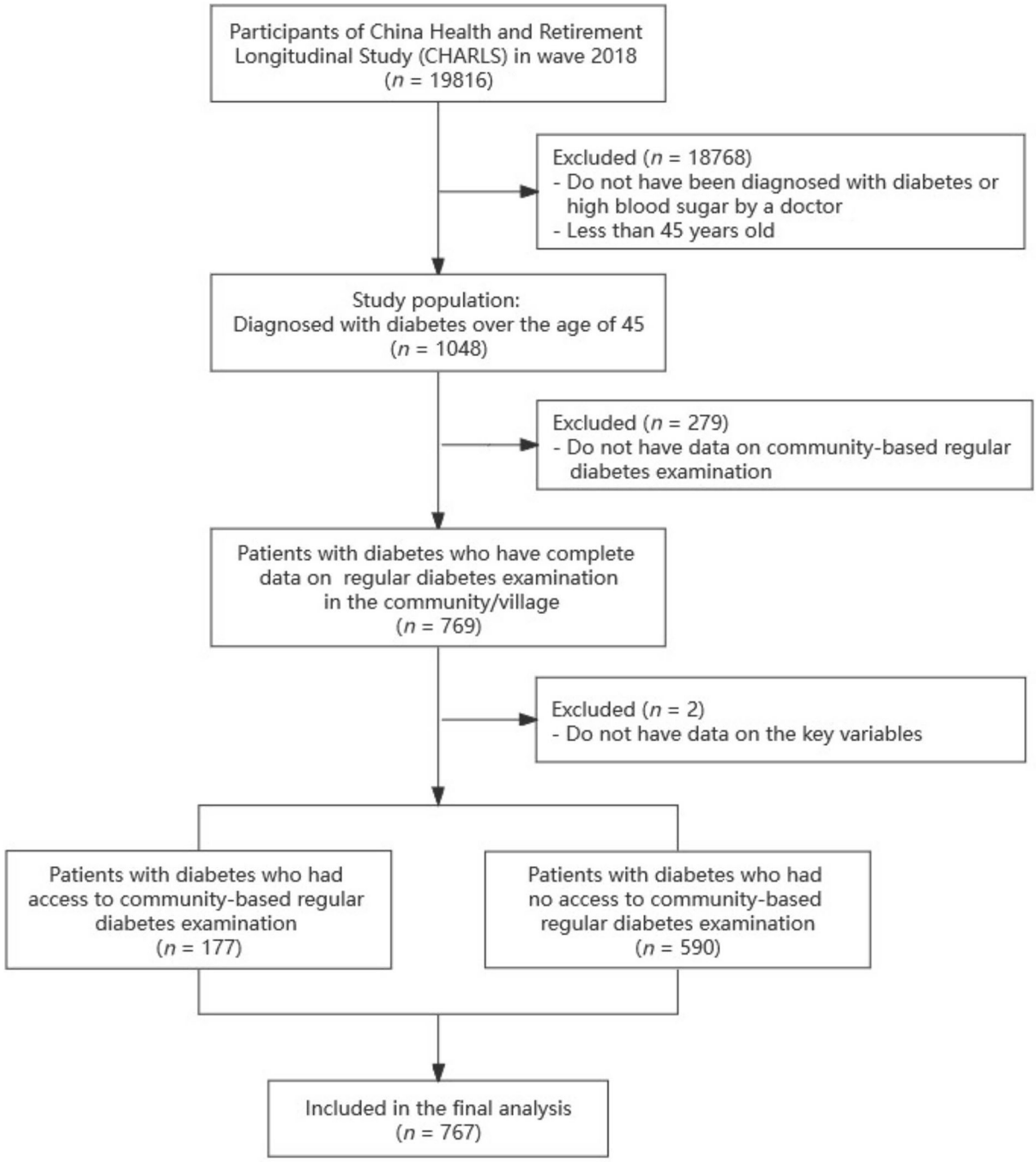

FIGURE 1
Process of sample inclusion.

Measures

Definition of healthcare utilization

We defined healthcare utilization in terms of outpatient and inpatient services utilization, which are dichotomous variables in the CHARLS data, by asking the respondents the single-choice questions of "In the last month, have you visited a public hospital, private hospital, public health center, clinic, or health worker's or doctor's practice, or been visited by a health worker or doctor for outpatient care? (Not including physical

examination)" and "Have you received inpatient care in the past year?" The answers were categorized as yes and no.

Core explanatory variable

In CHARLS, diabetes examination included blood glucose test, urine glucose test, fundus examination, and micro-albuminuria test. The core explanatory variable of the study was the availability of community-based regular diabetes examination, which is measured by the question of "During the last year, have you had diabetes examination by community/village doctors regularly?" Responses to this question were dichotomized into yes or no.

Covariates

Based on the Anderson model, the potential predictors associated with healthcare utilization can be constructed in four aspects: individual characteristics, health behaviors, health outcome, and contextual factors. The individual characteristics included sex (male/female), age (45–60/61–75/>75), marital status (married and live with spouse/other), SES, and reimbursement rates of medical insurance. SES was assessed using two indicators of economic condition and education level. Per capital household expenditure is a more accurate reflection of economic condition and can help mitigate information bias than income, especially in low-income rural areas (28). In the CHARLS data, per capital household expenditure was obtained by dividing total household expenditure by the number of household member and then grouped into quantiles, with quantile 1 indicating the poorest and quantile 3 indicating the richest. The level of education was classified into three groups: uneducated, primary school or below, and secondary school or above. The classification of reimbursement rates of medical insurance into high, low, and no insurance was according to the fact that of the listed medical insurance, government medical insurance, urban employee medical insurance, and private medical insurance reimburse at a significantly higher rate than other insurances (29).

Drinking, frequency of social interaction (almost daily/almost every week/not regularly/never), and time for physical activities were used to assess health behaviors. Three categories of drinking were established: never, more than once a month, and less than once a month. Social interaction in this study mainly refers to some forms of group activities and informal interactions that are unique to Chinese older adults, such as square dancing, playing cards/mah-jongg, interacting with friends, etc. Social interaction has been shown to be associated with health status and health service utilization of older adults (16, 30). Greater healthcare utilization may be linked to less social interaction (31, 32). The frequency of social interaction was classified in this study as almost daily, almost every week, not regularly, and never. Time for physical activities was measured with a reference to the International Physical Activity Questionnaire (IPAQ), and the calculated weekly durations were divided into quantiles, with quantile 1 indicating the least and quantile 3 indicating the most (33, 34). The health outcome was measured by a self-rated health question that classified health status as good, fair or poor.

Contextual factors included health education, type of address, and region (eastern/middle/western). Health education is a dichotomous variable. If the respondents were advised by a physician to perform any of weight control, exercise, diet, smoking control, and foot self-care, they were considered to have received health education. Options for the type of address comprised city/town center, combination zone between urban and rural areas, village, and special zone. The division of regions and address types were defined based on the National Bureau of Statistics (35).

Statistical analysis

Basic processing of data

We performed multiple imputation of five for observations with few missing values. Categorical data were described with frequency and percentage, and numerical data were described with mean and standard error (SE). The Stata 15.1 software was used for data analysis. Statistical significance was set at $p < 0.05$.

Concentration curve and concentration index

The concentration curve and concentration index (CI) were used to reflect inequalities in access to community-based regular diabetes examination by SES (economic condition and education level), type of address, and region. The CI is defined as twice the area between the concentration curve and the line of equity, and the concentration curve is obtained by plotting the cumulative percentage of the availability of community-based regular diabetes examination (Y-axis) against the cumulative percentage of the population ranked by economic condition quantiles, education level, type of address, and region (X-axis). The CI can be calculated using the following formula (36):

$$CI = \frac{2}{\mu \times cov(h, r)}$$

where h is the outcome of health event (the availability of community-based regular diabetes examination in this study), μ is the mean of h, and r is the fractional rank of individuals in the distribution used. The CI ranges between −1 and +1, and a value of zero denotes absolute fairness. If the CI takes a negative value, it means that the availability of regular diabetes examination in the community is more concentrated in the poor. Conversely, if the CI is positive, indicating community diabetes examination is more concentrated in the rich. Since the outcome variable in the study is binary, the bounds of CI do not vary between −1

and + 1. To correct this issue, we followed Wagstaff's suggestion (37), normalizing the CI by dividing estimated CI by 1 minus the mean (1–μ).

Propensity score matching

The other primary objective of this study was to estimate the impact of community-based regular diabetes examination on healthcare utilization among patients with diabetes. Given that the initial conditions of observed objects are heterogeneous, we applied propensity score matching (PSM) approach to reduce the potential bias caused by sample selection (38). The methodology of PSM is to make the observations as close as possible to the random experimental data through matching and resampling. According to the principles of PSM, the model for estimating the average treatment effect of the treated (ATT) was defined as:

$$ATT = E\left(y_{1i} \middle| D_i = 1\right) - E\left(y_{0i} | D_i = 1\right)$$

where D_i is the treatment variable. D_i is 1 when survey respondents are in communities where regular diabetes examination is available (treatment group); otherwise, D_i is 0 (control group). y_i is the outcome variable of healthcare utilization among patients with diabetes, y_{1i} and y_{0i} respectively indicated the healthcare utilization among patients with diabetes in the treatment and control group. The 1:4 neighbor matching with replacement matching method was used with a caliper of 0.05 in the base case scenario. To verify the matching effect, we examined the achieved percentage of the bias reduction of each covariate after matching. Adequate matching refers to the bias should be <10%. Then, binary logit regression models were performed to compare the outcomes in the treatment group and their matched control group, before and after the application of sampling weights provided by CHARLS.

In order to check the robustness of the results, we used the nearest 1:1 neighbor matching with the caliper and kernel matching for sensitivity analysis. Regarding the nearest 1:1 neighbor matching, a caliper range of 0.05 was set. Kernel matching used a quadratic kernel, and the bandwidth was set to 0.06.

Results

Characteristics of the sample

A total of 767 patients with diabetes were included in the study. Before matching, 177 respondents (23.08%) were in the treatment group (with access to community-based diabetes examination) and 590 (76.92%) in the control group (without access to community-based diabetes examination). For the utilization of healthcare services, the respondents who visited a doctor and were admitted to a hospital accounted for 21.90 and 28.55%, respectively. After matching, we found 489 respondents consisting of 166 in the treatment group and 323 in the control group.

Table 1 outlines the descriptive information of the respondents before and after PSM. Before PSM, the respondents in the treatment and control groups were comparable in sex, marital status, education level, economic condition, frequency of social activities, time for physical activities, self-rated health, and region, but were significantly different in age, reimbursement rate of medical insurance, drinking, health education, and type of address ($p < 0.05$). After PSM, no significant differences were observed for these characteristics between the treatment group and the control group ($p > 0.05$).

Inequalities in community-based diabetes examination

Figure 2 plots the concentration curves of inequalities on community-based diabetes examination for the four variable of interest, i.e., economic condition, education level, type of address, and region, with CIs approximately equal to −0.104 ($p = 0.0035$), −0.092 ($p = 0.0129$), −0.103 ($p = 0.0007$), and 0.025 ($p = 0.4971$), respectively. The relative position of the concentration curve and the equity line identifies the magnitude of inequalities. The concentration curves for economic condition, education level, and region were above their respective equity lines, indicating that community-based diabetes examinations were more concentrated among people in poor economic circumstances, with lower education levels, and in less developed areas. This suggests that there is inequality in the distribution of community-based diabetes examination, and the inequality favoring those who are poorer, less educated, and live in undeveloped areas. Although slightly below the equity line, the curve for geographical regions has a 95% confidence interval that contains 0, which indicates that community-based diabetes examinations were not statistically different across eastern, middle, and western regions.

Figures 3, 4 show the distribution of socioeconomically relevant variables at both the individual and regional levels for whether payment was required and the frequency of examination in the 177 samples from the treatment group. The proportion of those who did not have to pay for diabetes examinations was overwhelmingly dominant in all four variables, with a range of 62.0–88.5%. Among them, the educated and people in the western region had a higher percentage of not having to pay for diabetes examinations compared to the uneducated and people in the eastern and middle regions ($p < 0.05$). The frequency of diabetes examination was roughly identical across groups in terms of economic condition, education level, type of address, and region. The overall picture was that the highest frequency was two to six

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TABLE 1 Characteristics of the sample.

Variable	Before PSM		After PSM	
	Control group ($n = 590$)	Treatment group ($n = 177$)	Control group ($n = 323$)	Treatment group ($n = 166$)
Sex				
Male	278 (47.12)	73 (41.24)	138 (42.72)	70 (42.54)
Female	312 (52.88)	104 (58.76)	185 (57.28)	96 (57.83)
Age				
45–60	268 (45.42)	58 (32.77)**	133 (41.18)	56 (33.73)
61–75	275 (46.61)	101 (57.06)	169 (52.32)	96 (57.83)
>75	47 (7.97)	18 (10.17)	21 (6.50)	14 (8.43)
Marital status				
Married and lived with spouse	459 (77.80)	147 (83.05)	257 (79.57)	138 (83.13)
Other	131 (22.20)	30 (16.95)	66 (20.43)	28 (16.87)
Education level				
Uneducated	120 (20.34)	50 (28.25)	70 (21.67)	43 (25.90)
Primary school or below	246 (41.69)	69 (39.98)	151 (46.75)	67 (40.36)
Secondary school or above	224 (37.97)	58 (32.77)	102 (31.58)	56 (33.73)
Economic condition (quantile)				
Q1 (poorest)	154 (26.10)	61 (34.46)	97 (30.03)	56 (33.73)
Q2	198 (33.56)	65 (36.72)	120	59 (35.54)
Q3 (richest)	238 (40.34)	51 (28.81)	106 (32.82)	51 (30.72)
Reimbursement rate of medical insurance				
High	158 (26.78)	25 (14.12)**	63 (19.50)	25 (15.06)
Low	423 (71.69)	150 (84.75)	255 (78.95)	139 (83.73)
No insurance	9 (1.53)	2 (1.13)	5 (1.55)	2 (1.20)
Drinking				
Never	401 (67.97)	137 (77.40)**	237 (73.37)	129 (77.71)
More than once a month	47 (7.97)	16 (9.04)	23 (7.12)	16 (9.64)
Less than once a month	142 (24.07)	24 (13.56)	63 (19.50)	21 (12.65)
Frequency of social activities				
Almost daily	205 (34.75)	55 (31.07)	108 (33.44)	53 (31.93)
Almost every week	70 (11.86)	15 (8.47)	35 (10.84)	15 (9.04)
Not regularly	82 (13.90)	26 (14.69)	49 (15.17)	24 (14.46)
Never	233 (39.49)	81 (45.76)	131 (40.56)	74 (44.58)
Time for physical activities				
Q1 (least)	205 (34.75)	51 (28.81)	93 (28.79)	47 (28.31)
Q2	198 (33.56)	57 (32.20)	108 (33.44)	54 (32.63)
Q3 (most)	187 (31.69)	69 (38.98)	122 (37.77)	65 (39.16)
Health education				
Yes	409 (69.32)	154 (87.01)***	264 (81.73)	146 (87.95)
No	181 (30.68)	23 (12.99)	59 (18.27)	20 (12.05)
Type of address				
The center of city/town	157 (26.61)	30 (16.95)**	67 (20.74)	28 (16.87)
Combination zone between urban and rural areas	70 (11.86)	13 (7.34)	30(9.29)	11(6.63)
Village	357 (60.51)	134 (75.71)	224 (69.35)	127 (76.51)
Special area	6 (1.02)	—	2(0.65)	0(0.00)
Region				
Eastern	228 (38.64)	75 (42.37)	120 (37.15)	72 (43.37)
Middle	183 (31.02)	50 (28.25)	103(31.89)	43(25.90)
Western	179 (30.34)	52 (29.38)	100(30.96)	51(30.72)

(Continued)

TABLE 1 (Continued)

Variable	Before PSM		After PSM	
	Control group ($n = 590$)	Treatment group ($n = 177$)	Control group ($n = 323$)	Treatment group ($n = 166$)
Self-rated health				
Good	77 (14.18)	23 (13.77)	35 (10.84)	23 (13.86)
Fair	263 (48.43)	68 (40.72)	152 (47.06)	58 (40.96)
Poor	203 (37.38)	76 (45.51)	136 (42.11)	75 (45.18)

Percentages are in parentheses. Significance: 5% (**) and 1% (***) for χ^2 tests for each treatment group (with access to community-based diabetes examination) vs. the control group (without access to community-based diabetes examination).

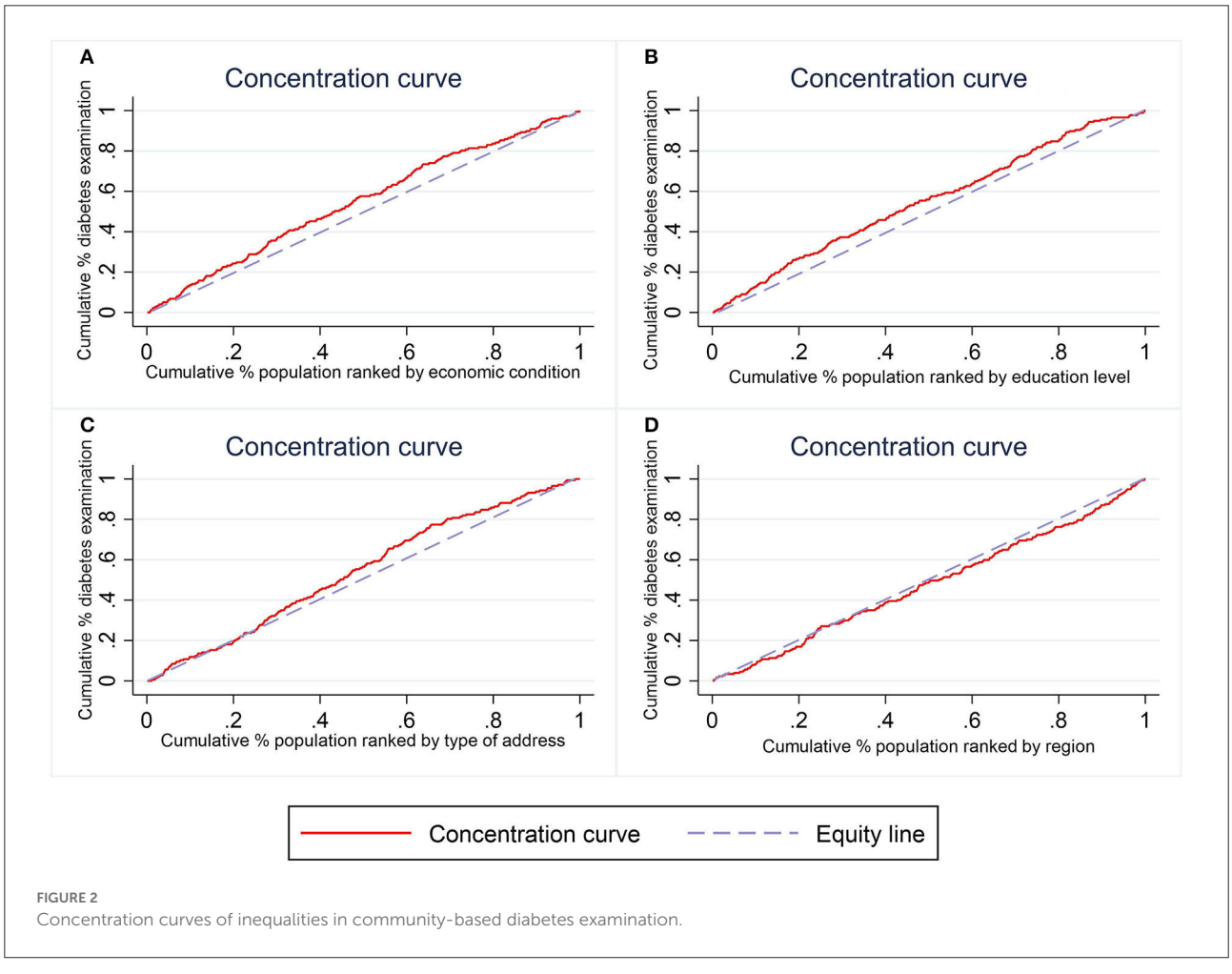

FIGURE 2
Concentration curves of inequalities in community-based diabetes examination.

times a year (43.3–61.5%), followed by once a year (15.4–32.0%), once or twice a month (13.8–26.0%), and once a week (0–10.1%).

Propensity score matching analysis

As illustrated in Figure 5, the propensity scores for the treatment and control groups overlapped sufficiently in distribution after matching. This suggested that it was likely to find an appropriate match for most control group respondents. Furthermore, according to the results of the balance test, the standardized differences (% bias) after matching were considerably reduced and were all within the 10% threshold (Figure 6). Consequently, the common support condition and matching effect were satisfied.

The unweighted logit analysis of the matched samples showed that the respondents with access to community-based diabetes examination not only had a higher probability of

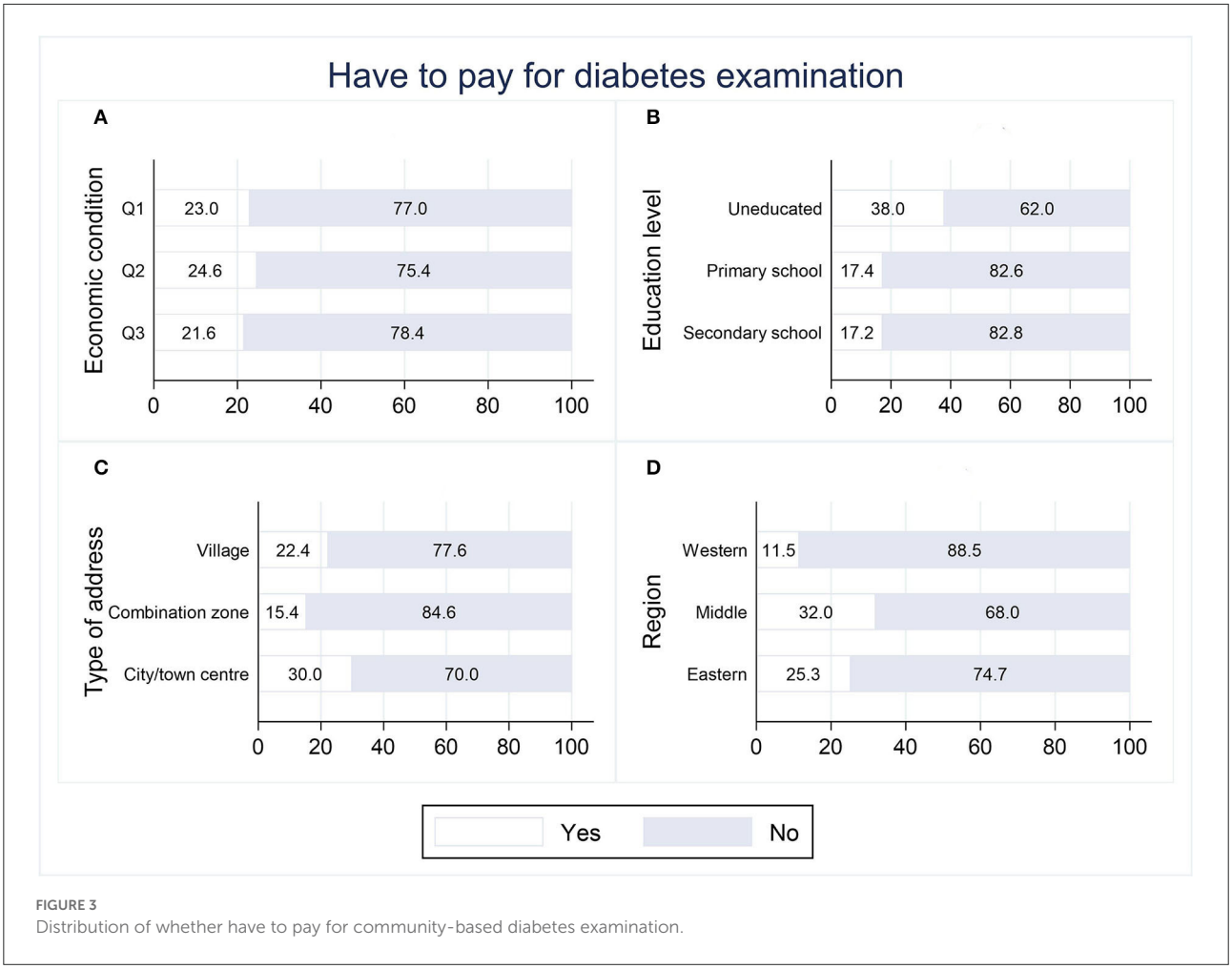

FIGURE 3
Distribution of whether have to pay for community-based diabetes examination.

outpatient care utilization (OR = 1.989, 95%CI: 1.156–3.974) but were also less likely to utilize inpatient care (OR = 0.544, 95%CI: 0.325–0.909). After the application of sampling weights, the respondents with access to community-based diabetes examination not only had a higher probability of outpatient care utilization (OR = 2.162, 95%CI: 1.138–4.107) but were also less likely to utilize inpatient care (OR = 0.569, 95%CI: 0.313–1.035) (Table 2).

Tables 3–5 present the results of sensitivity analyses. Both logit models and ATT estimations indicated that the increased probability of outpatient care utilization and decreased probability of inpatient care utilization were associated with community-based diabetes examination, no matter which matching method was used. Additionally, we combined the data from CHARLS 2015 and 2018 into a single data pool without distinguishing between years. The weighted analysis demonstrated the robustness of the results.

Discussion

To the best of our knowledge, this is the first study to examine the status and inequalities of community-based regular diabetes examination and its effect on the likelihood of healthcare utilization among patients with diabetes. The findings suggest that community-based regular diabetes examination is currently at a low level in China, and there are distributional inequalities across populations who are favorable to the socioeconomically disadvantaged. The PSM analysis confirmed that community-based regular diabetes examination was associated with increased outpatient care utilization and decreased inpatient care utilization.

Beyond our expectations, unlike most studies in which health resources are concentrated in people with advantageous SES (39–41), community-based diabetes examinations in this study were more concentrated among the disadvantaged (with worse economic condition and lower education level, and live in less developed areas). Possible reasons for this can

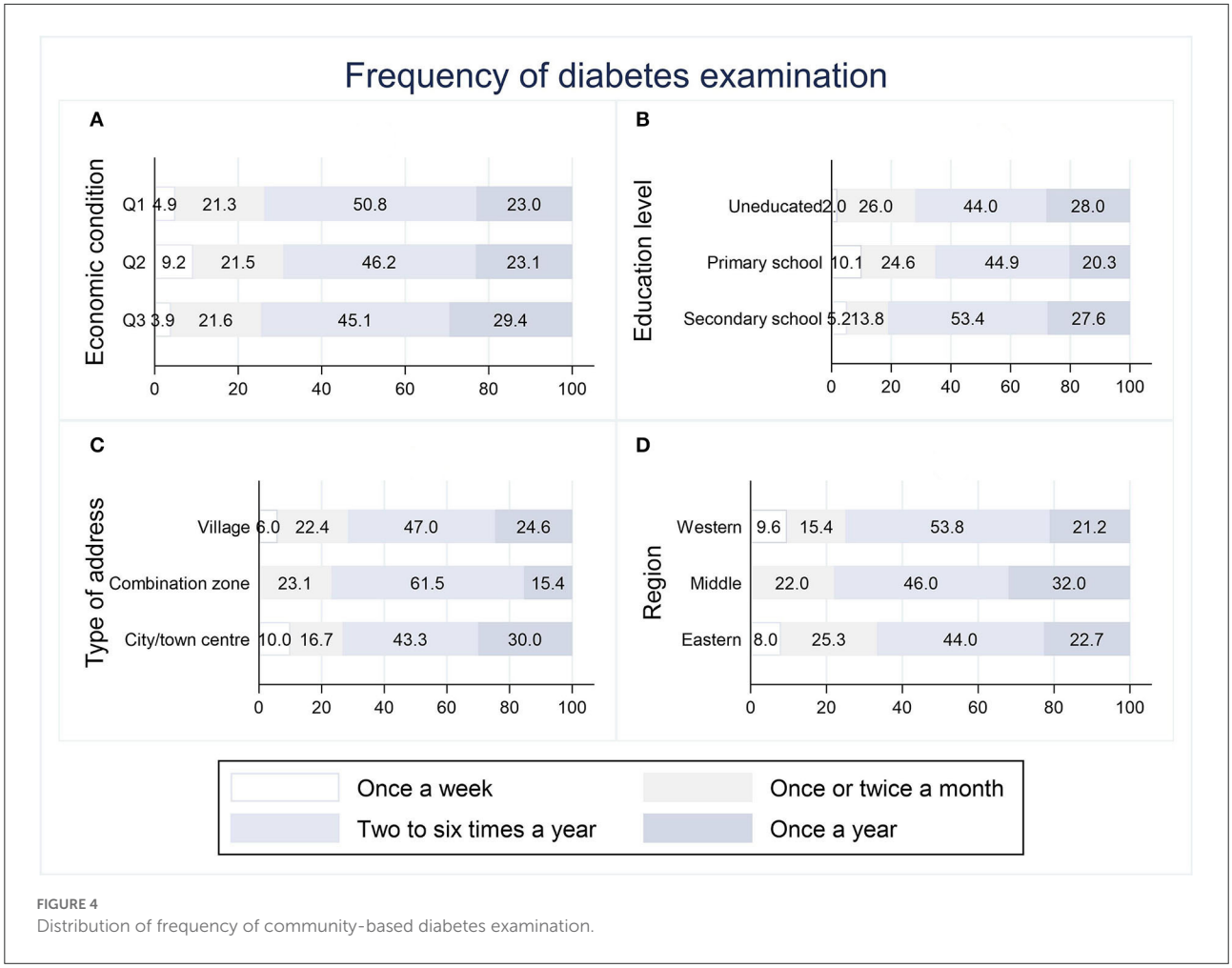

FIGURE 4
Distribution of frequency of community-based diabetes examination.

be attributed to the fact that low-socioeconomic groups are usually more concerned with less expensive or free public services and are associated with more frequent visits to primary healthcare services, whereas patients with a higher SES visit doctors more frequently and may be unaware of the availability of services such as diabetes examination in their communities (42, 43). Additionally, significant central government transfers are made to less developed areas, such as rural areas. Rural populations face greater barriers to healthcare services than urban populations, and rural diabetes patients perform worse in terms of diagnosis and control of the disease (19, 27). A hopeful and optimistic hypothesis is that government investment in rural primary diabetes examination will help alleviate this problem.

Despite such a distribution favors vulnerable populations, there is still an inherent health inequality. In terms of diabetes examination itself, health equity does not compensate for the poor by the denial of health rights to the rich. That is to say, people with higher SES are equally entitled to demand community-provided diabetes services. On the other hand, from the perspectives of healthcare delivery equity and efficient allocation of medical resources, the results indicated that community-based diabetes examination is less available to the wealthy (home care by themselves or access to tertiary care, which we do not know based on this dataset), which excludes them from being targeted for community-provided services, regardless of whether they would utilize those services or not. Regular diabetes examinations at the community level are sufficient for daily diabetes management, and increasing the availability of community-based diabetes examination among the rich could be a way to reduce occupation of specialized healthcare in routine chronic disease management.

In addition to being unevenly distributed across populations, the coverage of community-based diabetes examination was relatively narrow, with results showing that less than a quarter (23.08%) of respondents had access to it, and a portion of them had to pay for it. For the older generation in China, schooling as a child or adolescent is not a common option that most people can afford, making educational attainment an important indicator of social stratification (44). The uneducated generally reside in less

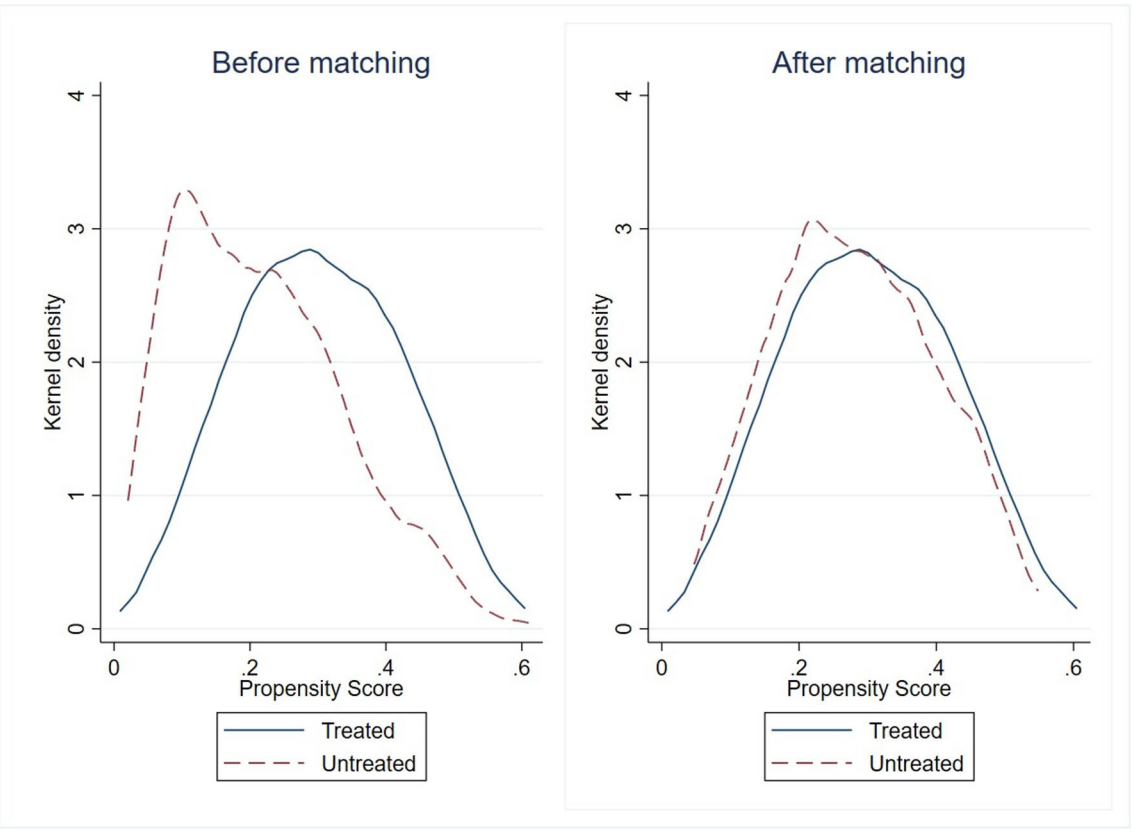

FIGURE 5
Kernel density estimates.

socioeconomically advantaged communities, which often pose barriers to health resources and services (45). In the case of this study, communities with a high proportion of uneducated residents were more likely to charge for diabetes examinations that were offered. As a result of its less developed economy, the western region has long received financial subsidies from the state and has a greater share of government healthcare expenditures. According to data on special transfer payments disclosed by the Ministry of Finance and the National Health Commission in 2021 (46), per capita subsidies for basic public healthcare in the western region were 2.15 and 1.15 times higher, respectively, than in the eastern and middle regions, and per capita government health expenditures were 1.10 and 1.27 times higher. This suggests that individuals in the west are more likely to be exempt from having to pay for community-based diabetes examination. In terms of frequency, the frequency that accounted for the highest percentage was 2–6 times per year, which is adequate for fundus examinations, micro-albuminuria tests, etc., but still far from sufficient for blood glucose test. Overall, the results indicate that community-based diabetes examination is currently at a low level of limited coverage and low frequency.

After controlling for confounding variables, PSM results suggested that community-based diabetes examination has a significant positive impact on outpatient care utilization among people with diabetes. While this result appears to contradict the original goal of "keeping chronic disease management in the community," it should also be noted that the findings show the potential of community-based diabetes examination to release health demands of person with diabetes. Some people avoid seeking healthcare due to stigma or time, financial, transportation, and knowledge constraints (47), but avoiding healthcare increases the disease's preventable risks for people with diabetes (23), resulting in a vicious cycle. Regular community-based diabetes examination can act as a booster for diabetes management. Of course, healthcare providers are unable to address multiple health concerns and provide all necessary medical advices during a single time-limited diabetes examination appointment (23), but increased utilization of outpatient services may help remedy this gap in the current

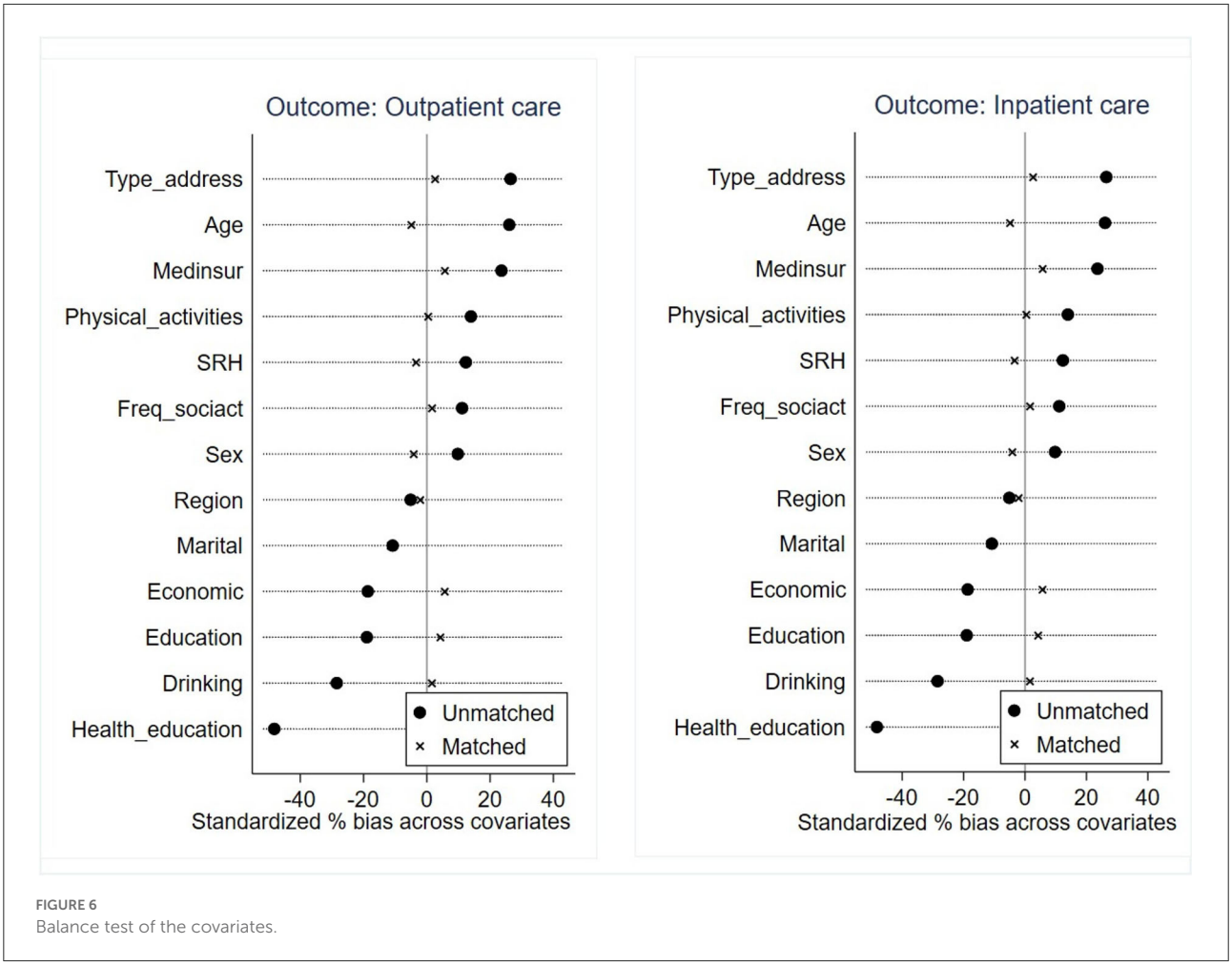

FIGURE 6
Balance test of the covariates.

TABLE 2 Effects of community-based diabetes examination on healthcare utilization (logit model).

Healthcare utilization	Unweighted			Weighted		
	OR[a]	SE	95%CI	OR[a]	SE	95%CI
Outpatient care utilization	1.989**	0.551	1.156–3.974	2.162**	0.708	1.138–4.107
Inpatient care utilization	0.544**	0.143	0.325–0.909	0.569*	0.174	0.313–1.035

Significance: 10% (*) and 5% (**); [a]Covariates including sex, age, marital status, education level, economic condition, reimbursement rate of medical insurance, drinking, frequency of social activities, time for physical activities, health education, self-rated health, type of address, and region were adjusted for calculation.

context of low examination frequency. Previous studies have found that regular health visits can ameliorate fear of disease examination and treatment, improve medical trust and self-efficacy, and increase health awareness for self-management and active treatment (48, 49). The study reaffirms this point of view. Additionally, community-based diabetes examination was found to have a negative and significant effect on inpatient care utilization. One plausible explanation is that outpatient care does not represent the severity of disease as inpatient visits do. Diabetes is a chronic condition that necessitates long-term management, and patients with diabetes who are properly managed in the community and by themselves do not require hospitalization unless they have other conditions unrelated to diabetes.

This study also adds to the literature by addressing endogeneity in the diabetes examination–healthcare utilization link. We employed the PSM approach to correct for the sample selection bias and potential structural confounding. This is achieved by performing analyses between participants who are exchangeable between those with and without access to community-based diabetes examinations, on the basis of a set of predictors derived from the Andersen model. In

TABLE 3 Sensitivity analyses for the effects of community-based diabetes examination on healthcare utilization.

Healthcare utilization	1:1 matching (128:122)			Kernel matching (137:134)		
	OR[a]	SE	95%CI	OR[a]	SE	95%CI
Outpatient care utilization	1.483*	0.353	0.929–2.366	1.581*	0.499	0.851–2.935
Inpatient care utilization	0.443**	0.144	0.235–0.838	0.762*	0.115	0.567–1.025

Significance: 10% (*) and 5% (**); [a]Covariates including sex, age, marital status, education level, economic condition, reimbursement rate of medical insurance, drinking, frequency of social activities, time for physical activities, health education, self-rated health, type of address, and region were adjusted for calculation.

TABLE 4 Average treatment effect (ATT) on the treated (with access to community-based diabetes examination).

Method	Outpatient care utilization		Inpatient care utilization	
	ATT	SE	ATT	SE
1:1 matching	0.251**	0.051	0.246**	0.059
Kernel matching	0.251**	0.043	0.246**	0.051

Significance: 5% (**).

doing this, observed differences in the outcomes (specifically, outpatient and inpatient care utilization) between the treatment and control groups are inferred to be the result of the treatment (community-based diabetes examination) alone (50). Our results show that the associations between community-based diabetes examination and healthcare utilization are robust net of the selection bias.

The extrapolation of the present study needs to be considered in conjunction with previous CHARLS studies. Previous CHARLS studies have shown, first, that self-reported rates of diabetes ranged between 5 and 7%, tending to underestimate the true prevalence of diabetes (51, 52). The lack of biomedical data in this study, the percentage of self-reported diabetes was considered to be the overall prevalence of diabetes and thus failed to derive diabetes awareness, which is important for engagement in community-based diabetes examination. Second, middle-aged and older adults who are younger and have a lower SES are more likely to be unaware that they have diabetes, due to neglect of their health and poor accessibility to health resources for medical examination. The less developed the region, the lower the level of agreement between the prevalence of diabetes and self-reported measurements of diabetes (52). The eastern region of this study had a higher proportion of the sample than the central and western regions, and the proximity of self-reports to diabetes prevalence varies across regions, whereas self-reports were associated with responses to community-based diabetes examination (CHARLS questionnaire procedure was set up such that data on community diabetes examination could only be collected from people who self-reported having diabetes), which could potentially influence the results of health inequalities in community-based diabetes examination. Third, some respondents who had diabetes but were unaware of the condition were excluded. It is possible that some respondents lived in communities where regular diabetes examinations were available at the time of interview but were unaware of them because many respondents are socioeconomically disadvantaged and face structural barriers to seeking health information. As a result, the actual coverage of community-based diabetes examinations may be underestimated. Furthermore, the limited dataset does not allow us to conduct additional analyses; with a small sample size on the one hand, some key variables were missing, such as smoking, and a health behavior variable was not included in this study; on the other hand with all selected variables from the CHALRS 2018 questionnaire, we were unable to analyze what was of added-value to the study but beyond the questionnaire. In addition, the lack of blood test data leads to an underestimation of diabetes prevalence. The percentage of self-reported diabetes is considered to be the total prevalence of diabetes and thus failing to derive diabetes awareness, which is important for engagement in community-based diabetes examination.

Conclusion

In conclusion, this study sheds new light on the inequalities of community-based regular diabetes examination and its impact on healthcare utilization in individuals with diabetes. We present new evidence of health inequalities that favor patients with low SES. Diabetes risk is increasing in China for both high- and low-SES individuals, but underserved patients of low SES are in greater need of additional support from the health system. Aside from that, overall health equity and resource allocation could be further optimized. At the same time, we observed that diabetes examination had a positive effect on the demand for

TABLE 5 Combined data for CHARLS 2015 and 2018: Effects of community-based diabetes examination on healthcare utilization (logit model).

Healthcare utilization	Unweighted			Weighted		
	OR[a]	SE	95%CI	OR[a]	SE	95%CI
Outpatient care utilization	1.260**	1.119	1.047–1.517	1.289**	1.136	1.049–1.584
Inpatient care utilization	0.849	0.088	0.694–1.039	0.801*	0.096	0.633–1.013

Significance: 10% (*) and 5% (**); [a]Covariates including sex, age, marital status, education level, economic condition, reimbursement rate of medical insurance, drinking, frequency of social activities, time for physical activities, health education, self-rated health, type of address, and region were adjusted for calculation.

outpatient visits. The message of our study is that expanding the coverage and depth of community-based regular diabetes examination should be considered by policymakers in public health and in other health policy priorities to strengthen disease control and management of diabetes and prediabetes, assist them in confronting their health needs, and promote health.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by Research Ethics Committees of Peking University. The patients/participants provided their written informed consent to participate in this study.

Author contributions

YC and QD contributed to the conception and design of the study. QD conducted the data reduction, statistical analysis, and drafted the manuscript. QD, YW, and YC contributed to the data interpretation and reviewed the manuscript. All authors have approved the manuscript before submission.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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The mediation path of physical multimorbidity on the vulnerability to health-related poverty of rural aging families in Ningxia, China: A cross-sectional survey

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Background: Vulnerability to health-related poverty can predict the probability of families falling into poverty due to health risk impact. In this study, we measured the vulnerability to health-related poverty and examined the mediation path of physical multimorbidity on the vulnerability to health-related poverty of rural aging families in Ningxia, China.

Methods: This cross-sectional study was conducted in Ningxia, China, in February 2019. A multi-stage stratified cluster-randomized design was used to obtain a representative sample in each county. We included participants aged 60 years and older, who had lived there for more than 1 year. A total of 3,653 rural residents older than 60 years old were selected as the research subjects. The three-stage generalized least square method was used to calculate the expected vulnerability to poverty. We used mediating effect model to test the mediation path of poverty vulnerability related to the physical multimorbidity.

Results: Under different poverty line standards, i.e., \$1.9/day as low vs. \$3.1/day as the high poverty line, the proportion of families that could fall into poverty in the future was 5.3 and 53.7%, respectively. The prevalence of chronic diseases and physical multimorbidity among rural residents >60 years old was 64.62 and 21.24%, respectively. The results of mediating effect test showed that self-rated health status (indirect effect $a \times b = -0.0052$), non-agricultural employment ($a \times b = -0.0046$), household cattle production ($a \times b = 0.0004$), housing type ($a \times b = -0.0008$), gift expenses ($a \times b = 0.0006$) and loan for illness ($a \times b = 0.0034$) were the mediation paths of poverty vulnerability related to the physical multimorbidity.

Conclusions: Concerted efforts are needed to reduce poverty vulnerability related to the physical multimorbidity. The strategy of alleviating poverty

should emphasis on promoting non-agricultural employment of vulnerable groups sustainability and developing rural economy, which are important paths to reduce family's vulnerability to health-related poverty.

KEYWORDS

physical multimorbidity, poverty vulnerability, propensity score matching, intermediary effect, cross-sectional study

Background

In 2013, China proposed the concept of "targeted poverty alleviation," where poverty caused by health problems was the primary factor (1). The state launched a series of Health Poverty Alleviation Policies, including signing management services for chronic diseases, paying attention to chronic disease prevention and control, and similar (1). It has been found that health-related poverty alleviation had an important role in overall poverty reduction, as in 2020, China completely eliminated absolute poverty (2). However, the problem of relative poverty still remains.

It has been estimated that nearly five million people might be at risk of returning to poverty during the 14th Five Year Plan period (3). The strategic plan for Rural Revitalization also proposes to further alleviate relative poverty by 2035 (4), as unstable poverty relief households and Marginal Poverty households could easily return to poverty again. In fact, different strategies are needed to safeguard this vulnerable groups (5). Focusing on safeguarding relatively poor people from encountering illness-induced poverty are of great significance for consolidation of the achievements of healthy poverty alleviation (6). In July 2017, Ningxia began to promote the alleviation of health-related poverty and implemented a comprehensive health poverty alleviation security policy for patients who become impoverished due to illness and who returned to poverty due to illness (7). According to available data, poverty induced by health problems accounted for 42% nationwide (8). A cluster sampling survey conducted in poor villages in Ningxia showed that 41.5% of the poverty cases were caused by diseases, which become the primary factor for rural families to return to poverty (9). In Guyuan, Ningxia, the patients with chronic diseases accounted for 60.59% of the total number of patients (10).

The economic burden of chronic diseases is an important part of health-related poverty (11). According to the World Health Organization, about 33% of the total disease burden among the elderly aged ≥60 years old in China is attributed to chronic diseases (12). The increasing prevalence of chronic diseases in the elderly and the decline of their ability to work do not only reduce the health capital and labor participation rate (13), but also significantly increase the medical expenditure of aging families (14). It has been estimated that by 2050, the population aging level will reach 30%, the elderly population will exceed 400 million, and the prevalence of chronic diseases among the elderly ≥60 years over in China will reach 75.8% (15). *Physical multimorbidity (suffering from two or more chronic diseases at the same time)* causes high economic costs to individuals and families, and more than one-third of the elderly are chronically illed (16, 17). Suffering from a variety of chronic diseases is significantly related to the increase of catastrophic medical expenditure (18). The high prevalence of chronic diseases and the burden of chronic diseases among the elderly have increased the probability of aging families returning to poverty due to illness, which has become the focus of a series of social policies such as "Healthy China" and "Population aging" (19). Vulnerability to health-related poverty is a prediction of the probability that families might encounter poverty in the future due to health-related issues. These individuals and groups usually share certain social and economic factors that increase their vulnerability to poverty. The vulnerability to health-related poverty can be used as a risk factor or early warning signal of returning to poverty due to illness.

According to previous studies, people living in Western rural areas of China, aging families, those with chronic diseases, and especially people prone to chronic diseases are at high risk of health-related poverty (20–23). The existing literature mainly explored the influencing factors of vulnerability to health-related poverty from the perspective of unexpected health risk (24–27), family resource endowments (28–34), risk response strategies (35–38), and health support system (39). Family resource endowment is the capital on which families depend for survival, including human capital, material capital, and social capital (40). Human capital is divided into education, health, and professional human capital. Previous studies have found that the role of educational human capital in reducing poverty vulnerability is the largest among human capital, which is of great significance for the long-term development of rural residents (4–49). Physical capital can also affect the impact of health risks. The occurrence of chronic diseases is often closely related to public health infrastructure (32). Previous studies have

Abbreviations: VEP, expected poverty vulnerability; FGLS, feasible generalized least squares; OLS, Ordinary Least Square; VEP_1, the expected poverty vulnerability calculated with the international poverty line of $1.9/day; VEP_2, the proportion of expected poverty vulnerability calculated with the international poverty line of $3.1/day; ATT, average treatment effect.

found that public health infrastructure such as clean drinking water and flushing toilets can improve residents' health to a certain extent (50–52).

At present, studies about mediation path of poverty vulnerability related to physical multimorbidity are limited. It is necessary to study the intensity and mode of mediation path. In this study, we measured the vulnerability to health-related poverty among aging families living in rural Western China, examined the net effect of physical multimorbidity on health-related poverty among aging families, and mediation path of vulnerability to poverty related to physical multimorbidity.

Methods

Data sources

A total of 5,643 rural residents from 171 villages in four counties of Ningxia, Western China, were surveyed in 2019. The investigation method involved multistage stratified random sampling. All administrative villages in each township of the four sample counties were divided into three levels according to the level of economic development, i.e., high, medium, and low. By using the random number table method, 40% of villages were selected as the sample villages, and 33 rural residents were systematically sampled as the survey samples. The survey method was a face-to-face inquiry survey. The survey subjects were all family members of the sample households. The subjects were rural residents aged >60 years old. People who met the following conditions were selected from the database for inclusion in the study: (1) permanent rural residents who have lived for more than 1 year in the area; (2) elderly ≥60 years old. Finally, 3,653 rural elderly were included in the study. Physical multimorbidity refers to the population with two or more chronic diseases previously diagnosed by doctors. The sample size calculation formula of counting data in descriptive research is $n = \frac{u_\alpha^2 \pi(1-\pi)}{\delta^2}$, The significance test level $\alpha = 0.05$ is usually adopted, and the allowable error $\delta = 0.1\pi$ is general. The prevalence of chronic diseases among the elderly in China in 2018 was 59.1% (53), means $\pi = 59.1\%$, The required sample size is calculated to be 267, The subjects included in this study meet the requirements of sample size.

Model and variables

Explained variable (Y): The vulnerability to health-related poverty

Vulnerability to health-related poverty predicts the probability that families will fall into poverty in the future due to unexpected health issues. The most common measurement method is expected poverty vulnerability (VEP) (41), which mainly uses three-stage feasible generalized least squares (FGLS) to quantify the family's vulnerability to health-related poverty in three following steps:

First, Ordinary Least Square (OLS) is used to estimate the income equation:

$$\ln Y_{it+1} = \beta X_{it} + e_{it} \tag{1}$$

where

Y_{it+1} refers to the income level of the rural population in the T+1 period, X_M refers to a series of observable variables that affect the family income level, including family demographic characteristics, health risk variables, family resource endowment variables, risk response strategies, and health support system variables. Considering the heterogeneity of rural population in different counties, townships, and villages, the residual square is regarded as the approximate value of income variance $\hat{e}_i^2$, and the residual square is used as the explained variable to construct the regression model of residual square $\hat{e}_i^2$ to individual characteristics:

$$\hat{e}_i^2 = \theta \times X_i + \eta_i \tag{2}$$

The estimated value and residual estimated value of Y_{it+1} can be obtained through formulas (1) and (2).

Second, heteroscedasticity structure is constructed as a weight for weighted regression, and the expected value (3) and variance (4) of future income logarithm are estimated:

$$\hat{E}\left[\ln Y_i \,|X_i\right] = X_i \widehat{\beta} \tag{3}$$

$$\hat{V}\left[\ln Y_i \,|X_i\right] = \widehat{\sigma}_{ei}^2 = X_i \widehat{\theta} \tag{4}$$

Finally, the poverty line is selected to estimate the vulnerability to poverty. This study used the international poverty line of $1.9/day and $3.1/day (34) as the poverty lines for measuring the vulnerability to poverty. The value of health poverty vulnerability was distributed between zero and one. Those who scored ≥0.5 were categorized as families highly vulnerable to poverty and those <0.5 as families with vulnerability to poverty (42, 43). The research subjects were aging rural families, so the lognormal distribution was more applicable. The logarithm of the poverty lineIn*l*is in formula (5):

$$\widehat{v}_i = \widehat{P}\left(\ln Y_i < \ln l \,|X_i\right) = \varphi\left(\frac{\ln l - X_i \hat{\beta}}{\sqrt{X_i \hat{\theta}}}\right) \tag{5}$$

Tobit model identifies health poverty vulnerability risk factors:

The value of vulnerability to health-related poverty is a limited continuous dependent variable. Therefore, the Tobit

TABLE 1 Variable definition.

Variables		Explanation	Code
Explained variable (Y)		Health poverty vulnerability	Measure with expected poverty vulnerability (VEP)
Explanatory variable (X)		Physical multimorbidity	1 = treatment group, 2 = control group
Control variable (C)		Gender	1 = male, 2 = female
		Age	continuous variable
		Marital status	1 = unmarried, 2 = married, 3 = divorced, 4 = widowed, 5 = other
		Family size	Household population
		Number of the labor force	The family working-age population, 15–64 years old
		Dependency ratio	1–labor force / family size
Resource endowment (M_1)	Human capital	Education level	1 = no schooling, 2 = primary school, 3 = junior high school, 4 = senior high school or above
		The average length of education of family(year)	No schooling = 0, primary school = 6, junior middle school = 9, senior high school and above = 12
		Self-rating health	1 = very good, 2 = good, 3 = average, 4 = poor, 5 = very poor
		Non-agricultural workers	1 = yes, 2 = no
	Material capital	Household livestock ownership (cattle)	continuous variable
		Housing type	1 = brick soil concrete, 2 = brick wood, 3 = Civil Engineering, 4 = full brick, 5 = cave
		Type of drinking water	1 = tap water, 2 = mountain spring water, 3 = hand press well water, 4 = cellar water, 5 = well water, 6 = River and lake water, 7 = pond and ditch water
		Toilet type	1 = water flushing type, 2 = biogas, 3 = Double urn funnel type, 4 = deep pit, 5 = toilet, 6 = dry toilet, 7 = no toilet
		Separation of housing and kitchen	1 = yes, 2 = no
	Social capital	Gift expenses(log)	Continuous variable (logarithm)
Risk response strategy (M_2)	Informal	Income from migrant workers	Continuous variable (logarithm)
		loans because of illness	1 = yes, 2 = no
	Regular	Low-income households	1 = yes, 2 = no
		Medical assistance	1 = yes, 2 = no
Health support system (M_3)	Health service accessibility	Physical accessibility	1≤30 min, 2 = 30–60 min, 3 = 60–90 min, 4 = >90 min
	Availability of health services	Chronic disease diagnosis and treatment institutions	1 = village clinics, 2 = township hospitals, 3 = county hospitals, 4 = private clinics, 5 = others

model was selected to screen the significant influencing factors of vulnerability to poverty. The measured value of vulnerability to poverty was taken as the dependent variable (V), and family demographic characteristics, health risk impact, family resource endowment, family risk response strategy and health support system are taken as the explanatory variable (X_j).

$$V = \beta 0 + \beta jXj + \varepsilon \quad (6)$$

Explanatory variable (X): Physical multimorbidity

Physical multimorbidity *(suffering from two or more chronic diseases at the same time),* The indicators of physical multimorbidity were obtained through the following questions in the questionnaire: "did you have a chronic disease diagnosed by a doctor in the past?", "if so, what are the diseases, and fill in the names of the three most serious diseases." We counted the number of chronic diseases in each participant to identify people who with physical multimorbidity.

Taking the elderly with physical multimorbidity as the treatment group and the elderly without physical multimorbidity as the control group, the propensity score matching method was used to match the two groups of *Control Variables* in order to maximize the control of confounding factors and data bias. First, the propensity scores of the treatment group and the control group were estimated. The logit model was used to calculate the tendency score, as follows:

$$Logit(\text{Multimorbidity}) = \beta_0 + \beta_1 X_h + \varepsilon_h \quad (7)$$

Second, a balance test and common support test were performed. A balance test was used to test whether there was a significant difference in each covariate between the matched treatment group and the control group and whether there was a significant difference in the joint distribution of covariates before and after matching. A common support test was used to ensure that propensity scores overlapped more between the treatment group and the control group (44). Finally, the "average treatment on the treated (ATT)" was obtained, i.e., the net effect of physical multimorbidity on poverty vulnerability.

TABLE 2 Description of basic family situation and vulnerability to poverty.

Variable	Observation	Mean	Std. Dev.	Min	Max
Poverty vulnerability value$_1$ ($\overline{X} \pm S$)	3,653	0.498	0.001	0.496	0.511
Poverty vulnerability value$_2$ ($\overline{X} \pm S$)	3,653	0.500	0.001	0.497	0.516
VEP$_1$* (%)	3,653	0.053	0.225	0	1
VEP$_2$ (%)	3,653	0.537	0.499	0	1
poverty line$_1$ (1.9$) (ln)	3,653	8.390	0.000	8.390	8.390
poverty line$_2$ (3.1$) (ln)	3,653	8.880	0.000	8.880	8.880

*VEP$_1$, the proportion of expected vulnerability to poverty calculated with the international poverty line of $1.9/day.
VEP$_2$, the proportion of expected vulnerability to poverty calculated with the international poverty line of $3.1/day.

Mediating variable (M): Mechanism test of mediating effect model

The family's vulnerability to health-related poverty was used as the explanatory variable (Y), *Physical multimorbidity* as the explanatory variable (X), and human capital (Education level, The average length of education of family, Self-rating health, Non-agricultural workers), material capital (Household livestock ownership, Housing type, Type of drinking water, Toilet type, Separation of housing and kitchen) and social capital (Gift expenses) in resource endowment as the intermediary variable (M_1) to test the possible path of family resource endowment in alleviating the impact of health risk on family's vulnerability to poverty. Taking the low insured households and medical assistance of risk response strategy as intermediary variables (M_2), this study tested the role path of risk response strategy in alleviating health impact. Taking the transit time and chronic disease diagnosis and treatment institutions in the health support system as intermediary variables (M_3), we tested their role in alleviating the health impact (Table 1).

The intermediary effect model can analyze the process and mechanism of the influence between variables. When studying the influence of explanatory variable X *(Physical multimorbidity)*

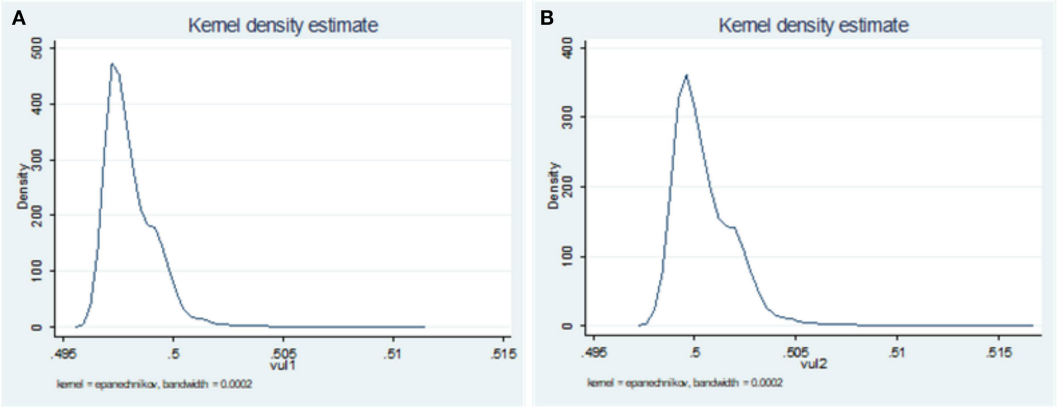


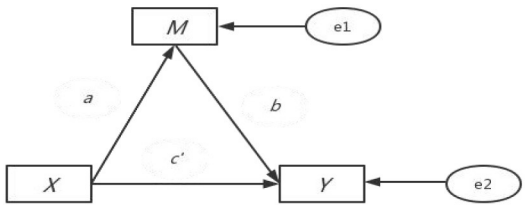
FIGURE 1
Kernel Density of vulnerability to poverty. **(A)** VEP$_1$-poverty line = 1.9$; **(B)** VEP$_2$-poverty line = 3.1$.

TABLE 3 Analysis on influencing factors of poverty vulnerability (3.1$).

Poverty vulnerability value (3.1$)	OR	St. Err.	*t*-value	*p*-value	[95% Conf]	Interval	Sig
Gender	−0.009	0.007	−1.29	0.196	−0.022	0.005	
Age	0.000	0.001	−0.60	0.552	−0.001	0.001	
Marital status	0.003	0.005	0.57	0.571	−0.006	0.012	
Family size	0.067	0.004	17.42	<0.001	0.059	0.075	***
Number of labor force	−0.049	0.006	−7.76	<0.001	−0.061	−0.036	***
Dependency ratio	−0.147	0.019	−7.89	<0.001	−0.183	−0.11	***
Education level	0.001	0.006	0.16	0.870	−0.011	0.013	
Average length of education of family	−0.002	0.002	−1.43	0.152	−0.006	0.001	
Self–rating health	−0.001	0.004	−0.29	0.775	−0.008	0.006	
Non–agricultural workers	0.016	0.014	1.15	0.249	−0.011	0.044	
Household livestock ownership (cattle)	−0.001	0.001	−1.23	0.220	−0.004	0.001	
Housing type	0.003	0.003	1.04	0.300	−0.002	0.008	
Type of drinking water	0.004	0.003	1.43	0.151	−0.001	0.009	
Toilet type	0.010	0.003	3.61	<0.001	0.004	0.015	***
Separation of housing and kitchen	0.014	0.007	2.00	0.046	0.000	0.028	**
Gift expenses (log)	−0.032	0.001	−31.25	<0.001	−0.034	−0.03	***
Income from migrant workers	−0.003	0.001	−3.48	0.001	−0.004	−0.001	***
Loans because of illness	0.029	0.008	3.74	<0.001	0.014	0.044	***
Low–income households	0.018	0.007	2.81	0.005	0.006	0.031	***
Medical assistance	0.029	0.011	2.72	0.007	0.008	0.050	***
Physical accessibility	0.002	0.003	0.56	0.579	−0.005	0.008	
Chronic disease diagnosis and treatment institutions	−0.011	0.006	−1.88	0.060	−0.022	0.000	*
Constant	0.005	0.061	0.08	0.938	−0.114	0.123	

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

on the explained variable Y *(The vulnerability to health-related poverty)*, *Physical multimorbidity* not only has a direct impact on *the vulnerability to health-related poverty*, but also an indirect impact on *the vulnerability to health-related poverty* through variable M (*Mediating variable)*; thus, M can be called the intermediary variable, and the model $X \rightarrow M \rightarrow Y$ reflecting the relationship between the three is called the intermediary effect model (45, 46). The mediating effect can be expressed as the product of coefficient b and coefficient a × b. This product term indicates how much of the effect of X on Y reaches Y through M. The independent variable of this study was category variable, so we used regression analysis to conduct intermediary analysis according to the stepwise method (54).



$$M = aX + e_1 \quad Y = c'X + bM + e_2$$

Control variable (C)

Gender, age, marital status, family size, labor force, and dependency ratio were used as control variables in family demographic characteristics (Table 1).

Results

Description of vulnerability to poverty among aging rural families

The vulnerability to poverty of aging rural elderly families calculated with the international poverty line of $1.9/day was 0.498 ± 0.001, and the proportion of vulnerable (VEP_1) families was 5.3%. The vulnerability to poverty value of aging rural families calculated with the international poverty line of $3.1/day was 0.5 ± 0.001, and the proportion of vulnerable (VEP_2) families was 53.7% (Table 2; Figure 1). Taking *Poverty vulnerability value (3.1$)* as the explanatory variable, family size, the number of the family labor force, dependency ratio, the toilet type in material capital and housing are separated from the kitchen, the logarithm of gift expenditure in social capital, the income of migrant workers in risk response strategy, loans due to illness, low-income

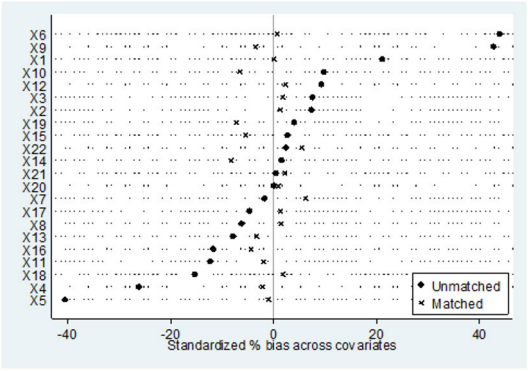


FIGURE 2
Standardized deviation diagram of covariates.

households, the level of chronic disease diagnosis and treatment institutions providing medical assistance and health support system all resulted as the factors affecting vulnerability to poverty. The level of chronic disease diagnosis and treatment institutions providing the medical assistance and health support system resulted as factors affecting vulnerability to poverty (Table 3).

Analysis of tendency score matching results

The prevalence of chronic diseases among rural elderly people > 60 years old was 64.62%, and the prevalence of physical multimorbidity was 21.24%. Nearest neighbor matching (1:1 ratio) was used to calculate the average treatment effect (ATT) of the treatment group. Before calculating ATT, a balance test and common support test were performed. As shown in Figures 2, 3 depicting the balance test results, the covariate standardization deviation (% bias) of the matched post-processing group and the control group was greatly reduced (both <10%). Figure 4 shows the results of the common support test, where the two groups of samples were basically in the common support range, while 15 samples in the control group were not in the common support range vs. only two samples in the treatment group. As shown, most of the observed values were in the common value range (on support), and the tendency score had greater overlap in the processing group and the control group.

As shown in Table 4, for the vulnerability to poverty of aging rural families calculated at the international poverty line of $1.9/day, the vulnerability to poverty of the matched post-treatment group and the control group were 0.043 and 0.032, respectively. The difference was 0.011, i.e., the net effect of the coexistence of chronic diseases on the vulnerability to poverty of aging rural families was 0.011. According to the vulnerability to poverty value of rural aging families calculated at the international poverty line of $3.1/day, the vulnerability to poverty values of the matched post-treatment group and the control group were 0.486 and 0.474, respectively. The difference was 0.012, i.e., the net effect of physical multimorbidity on the vulnerability to poverty of rural elderly families was 0.012. The results show that the difference of vulnerability value between the treatment group and the control group was 0.012, that is, compared with the families without chronic diseases and with only one chronic disease, the poverty vulnerability value of families with physical multimorbidity will increase by 0.012. This shows that families with physical multimorbidity will increase the probability of poverty vulnerability.

Analysis of intermediary effect of action path

Based on the analysis of the net effect of physical multimorbidity on poverty vulnerability, it is necessary to examine the mediation path further. As shown in Table 5, In the path with human capital as intermediary variable, the indirect effect of average level of family education was 0.0003, the contribution rate was 41.75%; self-rating health was −0.0052, the contribution rate was 82.80%; non-agricultural employment was −0.0046, the contribution rate was 2.57%. In the path with material capital as intermediary variable, the indirect effect of household cattle production was 0.0004, the contribution rate was 1.95%; Housing type was −0.0008, the contribution rate was 4.81%. In the path with social capital as intermediary variable, the indirect effect of gift expenses was 0.0006, the contribution rate was 0.8%; In the path with Risk Response Strategy as intermediary variable, the indirect effect of loans because of illness is 0.0034, the contribution rate was 2.17%. Analysis shows that self-rated health status, non-agricultural employment, household cattle production, housing type, gift expenses and loan for illness were the mediation paths of poverty vulnerability related to physical multimorbidity. These paths had a partial mediating role in the process of health-related vulnerability to poverty. Among these paths, the mediating effect of human health capital in family resource endowment was the largest, accounting for 82.8%; however, the total effect C was not significant. The sign of indirect effect a × b was opposite to that of direct effect C', indicating that the mediating effect of self-rated health results in vulnerability to poverty related to the physical multimorbidity existing in masking effect. The intermediary effect, direct effect, and total utility of non-agricultural employees in professional human capital in family resource endowment were statistically significant. Non-agricultural employment reduced the incidence of vulnerability to poverty. Household livestock ownership and housing type in

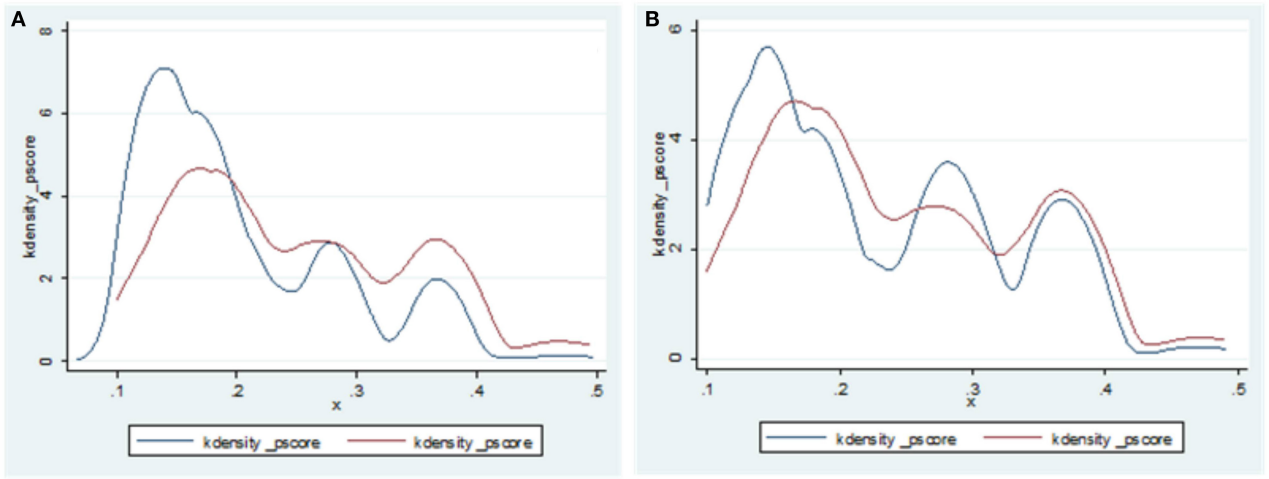


FIGURE 3
Balance test before **(A)** and after **(B)** matching between treatment group and control group.

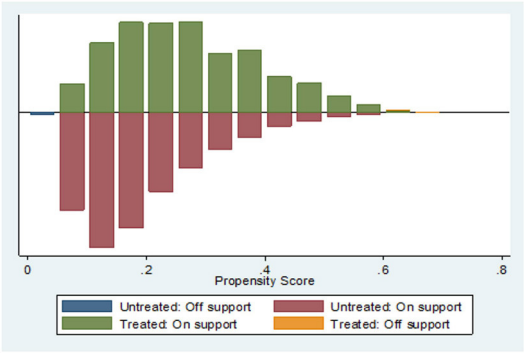


FIGURE 4
Common support test after matching between treatment group and control group. Untreated off support = 15; Treated off support = 2.

physical capital, gift expenditure in social capital and disease-related lending in risk response strategy also had a part in the intermediary effect. Disease-related lending alleviated the vulnerability to health-related poverty.

Discussion

We measured the vulnerability to health-related poverty of aging rural families using two poverty lines and analyzed the mediation path of physical multimorbidity on poverty vulnerability based on the survey data obtained in 2019 from aging rural families in Ningxia, China. The empirical analysis showed that: first, Taking the high poverty line as the standard, more than half of the households were vulnerable; second, Families with physical multimorbidity were more vulnerable than those without chronic diseases or with one chronic disease; third, the test of intermediary effect mechanism revealed that self-rated health status, non-agricultural employment, household cattle production, housing type, gift expenses and loan for illness were important ways to reduce family's vulnerability to health-related poverty.

Taking the vulnerability to poverty measured by the high poverty line as the explanatory variable, households with large population had a higher probability of poverty vulnerability; Households with large household labor force are less vulnerable. The type of toilet and the separation of kitchen and housing were risk factors of poverty vulnerability. Previous studies have found that labor migration can significantly reduce the family's vulnerability to health-related poverty (55, 56). Our study also revealed that income of migrant workers was associated with the vulnerability to poverty of family. It has been reported that low-income households and medical assistance have no impact on the vulnerability to poverty (57), which was contrary to our results that low-income households and medical assistance could reduce vulnerability to health-related poverty. We also found that the level of chronic disease diagnosis and treatment institutions were risk factors of the vulnerability to poverty. Suppose grass-roots medical institutions cannot meet the medical needs of chronic patients, thus making a considerable number of patients seek medical help from institutions above the county level. In that case, this tends to increase the disease economic burden of families of chronic patients, affecting their vulnerability to health-related poverty (1).

Intermediary effect mechanism test revealed that family human capital, material capital, social capital, and private lending in risk response strategy were important ways to reduce

TABLE 4 The net effect of physical multimorbidity on poverty vulnerability [neighbor (K = 1)].

	Before and after matching	Treated	Controls	Difference	S.E.	T–stat
VEP_1 (poverty line = 1.9$)	Unmatched	0.043	0.056	−0.014	0.009	−1.520
	ATT	0.043	0.032	0.011	0.018	0.570
VEP_2 (poverty line = 3.1$)	Unmatched	0.486	0.551	−0.065	0.020	−3.210
	ATT	0.486	0.474	0.012	0.042	0.280

TABLE 5 Intermediary effect test of vulnerability to poverty related to the physical multimorbidity.

VEP_2	a coefficient	b coefficient	Indirect effect (a*b)	Direct effect	Total effect	The proportion of total effect that is mediated
Education level	0.0041	0.0658	0.0003	−0.0808***	−0.0805***	−0.00335
Average length of education of family	0.0038	0.0647***	0.0003	0.0003	0.0006	0.4175
Self–rating health	−0.0751***	0.0691***	−0.0052***	0.0115	0.0063	−0.8280
Non–agricultural workers	−0.0677**	0.0687***	−0.0046*	0.1851***	0.1805***	−0.0257
Household livestock ownership (cattle)	0.006902 ***	0.0580***	0.0004**	0.0201 ***	0.0205***	0.0195
Housing type	−0.0130**	0.0629***	−0.0008*	−0.0162**	−0.0170**	0.0481
Type of drinking water	0.0099*	0.0622***	0.0006	0.0255***	0.0262***	0.0236
Toilet type	−0.0021	0.0659***	−0.0001	0.0659***	0.0658***	−0.0021
Separation of housing and kitchen	−0.0096	0.0666***	−0.0006	0.1451***	0.1444***	−0.0044
Gift expenses (log)	0 0.0060***	0.0935***	0.0006***	−0.0711***	−0.0705***	−0.0080
Income from migrant workers	0.0019	0.0643***	0.0001	0.0024	0.0025	0.0482
loans because of illness	0.0617***	0.0547***	0.0034**	0.1518***	0.1552***	0.0217
Low–income households	−0.0134	0.0672***	−0.0009	0.1228***	0.1219***	−0.0074
Medical assistance	0.0001	0.0647***	0.000008	0.0476*	0.0476*	0.0002
Physical accessibility	−0.0007	0.0649***	−0.000043	0.0487***	0.0487***	−0.0009
Chronic disease diagnosis and treatment institutions	−0.0081	0.0636***	−0.0005	−0.0764***	−0.0770***	0.0067

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

family's poverty vulnerability related to physical multimorbidity. It has been found that the deterioration of residents' health levels makes them face higher vulnerability to poverty. For every 10% decline in residents' health level, the vulnerability to poverty increases by 6% (58). Some previous studies have also found that self-rated health status was associated with the vulnerability to health-related poverty (59), which is consistent with the results of the present study. Engaging in non-agricultural work and social capital can help to reduce farmers' the vulnerability to poverty. Individual differences in non-agricultural employment and health contribute the most to vulnerability to poverty (60). Our results revealed that non-agricultural employees was an important intermediary path to reduce the incidence of the vulnerability to health-related poverty. Material capital can also help to cope with the impact of health risks. The amount of household livestock and other realizable assets can be used to measure material capital, which reflects the economic situation of families to a certain extent and may alleviate effect on

the vulnerability to health-related poverty (28). Gift spending in social capital also participates in the intermediary effect. Existing studies have reported that social capital has an external driving force on the family's livelihood capital (61). In the risk response strategy, lending due to illness also has a part of the intermediary effect, and it is an intermediary path to alleviates the vulnerability to health-related poverty. Some scholars have found that the intermediary effect of private lending is about 10%, which can reduce the vulnerability to poverty (36).

Implications for policy and practice

Understanding the intermediary path of poverty vulnerability related to physical multimorbidity of aging rural families may help to reduce the risk of vulnerable groups returning to poverty: first, To prevent the further development of chronic diseases and block the path of poverty, risk factors of multimorbidity such as dietary control, abstaining from tobacco, alcohol and physical activities should be targeted at an early state to prevent or delay the disease onset (62). The resource endowment of families is largely affected by the subjective initiative of family members through hard work, and non-agricultural employment, as improving labor skills can greatly enhance the family's ability to generate income (1), promote the development of rural labor economy and rural community construction, and form a good economic and social environment to improve farmers' ability to resist risks. Second, strategies for alleviation of systematic poverty should focus on promoting non-agricultural employment among vulnerable groups and continue to block the poverty trap through poverty alleviation in education and health. It is also necessary to focus on constructing rural family human capital. The higher the education level of rural residents, the lower their vulnerability to poverty (63). Education input-output is a relatively long-term process, and there is a lag effect on the embodiment of poverty alleviation effect. Third, the governance scheme for the health poverty vulnerability of rural elderly families should focus on improving the family coping ability. Primary care facilities should be strengthened to increase availability and accessibility while making the facilities affordable (64).

Strengths and limitations

Although we made a preliminary discussion on mediation path of the physical multimorbidity on vulnerability to poverty, due to the limited availability of data, the robustness of the conclusions of empirical research need to be further improved. With the emergence of higher quality data, the measurement of vulnerability to poverty or residents' vulnerability to health-related poverty and the discussion of relevant internal mechanisms could be further improved.

Conclusions

In the study, the health-related poverty vulnerability index was introduced as the risk warning signal of returning to poverty due to illness. In the process of poverty vulnerability related to the physical multimorbidity, self-rated health status, non-agricultural employment, household cattle production, housing type, gift expenses and lending due to illness were intermediary paths to alleviate vulnerability to poverty.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

Ethics statement

Ethical approval was granted by the Ethics Committee of Ningxia Medical University, Approval number, No. 2018-114. The patients/participants provided their written informed consent to participate in this study.

Author contributions

HQ conceptualized the research idea and design. WG participated in the research design, drafted the manuscript, analyzed, and interpreted the data. JD helped revise the manuscript and interpreted the data. KC, WW, BG, and ZH helped clean the data. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Multimorbidity and catastrophic health expenditure: Evidence from the China Health and Retirement Longitudinal Study

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Background: Population aging accompanied by multimorbidity imposes a great burden on households and the healthcare system. This study aimed to determine the incidence and determinants of catastrophic health expenditure (CHE) in the households of old people with multimorbidity in China.

Methods: Data were obtained from the China Health and Retirement Longitudinal Study (CHARLS) conducted in 2018, with 3,511 old people (≥60 years) with multimorbidity responding to the survey on behalf of their households. CHE was identified using two thresholds: ≥10% of out-of-pocket (OOP) health spending in total household expenditure (THE) and ≥40% of OOP health spending in household capacity to pay (CTP) measured by non-food household expenditure. Logistic regression models were established to identify the individual and household characteristics associated with CHE incidence.

Results: The median values of THE, OOP health spending, and CTP reached 19,900, 1,500, and 10,520 Yuan, respectively. The CHE incidence reached 31.5% using the ≥40% CTP threshold and 45.6% using the ≥10% THE threshold. It increased by the number of chronic conditions reported by the respondents (aOR = 1.293–1.855, $p < 0.05$) and decreased with increasing household economic status (aOR = 1.622–4.595 relative the highest quartile, $p < 0.001$). Hospital admissions over the past year (aOR = 6.707, 95% CI: 5.186 to 8.674) and outpatient visits over the past month (aOR = 4.891, 95% CI: 3.822 to 6.259) of the respondents were the strongest predictors of CHE incidence. The respondents who were male (aOR = 1.266, 95% CI: 1.054 to 1.521), married (OR = 1.502, 95% CI: 1.211 to 1.862), older than 70 years (aOR = 1.288–1.458 relative to 60–69 years, $p < 0.05$), completed primary (aOR = 1.328 relative to illiterate, 95% CI: 1.079 to 1.635) or secondary school education (aOR = 1.305 relative to illiterate, 95% CI: 1.002 to 1.701), lived in a small (≤2 members) household (aOR = 2.207, 95% CI: 1.825 to 2.669), and resided in the northeast region (aOR = 1.935 relative to eastern, 95% CI: 1.396 to 2.682) were more likely to incur CHE.

Conclusion: Multimorbidity is a significant risk of CHE. Household CHE incidence increases with the number of reported chronic conditions. Socioeconomic and regional disparities in CHE incidence persist in China.

KEYWORDS

multimorbidity, catastrophic health expenditure, elderly, China, economic burden

Introduction

The World Health Organization (WHO) defined the presence of two or more chronic conditions in the same patient as multimorbidity (1). The prevalence of multimorbidity increases by age, which is deemed as a great challenge for an aging society (2, 3). China has the largest population of old people in the world (4). By the end of 2021, the population aged 60 years and above had accounted for 18.9% (14.2% for those aged 65 years and above) of the total population in China (5). China entered into an aged society at an unprecedented speed (4). This is accompanied by rapid increase in the prevalence of chronic conditions (6). Coexistence of multiple chronic conditions is common in old populations (7). The estimated prevalence of multimorbidity in people over 60 years ranges from 6.4 to 76.5% (2.5–54.9% with three or more chronic conditions) in China due to heterogeneity of study methods (8). A study found that more than 60% of urban elderly over 70 years lived with multimorbidity, higher than that in some other countries (9).

Multimorbidity is an important cause of limitations in activities of daily life and declined quality of life in old people (2, 10). It is also associated with increased risk of death and economic loss (11, 12). The increased prevalence of age-related diseases (6), in particular multimorbidity, has a profound impact on the financial burden of the households and the society at large (12–15). Multimorbidity increases use of healthcare services at both outpatient and inpatient settings (9, 16). A study in Brazil found that patients with multimorbidity use medical services twice as much as those without multimorbidity (17). There exists a positive correlation between the number of chronic conditions and out-of-pocket (OOP) health spending (9, 16, 18). It was estimated that multimorbidity increases OOP health spending by 13% in Mexico (19). An Australian study reported that each additional chronic condition can increase the likelihood of severe financial burden due to healthcare by 46% (18).

Health expenditure is considered catastrophic once it jeopardizes the ability of a household to maintain usual standards of living (20). Catastrophic health expenditure (CHE) threatens the ability of the household to purchase other goods and services, potentially driving the household into poverty (21, 22). Previous studies have shown that even in the wealthy households with health insurance coverage, multimorbidity is significantly associated with the occurrence of CHE (12, 23). According to the WHO, global health spending is rising rapidly, and this trend is particularly profound in the low- and middle-income countries (LMICs) (24). The high-income countries have experienced an average annual growth of health expenditure of 4%, compared with 6% in the LMICs (24). Most LMICs still rely heavily on OOP payments for healthcare, despite certain progress in health insurance development (24, 25). China is one of the examples. Although China has achieved almost universal coverage of social health insurance, it provides limited financial protection for enrollees due to limited funding pools (13, 26). The OOP health spending as a proportion of total health expenditure in China has remained higher than the reasonable level defined by the WHO (27).

There is a paucity in the literature documenting the association between multimorbidity and CHE in China, despite extensive studies into the use and burden of healthcare services for individuals living with multimorbidity (9, 12, 28). Zhou et al. estimated that the incidence of CHE in the single elderly with multimorbidity in rural Shandong can be as high as 64.2% (29). Fu et al. identified a CHE incidence of 56.6% in the households with diabetic patients with multimorbidity in China (23). This study aimed to address the gap in the literature by determining the CHE incidence and its determinants in the households of old people in China with multimorbidity using a national representative dataset.

Methods

Data source

Data were extracted from the China Health and Retirement Longitudinal Study (CHARLS), a nationally representative longitudinal survey of Chinese people over the age of 45 years. The CHARLS started in 2011, collecting information regarding the sociodemographic characteristics of respondents and their health-related behaviors, health status, health insurance, and health services utilization (30). Study participants were recruited using a probability-proportional-to-size (PPS) sampling strategy across 28 provinces/regions in China. Data were collected through face-to-face computer-assisted personal interviews (30). The CHARLS obtained ethical approval from the Biomedical Ethics Review Committee of Peking University (IRB0000105IRB00001052–11015).

In this study, we used the data from the fourth wave of CHARLS conducted in 2018–2019. Eligible study participants included those who were 60 years or older, reported two or more chronic non-communicable diseases, and had a complete

record (no missing values). This resulted in a final sample of 3,511 households, with one respondent for each household, for data analyses.

Measurements

Multimorbidity

Multimorbidity was defined as coexistence of two or more chronic non-communicable diseases (1). In the CHARLS, respondents were asked to report 14 chronic conditions diagnosed by a medical doctor, including hypertension, dyslipidemia, diabetes, cancer or malignant tumor, chronic lung diseases, liver diseases, heart attack, stroke, kidney diseases, stomach and other digestive diseases, emotional, nervous and psychiatric problems, memory-related diseases, arthritis and rheumatism, and asthma. We counted the number of chronic conditions reported by each respondent.

Catastrophic health expenditure

There is currently no uniform threshold for defining catastrophic health expenditures (CHE), and there are two thresholds most commonly used in academia: the percentage ($\geq$ 10%) of health expenditure paid out of pocket (OOP) in total household expenditure (THE) (21, 31, 32) and OOP health spending as a percentage ($\geq$ 40%) of household capacity to pay (CTP) measured by non-food expenditure (14, 33–35). We set CHE as a binary variable:

$$CHE = \begin{cases} 0 \ if < \text{ threshold} \\ 1 \ if \geq \text{threshold} \end{cases}$$

OOP counted all out-of-pocket health spending of the respondent and his/her spouse (12, 13) including those for outpatient visits, hospital admissions, and medications over the past year.

CTP was calculated as household expenditure over the past year excluding the subsistence need for foods (12, 13), which covered communication (post, internet, telephone and cell phone), utility (water, electricity), fuel (gas, petrol, coal), local transportation (including parking), domestic help (babysitting, housekeeping, personal care), entertainment (printing materials, audios and videos, cinema, bars, travels), daily necessities (toiletries, kitchen supplies, clothing and bedding), restaurants and banquets, education and training, OOP health expenses (including direct and indirect medical expenses and no including portion paid by Medicare), fitness and beauty (make-up products, beauty salons, gym, massage), rents, maintenance and repairment (house, vehicle, appliance, communication products), governmental tax and fee, donations, and household items (furniture, decorative items, durable electronics, automobiles).

Household and respondent characteristics

The variables measuring household characteristics included geographic location (eastern, central, western, and northeastern), residency (urban, rural), household size (number of cohabited family members), and economic status. Overall, the eastern region is most developed while the western is least developed in mainland China (36). There is also a significant urban-rural disparity in socioeconomic development (37). Household economic status was measured using per capita non-health expenditure, which was subsequently divided into quartiles.

The respondent characteristics were measured by sex (male, female), age (years), marital status (married, others), educational attainment (illiterate, primary school, secondary school, university), number of chronic conditions (2, 3, 4, $\geq$5), hospital admissions over the past year (yes, no), outpatient visits over the past month (yes, no), and coverage (yes, no) of different types of health insurance. There were three major types of voluntary social health insurance programs: basic medical insurance for urban employees, basic medical insurance for urban residents, and new rural cooperative medical scheme. In some municipalities, a unified basic medical insurance program was established for both urban and rural residents.

Statistical analysis

Household and respondent characteristics were described using frequency distributions. Both mean and median (interquartile) values for household expenditure, OOP health spending, and CTP were presented.

We further explored the determinants of CHE with OOP not $<$ 40% of CTP as the criterion of catastrophic health expenditure. Because this threshold removes the rigid impact of household food expenditures, it can better avoid deviations in the measurement of catastrophic health expenditures for low-income households (14). The incidence of CHE was calculated and compared among the respondents with different individual and household characteristics through Chi-square tests. Multivariate logistic regression models were established to determine the predictors of CHE, as indicated by the adjusted odds ratio (aOR) with 95% confidence interval. The discriminatory validity and calibration ability of the logistic regression models were tested using the area under the ROC curve (AUC $>$ 0.75) and the Hosmer-Lemeshow Goodness-of-Fit (between the predicted value and the actual observed value) test ($p > 0.05$), respectively (38).

All statistical analyses were performed using SPSS 26.0 (IBM Corporation). A two-side p-value of $<$ 0.05 was considered statistically significant.

Results

Characteristics of study participants

The respondents had an average age of 69.37 (SD = 7.16) years: 58.4% were younger than 70 years. Just over half (53.0%) were male and 28.40% were illiterate. Most respondents were married (75.0%) at the time of the survey, were enrolled in the new rural cooperative medical scheme (63.8%), and reported more than two chronic conditions (64.8%). About one in eleven (11.3%) were admitted to a hospital over the past year and 11.4% visited outpatient clinics over the past month.

The vast majority of the households of the respondents were located in rural areas (77.2%) and had no more than two household members (69.1%). More than one third (34.8%) were sampled from the least developed western region (Table 1).

TABLE 1 Sociodemographic characteristics of study participants with multimorbidity ($n = 3511$).

Characteristics	*n*	%
Sex		
Male	1862	53.0
Female	1649	47.0
Age (Years)		
60–69	2051	58.4
70–79	1088	31.0
≥80	372	10.6
Marital status		
Married	2635	75.0
Else	876	25.0
Education		
Illiterate	997	28.4
Primary school	1590	45.3
Secondary school	872	24.8
University	52	1.5
Number of chronic diseases		
2	1236	35.2
3	903	25.7
4	611	17.4
≥5	761	21.7
Hospital admissions over the past year		
Yes	395	11.3
No	3116	88.7
Outpatient visits over the past month		
Yes	399	11.4
No	3112	88.6
Health insurance		
Basic medical insurance for urban employees	502	14.3
Basic medical insurance urban and rural residents	425	12.1
New rural cooperative medical scheme	2241	63.8
Basic medical insurance for urban residents	157	4.5
Others	82	2.3
None	104	3.0
Residency		
Rural	2712	77.2
Urban	799	22.8
Household size		
≤2	2426	69.1
>2	1085	30.9
Geographic location		
Eastern	983	28.0
Central	1034	29.5
Western	1223	34.8
Northeastern	271	7.7

Catastrophic health expenditure

The household expenditure data were positively skewed. The median values of THE, OOP health spending, and CTP reached 19,900, 1,500, and 10,520 Yuan, respectively. The incidence of CHE was 45.6% using the threshold of ≥10% THE, compared with 31.5% using the threshold of ≥40% CTP. It increased with the number of chronic conditions and decreased with rising household economic status. Although the households with higher economic status (measured by per capita non-health expenditure) spent more on medical care, their incidence of CHE were lower. Similarly, urban households had lower incidence of CHE, despite spending more on medical care (Table 2).

The incidence of CHE varied by the chronic conditions reported by the respondents. Regardless of the threshold adopted, the highest incidence of CHE was found in those who reported cancer, memory-related disorder, and stroke (Figure 1).

Determinants of catastrophic health expenditure

Sex (p = 0.001), age ($p < 0.001$), marital status ($p = 0.005$), education ($p < 0.001$), number of chronic conditions ($p < 0.001$), outpatient visits over the past month ($p < 0.001$), inpatient admissions over the past year ($p < 0.001$), health insurance ($p = 0.003$), residency ($p < 0.001$), household size ($p < 0.001$), geographic location ($p = 0.004$), and socioeconomic status ($p < 0.001$) were all found to be associated with the incidence of CHE in the univariate statistical analyses (Table 3).

The multivariate logistic regression models demonstrated good discriminatory validity (AUC = 0.777, 95% CI: 0.761 to 0.793) and calibration ability (Hosmer-Lemeshow $\chi^2 = 7.790$, $p = 0.454$). The results showed that CHE incidence increased by the number of chronic conditions reported by the respondents (aOR = 1.293–1.855, $p < 0.05$) and decreased with increasing household economic status (aOR = 1.622–4.595 relative the highest quartile, $p < 0.001$). Hospital admissions over the past

TABLE 2 Household burden of out–of–pocket (OOP) payment for medical expenditure and catastrophic health expenditure (CHE) of study participants (n = 3511).

Indicator	Number of chronic conditions reported by respondents				Household economic status (per capita non-health expenditure)				Residency		Total
	2	3	4	≥5	Q1 (Lowest)	Q2	Q3	Q4 (Highest)	Rural	Urban	
OOP medical expenditure											
Mean	4352	5427	7199	11495	5173	6635	6539	8344	5950	9121	6672
Median	720	1440	1800	3600	1200	1560	1440	2040	1440	1782	1500
(P25, P75)	(0, 3240)	(120, 4800)	(288, 6000)	(930, 9640)	(24, 4800)	(240, 5400)	(96, 5520)	(36, 6550)	(125, 4800)	(0, 7000)	(120, 5400)
Capacity to pay											
Mean	20634	21711	22719	24500	7861	13113	19180	48343	19142	32191	22112
Median	9350	10620	10920	12140	4370	8560	12200	28060	8739	18000	10520
(P25, P75)	(4356, 18790)	(5060, 22540)	(4860, 21900)	(5602, 26518)	(2196, 7900)	(4868, 14320)	(7048, 21885)	(13571, 49148)	(4300, 18305)	(9720, 33840)	(4900, 22028)
Household total expenditure											
Mean	31526	32927	33121	36092	9515	19399	30810	72973	28011	50610	33154
Median	18018	20100	20283	22672	5976	14100	23124	50820	16376	34560	19900
(P25, P75)	(8863, 34465)	(9600, 38520)	(10040, 37050)	(10636, 41531)	(3256, 10500)	(9970, 22400)	(17370, 34415)	(34330, 80260)	(8080, 30605)	(21070, 56500)	(9672, 37520)
CHE Incidence (%)											
10% household expenditure	35.4	43.5	50.2	61.1	60.8	51.4	40.4	29.9	47.6	38.9	45.6
40% capacity to pay	23.6	29.5	35.4	43.8	44.5	35.5	27.1	19.0	33.1	26.2	31.5

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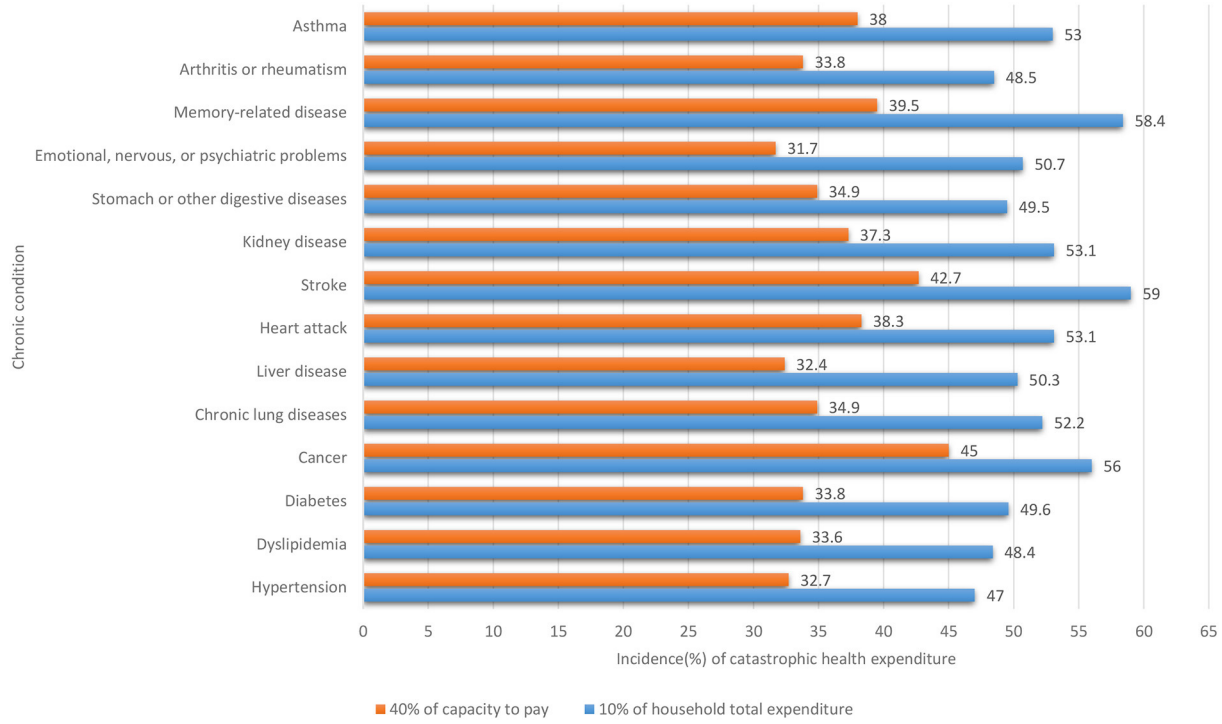

FIGURE 1
Incidence of catastrophic health expenditure by chronic conditions reported by respondents ($n = 3511$).

year (aOR = 6.707, 95% CI: 5.186 to 8.674) and outpatient visits over the past month (aOR = 4.891, 95% CI: 3.822 to 6.259) of the respondents were the strongest predictors of CHE incidence. The respondents who were male (aOR = 1.266, 95% CI: 1.054 to 1.521), married (OR = 1.502, 95% CI: 1.211 to 1.862), older than 70 years (aOR = 1.288–1.458 relative to 60–69 years, $p < 0.05$), completed primary (aOR = 1.328 relative to illiterate, 95% CI: 1.079 to 1.635) or secondary school education (aOR = 1.305 relative to illiterate, 95% CI: 1.002 to 1.701), lived in a small (≤2 members) household (aOR = 2.207, 95% CI: 1.825 to 2.669), and resided in the northeast region (aOR = 1.935 relative to eastern, 95% CI: 1.396 to 2.682) were more likely to incur CHE. Health insurance ($p = 0.065$) and urban-rural residency ($p = 0.663$) were not significant predictors of CHE incidence after controlling for other variables (Table 4).

Discussion

Multimorbidity is a significant risk of CHE. In this study, we found that 31.5% (≥40% OOP in CTP) to 45.6% (≥10% OOP in THE) households of old people (≥60 years) living with multimorbidity incurred CHE. This is lower than the CHE incidence (56.6%) revealed in another national representative study for households with diabetic patients with multimorbidity (23), even when our study participants were restricted to those with diabetes. The different results are a reflection of varied thresholds adopted: a more relaxed threshold (≥20% OOP in CTP) was adopted in the above-cited study. Nevertheless, it is clear that the households of old people with multimorbidity have a much higher incidence of CHE compared with the national average of 8.7% using the threshold of ≥40% OOP in CTP (39). We also found that household CHE incidence increases with the number of reported chronic conditions: in the households with a respondent reporting five or more chronic conditions, the odds of household CHE almost doubled that of those reporting only two chronic conditions. Empirical studies show that multimorbidity can lead to higher OOP health spending in both LMICs and high-income countries (12, 18, 40, 41).

Household incidence of CHE varies by the type of chronic conditions. We found that cancer, stroke, and memory-related diseases are the top three chronic conditions resulting in CHE: cancer ranked in top one using the threshold of ≥40% OOP in CTP, while stroke ranked in top one using the threshold of ≥10% OOP in THE. These results are consistent with the findings of other studies. Cancer is one of the most economically burdensome diseases, perhaps due to repeated

TABLE 3 Incidence of catastrophic health expenditure (CHE) by sociodemographic characteristics ($n = 3511$).

Characteristics	With CHE *n* (%)	Without CHE *n* (%)	χ^2	P
Sex			10.688	0.001
Male	632 (33.9)	1230 (66.1)		
Female	475 (28.8)	1174 (71.2)		
Age (Years)			28.923	<0.001
60–69	574 (28.0)	1477 (72.0)		
70–79	401 (36.9)	687 (63.1)		
≥80	132 (35.5)	240 (64.5)		
Marital status			7.765	0.005
Married	864 (32.8)	1771 (67.2)		
Else	243 (27.7)	633 (72.3)		
Education			20.668	<0.001
Illiterate	295 (26.6)	702 (70.4)		
Primary school	551 (34.7)	1039 (65.3)		
Secondary school	255 (29.2)	617 (70.8)		
University	6 (11.5)	46 (88.5)		
Number of chronic conditions			94.421	<0.001
2	292 (23.6)	944 (76.4)		
3	266 (29.5)	637 (70.5)		
4	216 (35.4)	395 (64.6)		
≥5	333 (43.8)	428 (56.2)		
Hospital admissions over the past year			295.160	<0.001
Yes	274 (69.4)	121 (30.6)		
No	833 (26.7)	2283 (73.3)		
Outpatient visits over the past month			179.901	<0.001
Yes	243 (60.9)	156 (39.1)		
No	864 (27.8)	2248 (72.2)		
Health insurance			18.281	0.003
Basic medical insurance for urban employees	125 (24.9)	377 (75.1)		
Basic medical insurance for urban and rural residents	154 (36.2)	271 (63.8)		
New rural cooperative medical scheme	732 (32.7)	1509 (67.3)		
Basic medical insurance for urban residents	44 (28.0)	113 (72.0)		
Others	21 (25.6)	61 (74.4)		
None	31 (29.8)	73 (70.2)		
Residency			13.826	<0.001
Rural	898 (33.1)	1814 (66.9)		
Urban	209 (26.2)	590 (73.8)		
Household size			59.454	<0.001
≤2	863 (35.6)	1563 (64.4)		
>2	244 (22.5)	841 (77.5)		
Geographic location			13.413	0.004
Eastern	274 (27.9)	709 (72.1)		
Central	324 (31.3)	710 (68.7)		
Western	405 (33.1)	818 (66.9)		
Northeastern	104 (38.4)	167 (61.6)		
Per capita non–health household expenditure			146.185	<0.001
Quartile 1 (Lowest)	391 (44.5)	488 (55.5)		
Quartile 2	312 (35.5)	567 (64.5)		
Quartile 3	237 (27.1)	639 (72.9)		
Quartile 4 (Highest)	167 (19.0)	710 (81.0)		

outpatient visits and hospitalizations and rare and expensive drug treatments (42). Similarly, the need of continuous rehabilitation care for stroke patients also imposes a heavy financial burden on households (43). In many countries with aged populations, memory-related disease conditions such as dementia have resulted in rapid growth of health and care burdens (44, 45).

Socioeconomic and regional disparities in CHE incidence persist in China, according to the findings of this study and others. We found that the households with higher household economic status have significantly lower odds of incurring CHE. This is a common phenomenon, not just for the households with old people living with multimorbidity (13, 23, 35, 46, 47). Income inequality may exacerbate catastrophic health spending in the households with low income (39, 46). China has prioritized central financial subsidies to the least developed western region in tackling socioeconomic disparity concerns (48). However, the developing regions receiving less central subsidies (such as the northeast region) may be exposed to a higher risk of CHE as is indicated by the findings of this study. Interestingly, the central and western regions are not significant in the regression results. There are regional differences in the allocation of health resources in China, which may lead to lower access to quality health services in the central and western regions (49). Low access to health services can lead to unmet health service needs of patients, thus not generating higher OOP health expenditures (50, 51). As our results show, health-seeking behavior is the most significant determinant of catastrophic health expenditure.

It is interesting to note that the urban-rural disparity in CHE incidence is insignificant after controlling for other variables in our study. Rural households usually have lower income, enjoy

TABLE 4 Predictors of incidence of catastrophic health expenditure: Results of logistic regression model ($n = 3511$).

Independent variable	P-value	B	SE	aOR	95% Confidence interval	
					Lower	Upper
Sex (Ref. female)						
Male	0.012	0.236	0.094	1.266	1.054	1.521
Age (Ref. 60–69 years)	0.005					
70–79	0.007	0.253	0.094	1.288	1.071	1.548
≥80	0.011	0.377	0.148	1.458	1.090	1.948
Marital status (Ref. else)						
Married	<0.001	0.407	0.110	1.502	1.211	1.862
Education (Ref. illiterate)	0.003					
Primary school	0.008	0.284	0.106	1.328	1.079	1.635
Secondary school	0.049	0.266	0.135	1.305	1.002	1.701
University	0.050	−0.996	0.507	0.369	0.137	0.998
Number of chronic diseases (Ref. 2)	<0.001					
3	0.019	0.257	0.110	1.293	1.043	1.603
4	<0.001	0.491	0.121	1.634	1.288	2.073
≥5	<0.001	0.618	0.114	1.855	1.483	2.320
Hospital admission over past year (Ref. No)						
Yes	<0.001	1.903	0.131	6.707	5.186	8.674
Outpatient visit over last month (Ref. No)						
Yes	<0.001	1.587	0.126	4.891	3.822	6.259
Health insurance (Ref. none)	0.065					
Basic medical insurance for urban employees	0.538	−0.191	0.311	0.826	0.449	1.519
Basic medical insurance for urban and rural residents	0.664	0.116	0.267	1.123	0.665	1.896
Basic medical insurance for urban residents	0.698	−0.135	0.348	0.874	0.442	1.727
New rural cooperative medical scheme	0.315	−0.247	0.245	0.781	0.483	1.264
Others	0.162	−0.567	0.405	0.567	0.256	1.256
Residency (Ref. urban)						
Rural	0.663	0.080	0.184	1.084	0.755	1.555
Household size (Ref. >2)						
≤2	<0.001	0.792	0.097	2.207	1.825	2.669
Geographic location (Ref. eastern)	0.001					
Central	0.551	0.067	0.113	1.070	0.857	1.335
Western	0.074	0.195	0.109	1.215	0.982	1.503
Northeastern	<0.001	0.660	0.167	1.935	1.396	2.682
Per capita non–health household expenditure (Ref. quartile 4)	<0.001					
Quartile 1	<0.001	1.525	0.137	4.595	3.513	6.009
Quartile 2	<0.001	1.113	0.135	3.043	2.335	3.965
Quartile 3	<0.001	0.484	0.132	1.622	1.251	2.102

lower welfare entitlements, and have lower access to quality health services than their urban counterparts (52, 53). This may lead to under use of healthcare services by rural residents (54). Indeed, our study participants were predominantly from rural households and their hospitalization rate is relatively low compared with the national average (55). Under use of healthcare services can lead to underestimation of CHE.

Health insurance is often considered as an important means of protecting individuals and families from CHE (56). However, it can be a double-edged sword if the funding pool is low, which can stimulate healthcare use without necessarily providing an adequate shield for CHE (13, 23). Some previous studies have found varied roles of different health insurance schemes in protecting households from CHE (47). However, we did not find any significant effects of the different insurance programs in their role of protecting households from CHE in comparison with those without any insurance. The new rural cooperative medical scheme has long been criticized for its limited role,

if any, in alleviating household poverty induced by medical expenses (57). Although the integration of health insurance for urban and rural residents may help reduce the urban-rural disparity (53, 58), the overall level of insurance entitlements remains to be low in comparison with the basic medical insurance for urban employees (26).

We also found that male respondents and those who were married, older, completed primary or secondary school education, and lived in a small (≤2 members) household were more likely to incur CHE. These factors are usually labeled as predisposing factors for healthcare services use (13, 59). For example, education can improve health literacy and encourage use of healthcare services (60). A larger household size is usually associated with higher awareness of care needs and higher capacity to pay for medical services (39, 47).

China faces a great challenge in preventing CHE as its population is continuing to grow older while household size is shrinking (4, 39). The health system reform should pay increasing attention to care for the old people living with multimorbidity. The current level of protection offered by the existing health insurance programs is inadequate, despite a high coverage (13, 26). Healthcare services should strengthen primary care, which has a function of preventing avoidable hospital care (61). It is important a adopt a patient-centered approach in primary care, in particular for those living with multimorbidity as care for one condition may influence the others. Meanwhile, socioeconomic disparities need to be addressed.

Limitations

Our study has some limitations. Firstly, data were collected through self-reporting, which may lead to underestimation of the prevalence of multimorbidity. The study participants may have some undiagnosed conditions, in particular in those living with low socioeconomic status. Secondly, the study did not assess severity of the chronic conditions due to unavailability of data. For example, sometimes a serious illness may cost more than two or more mild illnesses. Thirdly, the expenditure data are subject to recall bias. Fourthly, the study used a cross-sectional design. No causal relationships should be assumed.

Conclusions

Multimorbidity is a significant risk of CHE for households of old people in China. CHE incidence increases with the number of reported chronic conditions. Socioeconomic and regional disparities in CHE incidence persist. The health insurance programs have not played a role in preventing CHE in older people with multimorbidity.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found here: http://charls.pku.edu.cn/.

Ethics statement

The studies involving human participants were reviewed and approved by the Biomedical Ethics Review Committee of Peking University (IRB0000105IRB00001052–11015). The patients/participants provided their written informed consent to participate in this study.

Author contributions

Providing guidance for the overall content: WH, HY, and CL. Study design: WH, HL, EC, and WZ. Data analysis: HL, EC, and WZ. Writing and revising: WH and HL. Providing constructive suggestions for revisions: HY, CL, JL, EC, WZ, BL, JX, LZ, and WG. Embellishment: CL. Funding acquisition: WH and HY. All authors read and approved the final manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Utilization and out-of-pocket expenses of primary care among the multimorbid elderly in China: A two-part model with nationally representative data

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Background: Multimorbidity has become an essential public health issue that threatens human health and leads to an increased disease burden. Primary care is the prevention and management of multimorbidity by providing continuous, comprehensive patient-centered services. Therefore, the study aimed to investigate the determinants of primary care utilization and out-of-pocket expenses (OOPE) among multimorbid elderly to promote rational utilization of primary care and reduce avoidable economic burdens.

Methods: The study used data from CHARLS 2015 and 2018, which included a total of 4,384 multimorbid elderly aged 60 and above. Guided by Grossman theory, determinants such as education, gender, marriage, household economy, and so on were included in this study. A two-part model was applied to evaluate primary care utilization and OOPE intensity in multimorbid populations. And the robustness testing was performed to verify research results.

Results: Primary care visits rate and OOPE indicated a decline from 2015 to 2018. Concerning primary outpatient care, the elderly who were female ($OR = 1.51$, $P < 0.001$), married ($OR = 1.24$, $P < 0.05$), living in rural areas ($OR = 1.77$, $P < 0.001$) and with poor self-rated health ($OR = 2.23$, $P < 0.001$) had a significantly higher probability of outpatient utilization, whereas those with middle school education ($OR = 0.61$, $P < 0.001$) and better household economy ($OR = 0.96$, $P < 0.001$) had a significantly less likelihood of using outpatient care. Rural patients ($\beta = -0.72$, $P < 0.05$) may have lower OOPE, while those with better household economy ($\beta = 0.29$, $P < 0.05$; $\beta = 0.58$, $P < 0.05$) and poor self-rated health ($\beta = 0.62$, $P < 0.001$) occurred higher OOPE. Regarding primary inpatient care, adults who were living in rural areas ($OR = 1.48$, $P < 0.001$), covered by Urban Employee Basic Medical Insurance (UEBMI) or Urban Rural Basic Medical Insurance (URBMI) ($OR = 2.46$, $P < 0.001$; $OR = 1.81$, $P < 0.001$) and with poor self-rated health ($OR = 2.30$, $P < 0.001$) had a significantly higher probability of using inpatient care, whereas individuals who were female ($OR = 0.74$, $P < 0.001$), with middle school education ($OR = 0.40$, $P < 0.001$) and better household economy ($OR = 0.04$, $P < 0.001$) had a significantly lower tendency to use inpatient care. Significantly, more OOPE occurred by individuals who were women ($\beta = 0.18$, $P < 0.05$) and with better

household economy ($\beta = 0.40$, $P < 0.001$; $\beta = 0.62$, $P < 0.001$), whereas those who were covered by URBMI ($\beta = -0.25$, $P < 0.05$) and satisfied with their health ($\beta = -0.21$, $P < 0.05$) had less OOPE.

Conclusion: To prompt primary care visits and reduce economic burden among subgroups, more policy support is in need, such as tilting professional medical staff and funding to rural areas, enhancing awareness of disease prevention among vulnerable groups and so on.

KEYWORDS

multimorbidity, primary care, out-of-pocket expenses, two-part model, grossman theory, CHARLS, the elderly

Introduction

With changing lifestyles, increasing personal risk factors, and aging populations, multimorbidity has replaced infectious diseases as the major health burden in older adults, posing a clear challenge to the public health systems in all countries (1). Multimorbidity is defined as the coexistence of two or more chronic diseases in a person (2, 3), with global prevalence ranging from 12.9% (the whole population) to 95.1% (those aged 65 years and older) (4), while the prevalence in low-and-middle-income countries (LMICs) is on the rise (5–7). Multimorbidity is closely related to disability, decreased quality of life, premature death, unplanned hospitalizations, and increased consumption of health resources, which imposes a heavy strain on individuals and healthcare systems (7, 8).

To address serious conditions caused by multimorbidity, primary care has been strongly recommended as it placed an emphasis on patient-centered comprehensive, integrated, and continuous care services, which will be a critical link in the prevention and management of chronic disease (9, 10), and contribute to fulfill a large number of individual healthcare demands and reduce potential economic catastrophe led by multimorbidity. Currently, many countries are in the process of reforming the primary healthcare system. The National Health Service (NHS) in the UK is one of the most mature systems in the world, characterized by a rigorous community-based first visit and general practitioner based on referrals system (11). In Japan, the government is trying to establish a community-based integrated care system to provide supportive treatment, as the boundaries between primary care and secondary and tertiary care are blurred (10). In 2015, China implemented a hierarchical medical system centered on primary diagnosis and two-way referral to efficiently utilize medical resources. However, the system has encountered challenges. Residents are influenced by their own socioeconomic status or the service capacity of medical facilities to bypass primary care institutions for treatment at higher-level institutions (12, 13), causing lower visits rate in primary care institutions. The national bed occupancy rate in primary care institutions is just 54.7% (14). In Shanghai, only 53.48% of the urban population went to primary medical institutions for treatment (15), far lower than the 90% visits rate in the UK. Under this context, it is in urgent need to reveal the potential obstacles and economic burdens of primary care utilization to alter the attitudes of older adults toward primary medical institutions and revitalize medical resources.

Previous studies have scattered noted and made some progress the factors of healthcare utilization and expenses in different groups, which are age, gender, education, income, self-rated health, health insurance, etc. On the one hand, age was considered to be a key factor affecting the willingness to seek medical treatment for multimorbid patients (3, 16), while related studies showed no relationship between healthcare utilization and age (17). Women (16, 18) and those covered by health insurance (19) were generally more likely to use healthcare. The impact of education, income and occupation on healthcare utilization varies widely across countries. Studies in high-income countries (HICs) investigated that such factors were not related to primary care visits (20), while education and income were positively correlated with primary care visits in LMICs (21, 22). On the other hand, although age has also been pointed out as a favorable factor affecting costs (23, 24), other studies opposed the argument (25, 26). Patients who are married and living in underdeveloped areas had higher medical expenses. Self-rated health and socioeconomic factors such as income and education played a vital role in medical expenditure (19). The heterogeneity exhibited by the findings reflected the degrees of multimorbidity and the differences in healthcare systems across countries. To date, although previous research has focused on the determinants of healthcare utilization and expenditures in different groups, little detailed attention has been paid to the utilization of primary outpatient and inpatient services among the multimorbid elderly (5, 27). Additionally, research methods are also homogeneous, with most analyses of medical costs using multiple linear regression (28, 29) and quantile regression (7, 30), which takes less account of the characteristics, namely the presence of a small number of zeros and non-normal

distribution, resulting in biased estimates (31). Finally, the inclusion of factors on health care utilization and expenditure is fragmented and lacks a comprehensive approach for overall consideration in previous studies. Furthermore, ignoring the impact of individual health demands, as an antecedent demand (32), on utilization and expenditure behavior may give rise to difficulties in screening the true and reasonable use and costs.

Therefore, to fill the research gaps as mentioned above, the study will focus on the primary care utilization and expenses among older adults with multimorbidity using a two-part model, as well as validate determinants on utilization and expenditures based on the Grossman theory. The outcome of this study will benefit to understand the barriers and financial burden of primary care utilization among multimorbid groups, and provide targeted recommendations to further promote appropriate utilization and avoid excessive medical expenditures, ultimately contributing to rational allocation and efficient use of primary medical resources.

Materials and methods

Theory

To overcome the shortcoming of ignoring the impact of health demands on utilization and expenditure of health services, it is more appropriate to investigate medical use and expenditures in multimorbid groups from the perspective of health demand. Thus, Grossman theory, which affirms that healthcare utilization and spending behavior stems from the individual demand, was applied in this study to provide theoretical guidance to describe the factors influencing healthcare utilization choices and expenditures among multimorbid patients. This theory asserts that health can be viewed as a durable stock of capital that declines with age (32). In order to obtain or maintain health, individuals restore health and improve work productivity through using healthcare services and managing risk factor.

Due to the multi-layered and complex of medical services, Grossman has hypothesized that health demand is influenced by factors such as age, education, gender, marital status, income, and personal behavior (such as smoking, diet, and exercise) and so on (33, 34). The main assumptions have also been confirmed by several empirical studies. (i) The increase in age leads to a decline in personal health, which drives more medical demands. A study using Grossman-PLS model to predict key factors on the growth of healthcare spending in the middle east region revealed that aging and the relative wage rate were the statistically significant indicators (35). (ii) As individuals' incomes increase, their health and medical demands increase. Hartwig et al. (36) used macro panel data to test the validity of Grossman theory and confirmed that real wages were considered to be a robust predictor. (iii) More educated individuals have less demand for medical services and lower health expenditures. An analysis of health service demand in Costa Rica based on Grossman theory found that the key determinants of health care utilization were education level and self-assessed health (37). A study of health equality in social groups through the lens of health capital theory emphasized the deterministic role of education on health (38). (iv) The intervention of health insurance drives the patients' medical demands. On the basis of the health demand model, Sorkin argued that health insurance not only played a certain part in reducing the health care price, but also stimulated individual demand for medical services (39).

Data

The study used data from two waves of the China Health and Retirement Longitudinal Study (CHARLS) in 2015 and 2018. CHARLS is a biennial follow-up survey conducted by the National Development Research Institute at the Peking University, targeting Chinese residents aged 45 or older and their households. It is a comprehensive and informative database that covers many aspects of socioeconomic status and personal health status through one-to-one interviews with structured questionnaires in China. The baseline survey was conducted in 2011 using the probability proportional to size (PPS) sampling to select respondents from 150 counties, 450 villages, and about 17,000 individuals across 28 provinces in China. More detailed information can be found on the official CHARLS website (https://charls.charlsdata.com/index/zh-cn.html).

According to the study design, samples from 2015 and 2018 were excluded if they met any of the following criteria. (i) Individuals aged <60 years old. (ii) Individuals with one or no chronic disease (more details were shown in 2.3.1 below). (iii) Individuals seeking treatment due to violence, accident, vaccination, etc. (iv) Individuals with incomplete sample information. The final data set included 4,384 respondents in 2 waves, with 2,731 individuals in 2015 and 1,653 individuals in 2018, to form a pooled cross-sectional data. The details of the process are shown in Figure 1.

Measurements

Chronic diseases and multimorbidity

A total of 14 chronic diseases were contained in the CHARLS: hypertension, dyslipidemia [elevation of low-density lipoprotein, triglycerides (TGs), and total cholesterol, or a low high-density lipoprotein level], diabetes or high blood sugar, cancer or malignant tumor (excluding minor skin cancers), chronic lung diseases such as chronic bronchitis, emphysema (excluding tumors, or cancer), liver disease (except fatty liver, tumors, and cancer), heart attack (such as coronary heart disease, angina, congestive heart failure, or other heart

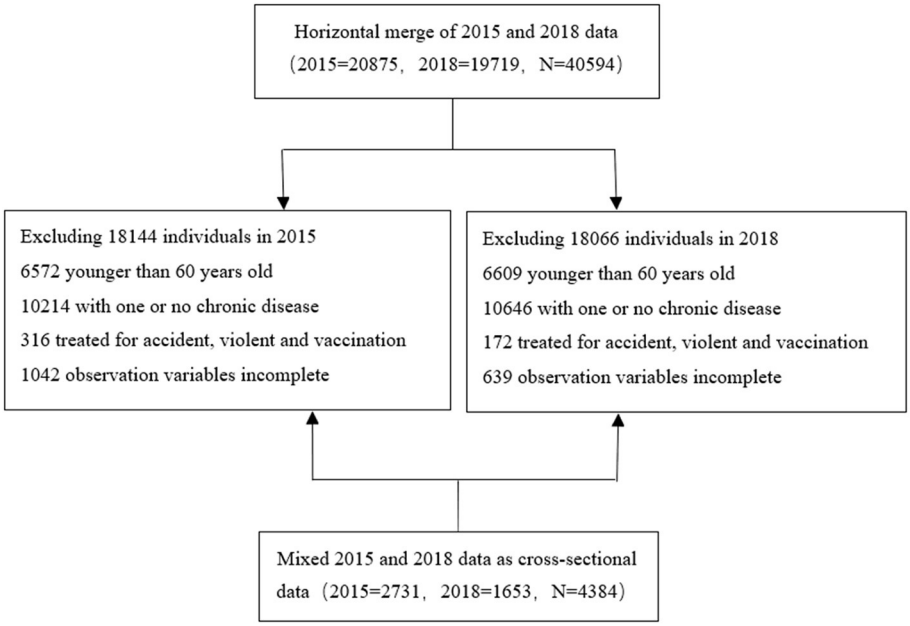

FIGURE 1
Sample inclusion flow chart.

problems), stroke, kidney disease (except for tumor or cancer), stomach or other digestive disease (except for tumor or cancer), emotional or psychiatric problems, memory-related disease, arthritis or rheumatism, asthma. The question in CHARLS regarding the presence of chronic diseases is "Have you ever been diagnosed with these chronic diseases by a doctor?." If respondents answered two or more chronic diseases, they were judged to be multimorbid.

Dependent variables

The outcome variables included in this study are primary outpatient care utilization and OOPE, primary inpatient care utilization and OOPE. The primary outpatient care utilization was measured by "Which medical provider did you visit most recently for outpatient care during the past month?" The primary inpatient care utilization was evaluated by "Which type of health facilities did you most recent visit for last inpatient care (hospital admissions) in the past year?" If they visited a community healthcare center, township hospital, health care post, or village clinic/private clinic, respondents were defined as having primary outpatient or inpatient care utilization and continued to ask about the OOPE.

The OOPE of primary outpatient and inpatient, defined as the expenditure after being reimbursed by health insurance, was measured by "How much did you pay out of pocket, after reimbursement from insurance for last outpatient care in the past month?" and "How much did you pay out of pocket for your last hospitalization in the past year?" in CHARLS. The first part of primary care utilization is a dichotomous variable (used/not used), and the second part of medical expenditure is a continuous variable ($\geq$0). Those who did not use primary care were excluded from the second part.

Independent variables

Based on Grossman theory, this research selected ten variables from CHARLS: gender, age (60$\sim$69, 70$\sim$79, 80$\sim$), education (illiterate, primary school, middle school, high school and above), marital status, residence, household economy (monthly per capita household consumption expenditure), health insurance [uninsured, UEBMI (Urban Employee Basic Medical Insurance), URBMI (Urban Rural Basic Medical Insurance), more than one, other insurance.], self-rated health (very good, good, fair, and poor), health satisfaction, and exercise. This study adopted household economy, which was considered more reliable, rather than personal income. Previous studies have shown that most rural older adults have unstable or almost no income, whereas the household economy can faithfully reflect the financial support that patients' families can provide during treatment (40, 41). Besides, there was a lack of personal income in the data.

Statistical analysis

Descriptive analysis was used to summarize primary care utilization and expenditures among multimorbid adults with different characteristics in reporting results as the frequency and percentage. Differences in categorical variables between groups were assessed by a chi-square test. A two-part model was applied to estimate determinants affecting the utilization and OOPE of primary care among multimorbid patients, by adjusted robust standard errors, odds ratios (OR), and coefficients of GLM. In addition, multiple imputation of Monte Carlo simulations was performed on the missing data to obtain the interpolated dataset, and each interpolated data set was analyzed to verify the robustness of the original model. Use the TPM command for data analysis and the margin command to obtain marginal effects in STATA 16.0 (Stata Corp.). The level of statistical significance was set as $P = 0.05$.

Previous studies have confirmed that medical expenditures are semi-continuous quantitative data, including zero and non-zero positive values with highly right-biased distribution (42, 43). In this case, the two-part model is more suitable than linear regression. Linear regression requires satisfying diverse regression assumptions, and its use may lead to biased estimates of the relationship between the outcome variables and observed variables. In contrast, two-part models are highly flexible and combine the advantages of parametric and non-parametric regressions (44), without the requirement to follow normal distribution and homoskedasticity criteria, facilitating the handling of highly complex medical costs and obtaining best-fit and unbiased estimations.

The two-part model divided the decision-making process into two steps. The first step applied a logit model to estimate the probability of using primary outpatient or inpatient services, and the second step adopted a GLM with gamma distribution and a logit link function to analyze the determinants of OOPE. Since the GLM directly provides estimates without any transformation (42). During data processing, 61 outpatients and 21 inpatients with zero medical expenditures, due to health insurance paid for all of the patients' medical expenses. The subsequent solution was to add a constant of 1 to the presence of true zeros so as to ensure that these samples entered the second stage of modeling (29, 45). The two-part model was as follows:

$$P_r\left(c_i > 0/x_i\right) = e^{\alpha+\beta X_i}/1 + e^{\alpha+\beta X_i}$$

P_r denotes individual healthcare decision-making behavior, x_i denotes sociodemographic and health factors influencing primary care utilization. P_r is a binary variable, if $c_i > 0$ means that patients seek treatment from primary care institutions, $P_r = 1$; if otherwise, it is $P_r = 0$.

$$\text{GLM with a logit link}: c_i = e^{\alpha+\beta X_i+\varepsilon_i}$$

c_i denotes the logarithm of primary outpatient and inpatient expenses; x_i denotes determinants of primary care utilization and expenses. ε_i is the random error term.

The final form of the two-part model is given by:

$$E\left(c_i/x_i\right) = P_r\left(c_i > 0/x_i\right) E\left(c_i/x_i, c_i > 0\right)$$

Patient and public involvement

The Biomedical Ethics Review Committee of Peking University approved CHARLS (IRB00001052-11015). No participants were involved in designing the study, analyzing the results, or writing the paper.

Results

Demographic characteristics

Table 1 presents the characteristics of the multimorbid elderly. A total of 4,384 elderly with multimorbidity, with the largest number of two chronic diseases (39.14%), followed by three chronic diseases (23.36%). Among the elderly, 41.54% were 70∼79 years old, 51.05% were women, 77.74% were married and 74.11% were rural patients. In terms of education, 28.10% were illiterate, and 52.37% had primary education, implying that the vast majority of multimorbid patients had a low level of education. Concerning health insurance, 21.72% were uninsured, 9.58% had UEBMI, and 62.68% had URBMI. Nearly 90% reported that their health was fair or poor, 60.79% were satisfied with their health, and 49.5% exercised regularly.

Utilization and OOPE of primary care

Figure 2 demonstrates the changes of the visit rate and OOPE from 2015 to 2018. The primary outpatient visits rate of multimorbid patients decreased from 29.48% in 2015 to 25.83% in 2018, and the inpatient rate diminished from 14.02 to 11.92%. The outpatient OOPE reduced from 279 RMB in 2015 to 243 RMB in 2018, and inpatient OOPE dropped from 1,457 to 1,271 RMB.

Table 2 shows the sample characteristics regarding utilization and OOPE of primary outpatient care. There were 1,232 multimorbid elderly using primary outpatient care. Individuals who were 60∼69 years old, female, less educated, married, covered by EUBMI, with poor self-rated health, and occasional exercises used more primary outpatient care. The chi-square test proved that there were significant differences in primary outpatient services utilization among all variables. The OOPE was higher for patients who were over 80 years old, male, better educated, married, living in urban areas, had

TABLE 1 Characteristics among the multimorbid elderly.

Variables		*N*	Percent (%)
Age	60∼69	1,680	38.32
	70∼79	1,821	41.54
	80∼	883	20.14
Gender	Man	2,146	48.95
	Woman	2,238	51.05
Education	Illiterate	1,232	28.10
	Primary school	2,296	52.37
	Middle school	337	7.69
	High school and above	519	11.84
Marital status	Unmarried	976	22.26
	Married	3,408	77.74
Residence	Central of city/town	815	18.59
	Urban–rural integration area	304	6.93
	Rural area	3,249	74.11
	Special area	16	0.36
Health insurance	No insurance	952	21.72
	UEBMI	420	9.58
	URBMI	2,748	62.68
	Two and above	195	1.57
	Other	69	4.45
Household economy	0∼299	1,036	23.63
	299∼657	1,049	23.93
	657∼880	1,394	31.80
	880∼1,510	905	20.64
Self-rated health	Very good	166	3.79
	Good	278	6.34
	Fair	1,929	44.00
	Poor	2,011	45.87
Health satisfaction	No	1,719	39.21
	Yes	2,665	60.79
Exercise	No	2,214	50.50
	Yes	2,170	49.50
Obs		4,384	100.00

URBMI or without insurance, better household economy, poor self-rated health, dissatisfied with health status, and occasional exercises. Further, the average OOPE differed greatly in certain variables. Patients aged over 80 years spent 1.5 times as much as those aged 70∼79 years. Those with a high school and above education spent about twice as much as those were illiterate. Urban patients spent ∼2.4 times more than rural patients.

Table 3 illustrates the characteristics concerning use and OOPE of primary inpatient care. A total of 580 multimorbid elderly used primary inpatient care. Older adults who were 70∼79 years old, less educated, married, living in rural areas, insured, better household economy, fair or poor self-rated health, and dissatisfied with their health used more primary inpatient services. The chi-square test showed that except for gender and age, other variables were greatly associated with the utilization of primary inpatient care. Patients who were 60∼69 years old, less educated, uninsured, better household economy, and dissatisfied with their health occurred higher OOPE. Notably, the elderly with the best household economy spent ∼1.6 times as much as those with the worst household economy.

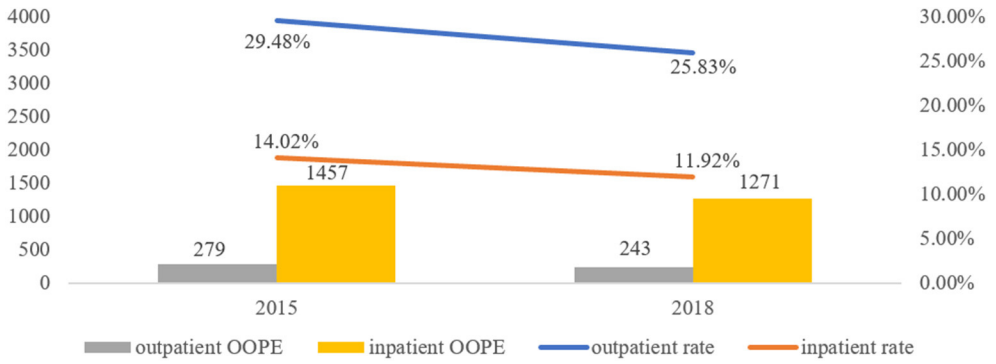

FIGURE 2
Primary care utilization and OOPE among the multimorbid elderly from 2015 to 2018.

Predictors of primary care utilization and OOPE

Table 4 shows the predictors of primary outpatient and OOPE. Older adults, especially those over 80 years old, were significantly less likely to use primary outpatient services ($OR = 0.80$, $P < 0.05$). It is of great significance that participants who were women ($OR = 1.51$, $P < 0.001$), married ($OR = 1.24$, $P < 0.05$) and living in rural areas ($OR = 1.77$, $P < 0.001$) were more likely to use primary outpatient care. And the OOPE was significantly lower for those who lived in urban-rural integration areas ($\beta = -0.66$, $P < 0.05$) or rural areas ($\beta = -0.72$, $P < 0.05$) compared to those who lived in rural areas. Older people with fair or poor self-rated health were 1.9 times or 2.23 times more likely to use primary outpatient care than those with very good self-rated health ($OR = 1.90$, $P < 0.001$; $OR = 2.23$, $P < 0.001$), and the former had significantly higher OOPE than the latter ($\beta = 0.62$, $P < 0.001$). In addition, patients with middle school education had a significantly lower propensity to use primary outpatient services and occurred lower OOPE compared to illiterate patients ($OR = 0.61$, $P < 0.001$; $\beta = -0.47$, $P < 0.001$). Besides, patients with better household economy were significantly less likely to use primary outpatient care ($OR = 0.96$, $P < 0.001$), but may incur higher OOPE ($\beta = 0.29$, $P < 0.05$; $\beta = 0.58$, $P < 0.05$).

Marginal effect of primary outpatient care manifested that the cost of patients aged 70∼79 years was significantly less than those aged 60∼69 years by 13 RMB. The expenditures for adults with middle school education were of remarkable significance lower than that of illiterate by 38 RMB. Patients covered by UEBMI or other insurance paid significantly less than those without health insurance by 30 and 35 RMB, respectively. The cost for women was of great significance higher than that for men by 20 RMB. It is significant that respondents with better household economy spent 105 RMB more than those with the worst household economy. Compared to those with good self-rated health, the expenses of respondents with fair or poor self-rated health were significantly higher by 22 and 64 RMB, respectively.

Table 5 revealed the predictors of primary inpatient care. Women were less likely than men to be hospitalized ($OR = 0.74$, $P < 0.001$), but may occur higher OOPE ($\beta = 0.18$, $P < 0.05$). Individuals with middle school education ($OR = 0.40$, $P < 0.001$) and better household economy ($OR = 0.04$, $P < 0.001$) had a significantly lower propensity to use primary inpatient care. Regarding cost, OOPE was significantly lower for those with high school or higher education ($\beta = -0.41$, $P < 0.001$) whereas higher OOPE may occur among those with better household economy ($\beta = 0.40$, $P < 0.001$; $\beta = 0.62$, $P < 0.001$). The likelihood of using primary inpatient care for those who had UEBMI ($OR = 2.46$, $P < 0.001$), URBMI ($OR = 1.81$, $P < 0.001$), and other insurance ($OR = 2.15$, $P < 0.05$) were 2.46, 1.81, and 2.15 times than the uninsured group. And OOPE was significantly lower in the URBMI group than in the uninsured group ($\beta = -0.25$, $P < 0.05$). It is significant that seniors who living in rural areas ($OR = 1.48$, $P < 0.001$), with poor self-rated health ($OR = 2.30$, $P < 0.001$) were more greatly likely to use primary inpatient care, and those who were satisfied with their health would have lower OOPE ($\beta = -0.21$, $P < 0.05$).

Marginal effects of primary inpatient care indicated that patients with middle school education or high school and above education spent significantly less than illiterate patients by 135 and 84 RMB, respectively. It is of great significance that participants who were satisfied with their health had lower expenditures of 45 RMB than those who were dissatisfied with their health. The cost for those who exercised regularly was significantly lower than for those who exercised occasionally by 42 RMB. It is of great significance that rural patients spent 30 RMB more than urban persons. Individuals with better or best household economy cost significantly more than those with the worst household economy by 29 and 50 RMB, respectively. It is

TABLE 2 Characteristics of primary outpatient care utilization and OOPE among the multimorbid elderly ($N = 1,232$).

Variables	*N*	Outpatient rate (%)	*P*-value	Mean OOPE(RMB)
Age			<0.001	
60∼69	518	30.83		241
70∼79	515	28.28		219
80∼	199	22.54		407
Gender			<0.001	
Man	505	23.53		280
Woman	727	32.48		243
Education			<0.001	
Illiterate	400	32.47		229
Primary school	669	29.14		282
Middle school	54	16.02		322
High school and above	109	21.00		447
Marital status			<0.001	
Unmarried	202	20.70		240
Married	1,030	30.22		262
Residence			<0.001	
Central of city/town	144	30.83		522
Urban–rural integration area	58	19.08		230
Rural area	1,027	31.61		221
Special area	3	18.75		825
Health insurance			<0.001	
No insurance	215	22.58		267
UEBMI	88	20.95		213
URBMI	864	31.44		268
Two and above	41	21.03		205
Other	24	34.78		98
Household economy			<0.001	
0∼298	177	17.08		204
299∼656	182	17.35		188
657∼879	761	54.59		269
880∼1,510	112	12.38		376
Self-rated health			<0.001	
Very good	23	13.86		160
Good	54	19.42		173
Fair	490	25.40		183
Poor	665	33.07		324
Health satisfaction			<0.001	
No	538	31.30		273
Yes	694	26.04		247
Exercise			<0.001	
No	714	32.25		204
Yes	518	23.87		334

TABLE 3 Characteristics of primary inpatient care utilization and OOPE among the multimorbid elderly ($N = 580$).

Variables	*N*	Inpatient rate (%)	*P*-value	Mean OOPE(RMB)
Age			0.180	
60∼69	212	12.62		1,437
70∼79	261	14.33		1,256
80∼	107	12.12		1,328
Gender			0.151	
Man	300	13.98		1,210
Woman	280	12.51		1,470
Education			<0.001	
Illiterate	189	15.34		1,454
Primary school	317	13.81		1,331
Middle school	17	5.04		1,209
High school and above	57	10.98		1,004
Marital status			0.007	
Unmarried	104	10.66		1,327
Married	476	13.97		1,337
Residence			<0.001	
Central of city/town	74	9.08		1,351
Urban–rural integration area	30	9.87		1,499
Rural area	475	14.62		1,319
Special area	1	6.25		3,001
Health insurance			<0.001	
No insurance	67	7.04		1,660
UEBMI	74	17.62		1,354
URBMI	413	15.03		1,285
Two and above	14	7.18		1,300
Other	12	17.39		1,195
Household economy			<0.001	
0∼298	68	6.56		959
299∼656	68	6.48		1,322
657∼879	394	28.26		1,368
880∼1,510	50	5.52		1,599
Self-rated health			<0.001	
Very good	10	6.02		1,303
Good	16	5.76		1,857
Fair	200	10.37		1,261
Poor	354	17.60		1,355
Health satisfaction			<0.001	
No	284	16.52		1,409
Yes	296	11.11		1,265
Exercise			<0.001	
No	378	17.07		1,339
Yes	202	9.31		1,210

TABLE 4 Predictors of primary outpatient care utilization and OOPE among the multimorbid elderly.

Variables	Logit		Glm		Marginal effect
	OR	RE	Coef.	RE	*dy/dx*
Age (ref 60∼69)					
70∼79	0.92**	0.08	−0.14	0.10	−13*
80∼	0.80**	0.09	0.11	0.18	−2
Gender (ref man)					
Woman	1.51***	0.12	0.04	0.01	20***
Education (ref illiterate)					
Primary school	0.95	0.08	*0.11*	*0.11*	6
Middle school	0.61***	0.11	−0.47**	0.20	−38***
High school and above	0.78*	0.11	−0.15	0.18	−1
Marital status (ref unmarried)					
Married	1.24**	0.13	−0.06	0.14	5
Residence (ref central of city/town)					
Urban–rural integration area	0.98	0.19	−0.66**	0.33	−48
Rural area	1.77***	0.21	−0.72**	0.29	31
Special area	1.05	0.77	0.22	0.74	28
Health insurance (ref no insurance)					
UEBMI	0.78	0.13	−0.38*	0.23	−30**
URBMI	1.17	0.11	−0.04	0.15	3
Two and above	0.91	0.29	−0.91	0.24	−29
Other	1.58*	1.10	−0.44***	0.32	−35**
Household economy (ref 0∼298)					
299∼656	1.10	0.13	−0.01	0.16	3
657∼879	0.96***	0.62	0.29**	0.15	105***
880∼1,510	0.91	0.13	0.58**	0.26	21
Self-rated health (ref very good)					
Good	1.64*	0.45	0.05	0.29	14
Fair	1.90***	0.44	0.14	0.20	22***
Poor	2.23***	0.54	0.62***	0.23	64***
Health satisfaction (ref no)					
Yes	1.10	0.09	−0.09	0.11	−2
Exercise (ref no)					
Yes	0.92	0.07	−0.30***	0.11	18
Constant	0.40***	0.13	5.75***	0.37	
Obs	4,384		1,232		
Prob > chi^2	<0.001				
Pseudo R^2	16.17				

***Significant at 1%; **significant at 5%; *significant at 10%.

significant that patients with poor self-rated health had higher spending of 88 RMB than those with very good self-rated health.

Robustness test

In order to further verify the robustness of the above findings, this study performed multiple imputation on missing data and obtained some datasets, regressed each dataset separately and verified the robustness of the results. The results indicated that the relationship between the observed variables and utilization and cost is more consistent with the original conclusions, which strongly validated the reliability of the original outcomes. The regression results for the interpolated data also demonstrated that gender, education, household economy, and self-rated health were all associated with primary

TABLE 5 Predictors of primary inpatient care utilization and OOPE among the multimorbid elderly.

Variables	Logit		Glm		Marginal effect
	OR	RE	Coef.	RE	*dy/dx*
Age (ref 60∼69)					
70∼79	1.18	0.13	−0.16	0.10	−6
80∼	1.13	0.09	−−0.03	0.12	11
Gender (ref man)					
Woman	0.74***	0.07	0.18**	0.09	−8
Education (ref illiterate)					
Primary school	0.86	0.08	−0.05	0.10	−31
Middle school	0.40***	0.11	−0.27	0.17	−135***
High school and above	0.78	0.11	−0.41***	0.15	−84***
Marital status (ref unmarried)					
Married	0.87	0.11	0.03	0.11	−14
Residence (ref central of city/town)					
Urban–rural integration area	1.11	0.26	0.17	0.22	45
Rural area	1.48	0.22	−0.12	0.22	30**
Special area	0.81	0.95	0.86***	0.22	148
Health insurance (ref no insurance)					
UEBMI	2.46***	0.48	−0.19**	0.18	95**
URBMI	1.81***	0.26	−0.25**	0.13	37
Two and above	0.93	0.30	−0.34*	0.24	44
Other	2.15**	0.84	−0.38	0.25	−52
Household economy (ref 0∼298)					
299∼656	1.03	0.18	0.33*	0.17	26
657∼879	0.04***	0.73	0.40***	0.23	29***
880∼1,510	0.99	0.20	0.62***	0.12	50**
Self-rated health (ref very good)					
Good	0.85	0.36	0.11	0.30	19
Fair	1.49	0.51	0.13	0.22	26
Poor	2.30***	0.80	0.29	0.22	88**
Health satisfaction (ref no)					
Yes	0.94	0.10	−0.21**	0.10	−45**
Exercise (ref no)					
Yes	0.69***	0.69	−0.04	0.09	−42**
Constant	0.04**	0.01	7.38***	0.32	
Obs	4,384		580		
Prob > chi^2	<0.001				
Pseudo R^2	14.54				

***Significant at 1%; **significant at 5%; *significant at 10%.

care utilization, while education, residence, household economy, self-rated health and so on were associated with OOPE of primary care (shown in Table 6).

Discussion

Globally, health systems are increasingly challenged to care for older adults with complex multimorbidity. The study used nationally representative data and a two-part model to clarify current primary care utilization, OOPE and its associated impacts on the multimorbid elderly. The primary outpatient visits rate of multimorbid patients dropped from 29.48% in 2015 to 25.83% in 2018, and the inpatient rate reduced from 14.02 to 11.92%. The outpatient OOPE declined from 279 RMB in 2015 to 243 RMB in 2018, and inpatient OOPE decreased from 1,451 to 1,271 RMB. On the one hand, primary outpatient and inpatient utilization were both influenced by gender, marital status, education, self-rated health and household

TABLE 6 Robustness test.

Variables	Outpatient		Inpatient	
	OR	Coef.	OR	Coef.
Age (ref 60∼69)				
70∼79	0.95**	−0.14	1.78	−0.23
80∼	0.74**	0.22	2.57	−0.03
Gender (ref man)				
Woman	2.58***	0.04	0.74***	0.28**
Education (ref illiterate)				
Primary school	0.92	0.22	0.67	−0.05
Middle school	0.74***	−0.47**	0.73***	−0.27
High school and above	0.65**	−0.25	0.85**	−0.42***
Marital status (ref unmarried)				
Married	2.37**	−0.06	0.95	0.03
Residence (ref central of city/town)				
Urban–rural integration area	0.98*	−0.65**	2.46	0.27
Rural area	2.94***	−0.73**	2.73	−0.22
Special area	2.02	0.28	0.78	0.86***
Health insurance (ref no insurance)				
UEBMI	0.72	−0.32*	2.78***	−0.29**
URBMI	2.25	−0.23	2.92***	−0.25**
Two and above	0.82	−0.84	1.23	−0.34*
Other	2.67*	−0.44***	2.34**	−0.38
Household economy (ref 0∼298)				
299∼656	2.28	0.02	2.03	0.36**
657∼879	0.94***	0.30**	0.04***	0.37***
880∼2,520	0.92**	0.67**	0.99**	0.45***
Self-rated health (ref very good)				
Good	2.45**	0.05	1.45	0.22
Fair	2.98***	0.24**	1.91**	0.23*
Poor	2.27***	0.64***	2.21***	0.29**
Health satisfaction (ref no)				
Yes	2.35	−0.09	0.94	−0.22**
Exercise (ref no)				
Yes	0.98	−0.30***	0.69***	−0.12
Constant	0.40***	5.75***	0.04**	7.38***
Obs	6,065		6,065	
Prob > chi^2	<0.001		<0.001	
Pseudo R^2	13.37		12.35	

***Significant at 1%; **significant at 5%; *significant at 10%.

economy, whereas health insurance and exercise frequency also were related to inpatient utilization. On the other hand, education, residence, household economy, self-rated health and exercise frequency were associated with primary outpatient expenditures, as well as gender, education, health insurance, household economy and health satisfaction were relevant to primary inpatient expenses.

In this study, primary care visit rates and OOPE trended downward from 2015 to 2018. Yang et al. (46) observed a decreasing trend in primary outpatient visits whereas an increasing trend in large hospital outpatient visits among the middle-aged and older adults in Chinese referral system. Ganguli et al. (47) surveyed primary care utilization among commercially insured adults and found a 24.2% decrease in

primary care visits and a $9.4 increase in OOPE per visit. But there are some studies confirmed that a sound primary care service system is conducive to the reduction of OOPE (48, 49). It is well-known that the primary care improves health outcomes and reduces economic burden. Despite a series of favorable policies to launch a hierarchical medical system in China, the dearth of decentralization of professionals and medical technology to the primary healthcare facilities (50), and the lack of change in perceptions of primary care visits have led to a decline in the utilization of primary care services. Possible explanations for the shrinkage in OOPE are that the continuity treatment in primary care institutions prevents the escalation of disease severity among multimorbid patients and higher health insurance reimbursement in primary care institutions than in secondary and tertiary hospitals (51), thereby reducing the financial burden on patients.

Factors related to primary outpatient care utilization and OOPE

This study reported that older adults aged 80 and above used fewer primary outpatient services. Due to biological aging, decline in physiological function, and exposure and accumulation of risk factors throughout the lifespan, the elderly place higher expectations on healthcare (52). Furthermore, this study also reported that patients who are female, married, and living in rural areas tended to utilize more primary outpatient care, which was in line with the result of a Swedish study that females more frequently use primary care (53). The plausible reasons may be that women have strong perceptions of illness for their physical vulnerability (28), and the convenient accessibility of primary care facilities stimulates them to use primary outpatient care. Thirdly, as demonstrated in this study, married populations were more likely to use primary outpatient care, which was supported by a longitudinal study that assessed the relationship between marriage and multimorbidity across countries (54). The benefit of marriage is that spouses may provide adequate financial and psychological support, and promptly urge and accompany them to receive the necessary treatment (55). Fourthly, consistent with a prior study (56), the result suggested that rural residents were more likely to use primary outpatient services. In most cases, patients who lived in rural areas are susceptible to transportation restrictions, and are trust in primary physicians with fewer communication barriers such as professionalism and terminology understanding (57), which increase primary outpatient care visits by rural patients. Finally, the results from this study suggested that the impact of education and household economy were negative for frequent primary outpatient utilization. Since the healthcare system in China allows patients freely to choose any healthcare institution (58), patients with higher education and better household economy are more likely to choose large hospitals where they can provide better care.

The research assumed that rural patients had lower OOPE than urban patients. Compared to urban areas, rural primary care facilities are mostly equipped with drugs from the national essential drug list and have relatively more low-priced drugs (12), so the cost may be reduced. Additionally, as reported in this study, since more educated patients with better health literacy are able to effectively reduce the risk of multimorbidity and improve physical function by managing health risk factors, education was negatively associated with OOPE. And some prior studies indicated that household economy is one of the powerful factors affecting expenses (59, 60). Wealthy households have more disposable funds and are less constrained by medical prices during treatment, which in turn consumes more and more expensive drugs or tests resulting in higher OOPE. Besides, this study also demonstrated that patients who perceived themselves to be in better health and exercised regularly had lower OOPE. The plausible reason may be that the ones who have positive attitudes toward their health, and proactively regulate their lifestyle and mindset, tends to achieve protective health outcomes by reducing functional impairment through moderate health activities (61), which subsequently reduce healthcare costs.

Factors related to primary inpatient care utilization and OOPE

This study confirmed the results of previous research that women were significantly less likely to use inpatient services than men (62). The plausible reason may be that many women in China are fully engaged with families and do not have sufficient income to afford the relatively expensive inpatient expenses (63). Besides, similar to previous studies (59, 64), those with higher education and better household economy were negatively correlated with primary inpatient care utilization. Although some other prior research indicated a positive association between income and healthcare utilization in LMICs (65), this pattern is more applicable to secondary and tertiary hospitals than to primary hospitals. This is because the purchasing power of patients with better education and higher incomes increase their access to healthcare in secondary or tertiary hospitals. Additionally, this study also demonstrated that different types of health insurance had different effects on primary inpatient care utilization, which was consistent with previous findings (30, 66). Patients with health insurance generally had a higher utilization than those uncovered by any health insurance, because health insurance improves their affordability by paying a proportion of total health expenditure (67, 68). Similar to existing empirical study (66), those with health insurance were more likely to utilize primary inpatient care while health insurance was

insignificant in driving primary outpatient use. The rational explanation is that outpatient claims cover fewer types of illness and lower reimbursement rates for outpatient care (28). Finally, in conformity with prior studies (69, 70), individuals who lacked exercise and had poorer self-rated health used healthcare more frequently than those who exercise in moderation. A reasonable explanation is that inadequate exercise or poor self-rated health can directly affect health outcomes in older adults, leading to more primary hospitalization utilization.

Similar to the results of previous studies (62, 71), women have significantly higher OOPE than men. Compared with men, women have a higher probability to delay hospitalization for family or financial reasons, increasing the severity of diseases and causing more complications, which result in an escalation of expenditures. Moreover, this study also found that OOPE was higher for those with better household economy. This is because patients with better household economy place more value on the quality of medical care provided by medical institutions and post-treatment health outcomes than on medical expenses (72, 73). In accordance with previous research (74), the study also proved that the OOPE of patients with health insurance was significantly lower than those uncovered by any health insurance. The reason is that a proportion of medical expenses can be reimbursed by health insurance, which will directly reduce the economic burden related to hospitalization. Besides, patients with UEBMI had higher OOPE than those with URBMI in this study. Empirical studies in China (75), Germany (76) and Thailand (77) also reported a similar situation, that is, medical insurance with more generous reimbursement is prone to occur higher OOPE. And UEBMI targets groups with relatively higher social status and easier access to treatment. In addition, the finding of this study suggested that individuals who were more satisfied with their health status could better control medical expenses, as positive attitudes occur more health-promoting behaviors and decrease expenses (78).

Policy implications

By 2050, the elderly population in China will account for half of the total population (79), which may result in an epidemic of chronic diseases in the elderly. Thus, the country needs to adjust its disease management strategies in advance to prevent the prevalence of complex multimorbidity. Then, focus on vulnerable groups such as women, less educated and poorer self-rated health, and take targeted interventions to enhance their awareness of disease prevention and reduce inappropriate medical expenses. Since the geographical constraints and urban-rural disparities would exacerbate inequality in medical services and expenses, consequently local governments or other social organizations need to provide additional financial, professional and equipment support to bridge the gap in the quality of health services between rural and urban areas. Finally, given the prevalence of multimorbidity and healthcare systems still oriented toward a single disease, patient-centered care should be reconsidered and emphasized to more effectively manage comorbidities and improve the quality of life (80, 81).

Strengths and limitations

The strengths of this study were as follows. First, since few studies has emphasized and segmented primary outpatient and inpatient service utilization and expenditure among elderly patients with multimorbidity, focusing on the multimorbid groups with severe disease burden can fill the corresponding research gap. And it will also benefit strengthening of primary management of chronic diseases and advancing the construction of an orderly hierarchical medical system. Second, guided by the health demand model of Grossman theory to screen variables, this study ensures that the variable selection takes into account the influence of health demand on subsequent behavior and the scientific factor inclusion, which will overcome the shortcoming of ignoring the impact of health demand. Finally, a two-part model was introduced to investigate the determinants of primary care utilization and expenses so as to systematically capture the current utilization status and economic burden among the multimorbid elderly. Two-part models have the flexibility to deal with the highly skewed and some zeros of health expenses to compensate for the shortcomings of single method such as linear regression (82, 83).

However, this study also had some limitations. First, the cross-sectional studies have their limitations in drawing causality conclusions. Future research will be recommended to implement data collection at different time points to improve causal inference. Furthermore, some variables in CHARLS were subjective judgments of participants, such as self-rated health and health satisfaction, hence the recall bias and the effect of social desirability can't be ruled out.

Conclusion

Guided by Grossman theory, this study applied a two-part model to validate the determinants affecting primary care utilization and expenditures among the multimorbid elderly. The primary care visit rates and OOPE declined from 2015 to 2018. Determinants, such as gender, education, residence, health insurance, household economy and self-rated health were strongly associated with primary care utilization and

expenditures. Other factors, such as health satisfaction, exercise frequency had fewer impacts on these. The findings will provide new evidence for developing targeted policies and interventions to promote rational utilization of primary care and reduce avoidable economic burdens.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found here: https://charls.charlsdata.com/index/zh-cn.html.

Author contributions

WL guided the whole process and reviewed the manuscript. YC carried out the data analysis and drafted the manuscript. All authors read and approved the manuscript before submission.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Preferring self-management behavior of patients with chronic kidney disease

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This study explores the preferred behavior of self-management among chronic kidney disease (CKD) patients and offers suggestions for different patients from personalized medicine. According to some related references, a questionnaire was designed in 2020 to collect data from 131 patients with CKD in a general hospital. The Sampling patients showed no difference in their disease progress. The questionnaire covered two aspects of demographic and behavior with 29 items on six dimensions. Statistical methods such as a descriptive analysis of the F test in behavior dimensions on demographic characteristics and Principal component analysis from items have been applied to classify some kinds of self-management behavior into different groups. In the demographic insight, employment status closely relates to self-management behavior, and income is insignificant. In the behavior aspects, according to some key items, we found four types of self–management behavior preferred in the sorting: cognitive-knowledge, Diet-exercise-medical, emotion management, and exercise-medical, which were defined by behavior dimensions. Although patients had the same disease progress, their self-management behavior mainly existed in four types based on critical factors. According to their favorite behavior and personality group, healthcare stakeholders can offer lean support for improving patients' self-management of CKD in China.

KEYWORDS

self-management behavior, principal component analysis, *F*-test, healthcare, CKD

Introduction

Chronic kidney disease (CKD) is a common lifelong disease in clinical science. It is prolonged and debilitating (1), posing a significant threat to public health. It has been estimated that there are more than 70 million CKD patients globally (2). According to the World Health Organization, 14 out of every 100,000 people will die from CKD in 2030. Patients with CKD must self-manage their illness to a large extent to slow disease progression (3). Lean implementation of chronic disease management (CDM) significantly benefits individuals, society, and the economy (4).

In general, there are four CDM models centered on CDM. Stanford model improves patient self-efficacy through a chronic disease self-management program (CDSMP) (5). The Flinders Model (FM) proposes that a patient is the ultimate decision-maker and emphasizes that doctors and patients make joint decisions and share responsibilities (6). Expert Patients Program (EPP) emphasizes that patients participate in medical decision-making and any self-management project to establish continuous feedback, evaluation, and assessment mechanism (7). The Chronic Care Model (CCM) emphasizes that patients should be involved in medical decision-making (8). The above CDM models show that patient self-management behaviors are crucial in optimizing diagnosis and treatment plans, ensuring patients' safety, and improving patient compliance with treatment (9). Self-management is generally defined as the daily management of chronic conditions by individuals during a period of the disease (10).

Although self-management behavior is a complex endeavor, which is influenced by the stage of the disease (11), demographic characteristics (12), and so on, with the joint participation of both medical staff and patients, it centers on the patient's sense of responsibility for their health, and requires the patient's adjustment and to control their behaviors (13), including beneficial behaviors such as daily diet, physical exercises, mental health, and disease treatment (14). Finally, it leads to a higher quality of life (15). Studies reported that the multiple self-management strategies adopted by chronic disease patients eventually follow a specific trend and pattern. These trends and patterns affect chronic disease progression (9). Patterns have certain differences (16). This is conducive to eliminating waste and improving medical efficiency and quality (17). Therefore, from the perspective of the influencing factors of self-management, self-management is not that patient finishing every management works by themselves, which need some lean support from the related stakeholders, such as a doctor, family, and society environment. So what kind of support should they offer from a broader?

This study identifies patient self-management behavior patterns to establish systematic lean healthcare support from the related stakeholders for chronic disease patients using data from patients' surveys. In the methodology, Behavior pattern recognition is to distinguish behavior differences from the environment and make decisions for different types of people (18), which aims to extract information features and classify them into different groups (19). In general, behaviors often have independent multi-attribute features; therefore, most studies use principal component analysis to reduce the dimensionality to extract key features (20) and recognize patterns (21). This study applied the Test and Principal component method to study Self-management behavior using the actual data survey of chronic disease patients.

The following contents of this study are organized as follows: Section Methods introduces methods, Section Results shows results, Section Discussion is the discussion, and Section Conclusions offers conclusions.

Methods

Study design

This study used purposive sampling to enroll subject patients diagnosed with CKD in a general hospital in southwest China for one month. All of the included patients came from the CKD outpatient department. The estimated sample size in the empirical case was more than 100 subjects who could answer the survey questions face to face. Another inclusion criterion is that these outpatients had no disease progression, which can be a control variable to reveal some effective self-management behavior in the same disease group. This study enrolled the sample size of subjects to be not less than 130 subjects, thinking about a 30% questionnaire loss rate.

Behavior instrument

Most studies constructed an assessment scale for chronic disease self-management behavior based on some relevant theories in chronic disease self-management. Four self-management models, as mentioned before, put forward that different chronic diseases need to design with specific survey scales (22). The first part of the questionnaire is demographic characteristics designed for six items. The second part is based on the three major tasks of chronic disease self-management as daily life management, medical management of diseases, and emotional and cognitive management (23). This study designed six behavioral dimensions including 29 items, namely treatment management with five items, exercise behaviors with four items, diet behaviors with five items, emotional management with five items, disease cognition with five items, and self-management knowledge with five items. The questionnaire was scored using a five-point Likert scale, and each item was evaluated on an agreement scale of 1–5. Higher scores indicate preferring the self-management behavior of patients. These 29 items are all categorical variables, as shown in Table 1. The score variables of the six behavior dimensions are y_{ij} $(i, j\varepsilon(1\ldots,6))$.

Ethical considerations

This study was reviewed and approved by the ethics review committees of West China Hospital (2020-740). All participants provided informed consent before participation in the study. The research purposes and procedures were explained to each subject, and before the informed consent form was signed, each subject was informed that they could withdraw from the study at

TABLE 1 Questionnaire dimensions and items.

Dimensions	Questionnaire items	Variables
Medical management	Follow the doctor's advice to take medications and perform various treatments on time	y_{11}
	Strictly record blood pressure, weight, and other indicators every day	y_{12}
	Do not take non-doctoral drugs on your own	y_{13}
	Disinfect the room on time, maintain ventilation, and actively eliminate infection factors (to prevent respiratory, urethral, skin infections, etc.)	y_{14}
	Report abnormal symptoms to the doctor or nurse promptly	y_{15}
Exercise behaviors	Appropriate aerobic exercise (3 times/week, 30min/time), walking, cycling, Tai Chi, etc.	y_{21}
	Do not engage in strenuous exercises such as playing ball and riot walk	y_{22}
	Live and rest according to the schedule	y_{23}
	Self-massage regularly	y_{24}
Diet behaviors	Eat low-salt, less fried foods, and fresh vegetables	y_{31}
	Follow the doctor's advice to eat quantitative protein and calcium	y_{32}
	Quit smoking, alcohol, coffee, and spicy food	y_{33}
	Maintain clean eating habits	y_{34}
	Regular and quantitative eating	y_{35}
Emotional management	Anxiety, irritability, depression, and other adverse symptoms	y_{41}
	Happy and cheerful	y_{42}
	Talk to others when you are troubled	y_{43}
	Establish a variety of hobbies and interests	y_{44}
	Proactively resolve conflicts between self and others	y_{45}
Disease cognition	Typical symptoms of chronic kidney disease in the early, middle, and late stages	y_{51}
	The various hazards of chronic kidney disease	y_{52}
	Various common treatments for chronic kidney disease	y_{53}
	Common drugs and adverse reactions to chronic kidney disease	y_{54}
	Normal values of various biochemical indexes of chronic kidney disease	y_{55}
	Chronic Kidney Disease Complications	y_{56}
Self-management knowledge	The importance of compliance	y_{61}
	The importance of self-management behavior	y_{62}
	Knowledge of diet, exercise, and lifestyle habits	y_{63}
	Methods of regulating adverse psychological reactions	y_{64}

any time and that their rights would not be affected. They were also informed that the data obtained from the questionnaires would be provided only for educational use and would not be disclosed after the study was completed.

Data analysis

A total of 131 valid questionnaires were distributed. The Cronbach's coefficient of each dimension of the questionnaire is greater than 0.7 databases, with high internal consistency. KMO values of all dimensions are greater than 0.7, with high validity. The encoded data were calculated and analyzed using the software SPSS 26.0. The statistical analyses included descriptive statistics, *F*-test, and principal component analysis for multiple variables. The *F*-test method was used to discriminate differences in self-management behavior dimension on demographic characteristics, which are control variables. $\alpha = 0.05$ is the test level, and the *P*-values are two-sided probabilities.

Results

Demographic

The demographic information characteristics of the sample patients are shown in Table 2. The F test for six behavior dimensions on six characteristics can be seen in the Appendix on gender, education level, employment status, disease expenditure, household income, and age. The whole F test results show in Table 3 between demographic and behavior.

According to Table 3 and the Appendix Tables, from the demographic insight, gender and income are not statistically significant for self-management, while educational background, employment status, disease expenditure, and age have significant differences, though the impact is uneven. Employment status substantially affects the five dimensions other than emotional management, and the patient's educational background and disease expenditure impact emotional management. The higher the education level and the less disease expenditure, the better the emotional management of patients. In the dimension of disease cognition, the patient's age, employment status, and disease expenditure are impact factors. Further analysis found that the poorer the patient's employment, the younger the patient, and the less the disease expenditure, the lower the patient's cognition of the disease. On the contrary, unemployed patients, middle education and middle age, have a high score in self-management, which is similar to Audulv's study (24).

Principal component

With principal component analysis of 29 items, five principal item components with eigenvalues >1 were obtained, which can

TABLE 2 Demographic information of CKD patients ($n = 131$).

Demographic characteristics	Number	Percentage/%
Gender		
Male	62	47.33
Female	69	52.67
Age (years)		
35>	50	38.17
[35,55]	67	51.15
>55	14	10.69
Employment status		
Yes	85	64.89
No	46	35.11
Education level	22	16.79
Junior high school and below	41	31.30
High school or secondary school	68	51.91
University and above		
Household income (RMB/month)		
5,000<	9	6.87
[5,000, 10,000]	71	54.20
>10,000	51	38.93
Disease expenditure (RMB/month)		
1,000<	31	23.66
[1,000, 2,000]	78	59.54
>2,000	22	16.79

explain 71.803% of the original information cumulatively (see Table 4). The explanation level of the fifth principal component is 3.775%, which is <5%. The first four principal components are finally extracted, and the interpretation degree is 68%. The explanatory variables (items) are sorted according to the descending order of the factor load of 4 principal components in Table 5. According to the 4 principal components, the corresponding self-management pattern can be summarized. See Table 6 for principal components, explanatory variables, and patterns.

According to the eigenvalues of the 4 principal components in Table 6, F_1 is the highest one which means disease Cognition-Knowledge pattern dominates. The component loads show that F_2 has a strong positive correlation with ten items in the dimensions of diet, exercise, and medicine management. The eigenvalues of F_2,F_3 and F_4 decrease in order; that is, among the self-management patterns of CKD patients, the preference for the Diet-Exercise-Medicine pattern, Emotion pattern, and Exercise-Medicine pattern decreases in order.

In the self-management pattern, exercise and medicine appeared two times among the four patterns, so it is the primary behavior that leads patients to self-management. Diet behaviors, emotional management, disease cognition, and self-management knowledge only appeared once in each self-management pattern.

According to the principal component analysis results, there is a progressive relationship among the four self-management patterns. Firstly, to improve patients' self-management behavior, patients' cognition of the disease and related knowledge of self-management should be strengthened so that patients understand the disease's causes and can better cooperate with the doctor's advice. After certain basic cognition, patients should be further told to control their diets, exercise appropriately, and cooperate with medication according to the doctor's requirements, namely the Diet-Exercise-Medicine pattern. Good emotions have a positive impact on patients' conditions. It is also vital for patients to manage their emotions well under the condition of ensuring good diet habits. Finally, the importance of exercise and medication management is emphasized again in the Exercise-Medicine pattern, indicating that these two aspects are challenging for patients to form habits, which need to be reminded again and paid more attention to it.

Discussion

According to social cognitive theory (25), a patient's self-management behavior, individual factors, and environmental factors interact. Based on these interaction results, the study puts forward the following suggestions for China outpatients with CKD to improve and support the patient's self-management ability.

For patients, the self-management ability of employed patients in the five dimensions is significantly lower than that of unemployed patients. So, employed patients need to strengthen their awareness and ability in self-management behaviors. Patients should increase interactive communication with medical professional institutions and follow expert opinions. They should maintain a certain exercise frequency and diet habits (24). Exercise intervention is also an effective way to improve CKD patients' self-management ability (26). At last, CKD patients should attach importance to multi-dimensional self-management of disease balance and actively accept systematic self-management services in personality.

For health care providers, medical service providers are an important subject for patients to receive self-management support in the chronic disease care model (CCM) (27), such as hospitals and public health communities (28). This article recommends that medical service providers provide customized intervention programs for patient groups based on chronic kidney disease. Medical service providers should identify patients' demographic characteristics, diagnose patients' self-management patterns, capture and improve the weaknesses of self-management capabilities and implement precise self-management interventions using information technology (29)

TABLE 3 All *F*-test results.

Dimensions	Demographic characteristics					
	Gender	Education	Employment status	Disease expenditure	Income	Age
Medical management			*			
Exercise behaviors			*			
Diet behaviors			*			
Emotional management		*		*		
Disease cognition			*	*		*
Self-management knowledge			*			

*Means significant.

TABLE 4 Initial eigenvalues and variance.

Composition	Eigenvalues	Variance percentage	Cumulative value %
F1	14.636	50.470	50.470
F2	1.836	6.331	56.800
F3	1.724	5.943	62.744
F4	1.533	5.285	68.028
F5	1.095	3.775	71.803

TABLE 5 Principal component and factor (item) load matrix.

Item	F1	Item	F2	Item	F3	Item	F4
y_{53}	0.820	y_{34}	0.731	y_{45}	0.818	y_{24}	0.824
y_{55}	0.801	y_{31}	0.690	y_{44}	0.812	y_{15}	0.675
y_{54}	0.789	y_{11}	0.679	y_{42}	0.782	y_{12}	0.502
y_{56}	0.774	y_{33}	0.655	y_{43}	0.718		
y_{52}	0.763	y_{35}	0.641	y_{41}	0.666		
y_{63}	0.651	y_{32}	0.629				
y_{62}	0.638	y_{23}	0.606				
y_{61}	0.637	y_{22}	0.579				
y_{51}	0.635	y_{13}	0.551				
y_{64}	0.585	y_{15}	0.546				

from social insight (30). For example, for middle-aged and elderly, high-employment, high-education, and medium-expenditure patients with weaker diet behaviors capabilities, hospitals can popularize healthy diet knowledge courses and customize meal lists with the Internet and smart wearable devices to improve patients' cognition and knowledge behavior.

In the social environment, the public generally lacks emotional management (31). Some patients with CKD pay attention to emotional management only in this study. Compared with simply taking medication as prescribed by a doctor, it is more difficult for patients to change their lifestyles, which are hindered by chronic pain and fatigue, interrupted habits, and lack of family support (24). So support from the environmental aspects is added, such as online devices in the patient's home (32).

TABLE 6 Principal components, items, and patterns.

Principal component	Items	Related dimensions	Self-management pattern
F_1	$y_{51}, y_{52}, y_{53}, y_{54}, y_{55}$ $y_{56}, y_{61}, y_{62}, y_{63}, y_{64}$	5,6	Cognition-knowledge
F_2	$y_{31}, y_{32}, y_{33}, y_{34}, y_{35}$ $y_{22}, y_{23}, y_{11}, y_{13}, y_{15}$	3,2,1	Diet-exercise-medicine
F_3	$y_{41}, y_{42}, y_{43}, y_{44}, y_{45}$	4	Emotion
F_4	y_{21}, y_{24}, y_{12}	2,1	Exercise-medicine

Conclusions

To conclude, based on the inductive assumption that patient's self-management need supports from stakeholders, this study investigated and analyzed the cross-sectional data of 131 patients with CKD self-management scale, used the *F*-test to find some demographic characteristics of behavior, and the principal component method to identify the self-management pattern of chronic disease patients among outpatients. The analysis results show that patient with different demographic characteristics has formed four patterns, such as diet behaviors, emotional management, disease cognition, and self-management knowledge to manage their disease. Our study's results help to clarify the self-management behavior patterns and characteristics of different chronic patients, especially for employees, providing a basis for improving the self-management behavior of patients with CKD from three sectors: patients, providers, and society. However, this study

only investigated the outpatients of the Nephrology Department and was limited by the scope and number of samples; the results still need more sample tests. This study also has other limitations, such as the lack of detailed patient clustering analysis and more explanations of why the employment status is the most significant, which will be further discussed in subsequent studies.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

This study was reviewed and approved by the Ethics Review Committees of West China Hospital (2020-740). All participants provided informed consent before participation in the study.

Author contributions

XH supervised, reviewed, and edited. YW conceptualized and wrote the first draft. CF, LL, and UK participated in proofreading, reviewing, and editing. FR did formal analysis and editing. XZ reviewed and edited. All authors read and approved the final manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.973488/full#supplementary-material

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Macro-economic determinants, maternal and infant SDG targets in Nigeria: Correlation and predictive modeling

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Objectives: Unambiguously, Nigeria is off-track in achieving the health-related SDGs. Consequentially, this study aligns with SDG 3 which calls for *"good health and wellbeing for people by ensuring healthy lives and promoting wellbeing for all at all ages"*. This article examines the combined effect of health expenditure and other key macro-economic factors on health indices such as maternal and newborn and child mortality in Nigeria. Contrary to existing literature, we formulated a model that predicts the level of macro-economic determinants needed to achieve the SDG targets for maternal and newborn and child mortality in Nigeria by 2030.

Methodology: The study used Autoregressive Distributed Lag (ARDL), which is usually used for large T models. The study period spans from 1995 to 2020.

Results: We found a significant negative relationship between health outcomes and macro-economic determinants namely, household consumption, total health expenditure, and gross fixed capital while we determined a significant positive relationship between health outcomes and unemployment. Our findings are further supported by out-of-sample forecast results suggesting a reduction in unemployment to 1.84 percent and an increase in health expenditure, gross fixed capital, household consumption, control of corruption to 1,818.87 billon (naira), 94.46 billion (naira), 3.2 percent, and −4.2 percent respectively to achieve SDG health targets in Nigeria by 2030.

Policy implication: The outcome of this result will give the Nigerian government and stakeholders a deeper understanding of the workings of the macro-economic factors, concerning health performance and will help position Nigeria, and other SSA countries by extension, toward reducing maternal mortality to 70 per 100,000 and newborn and child mortality to 25 per 1,000 births by 2030. The African leaders should consider passing into law the need for improvement in macro-economic factors for better health in Africa. We also recommend that the Nigerian government should steadily increase health expenditure to reach and move beyond the forecast level for improvement in maternal and infant mortality, given the present low and unimpressive funding for the health sector in the country.

KEYWORDS

health outcome, macro-economic factors, ARDL (autoregressive distributed lag), SDG, Nigeria

Background to the study

Health is recognized as an important aspect of human and economic development for both developing and developed countries. Therefore, the United Nations (UN) Millennium Development Goals (MDGs) from 2000 to 2015 and the Sustainable Development Goals (SDGs) from 2015 to 2030 underscore the importance of good health for economic development and socioeconomic progress. Developed countries are increasing their investment in health expenditure and reforms to improve health outcomes and accelerate progress toward achieving Universal Health Coverage (UHC) (1). In Africa, the political will of the national leaders to improve health was demonstrated through the Abuja Declaration meeting held in Nigeria in 2001, which called for governments to increase their funding for health. Despite the Abuja Declaration, the maternal mortality rate in Nigeria in 2015 was 856, and in 2020, it reduced to 512. This drop in the maternal mortality rate was among the highest in sub-Saharan Africa (SSA), with 20 percent of the world's maternal deaths occurring in Nigeria.

Given the peculiarities of the Nigerian health sector (high maternal and child mortality), we incorporated macro-economic factors into the health framework and formulated a model that predicts the level of health expenditure and macro-economic determinants that can achieve by 2030 the SDG targets for maternal and child mortality in Nigeria. A gap exists in the literature in this regard, which this study aims to address. Adegoke et al. (2) indicate that if the government could permit an enabling environment through timely interventions by controlling corruption, inflation, and other economic problems, it is possible to reduce maternal and child deaths while the lifespan of the population is enhanced, *ceteris paribus*. Therefore, it is instructive to confirm the effect of macro-economic factors and compute the level of macro-economic factors necessary to achieve the SDG targets for maternal and child mortality in Nigeria.

Indisputably, Nigeria is very far from the target of 70 per 100,000 live births stipulated in the United Nations SDGs target for maternal mortality. The SDGs also aim to reduce the mortality of children under-five to 25 deaths per 1,000 live births by 2030. The under-five mortality rate in Nigeria in 2020 was 59, which was above the target of 25. While, life expectancy at birth in Nigeria was 54.8 in 2020, in similar sub-Saharan African countries like Mauritius, Rwanda, Botswana, and Senegal, it was 75, 70, 69.8, and 68.8 respectively. Apart from the high mortality and low life expectancy in Nigeria, accessibility to healthcare is another crucial issue. According to Amedari and Ejidike (3), the lack of access to quality healthcare was linked to the wasteful use of primary care services at referral centers, the absence of adequately functioning primary health centers (PHCs), and corrupt practices in the health sector. Their study identified corruption as one of the determinants of health accessibility in Nigeria. Therefore, the health–macro-economic nexus could have a mediating impact on access problems through the control of corruption because the issue of corruption cuts across all levels, i.e., the government personnel and health personnel in the country cannot be fully exempted from corruption. For example, corrupt government personnel may not approve the establishment of adequate health centers that can benefit the citizens, and corrupt health personnel could sabotage the effort of the government in providing health facilities and materials. If the issue of corruption, which represents one of the ingredients for a functional macro-economic structure, can be resolved, then access problems in the health sector will be automatically controlled.

Given the prevailing health challenges in Nigeria, it is clear that the rates of improvement in the health outcomes in the country are far below the SDG targets, particularly SDG 3.8 on universal health coverage, and this is quite worrisome. Currently, Nigeria has a high child and maternal mortality coupled with inadequate health coverage and an unfavorable macro-economic environment marked by a high inflation rate, poor education, low investment rate, and high corrupt practices. This calls for an accelerated effort to achieve sustainable improvement in health outcomes. An analysis of the health-macro-economic nexus may be needed to determine if the core macro-economic factors could impact maternal and infant health outcomes for better performance. Most of the prior investigators considered only the effect of public health expenditure on health outcomes, and the increase in public health expenditure alone may not achieve the desired impact on maternal and infant mortality. The few studies that incorporated other determinants of health outcomes limited their selection to GDP per capita and socioeconomic factors (4, 5), and have emphasized the impact of macro-economic factors on health outcomes proxied as life expectancy at birth and under-five mortality, with an exclusion of maternal mortality. Moreover, no study has yet rendered an out-of-sample forecast for the macro-economic determinants and public health expenditure based on the United Nations Sustainable Development Goals for the year 2030 for maternal and child mortality. Drawing from the work of Adebayo et al. (6) and Xie et al. (7), the objectives of this research are:

i Examine the combined effect of health expenditure and other key macro-economic factors on health indices such as maternal and infant mortality in Nigeria.
ii Compute the level of health expenditure that could achieve the SDG targets for maternal and infant mortality in Nigeria by 2030.
iii Compute the level of macro-economic variables that could achieve the SDGs target for maternal and infant mortality in Nigeria by 2030.

Motivation of the study

In Nigeria, public health expenditure has increased without a corresponding improvement in health outcomes as proxied by maternal mortality, infant mortality, and life expectancy at birth. Nigeria has been the fourth leading country in Sub-Saharan Africa in terms of maternal deaths since 1998. In Nigeria, maternal deaths from 1990 to 2017 averaged 163.1 million, which is quite large when compared to other SSA countries. In 2000, the Nigerian government spent 2.64% of the GDP on health. In 2005, the expenditure on health increased to 3.81%, while in 2018, it increased to 3.9%, which is about 340.45 billion nairas (8). The inability of the Nigerian government to achieve efficiency of production despite the increase in public health expenditure may be attributed to the failure to account for the impact and magnitude of the macro-economic factors (i.e., health expenditure and other factors). The efficiency of production in the Nigerian health sector can be described as the ability of a health system's management unit to generate the maximum health service outputs from a given set of inputs (9).

Although in 2001 the African leaders recommended investing 15 percent of the total budget in health and the same year the Macro-Economic Commission recommended an investment of 12 percent of GDP (10), the maternal and infant mortality rates in Nigeria have remained high among other countries from sub-Saharan Africa.

Despite many articles on the health-expenditure nexus in Nigeria (11–15), it was discovered that only a few studies [like (4, 5)] emphasized the impact of macro-economic factors on health outcomes proxied as life expectancy at birth and under-five mortality, with the exclusion of maternal mortality. Maternal mortality may have been excluded because the other authors believed it was unimportant in determining health outcomes, even though Nigeria had the highest maternal mortality rate in the world, trailing only South Sudan, Chad, and Sierra Leone. Moreover, the other studies on macro-economic determinants of health outcomes were specifically done for developed countries [see (16–19)]. Thus, this study contributes to the research literature in three distinct ways.

First, it captures the impact of macro-economic factors on maternal and infant mortality because the exclusion of maternal mortality in a Nigerian health outcome model may be faulty. After all, maternal mortality is a major health challenge in Nigeria. Second, this study incorporates core macro-economic factors like unemployment, household consumption, gross capital formation, total health expenditure, control of corruption, and education that can explain the intricacies of elements (20). Third, this study renders an out-of-sample forecast for the macro-economic determinants based on the SDG targets for maternal and newborn and child mortality because the ability to forecast the magnitude of the macro-economic factors will guarantee better health outcomes that will position the country to achieve its SDG targets and universal health coverage, which is uncommon in the literature.

This article is organized as follows; following the introduction is the motivation, the literature review and the theoretical framework are documented in section Literature review. Section Theoretical framework and methodology addresses the methodology and model estimation, and the discussion of results. Section Policy implications, recommendations, and conclusion contains the policy implications, recommendations, and conclusion.

Literature review

Conceptual review

Nigeria's health and macro-economic factors

Nigeria is regarded as the economic giant of Africa, but the country has not performed up to the expectations and desires of the citizens of this great country, especially in terms of health financing and health outcomes. Between 2000 and 2016, the government spent only 0.58 percent of the GDP on health, which is rather low given its high population. While public health expenditure remained at 0.58 percent of the GDP in 2018, maternal deaths in 2017 were 917, while child mortality was 100, with a life expectancy of 53 years, which is one of the lowest in sub-Saharan Africa. In 2017, the productivity growth rate was as low as 0.52 percent, with an inflation rate of 16 percent. In 2018, the GDP growth rate was 1.92 percent. Nigeria is considered a country with great potential, but the country has not been able to translate its endowed physical and human resources into better health outcomes, possibly because less attention is given to health. It has been investing a higher proportion of its income in overseas healthcare while the health facilities available in the country are outdated and inadequate and there is an incessant strike by the doctors due to poor remuneration (21, 22).

Structure of the Nigerian health system

The structure of a healthcare system can be described as the organization or arrangement of healthcare units. Better still, it is an organogram reflecting who, where, and when to access the health facilities. In Nigeria, the health structure is divided into three.

The federal government is responsible for the tertiary healthcare system, usually called teaching hospitals. The teaching hospitals operate based on referrals. Often, patients are expected to have consulted the lower levels of the health system before tertiary healthcare because teaching hospitals deal with large volumes of patients with severe cases. The tertiary health systems are better equipped with state-of-the-art equipment and skilled medical practitioners than the other healthcare units. The federal government also directs the activities of primary and secondary healthcare centers.

The state government directs the secondary healthcare system and it exists as general hospitals, comprehensive health centers, and specialized hospitals. At the secondary level, both public and private health practitioners are involved.

A primary health structure (PHS) or primary healthcare is the grassroots healthcare center and the first point of contact for patients in Nigeria. At this level, patients are attended to by nurses and community health workers rather than qualified doctors. In a situation where qualified doctors are not available at primary healthcare centers, people tend to self-refer themselves to the next level of healthcare structure.

Empirical evidence

The relationship between public health spending and health outcomes

Ogbuagu and Olunkwa (11) studied the relationship between capital health expenditure and infant and maternal mortality ratios (MMR) by adopting the Autoregressive Distributed Lag (ARDL). The study produced a mixed result in which in the short run the relationship between health expenditure and income was positive and in the long run it was negative. Ogunjimi and Adebayo (12) examined the relationship between health expenditure, health outcomes, and economic growth in Nigeria from 1981 to 2017. This study adopted the Toda-yamamoto causality framework and it showed a unidirectional causality from health expenditure to infant mortality while there was no causality between real GDP and infant mortality. It also showed a unidirectional causal relationship between health expenditure and real GDP and life expectancy and maternal mortality, and a unidirectional causal relationship between real GDP and health expenditure. The study also used the ARDL to investigate if a long-term relationship exists among the macro-economic variables used, and the result was affirmative.

Eboh et al. (14) investigated the impact of public health expenditure on the infant mortality rate in Nigeria. The study made use of an ex-post facto research design and time series data spanning a period of 24 years (1994–2017), sourced from the Central Bank of Nigeria statistical bulletin 2016 and the World Bank. Descriptive statistics were used to analyze the data while the ordinary least squares technique was used to estimate the model. The study's findings revealed that the Nigerian government's health recurrent and capital expenditure had a significant negative effect on infant mortality rates over the 24-year period under consideration. Also, health recurrent expenditure had a more significant negative effect on the infant mortality rate than health capital expenditure in this study. Aronu and Bilesanmi (23) used statistical tools such as the unit root test, Granger causality tests, and least square regression analysis to examine the impact of the federal government's spending on health, agriculture, transportation, and communication on infant and maternal mortality rates. The study revealed that the federal government's expenditure on health had a significant negative impact on infant and maternal mortality in Nigeria, which implies that as the federal government increased its expenditure on health, the rate of infant and maternal mortality decreased. Edeme et al. (15) investigated the effect of public health expenditure on health outcomes in Nigeria, as captured by life expectancy at birth and infant mortality rates, utilizing the ordinary least squares technique. The study found that public health expenditure and health outcomes have a long-term equilibrium relationship. It also revealed that a rise in public health expenditure improves life expectancy and reduces infant mortality rates. In addition, the urban population and HIV prevalence rate significantly affected health outcomes, while per capita income exhibited no effect on health outcomes. The findings, therefore, suggest that public health expenditure remains a necessary component in improving health outcomes in Nigeria. Boachie and Ramu (24) examined public health expenditure and health status in Ghana. In their study, they examined the impact of public health spending on health status in Ghana for the period 1990–2002, employing standard OLS and Newey-White estimation. After controlling for real per capita income, literacy level, and female participation in the labor market, the study found that the declining or falling infant mortality rate in Ghana was influenced by public health spending, among other factors. Thus, they concluded that public healthcare expenditure is associated with an improvement in health status through a reduction in infant mortality.

Macro-economic determinants of health outcomes

Agbatogun and Opeloyeru (5) investigated the impact of macro-economic factors on under-five mortality in Nigeria from 1980 to 2017 using ARDL and found government health expenditure as the only significant determinant of under-five mortality, and factors such as immunization rates, GDP per capita, literacy rates, and health workers did not affect under-five mortality. Zhou et al. (19) investigated the role of macro-economic indicators on healthcare costs in 21 emerging economies of the world using a dataset that spanned from 2000 to 2018. The data were analyzed using the generalized method of moments (GMM) and the result revealed tax revenue, labor force participation, and GDP per capita as significant determinants of healthcare cost. The healthcare cost was represented by public healthcare expenditure. The study also revealed a non-linear relationship between public health expenditure and economic growth.

Romeo (25) investigated the macro-economic determinants of health crises in 25 SSA countries and employed a logit model to analyze the data spanning from 1995 to 2012. The result revealed international migration flows, the ratio

of short-term debt to currency reserves, and the organization of the healthcare system as the determinants of health crises (expressed as differences in life expectancy at birth) in SSA. Naik et al. (26) reviewed the macro-economic determinants of health and health inequalities. Based on the existing literature on determinants of health, a conceptual framework was formed and the following variables were identified as the possible determinants of health: healthcare expenditure, housing, and environmental factors such as pollution and climate change.

Thompson et al. (27) studied the effect of structural adjustment programs on child and maternal health by employing observational and quasi-experimental articles published. They found that structural adjustment programs had a detrimental impact on child and maternal health outcomes because the programs impeded access to quality and affordable healthcare and also had a negative impact on the social determinants of health, such as income and availability of quality and affordable healthcare. Ogunleye (28) investigated the relationship between health and growth and also examined socioeconomic determinants of health outcomes in SSA from 1980–2003. The study incorporated alcohol consumption, urbanization, carbon emissions, food availability, and education as the socio-economic and environmental variables that can determine life expectancy at birth and child health outcomes among the selected SSA countries. The study identified alcohol consumption, urbanization, and carbon emissions as significant determinants of health outcomes using the GMM estimation technique.

By reviewing the extant literature in the area of health outcome determinants (17), investigated the social determinants of health outcomes in the world's poorest countries. The study revealed the need to be country-specific in deciding the determinants of health outcomes in poor countries so that appropriate policies that are peculiar to country-specific circumstances can be explored. Fayissa and Gutana (29) investigated the determinants of health status in SSA. The three core determinants were economic (represented by the ratio of health expenditure to GDP and the per capita food availability index), social (represented by the illiteracy rate and alcohol consumption), and environmental (determined by urbanization rate and carbon-dioxide emission per capita index). One-way and two-way panel data analyses were carried out, and the result of the two-way panel analysis revealed that a decrease in the illiteracy rate and an increase in the food availability index positively influenced life expectancy at birth.

Subramanian et al. (16) discussed the relative importance of wealth, degree of quality, and public health expenditure on health in both developed and developing nations. The study also established a reciprocal relationship between poverty and poor health. The result of the discussion ought to have served as a policy recommendation to the government, but the study was carried out without any empirical analysis to support the claims discussed in the study. Sede and Ohemeng (30) investigated the socioeconomic determinants of life expectancy in Nigeria from 1980 to 2011 using VAR and VECM frameworks. The result revealed per capita income, education, and government expenditure on health as insignificant in determining life expectancy at birth, while unemployment and nominal exchange rates were significant determinants of life expectancy.

Conceptual framework

Figure 1 presents a brief overview of the entire study. This section explains the interconnectivity among the objectives of the study. First, the framework identifies three sources of health financing, namely, private, public, and external. Private health expenditure comprises of out of pocket (OOP) spending and private health insurance schemes; the private health insurance schemes were rated as the highest source of health expenditure in SSA, while in OECD countries public health expenditure (PHE) was the highest. The donor's contribution (DC) is the external source. PHE consists of domestic general government health expenditure and the government's contributions to the national health insurance scheme (NHIS). It is expected that total health expenditure will improve health outcomes, such as child and maternal mortality. According to the literature, health outcomes can be influenced by numerous factors. Among them are behavioral (lifestyles and nutrition), biological (genetics), ecological (environment), socio-cultural (political), and macro-economic (macro-economic) factors, which are the major focus of this study.

In this study, we considered the effects of total health expenditure, gross capital formation, control of corruption, unemployment, and household consumption on health outcomes represented by maternal and child health. It is strongly believed that these factors will positively affect health outcomes. An improvement in health outcomes will increase female labor force participation because women who might have died due to maternal complications will be absorbed into the general labor force, thereby increasing female labor force participation and labor productivity. The survival of a child will increase labor force participation and labor productivity in Nigeria because a reduction in child mortality significantly relate to higher life expectancy while life expectancy is the most remarkable determinant of modern economic development. A reduction in maternal deaths will also enhance gender equality because the Nigerian economy will have more women to compete with men, especially in male-dominated professions. A reduction in both maternal and child mortality will increase the adult survival rate and life expectancy at birth. An improvement in health outcomes will enhance the efficiency of output.

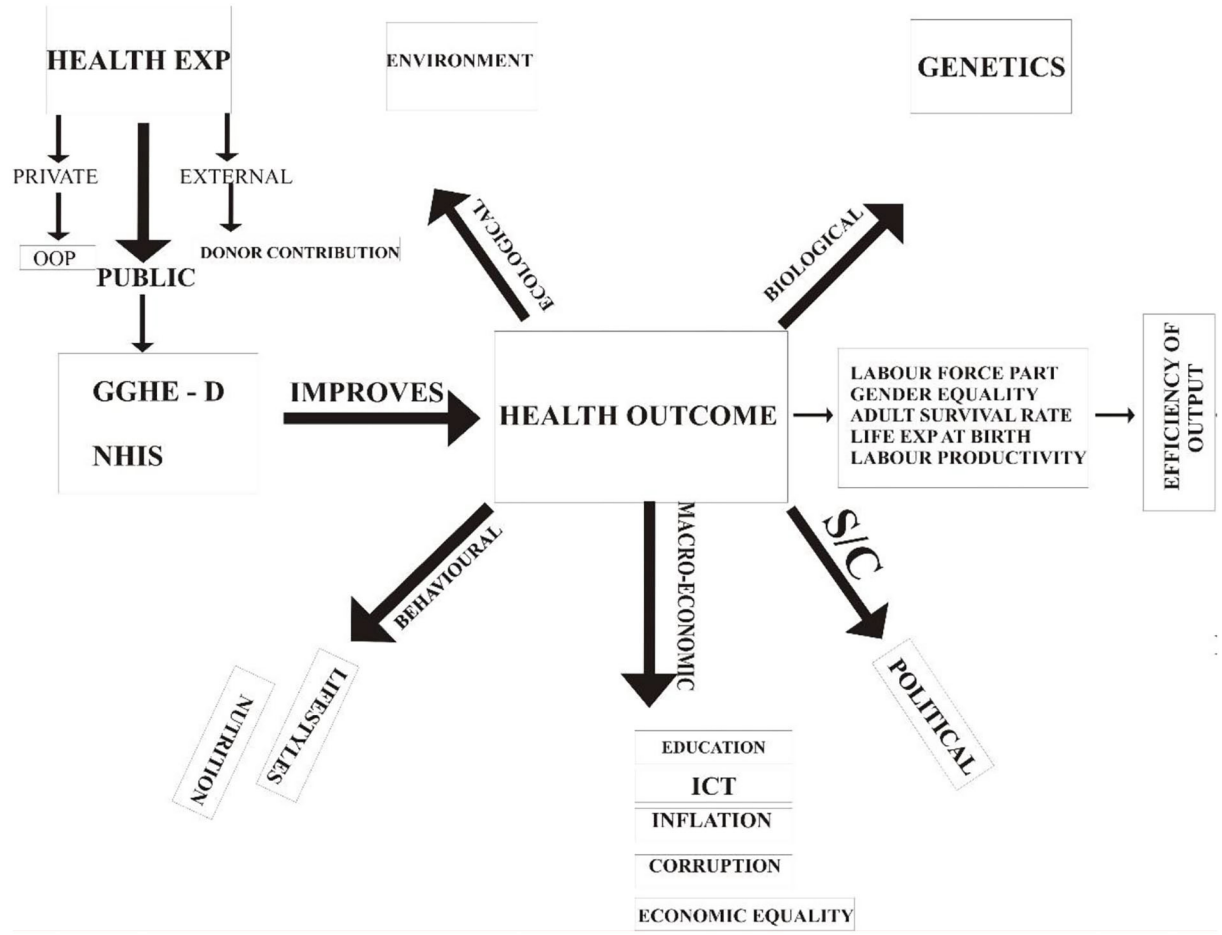

FIGURE 1
A conceptual framework connecting the effects of health expenditure and other determinants of health outcomes. Source: Authors' computation.

Theoretical review

Materialist theory of health

The materialist theory proposes that inadequacy in an individual's income level leads to a lack of resources to cope with the stresses of life and thus results in ill health. Goldberg et al. (31); Frohlich et al. (32); Macintyre (33); Wilkinson (34), postulated that social comparison, humiliation, and shame are important mechanisms by which those who have lower social status as determined by income, education, and the nature of employment (low-status employment) have poorer health outcomes than their rich counterparts. From the perspective of the materialist theory, it can be inferred that an individual's income level will be inadequate given socioeconomic factors such as poverty, income inequality, unemployment, underemployment, lack of education, civil unrest, political instability, and poor wage structure. These factors will greatly affect the health outcome of such an individual.

Neo-materialist theory of health

As a subset of materialist theory, the neo-materialist approach is concerned with how nations, regions, and cities differ in the distribution of economic and other resources among the population (35). The distribution of resources can vary widely from country to country (for example, gross national income). The neo-materialist view, therefore, directs attention to both the effects of living conditions (social determinants of health) on individuals' health and how society decides to distribute resources among the citizens which indirectly affects the health outcomes of people.

Life course perspective

Lu and Halfon (36) provide a lens through which maternal and infant health mortality can be analyzed (36). The Life Course Perspective (LCP) theory was proposed against the backdrop of maternal challenges that result in birth outcome discrepancies (36). It borrows conceptually from early programming (37)

and cumulative pathways to demonstrate how the environment influences growth (38). Both the early programming and cumulative route processes were derived from large British birth cohort research done during the 1930s (36). The early programming mechanism arose from the Barker hypothesis, which states that human development is especially sensitive to prenatal and early childhood experiences (39). It argues that these early experiences have long-term health effects, such as the development of diabetes and cardiovascular disease (37). In contrast, the cumulative path mechanism investigates the effects of accumulation and adaptation to persistent social and physical stressors, sometimes referred to in the literature as "wear and tear," on human development and health (36, 38, 40). These stresses may include homelessness, prejudice, infectious diseases, and health-related activities [e.g., smoking; (36)]. The LCP integrates both theories by proposing that women who experience chronic stress (e.g., recurrent experiences of racism and discrimination, displacement, and intergenerational poverty) are at increased risk of adverse health outcomes, particularly when these experiences occur during critical developmental periods such as prenatal development, adolescence, and pregnancy (36, 40).

Historical trauma theory

The Historical Trauma (HT) theory provides an alternative lens for comprehending socioeconomic determinants by identifying the effect of traumatic experiences on the health outcomes of marginalized groups as a result of targeted oppression. It emerged from the study of Jewish Holocaust survivors as researchers investigated the phenomenon that survivors' offspring were more likely than the general population to suffer from mental health conditions such as post-traumatic stress disorder, despite not having directly experienced the Holocaust (41). This queried the ability of generations to biologically, socially, and culturally "inherit" mental and physical health disorders (42). Recent research has applied HT to Mexican Americans (43).

Theoretical framework and methodology

Theoretical framework

To examine the health outcomes as measured by infant and maternal mortality in Nigeria, this study follows the work of Mosley and Chen (44) who came up with a model that sees socioeconomic determinants acting through biological mechanisms to influence mortality. Based on this approach, the underlying socioeconomic (e.g., social, economic, biological, and environmental) status manifests itself in proximate determinants (maternal fertility, environmental contamination, disease control, etc.). The values of these variables influence the risk of disease, which is linked to the probability of death. Based on this framework, the factors that affect the death of mothers and children can be written as:

$$maternal = f\left(phe, cons, gfc, unemp, cor\right) \quad (1)$$

$$child = f\left(phe, cons, gfc, unemp, cor\right) \quad (2)$$

Methodology

Model specification

We can specify the econometric model for the relationship between health outcomes (child and maternal mortality) and public health expenditure and other control variables in Nigeria as follows:

$$maternal_t = \beta_0 + \beta_1 phe_t + \beta_2 cons_t + \beta_3 gfc_t + \beta_4 unemp_t + \beta_5 cor_t + \varepsilon_t \quad (3)$$

$$child_t = \beta_0 + \beta_1 phe_t + \beta_2 cons_t + \beta_3 gfc_t + \beta_4 unemp_t + \beta_5 cor_t + \varepsilon_t \quad (4)$$

Where the notations include child mortality $(child)$, maternal mortality $(maternal)$, household consumption $(cons_t)$, gross fixed capital formation (gfc_t), unemployment $(unemp_t)$, and control of corruption (cor_t), and ε_t is the error term.

Estimation technique

Given the characteristics of the macro-economic variables in Nigeria, a more dynamic method of analysis that allows for different orders of integration is needed. Fortunately, Pesaran et al. (45) have developed a new ARDL model which has more advantages over other approaches (46). Significantly, the ARDL approach can be applied irrespective of whether the regressors are I(1) or I(0), or a combination of both. Also, in using the ARDL approach, dummy variables can be included in the analysis, which is not permitted in the Johansens method (47). Following the work of Kirikkaleli et al. (48) and Xie et al. (7); the ARDL models are specified to achieve the objectives of the empirical study. We specified the relationship in the ARDL (p,q) model which forms the basis for the Bounds approach to co-integration as follows:

$$\begin{aligned}\triangle maternal_t = {} & \theta_1 v_{t-1} + \sum_{j=1}^{p} \lambda_{1j} \triangle maternal_{t-j} + \sum_{j=0}^{q} \gamma_{1j} \triangle phe_{t-j} \\ & + \sum_{j=0}^{q} \delta_{1j} \triangle cons_{t-j} + \sum_{j=0}^{q} \varphi_{1j} \triangle gfc_{t-j} + \sum_{j=0}^{q} \omega_{1j} \triangle unemp_{t-j} \\ & + \sum_{j=0}^{q} \vartheta_{1j} \triangle cor_{t-j} + \upsilon_{1t}; \quad t = 1, 2, \cdots, T \end{aligned} \quad (5)$$

$$\begin{aligned}\triangle child_t &= \theta_2 v_{t-1} + \sum_{j=1}^{p} \lambda_{2j} \triangle child_{t-j} + \sum_{j=0}^{q} \gamma_{2j} \triangle phe_{t-j} \\ &+ \sum_{j=0}^{q} \delta_{2j} \triangle cons_{t-j} + \sum_{j=0}^{q} \varphi_{2j} \triangle gfc_{t-j} + \sum_{j=0}^{q} \omega_{2j} \triangle unemp_{t-j} \\ &+ \sum_{j=0}^{q} \vartheta_{2j} \triangle cor_{t-j} + \upsilon_{2t}; \quad t = 1, 2, \cdots, T \end{aligned} \tag{6}$$

We conducted a forecasting analysis based on the time series econometric models in Eqs. 3.5 and 3.6. The prediction was explored by forecasting values of health expenditures that are necessary to be achieved for the realization of maternal and infant mortality targets by 2030 for each of the dependent variables. In the end, we are interested in the future values of the $outcomes_t$ series, that is, the forecast values of maternal and child maternity for the period t_{2030}based on the future values of the regressors as specified in Eq. 3.7.

$$outcomes^{*f}_{t_{2030}} = \hat{\delta}_0 + \hat{\delta}_1 phe^{f}_{t_{2030}} + \hat{\beta} macro^{f}_{t_{2030}} \tag{7}$$

where $outcomes^{*}_{t_{2030}}f$ are predetermined values of maternal and child maternity based on UN standards, $\hat{\delta}_0$, $\hat{\delta}_1$, and $\hat{\beta}$ are the estimated long-run parameters, $phe^{f}_{t_{2030}}$ and $macro^{f}_{t_{2030}}$ are the predicted values of public health expenditure and other macro-economic variables for the year 2030 which will help to achieve the SDG targets of reducing infant mortality per 1,000 live births to <25 and maternal mortality of 70 per 100,000 live births. With these forecast values as the outcomes, the required public health expenditure value that would be required to achieve Agenda 2030 can be obtained by solving the underlying estimated model for the independent variable (health expenditure) based on the known future value of the dependent variable.

Data sources and selection

The data was sourced from the World Development Indicators for the period 1980 to 2020. The data was selected based on the peculiar features of the Nigerian economy. The maternal and infant mortality data were selected given the huge mortality rate recorded in the country from 1980 to date. Data on unemployment, control of corruption, public health expenditure, and other macro-economic determinants were selected based on their stringent peculiarities in the country.

A priori expectations

We expect a negative relationship between health expenditure and health outcomes such that higher health expenditure may be expected to improve health outcomes by reducing maternal and child mortality [see (5, 49–51)]. Also, a negative relationship is expected between health outcomes and public health expenditure per capita, household consumption, and gross fixed capital. On the contrary, a positive relationship is anticipated between health outcomes, such as maternal and child mortality (as well as modern educational tools and other variables such as unemployment).

Discussion of the results

Despite various attempts by African leaders to increase health expenditures for better health outcomes, the health outcomes in Nigeria are perversely poor and health expenditures are inadequate. The severity of the Nigerians' health challenges calls for urgent attention that could resolve the prevailing health emergency in the country. In an attempt to proffer solutions to health challenges in the Nigerian health sector, we established a link between health and macro-economic factors.

TABLE 1 The effect of macro-economic determinants on health outcomes.

ARDL	Maternal mortality	Child mortality
ECT(-1)	−0.1215***	−0.1805***
	(0.0112)	(0.0139)
ΔHealth	−0.0353***	−0.0622***
	(0.0062)	(0.0105)
ΔGFC	−0.0147***	−0.0022
	(0.0052)	(0.0044)
ΔUnemployment	0.0017*** (0.0005)	0.0025***
		(0.0005)
ΔConsumption	−0.0184** (0.0083)	−0.0249**
		(0.0078)
ΔCont. corruption	−0.0133 (0.0088)	−0.0128
		(0.0089)
Health	−0.2908***	−0.3446***
	(0.0646)	(0.0286)
GFC	−0.1211***	−0.0123***
	(0.0358)	(0.0249)
Unemployment	0.0143** (0.0060)	0.0139***
		(0.0033)
Consumption	−0.1516** (0.0601)	−0.1380**
		(0.0515)
Cont. corruption	−0.1097 (0.0705)	−0.0713
		(0.0516)
F (Bounds test)	16.850***	24.211***
Serial correlation	1.6978 [0.1444]	0.9504
		[0.5097]
Heteroscedasticity	1.1081 [0.4070]	1.6571
		[0.1639]

This table presents the results of ARDL for the impacts of macro-economic factors on health outcomes in Nigeria. The health outcomes are maternal mortality and infant mortality. "Δ" represents short-run estimate while the absence represents long run. The standard errors associated with the coefficients are in round brackets while the *p*-values of the diagnostic tests are in square brackets. ***, **, and * represent 1, 5, and 10% statistical significance respectively.

The result of the analysis provided answers to the research hypothesis that the combined effect of health expenditures and macro-economic factors will not impact health outcomes in Nigeria. On the whole, all variables of interest are significant, as shown by the estimated correlation coefficients. The strength of the relationship, in most cases, is quite strong and has the expected signs with no indication of multicollinearity among the regressors.

Table 1 contains the ARDL results on the effect of macro-economic determinants on health outcomes proxied by maternal mortality and child mortality. We found a significant negative relationship between health outcomes and household consumption both in the short run and long run. The results show that a percentage change in household consumption significantly reduces maternal and child mortality by −0.1516 and −0.1380 percent, respectively. We also identified a significant negative relationship between total health expenditure and health outcomes. An increase in health expenditure caused reductions in maternal and infant deaths. A percentage change in health expenditure significantly reduced maternal and child mortality by −0.2908 and −0.3446 percent, respectively. We also discovered a significant negative relationship between gross fixed capital and health outcomes, which means an increase in domestic investment in Nigeria will lead to reductions in maternal and infant deaths in the country. A percentage change in gross fixed capital significantly reduces maternal and child mortality by −0.1211 and −0.0123 percent respectively. The relationship between control of corruption and health outcomes is also negative but not significant in both the short run and long run. The forecasting results in Table 2 revealed the need to increase health expenditure in the country to 987.21, 1,260.57, and 1,818.87 billion naira by 2025, 2027, and 2030, respectively. In 2019, the health expenditure in the country was 474.24 billion naira, which suggests a drastic increase in health expenditure is needed in the country if the country aims to meet the SDGs on maternal and infant health by 2030. The consumption level must increase to 3.2 percent from its present level in 2019. Also, the control of corruption must increase to −4.2 percent so that the country can achieve Agenda 2030. The unemployment rate in the country was 8.5 percent in 2019. Our forecasting results suggest a reduction in the unemployment rate of 1.84 percent by 2030, and domestic investment must increase to 94.46 billion naira to enable the country to meet its SDG health targets. In 2019, the domestic investment in the country was 24.62 billion naira, which is very far from the projected level.

Comparison with previous empirical studies and discussion of the findings

Table 1 contains the ARDL results on the effect of the macro-economic determinants on health outcomes proxied by maternal mortality and child mortality. We found a significant negative relationship between health outcomes and household consumption. Household consumption is a variable that represents the citizens' standard of living (poverty level), which means an increase in the standard of living will cause a reduction in maternal and infant deaths. This result aligns with *a priori* expectations but is inconsistent with extant literature. For instance, Kilanko (52) found an insignificant positive relationship between household consumption and health outcomes in 14 West African countries. We also found a significant negative relationship between total health expenditure and health outcomes with an increase in health expenditure reducing maternal and infant deaths, which is consistent with the existing literature [see (51, 52)].

When we get a significant negative relationship between gross fixed capital and health outcomes, it means an increase in domestic investment in Nigeria will lead to reductions in maternal and infant deaths in the country. When more money is expended on capital equipment that can enhance the health infrastructure, then the number of pregnancy-related deaths and infant deaths will be reduced. This result conforms to *a priori* expectations. The relationship between control of corruption and health outcomes is also negative [as expected, also in line with Hsiao et al. (53)] but insignificant, which means an increase in control of corruption could signal a reduction in maternal and infant deaths. However, it is insignificant, probably because of the high level of corruption existing in the Nigerian health system or the type of measurement of corruption (control of corruption) adopted in this study.

The results also showed a significant positive relationship between health and unemployment. Reductions in unemployment lead to reductions in maternal and infant mortality and vice-versa. Our findings align with *a priori* expectations and previous studies (30) on the Nigerian economy.

Policy implications, recommendations, and conclusion

Policy implication

i. The government, enforcement agencies, and relevant stakeholders in Nigeria should establish another agency apart from the EFCC and ICPC specifically for the control of corruption in the health industry, e.g., the **National Agency for Control of Corruption in Health (NACCH)**.
ii. African leaders should come together to embrace the need for better macro-economic factors for health improvement just as they did in 2001 to recommend an increase in public health expenditure for better health outcomes. Despite the recommendations for an increase in health financing, the health outcomes are poor because many of the countries in Africa did not increase the portion of their income or budget allotted to health as they believed doing so would

TABLE 2 The United Nations' 2030 SDG health targets and forecasts of public health expenditures and non-health factors in SSA countries.

Forecasts	Maternal	Child	Health expenditure	GFC	Unemployment	Cons.	Corrupt.
2025	139.4	36.9	987.21	51.27	3.70	1.74	−2.28
2027	105.5	29.2	1,260.57	65.46	2.80	2.23	−2.91
2030	69.5	20.6	1,818.87	94.46	1.84	3.21	−4.20

The SDG targets for maternal and child under-five mortality are 70 per 100,000 and 25 per 1,000 live births, respectively. The health and non-health factors are health expenditure, gross fixed capital formation, unemployment, consumption, and control of corruption.

affect other sectors in their country. Our recommendation is all-inclusive because the benefits of improvement in macro-economic factors will not be limited to the health sector alone. In the process of improving the health system through better macro-economic factors, the whole economy will be improved. For example, an **improvement in macro-economic factors for better health in Africa** could be passed into law.

iii. Unnecessary generalizations must be avoided when dealing with health issues because each country has its own peculiar health problems that may require specific intervention. For example, the health expenditure needed to reduce maternal mortality in South Africa may not be able to reduce maternal mortality in Nigeria.

Recommendations

Based on our analysis, we recommend:

i. The government should consider macro-economic factors as key determinants of health outcomes in Nigeria because prior studies did not account for the role of core macro-economic determinants in explaining maternal and under-five health outcomes.

ii. We also recommend that the Nigerian government should steadily increase health expenditure to reach and move beyond the forecast level of 1.818 billion naira, specifically, if Nigeria wants to achieve the SDG targets related to maternal and infant mortality, given the present low and unimpressive funding toward the health sector in the country. While, in general, an increase in health expenditure will indirectly increase life expectancy at birth in the country, which is regarded as one of the lowest in the world; a reduction in maternal and child mortality will result in an improvement in life expectancy at birth.

iii. The country's unemployment rate was 8.5 percent in 2019. Our forecasting results indicate that a 1.84 percent reduction in the unemployment rate could be a reality in the country by 2030.

iv. Domestic investment must increase to 94.46 billion naira to propel the country toward actualizing Agenda 2030. In 2019, the domestic investment in the country was 24.62 billion naira, which is very far from the projected level.

v. Household consumption represents the poverty level of the citizens. Therefore, the government must put in place strategies or reforms that can increase the household consumption level to 3.21 to achieve SDG targets for maternal and under-five child health outcomes.

Conclusion

This study confirms total health expenditure, unemployment, household consumption, and gross fixed capital as significant macro-economic determinants of maternal and infant health outcomes in Nigeria. The results of the forecasts suggest the need for improvement of macro-economic determinants so that the country is positioned to achieve Agenda 2030. Health expenditure has been identified as a necessary prerequisite for the improvement of health outcomes (54). Health expenditure, therefore, is an all-encompassing factor that covers all the expenses incurred on health issues, prevention, pharmaceutical costs, diagnostic costs, and health-related programs (including training, research, awareness, and development), but health financing is a critical component of the health system that provides the resources needed to cover health expenditures.

In this study, our emphasis was on the total health expenditure, a combination of private, public, and donor contributions. A disaggregation of the sources of health expenditure could have enabled us to document the effect of health expenditures and macro-economic factors on health outcomes based on different sources of health expenditures.

In addition, to contribute more to the literature, we could have incorporated different measures of corruption. In this study, the focus was limited to corruption control. Different measures of corruption could have reflected the effect of corruption on health outcomes from different perspectives. For future work and subject to data availability, control variables such as GDP per capita, public health expenditure, private health expenditure, and different measures of corruption, may be considered which could change the signs, the statistical significance of the coefficients, and out-of-sample projections.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found here: World Development Indicators, Penn World Table.

Author contributions

YA: conceptualization, project administration, literature review, methodology and policy implications, data analysis, methodology, and interpretation of results. GG and JM: project administration, interpretation of results, and supervision. All authors contributed to the article and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Income-related health inequality among rural residents in western China

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Objective: Health equality has drawn much public attention in both developed and developing countries. China, the largest developing country, has implemented a new round of health system reform to improve health equality since 2009. This study aims to examine the magnitude and sources of income-related health inequality in western rural regions of China.

Methods: Data were obtained from the Survey of Rural Economic and Social Development in Western China conducted in 2014, in which 14,555 individuals from 5,299 households in 12 provinces were included. Health outcome variables of interest were self-rated health status, prevalence of chronic disease and four-week illness. Concentration index was calculated to assess magnitude of income-related health inequality, and nonlinear decomposition analysis was performed to identify the sources of health inequality.

Results: The Concentration indexes for poor self-rated health status, prevalence of chronic disease and four-week illness were −0.0898 ($P<0.001$), −0.0860 ($P<0.001$) and −0.1284 ($P<0.001$), respectively. Income and education were two main sources of health inequality, accounting for about 25−50% and 15% contribution to the inequality. Ethnicity made <10% contribution to income-related health inequality, and enrollment in New Rural Cooperative Medical Scheme contributed to <1%.

Conclusion: This study found slight income-related health inequality among rural residents in western China, implying that although China has made substantial progress in economic development and poverty alleviation, health inequality in western rural region should still be concerned by the government. To achieve health equality further, the Chinese government should not only strengthen its reimbursement mechanism of the current health insurance scheme to improve affordability of primary healthcare for residents in western rural regions, but also implement health poverty alleviation policies targeting socioeconomically vulnerable population and ethnic minorities in future.

KEYWORDS

health inequality, income-related, China, western rural area, concentration index

1. Introduction

Achieving health equality is a widely recognized goal of public policy and health systems around the world (1). The third of Sustainable Development Goals put forward by the United Nations in 2015 calls for all countries to take action to ensure good health and wellbeing for all (2). During the past several decades, although the general population health status has improved, socioeconomic-related health inequality has remained persistent or even widened in both developed and developing countries (3–8). To achieve equality in health, the WHO proposed several initiatives at both the global and national levels, including identifying disadvantaged subgroups and focusing on low- and middle-income countries or regions (9, 10). According to the WHO, health inequality is defined as observable differences in health across subgroups (demographic, economic, ethnic, regional, social, etc.) within the overall population (11). In recent years, the WHO conducted a holistic review of social determinants of health to explore causes of health inequality and monitor its changing trends, and has suggested that income, education, and ethnicity were common social determinants of health (9).

China, as the largest middle-income country in the world, has achieved unprecedented progress in economic development since Reform and Opening-up in 1978. Although population health has gained continuing increasement thereafter, health inequality remained a serious issue, which posed challenges to the social and economic sustainable development (12, 13). In 2009, China started a new round of health system reform to improve population health and equality. Later, in 2016, the Chinese central government approved the <Healthy China 2030 Plan>, which provided a guideline for promoting health for all (14). Achieving health equality is a priority in this ambitious plan.

Researchers home and abroad have conducted many studies to examine the extent and causes of health inequality in China. They found that income-related self-reported health inequality remained or had increased during the past years (15–19), and inequality persisted in quality of life, prevalence of hypertension, maternal mortality, and child malnutrition (20–23). In contrast, only one study found decreased income-related inequality in self-rated health during the period of 2010 to 2014 (24). Pro-poor inequality was also remained during the period of the COVID-19 pandemic (25). The current literature consistently suggested that equality-oriented programs should be implemented to support vulnerable groups. However, conclusions regarding health inequality in China were only drawn based on studies among the overall population, which failed to show variations in subpopulations. As far as we know, there has been sparse research on income-related health inequality among residents in the western rural areas of China. Health inequality in this population worth further exploration for several reasons. First, rural western China is much less economically developed comparing to the rest areas. Second, western China is populated by ethnic minority groups. According to the 7th China National Census conducted in 2020, 70.2% of ethnic minority populations were concentrated in western China (26). Third, people living in the western rural regions have lower access to health resources and healthcare services than those residing in the eastern and central regions.

To fill the research gap, this study assessed the magnitude of income-related inequality in health status among adults and examined the socioeconomic determinants of health inequality, using data from a wide range of rural western regions and large-scale sampled residents. This study contributes to the understanding of health inequality in western rural regions and provides policy implications for improving health status and equality among vulnerable populations.

2. Materials and methods

2.1. Data and sample

Data were obtained from the Chinese Western Ethnicity Economic Survey (CWEES), which was conducted by the School of Economics, Southwestern Minzu University in 2014 (27). More details of this survey can be found in the book published by Zheng (28). The CWEES contains a wide range of information covering demographic characteristics, health status and social security, rural–urban migration, wellbeing, household income and expenditure, etc. Multiple stage sample methods were used to retrieve respondents from 12 provinces in the rural regions of western China. Two counties from each province were firstly selected using the purposive sampling method. Then, villages and households were drawn from the residents' registration system, using the probability proportionate to size sampling (PPS) method. All members of the sampled households were interviewed face-to-face by trained interviewers. Finally, a total of 23,172 individuals from 5,967 households were sampled and interviewed. For the present study, the inclusion criteria were: (1) aged 18 and older; (2) had no missing values in both health variables and independent variables. In total, 4,766 observations aged lower than 18 were excluded and 3,851 was excluded because of missing values. At last, 14,555 adults from 5,299 households were included for analysis.

2.2. Measurement

2.2.1. Measurement of health status

The primary outcome variable of interest was self-assessed health. Self-assessed health is a powerful predictor of mortality and objective health status in the general population (29, 30),

and has been widely used to measure socioeconomic inequalities in health (31–33). In this survey, self-assessed health was measured based on the question "How do you assess your health status?" with a five-point scale response: (1) very good; (2) good; (3) fair; (4) poor; (5) very poor. Following previous studies (24, 34), self-assessed health was dichotomized into two categories: (0) good (very good and good); (1) fair/poor (fair, poor, and very poor).

The second outcome variable was the prevalence of chronic disease, which was measured by the question "Are you currently suffering from chronic disease?" Answers to this question could be (0) no and (1) yes. Chronic diseases not only cause a mass of disability and premature deaths worldwide, but also lead to high financial burden (35, 36). Chronic diseases pose a heavy global public challenge, especially to developing countries and rural areas (37).

The third outcome variable was the prevalence of illness during a four-week period, which was measured by the question "Have you been ill during the last 4 weeks?" Answers to this question were: (0) no and (1) yes.

2.2.2. Independent variables

Independent variables were factors that are widely known to be related to individuals' health status and thus to be associated with health inequality (38). Three domains of factors were included: demographic characteristics, socioeconomic status, and other variables. Demographic variables were gender and age. Age was categorized into six groups: (1) 18–24; (2) 25–34; (3) 35–44; (4) 45–54; (5) 55–64; (6) 65 years and above.

Socioeconomic variables included income, education level, and occupation status. Per capita household income was used to measure respondents' economic status and calculate the concentration index. Following a previous study (39), income was transformed into its natural logarithm value in multivariate regression models to decrease the variability of data. Education level was coded as five groups: (1) illiteracy; (2) primary school; (3) middle school; (4) senior school; and (5) undergraduate. Occupation status was divided into six groups: (1) agricultural work; (2) employed; (3) self-employed; (4) student; (5) retired; and (6) unemployed.

Other independent variables included ethnicity, health insurance enrolment, and marital status. Ethnicity was a dichotomous variable, (0) Han and (1) ethnic minorities. The New Rural Cooperative Medical Schemes (NRCMS) was a health insurance scheme launched for rural China in 2003, which covered about 97% of the rural population by 2013 (40). Enrolment in the NRCMS was coded as 1, and as 0 otherwise. Marital status was classified into four categories: (1) married; (2) separated/divorced; (3) widowed; and (4) unmarried.

2.3. Statistical analysis

Descriptive statistics was conducted to show basic characteristics of the respondents. The chi-square test was used to examine differences in health status across subgroups. The probit multivariate regression model was employed to examine the association between health outcomes and independent variables. Concentration curve and concentration index, widely used approaches based on the relative invariant principle, were used to measure health inequality. Following Wagstaff's guidelines, we first plotted a concentration curve to examine income-related inequality in health status (41). The concentration curve displayed the cumulative share of fair/poor self-assessed health (or presence of chronic disease and four-week illness) against the cumulative share of population, ranked by income from the lowest to the highest. The concentration curve intuitively displayed the distribution of health in the overall population. Second, we calculated the concentration index to quantify the degree of inequality in health, which was defined as twice the area between the concentration curve and the line of equality (the 45-degree diagonal line). Its value ranges from −1 to 1. When the concentration curve lies above the line of equality, it takes negative value and indicates that fair/poor self-assessed health is unevenly distributed among the poor, and vice versa. When the concentration curve coincides with the line of equality and the concentration index equals to zero, it means that there is no inequality in health. The covariance approach was used to compute the concentration index using "conindex" command in Stata (42):

$$C = \frac{2}{\mu} cov(h,\ r) \tag{1}$$

where, C is the concentration index, h denotes the health variable and μ is its mean, r is the fractional rank of income, and cov means covariance between health variable and rank in income distribution. Robust standard errors clustering on household level was used to correct potential cluster sampling.

A decomposition method was employed to explain inequality in health and distinguish the contribution of various independent variables to the concentration index for the health variable (43). The concentration index for health variable could be written as:

$$C = \sum_i \frac{\beta_i^m \overline{x_i}}{\mu} C_i + \frac{GC_\varepsilon}{\mu} \tag{2}$$

where, $\overline{x_i}$ is the mean of i_{th} independent variable, β_i^m is its marginal effect and C_i is its concentration index, $\frac{\beta_i^m \overline{x_i}}{\mu} C_i$ means the contribution of i_{th} variable to the concentration index for health and $\frac{GC_\varepsilon}{\mu}$ is the contribution of the residual term. We

TABLE 1 Descriptive statistic for health status, demographic, socioeconomic and other characteristics of the Chinese western rural adults in 2014 ($N = 14,555$).

Variables	Total, *N* (%)	Self-rated health status[#]		Chronic disease[#]		Four-week Illness [#]	
		Good, *N* (%)	Fair or poor, *N* (%)	No, *N* (%)	Yes, *N* (%)	No, *N* (%)	Yes, *N* (%)
Total	1,4555	8,458 (58.11)	6,097 (41.89)	1,0631 (73.04)	3,924 (26.96)	1,2066 (82.90)	2,489 (17.10)
Gender							
Female	6,972 (47.90)	3,767 (54.03)	3,205 (45.97)	4,870 (69.85)	2,102 (30.15)	5,581 (80.05)	1,391 (19.95)
Male	7,583 (52.10)	4,691 (61.86)	2,892 (38.14)	5,761 (75.97)	1,822 (24.03)	6,485 (85.52)	1,098 (14.48)
Age groups							
18−24	1,918 (13.18)	1,604 (83.63)	314 (16.37)	1,837 (95.78)	81 (4.22)	1,824 (95.10)	94 (4.90)
25−34	2,793 (19.19)	2,133 (76.37)	660 (23.63)	2,529 (90.55)	264 (9.45)	2,572 (92.09)	221 (7.91)
35−44	3,062 (21.04)	1,867 (60.97)	1,195 (39.03)	2,425 (79.20)	637 (20.80)	2,637 (86.12)	425 (13.88)
45−54	2,811 (19.31)	1,489 (52.97)	1,322 (47.03)	1,942 (69.09)	869 (30.91)	2,285 (81.29)	526 (18.71)
55−64	2,151 (14.78)	821 (38.17)	1,330 (61.83)	1,132 (52.63)	1,019 (47.37)	1,546 (71.87)	605 (28.13)
65+	1,820 (12.50)	544 (29.89)	1,276 (70.11)	766 (42.09)	1,054 (57.91)	1,202 (66.04)	618 (33.96)
Marital status							
Married	1,1426 (78.50)	6,338 (55.47)	5,088 (44.53)	8,057 (70.51)	3,369 (29.49)	9,348 (81.81)	2,078 (18.19)
Separated/divorced	154 (1.06)	84 (54.55)	70 (45.45)	124 (80.52)	30 (19.48)	129 (83.77)	25 (16.23)
Widowed	737 (5.06)	256 (34.74)	481 (65.26)	384 (52.10)	353 (47.90)	500 (67.84)	237 (32.16)
Unmarried	2,238 (15.38)	1,780 (79.54)	458 (20.46)	2,066 (92.31)	172 (7.69)	2,089 (93.34)	149 (6.66)
Education							
Illiteracy	3,155 (21.68)	1,232 (39.05)	1,923 (60.95)	1,723 (54.61)	1,432 (45.39)	2,245 (71.16)	910 (28.84)
Primary school	4,490 (30.85)	2,315 (51.56)	2,175 (48.44)	3,060 (68.15)	1,430 (31.85)	3,589 (79.93)	901 (20.07)
Middle school	4,497 (30.90)	3,018 (67.11)	1,479 (32.89)	3,675 (81.72)	822 (18.28)	4,001 (88.97)	496 (11.03)
Senior school	1,566 (10.76)	1,175 (75.03)	391 (24.97)	1,367 (87.29)	199 (12.71)	1,428 (91.19)	138 (8.81)
Undergraduate	847 (5.82)	718 (84.77)	129 (15.23)	806 (95.16)	41 (4.84)	803 (94.81)	44 (5.19)
Employment status							
Agricultural work	9,827 (67.52)	5,564 (56.62)	4,263 (43.38)	7,152 (72.78)	2,675 (27.22)	8,100 (82.43)	1,727 (17.57)
Employed	1,322 (9.08)	1,022 (77.31)	300 (22.69)	1,177 (89.03)	145 (10.97)	1,207 (91.30)	115 (8.70)
Self-employed	684 (4.70)	469 (68.57)	215 (31.43)	569 (83.19)	115 (16.81)	616 (90.06)	68 (9.94)
Student	658 (4.52)	541 (82.22)	117 (17.78)	633 (96.20)	25 (3.80)	622 (94.53)	36 (5.47)
Retired	282 (1.94)	124 (43.97)	158 (56.03)	145 (51.42)	137 (48.58)	204 (72.34)	78 (27.66)
Unemployed	1,782 (12.24)	738 (41.41)	1,044 (58.59)	955 (53.59)	827 (46.41)	1,317 (73.91)	465 (26.09)
Ethnicity							
Han	6,335 (43.52)	3,933 (62.08)	2,402 (37.92)	4,641 (73.26)	1,694 (26.74)	5,517 (87.09)	818 (12.91)
Minority	8,220 (56.48)	4,525 (55.05)	3,695 (44.95)	5,990 (72.87)	2,230 (27.13)	6,549 (79.67)	1,671 (20.33)
NRCMS							
No	671 (4.61)	430 (64.08)	241 (35.92)	533 (79.43)	138 (20.57)	575 (85.69)	96 (14.31)
Yes	13,884 (95.39)	8,028 (57.82)	5,856 (42.18)	10,098 (72.73)	3,786 (27.27)	11,491 (82.76)	2,393 (17.24)

NRCMS, New Rural Cooperative Medical Scheme. [#] Chi-square test was used to compare differences among subgroups. All tests were significant at the $p = 0.01$ level, except for the difference in prevalence of four-week illness between the enrollees of NRCMS and the non-enrollees.

examined income-related health inequality both among the total sample and separately among the Han and the ethnic minority subgroups. Furthermore, we used the relative index of inequality (RII) and slope index of inequality (SII) (44) to examine education-related health inequality. RII measured the ratios in prevalence of poor health, chronic disease, and four-week illness between the lowest educated and highest educated persons, while SII capture the absolute differences in prevalence (45).

All statistical analyses were conducted using Stata 15.1.

TABLE 2 Concentration index for health status of Chinese western rural adults in 2014 ($N = 14,555$).

	Self-assessed health status		Chronic disease		Four-week illness	
	CCI (Robust SE)	*P*	CCI (Robust SE)	*P*	CCI (Robust SE)	*P*
Total population	−0.0898 (0.0075)	<0.001	−0.0860 (0.0092)	<0.001	−0.1284 (0.0128)	<0.001
Han	−0.1089 (0.0120)	<0.001	−0.1042 (0.0137)	<0.001	−0.1105 (0.0227)	<0.001
Minority	−0.0698 (0.0093)	<0.001	−0.0718 (0.0121)	<0.001	−0.1176 (0.0149)	<0.001

CCI, concentration index; SE, standard error.

3. Results

3.1. Basic characteristics of respondents

Table 1 shows the basic characteristics of the 14,555 respondents. The majority of respondents (58.11%) assessed their health as good or very good, while about 41.89% rated their health as fair, poor, or very poor. Most of the adults reported having no chronic disease (73.04%) or illness during the last 4 weeks (82.90%). The proportion of respondents rating fair/poor health and the presence of chronic diseases or illness differed across subgroups. Specifically, respondents who were males, aged 18–24 years, Han ethnicity, and those who did not enroll in NRCMS were more likely to rate very good or good health comparing to their counterparts. Furthermore, the prevalence of chronic diseases and the prevalence of four-week illness in males, those aged 18–24 years, and respondents of Han ethnicity were lower than in other groups.

About 50% of the respondents had an education level of lower than primary school, and the cumulative percentage of senior school and undergraduate was ∼15%. Respondents with lower education levels were more likely to rate their health as fair/poor than those who had higher education levels. Similarly, the prevalence of chronic disease and four-week illness was higher in the low-educated groups than that in high-educated groups. As shown in Supplementary Table 1, the SIIs for poor health status, chronic disease, and four-week illness between the lowest educated and the highest educated were significantly negative, and the RIIs were significantly positive at 0.001 level. About 68% of the respondents were engaged in agricultural work, while only 18% were employed, self-employed or were students. Fourteen percent of the respondents were retired or unemployed, these respondents were more likely to rate their health status as fair/poor or report higher presence of chronic diseases and four-week illness than other groups did.

3.2. Concentration index for health status

Table 2 displays the concentration indexes for the three outcome variables. The concentration indexes for self-rated health status, prevalence of chronic disease, and morbidity of illness were −0.0898, −0.0860, and −0.1284, respectively, all were significant at 0.001 level. Figure 1 intuitively displays the distribution of health in relation to income. The concentration curves for the three health variables lie above the equality lines. The significantly negative CCI values and the location of concentration curves indicate that fair/poor self-rated health, chronic disease, and four-week illness were unevenly concentrated among the poor. In other words, the poor were more likely to have worth health than the rich. Similarly, the concentration indexes for the three health variables among the Han or among the minorities were all significantly negative at 0.001 level.

3.3. Decomposition of concentration index for health status

Table 3 displays the contribution of each factor to inequality in health. Demographic, socioeconomic, and other variables explained the majority of the inequality, ∼99% of self-assessed health, 94% of chronic disease, and 90% of four-week illness. The significantly negative coefficients of income and education level indicate that respondents with higher income or better education were less likely to rate their health status as fair/poor or report chronic disease than respondents with lower income or lower education. According to the decomposition results, socioeconomic status was the main source of inequality. Income made 52, 25, and 40% of the contribution to inequality in self-assessed health, chronic disease, and four-week illness, respectively. Education also made about 15–23% contribution to pro-poor inequality, except for primary school, which only made about 1–3% negative contribution. Employment status made lower than 10% contribution to inequality in health; however, not all employment statuses were significant. As for other factors, ethnicity was significantly associated with health outcomes. The corresponding coefficients of ethnicity for self-rated health status, prevalence of chronic disease, and four-week illness were 0.21 ($P < 0.001$), 0.05 ($P < 0.05$) and 0.33 ($P < 0.001$). Comparing to the Han, people of minority ethnicities were more likely to rate a fair/poor health status and report four-week illness. Ethnicity made about 7, 2, and 11% contribution

to inequality in self-rated health status, prevalence of chronic disease, and four-week illness, respectively. With respect to health insurance scheme, NRCMS was significantly positively associated with the presence of chronic disease ($\beta = 0.14$, $P < 0.05$) but not related to self-assessed health status and four-week illness. The contribution of NRCMS to health inequality was < 1%, ranging from 0.18 to 0.56%.

4. Discussion

Using large scale of samples, this study examined the magnitude and source of health inequality among adults in rural western China based on the concentration index approach. We found that all concentration indexes for the three health status variables were negative but small, indicating that slight pro-poor income-related inequality existed in health. In addition, nonlinear decomposition of CCI demonstrated that income and education level were the main sources of health inequality. Besides, ethnicity and NRCMS made smaller contribution to health inequality.

4.1. Magnitude of income-related health inequality

Comparing to previous findings, our study found that pro-poor income-related health inequality in rural regions of western China was attenuated. The concentration index for self-assessed health status among our sample was lower than that for the total population (29). Moreover, we found that pro-poor inequality existed in the prevalence of self-reported chronic disease. This finding was in contrast to several previous studies, which found pro-rich inequality in prevalence of self-reported hypertension (22), diabetes (46), or other chronic disease (47, 48) among rural residents. However, Cao found that the prevalence of tested hypertension was unequally concentrated among the poor respondents in China (49), which as consistent with our findings. We also found pro-poor inequality in the prevalence of four-week illness. Similarly, small and negative concentration indexes for the prevalence of four-week illness and prevalence of chronic disease were found among rural residents in Yunnan province, an ethnic frontier region in southwest China (50). In sum, the negative CCI values for the three health variables in our study provide robust evidences for attenuated pro-poor health inequality among rural residents in western China.

4.2. Source of income-related health inequality

Firstly, according to the decomposition results, the main driver of pro-poor income-related health inequality was income, followed by education. These findings are in accordance with

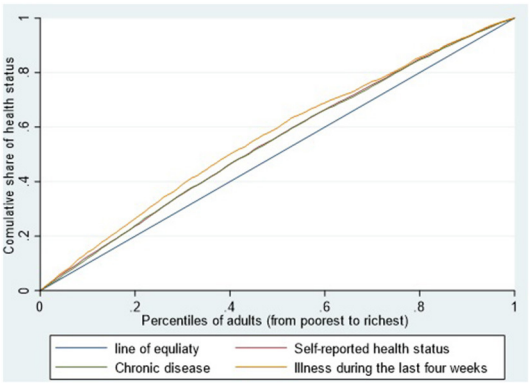

FIGURE 1
The concentration curve of health status among Chinese western rural adults in 2014 (N = 14,555).

findings from developed countries (39, 51). Several reasons may explain why income and education contribute much to health inequality. First, socioeconomic disparity may directly result in differences in health determinants, such as nutrition, diet, and eating habit (52). People with higher income could have better access to healthy food and nutrition than those making less income. Second, socioeconomic status is related to physical activities and health behaviors, such as heavy physical work, smoking, and drinking (50). Unhealthy behaviors may lead to high prevalence of chronic disease and four-week illness. Third, the rich usually have better access to health care and health literacy to seek healthcare when they are ill than the poor (25). Such inequity in healthcare could also exacerbate health inequality. The finding that health inequality is mainly due to disparities in socioeconomic determinants of health highlights that the government should not just give priority to economic development, but also pay attention to equality in income distribution and resource allocation, especially focusing on poverty alleviation policies targeting vulnerable groups.

Secondly, it is important to note that ethnicity makes about 2–11% contribution to pro-poor income-related health inequality among our sample. The ethnic minorities not only had lower income than the Han population, but also reported poorer health status. Such inequality was supported by study conducted by Castro Campos et al. (53), Ouyang and Pinstrup-Andersen (54), and Wang et al. (55). According to our descriptive and regression results, there was a small difference in the prevalence of chronic disease between ethnic minorities and the Han population; however, gaps existed in self-reported health and the prevalence of four-week illness. Residential environment of ethnic minorities is an important risk factor of poor self-reported health and four-week illness (56). Ethnic minorities usually live in remote and mountainous regions with a harsh natural environment, which may contribute to their poor health status and high prevalence of illness (50).

TABLE 3 Decomposition of concentration index for health status of Chinese western rural adults in 2014 ($N = 14,555$).

Variables	CCI_k	Self–rated health status		Chronic disease		Four–week illness	
		Coefficient	Contribution (%)	Coefficient	Contribution (%)	Coefficient	Contribution (%)
Gender (ref. Female)							
Male	0.01	−0.16***	0.63	−0.13***	0.64	−0.17***	0.69
Age (ref. 18–24)							
25–34	0.04	0.23***	−1.64	0.31***	−2.91	0.22**	−1.63
35–44	0.01	0.61***	−1.46	0.74***	−2.46	0.50***	−1.37
45–54	0.05	0.83***	−8.62	1.05***	−15.98	0.71***	−9.10
55–64	−0.06	1.14***	9.33	1.40***	17.82	0.97***	11.02
65+	−0.13	1.31***	20.02	1.59***	38.92	1.09***	24.70
Marital (ref. Married)							
Separated/divorced	0.08	0.13	−0.11	−0.22	0.21	0.03	−0.03
Widowed	−0.06	−0.01	−0.03	−0.16**	−0.59	0.02	0.06
Unmarried	0.04	−0.01	0.07	−0.06	0.44	−0.03	0.16
Education (ref. Illiteracy)							
Primary school	−0.05	−0.09**	−1.49	−0.13***	−2.65	−0.08*	−1.25
Middle school	0.07	−0.24***	5.46	−0.30***	8.40	−0.24***	5.38
Senior school	0.15	−0.38***	5.86	−0.43***	7.60	−0.29***	4.13
Undergraduate	0.23	−0.49***	6.09	−0.60***	8.05	−0.38***	4.23
Occupation (ref. Agricultural work)							
Employed	0.26	−0.12**	2.78	−0.13*	3.83	−0.001	0.03
Self–employed	0.25	−0.10	1.16	−0.14*	1.98	−0.14*	1.59
Student	0.03	0.17*	−0.20	0.02	−0.02	0.14	−0.17
Retired	0.19	−0.10	0.40	0.09	−0.45	0.04	−0.16
Unemployed	−0.08	0.17***	1.79	0.29***	4.22	0.08*	0.92
Ethnicity (ref. Han)							
Minority	−0.06	0.21***	7.03	0.05*	2.06	0.33***	10.67
NRCMS (ref. No)							
Yes	−0.003	0.05	0.18	0.14*	0.56	0.06	0.18
Ln per capita income	0.07	−0.18***	51.53	−0.07**	24.83	−0.14***	39.52
Total explained			98.79		94.47		89.57
Residual terms			1.21		5.53		10.43

CCI_k, concentration index for variable k; ref., reference to; NRCMS, New Rural Cooperative Medical Scheme. *P < 0.05; **P < 0.01; ***P < 0.001.

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Furthermore, remote rural residential environments are always accompanied by poorer health infrastructure and fewer health professionals (57). Thus, the ethnic minorities usually have many barriers in utilizing healthcare, such as geographical accessibility, cultural acceptability, financial affordability, and health resource availability (58). Once they are ill, they face more difficulties in seeking high-quality medical treatment services than people living in the eastern and central regions of China.

Thirdly, we found that NRCMS also made a low percentage of contribution to pro-poor income-related health inequality. This finding was consistent with previous study which demonstrated that China's health insurance scheme could lead to health inequality (17). A study in Canada and America also supported that health insurance enrolment contributed to income-related health inequality (38). In this study, we found that the NRCMS contributed to inequality in the prevalence of chronic disease but not in self-rated health or four-week illness. One possible explanation could be that the benefit package of NRCMS did not cover treatment for chronic diseases. As previous studies found, the NRCMS reimbursement policy had little effect on healthcare utilization and financial protection for respondents with chronic disease (59, 60). This finding implies that the NRCMS should be strengthen with respect to reimbursement policy toward chronic disease preventive and treatment care.

4.3. Policy implications

This study contributes to the understanding of the situation and sources of health inequality in rural regions of western China. These findings have several important policy implications. Firstly, the high contribution of income to health inequality illustrates that income is still the main contributor to inequality. To narrow the disparity in health status across income, the government should continue to implement targeted poverty alleviation policies, which have been proofed an effective strategy to attenuate health inequality (61). Based on the order of contributions and each factor made, people with low income, ethnic minorities, people with low education attainment, and those with chronic diseases should be primarily targeted by poverty alleviation policies. Secondly, to improve health of the minorities, more health promotion measures should be taken, such as to improve access to high-quality primary healthcare, acceptability, and health literacy. Furthermore, healthcare providers may provide telehealth care for the western rural residents, especially for those living in mountainous regions with geographic barriers (61, 62). Thirdly, to improve the contribution of NRCMS to promote health equality, the government should improve the affordability of healthcare by strengthening the health insurance reimbursement policies on both preventive and outpatient care for patients with chronic diseases.

4.4. Strengths and limitations

This research has two notable strengths. First, the data were obtained from a large-scale survey conducted in rural regions of western China. To the best of our knowledge, it is the first survey focusing on rural western China and covers a wide range of regions (12 provinces and 24 counites) and residents. Based on the large-scale samples, we could validly examine income-related health inequality among residents living in rural regions of western China. Second, three subjective health outcomes were used to measure health status, which could provide robust evidence of inequality in health.

However, our study has four limitations. First, the cross-sectional survey was conducted in 2014. It cannot reflect the changing trends of health inequality in recent years. Further research on health inequality could use longitudinal data, if available, to examine the changing trends of inequality in the fight against poverty progress in China during the past 8 years. Second, the decomposition of CCI with cross-sectional survey data could display the contribution of socioeconomic characteristics and other factors to health inequality; however, it could not verify the causal relationship between independent variables and health status. Causal inference methods, such as difference-in-difference, are needed to examine the causal link between public health policy and health (63). Third, the measurement of health status was self-rated or reported. The rich may have higher health expectations and hence report poorer health and higher prevalence of chronic disease or illness, which may lead to underestimation of the magnitude of health inequality in reality (34). Future research may use objective indicators of health, such as biomarkers, mortality, nutrition and so on. Fourth, 3,851 observations, which accounted for 21% of the sampled adults, were excluded for missing values. The missing values were more concentrated in older adults, socioeconomic deprived, and those with poor health status. Thus, the missing data may lead to underestimated bias in health inequality.

5. Conclusions

This study found evidence that there remains an attenuated income-related health inequality among adults in Chinese western rural areas. To eliminate health inequality and achieve health for all, a targeted poverty alleviation policy and equal education opportunity program targeting vulnerable groups should be implemented continuously in the future. Moreover, a targeted policy toward ethnic minorities living in remote areas should be designed and implemented to promote equal access to high-quality primary healthcare. Furthermore, the government should also strengthen the health insurance reimbursement policies for residents with chronic disease to promote health equality.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

CL and CT participated in concept, study design, data analysis, interpretation, and writing the manuscript. All authors reviewed and approved the final manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

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Raising sons or daughters for old age? Influence of children's gender on intergenerational family support in rural families

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Background: Under the background of miniaturization of family size and a growing number of young and middle-aged population outflow in rural China, the study of family pension mechanism in rural China from the perspective of changes in the pension functions of son and daughter will not only help to deepen the understanding of the change rules of China's family system, but also provide important reference for the future design of rural pension system.

Data and method: The data come from the China Family Tracking Survey (CFPS), a nationwide social survey project runs by the Social Science Research Centre of Peking University. After excluding missing data, we obtained a valid sample of 11,207 sons and 2028 daughters in four data periods. We applied a fixed effects model for the analysis.

Results: In rural areas, sons mainly provide economic support, while daughters mainly provide life care, thus forming a gender-based division of labor. With increasing off-farm job opportunities for daughters, they provide more economic support for their parents, but the time they spend on housework for their parents is reduced. As the number of children in a family has increased, daughters' role in supporting their parents has decreased. This research shows that although the traditional son-centered pension mode in China has not completely disintegrated, it has changed significantly. The findings reveal that changes in family size and improvements in women's status are important factors in changing family support patterns.

Discussion: Different from the thought research about intergenerational relationship for a whole model, this article from the family internal different subjects role identity, shows the characteristics of the individual in the family, is conducive to theoretically explore the tension in the intergenerational relationship, individual and family which is helpful to understand the contemporary China's rural family generation ethics and intergenerational solidarity model. Families are classified more carefully according to the number, size and gender of children in the family, so as to fully show the heterogeneity and complexity of intergenerational relationships and old-age care models in rural families with different structural types. The discussion of

the above issues has refined the description of rural family pension resources in China, which has certain reference significance for improving rural pension policies and actively dealing with the aging population.

KEYWORDS

raising sons for old age, raising daughters for old age, children's gender, size of family, intergenerational support

1. Introduction

The concept of "raising sons for old age" exists in traditional rural China. With the aging of China's population and the economic and social changes in rural areas, the role of daughters in the family pension has gradually increased and has become a major trend in modern rural areas. The mode of "daughter support" not only breaks the division of labor in traditional family support, with sons as the core, but also reshapes the division of responsibilities in rural families. An increasing number of studies suggest that daughters are better than sons at providing economic support and life care (1–3). The new concept of daughter pension has been gradually accepted and recognized in rural societies; thus, daughter pension has become a new element of China's rural social pension pattern.

At present, academic research on rural old-age care in China mainly focuses on family old-age care, family structure, traditional gender concepts and support mechanisms.

Due to the lack of social security in traditional rural society, the family has assumed the main function of old-age care. In rural families in China and East Asia, children, especially sons, assume the responsibility of supporting their parents (4, 5). He et al. (6) asserted that the system of support for elderly people in rural China is based mainly on people providing feedback and caring for the old; indeed, in traditional farming society, single-endowment resources determine the dominant position of the family endowment (7). In traditional societies, production activities depend mainly on physical strength, and sons perform the dual function of producing labor and offspring. Therefore, bearing and rearing sons is considered a rational and less risky investment than raising daughters (8). Yin et al. (9) similarly found that in a society with relatively low productivity, because men are physically stronger than women and have more endurance and energy, people in China and East Asia are motivated to have boys.

In practice, the changes in the modern family structure have caused a situation in which daughters support their parents (10). As families have become smaller, the traditional role of sons as providers for their parents is no longer feasible to meet the true needs of rural social development, and daughters have also become providers to meet the needs of their elderly parents (11). Modern urban development has dismantled the traditional concept of filial piety (1), but at the same time, urbanization has improved the ability and willingness of daughters to support their parents and motivated them to do so. Horowitz (12) wrote that male migrant workers have contributed to the weakening of the concept of support, making daughters more important in providing for their parents and changing the nature of the family (13, 14). Sons who cannot directly assume the responsibility of supporting their parents provide economic support to their sisters, who in turn support their parents through the performance of certain household tasks (11).

The traditional concept of gender has also had a great impact on the ways in which children support their parents; it has been influenced by Confucianism, which holds that the purpose and meaning of having children is to provide "support"; i.e., sons are the most reliable resource for parents (15). Moreover, elderly people rely mainly on family members for their pension, and supporting parents in their old age is crucial (16). Ross and Alison (17) proposed the gender consciousness theory to explain that men play the role of material suppliers, while women play the role of family caregivers. When people raise children to support them in their old age and retirement, daughters do not play a role; instead, only sons play a role, as they are the most reliable resources for retirement (18). Preference for a certain gender (mainly for boys) has been a common phenomenon influencing fertility intentions in Chinese society (19). Most farmers have a strong fertility value orientation toward boys (20). Among people's reproductive objectives, the most important factors are the traditional concept of family legacy and the fact that people raise children so that these children can provide for them when they are old; these objectives constitute the root cause of people's universal preference for boys (21). In this paper, parents' preference for boys is based mainly on the traditional concept of family legacy and parents' practical need for support in their old age. People believe that having more children will make them happier, although it is mainly sons who will provide them with security in their old age; parents do not have great expectations of their daughters (22), and the responsibility of sons to support their parents leads parents to prefer their sons (21). This preference for boys over girls often leads to discrimination against daughters in parenting and intergenerational communication (23, 24).

Other scholars have found obvious differences between sons and daughters in terms of the support mode, time spent and rules that apply to them (3); specifically, daughters tend to

care for parents' life needs and emotional support, and sons tend to provide economic assistance (25). Zeng et al. (25) found that due to gender-based psychological and physical differences, daughters often play a more practical role than sons in spiritual comfort and life care, which is more relevant to their parents' retirement needs. In addition, traditional principles dictate that the reciprocal relationship between generations emanates mainly from the Confucian principle of "reciprocating kindness"; that is, children support their parents in return for their parents' kindness in raising them Yan (26). When distinguishing the motivations of daughters and sons to support their parents, it has been found that the motivation of sons is based on "responsibility," while that of daughters is based on "emotion" (25). Hence, daughters' support has become increasingly instrumental in current support practices in rural areas, and daughters have contributed immensely to meeting their parents' needs for life care and emotional support (2).

As rural areas have modernized, traditional concepts have continuously changed. The process of rural modernization has blurred the differences between genders in social production and narrowed the gender gap in intergenerational support (27). Daughters have assumed an increasingly prominent role in supporting their parents (10, 28, 29). Silverstein et al. (30) stated that daughters may be more filial than sons and more willing to take care of their elderly parents. The new concept of daughters' support for their parents has gradually been recognized by some villagers (31). Today, the idea of raising children to provide for old age and equating more children with more happiness has also changed; having children generally no longer refers to having sons (13, 32). The promotion of the role of daughters as providers for their parents has depended on the weakening of traditional gender systems and concepts (33) and the development of a modern consciousness (34).

In addition, spiritual support is directly related to elderly people's health, quality of life and happiness. As society has developed, the needs of older people in rural areas have changed from food and clothing to spiritual fulfillment. The needs of elderly people in rural areas are not limited to material needs, such as food, clothing and warmth, but also include spiritual comfort. Studies have found that daughters provide more emotional and functional support to their elderly parents than sons do (35, 36). The number of children in a family also affects the welfare of elderly individuals, as it is difficult for an only child to effectively meet the emotional needs of his or her parents (37).

Scholars in China and abroad have widely studied old age in rural areas and obtained relatively rich findings. However, research on rural pensions has fallen short. First, most current research has focused on family pensions as a whole. However, is there any significant difference in the level of support for parents' pensions provided by children within the same family based on gender? How does the gender of children affect the economic support and living care provided to parents in their old age? Second, research on family pensions has focused mainly on economic support, and the difference between genders in how much life care is provided remains unclear. Considering the improvement in women's economic and social status, what is their current status and role in supporting their parents? Can women promote a division of labor among children supporting their parents and improve the level of rural family pensions? In this paper, we use "gender role theory" and "resource endowment theory" to combine economic support with life care and, from the perspective of family support, explore whether and what kinds of differences exist in children's support for their parents as well as the change mechanism that causes gender-based differences in children supporting their parents.

2. Analytical framework and research hypothesis

Parents' pension benefits are realized in two ways (Figure 1). The first is that the son is the main provider of the parents. The son is considered the single resource for the parents' pension in traditional society, dictating the level of the parents' pension welfare. The second is that daughters provide important support to their parents. In traditional societies, sons and daughters act as a single resource for their parents' pension and jointly decide the level of parents' pension welfare through a specific family division of labor.

2.1. Gender-based differences in children's support of their parents

As the structure of the rural population has changed and rural modernization has accelerated, the gender lines in social production have gradually blurred, and the gender gap in children's intergenerational support has also narrowed (27). As a result, gender-based differences in social production have become increasingly unclear. Some studies have found that with the increasing role of daughters in family support, the gender gap in providing for parents has gradually also narrowed, although it remains significant (33). In rural areas, it is traditional to for couples have children as security for their old age, and this idea is still deeply rooted in people's hearts (22). Xu (11) found that daughters in rural families participate in their parents' retirement activities, but sons still play a greater role in their parents' pensions than daughters do. In addition, as the gap between children's education level and income has narrowed, men and women have become more equal. In rural areas, even though the level of support provided by daughters has improved, traditional ideas about having children for security in old age and "having more children for more happiness" have remained influential. Accordingly, we propose the following hypothesis.

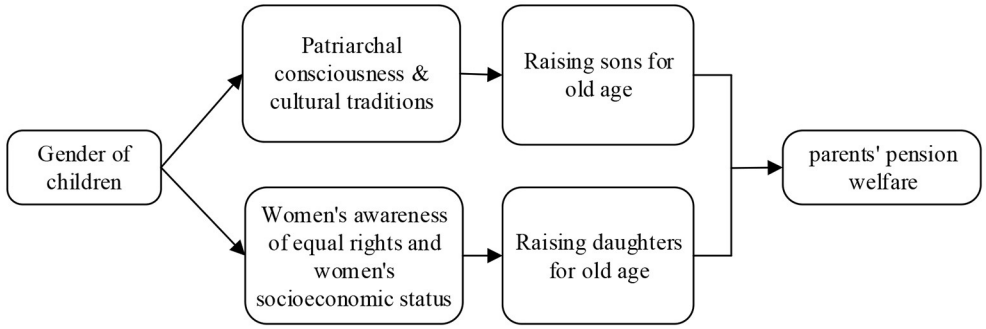

FIGURE 1
Theoretical research framework diagram.

Hypothesis 1: In rural families, there is still a traditional pension model based on sons being the main providers, and sons contribute more than daughters to their parents' pensions, but the gap between sons and daughters is narrowing.

2.2. Process by which children have changed the way they support their parents

In rural areas of China, all sectors of society have paid extensive attention to the fact that women are now supporting their parents. Two aspects of the narrowing of the gender gap in how children support their parents have mainly been considered: on the one hand, the role of men in supporting their parents has weakened, and on the other hand, the role of women in supporting their parents has increased. The second aspect is the most important, so this study focuses on socioeconomic status, education level, number of children in the family and other aspects to explore the impact of the gender gap on the ways in which children support their parents.

First, we consider the impact of children's socioeconomic status on parental support. Children's socioeconomic status directly affects the level of support they provide to their parents and is generally positively correlated with the economic support that they provide Zhang and Luo (38). Studies have found that in rural families, a certain gap remains between daughters and sons in terms of the level of economic support that they provide to their parents, but this gap is expected to gradually narrow as daughters' socioeconomic status improves (39). With adjustments in the industrial structure and the development of the tertiary industry, people no longer obtain income from wages for manual labor, and the sources of women's income, which has improved, have changed. These changes in income sources have led to daughters providing more support to their parents.

Second, the role of education as a relatively scarce resource allowing children to support their parents should not be underestimated. The more resources children have, the more likely they are to provide additional support (40, 41). Studies have found that the higher the children's education level, the greater their role in supporting their parents (26) and that offspring with higher education levels can provide more resources to their parents' pensions. Some scholars have conducted quantitative analyses using children's number of years of education to determine whether there are significant differences in how children support their parents based on education level. The results indicated that when children have 17 years of education, i.e., they have gone to college, there is no significant difference in the level of economic support provided by sons and daughters (11). Other studies have found that when daughters have studied for 12 years, i.e., they have finished high school, there is also no significant difference in the amount of care and support sons and daughters provide to their parents; moreover, studies have found that as education levels continue to increase, the role of daughters in caring for parents could exceed the role of sons (33).

Finally, the number of children in rural families not only affects the pension resources available to the elderly, but also is the basis for the division of pension responsibilities among children in such families (42, 43). The division of labor among children is the result of family members' subjective demands and emotional relationship negotiation under the restriction of the external environment. With the process of modernization and the decline of patriarchal system, daughters play a more and more prominent role in the family pension; thus, daughters are becoming increasingly involved in supporting their parents. However, the daughter's pension responsibility in a family with many children is more of an auxiliary responsibility. Parents and society have relatively low expectations for daughters regarding support of the elderly in families with many children, which may lead to the "mutual discharge of responsibilities" among children

in rural families with many children, resulting in "free riding" behavior, thus reducing the level of parents' pension welfare.

In summary, in this paper, the following hypotheses are put forward.

Hypothesis 2: The higher a daughter's socioeconomic status is, the greater level of support she provides.

Hypothesis 3: The more educated a daughter is, the more support she will provide.

Hypothesis 4: The proportion of support provided by daughters decreases in families with more children.

3. Data sources and descriptive statistics

3.1. Data description

In this paper, we use data from the Chinese Household Tracking Survey (CFPS), a comprehensive nationwide social survey project organized by the Center for Social Sciences Survey at Peking University. The project adopts a sampling method, covering individual-level, family-level and social-level statistics, and the sample data cover 25 provinces, municipalities and autonomous regions in China (all except Hong Kong, Macao and Taiwan, Hainan, Qinghai, Tibet, Xinjiang, Inner Mongolia and Ningxia). In the survey, 2010 is the baseline, with surveys conducted every 2 years. To date, five periods of data have been published: 2010, 2012, 2014, 2016 and 2018. In this paper, we use four periods of panel data: 2010, 2012, 2016 and 2018. Data for 2014 are excluded because no survey was conducted that year on the parent-child relationship.

The CFPS data include information on financial support and household care provided by multiple children to elderly individuals, laying a foundation for in-depth study of variations in the level of support that children provide to their parents. As minor children are not economically able to support their parents, the sample in this research includes rural elderly people who are over 60 years of age and have children who are older than 18. In addition, because the data for each family include rural elderly individuals and their spouses, to avoid repeated calculations, we retain in the sample only one person older than 60 from each family. After eliminating data for which values are missing, we obtain 11,207 valid samples in the four data periods: 9,179 sons and 2,028 daughters.

In this paper, the core explained variables are "whether children provide their parents with economic support" and "whether children help their parents with housework and take care of their parents," both of which are dichotomous. In this paper, the core explanatory variable is children's gender. In addition, the model controls for the children's age, marital status, years of education and type of occupation. The specific index system is shown in Table 1.

3.2. Descriptive statistics

Based on our research sample, we perform a descriptive analysis of the main characteristics of daughters and sons in rural families. As shown in Table 2, overall, in rural families, the average number of years of sons' education is slightly higher than that of daughters, the proportion of sons engaged in non-farm work is 7.35% greater than that of daughters, and the unemployment rate among sons is 7.58% lower than that among daughters. The preference of rural families for having boys is partly corroborated by the fact that when a resource, such

TABLE 1 Indicator system.

Variable name	Variable symbol	Description of indicator assignment
Economic support	*eco*	Whether children provide financial support to their parents: The value is 1 for yes and 0 for no.
Life care	*lif*	Do children help their parents with housework and care for their parents? The value is 1 for yes and 0 for no.
Children's gender	*gen*	For sons, the value is 1; for daughters, the value is 0.
Marriage	*mar*	When individuals are married, the value is 1; when they are not married, the value is 0.
Age	*age*	People's actual age
Education	*edu*	Years of education: illiteracy has a value of 0; primary school has a value of 6; junior high school has a value of 9; high school has a value of 12; junior college assignment has a value of 15; university education has a value of 16; a master's degree has a value of 18; and a PhD has a value of 22.
Number of children	*siz*	The actual number of children
Non-farm work	*nag*	Individual is employed in farm work: yes has a value of 1; no has a value of 0.
Agricultural production	*agr*	Individual is engaged in agricultural production: yes has a value of 1; no has a value of 0.
Household registration	*huj*	An urban hukou has a value of 1; a rural hukou has a value of 0.

TABLE 2 Descriptive statistics of children's characteristics.

Variable	Categories/Indicators	Rural			Urban		
		Daughter	Son	Sum	Daughter	Son	Sum
Age (in years)	Mean	38.27	41.02	40.63	38.93	41.44	40.79
	Standard deviation	9.97	8.66	8.90	9.26	8.91	9.07
Education (in years)	Mean	7.23	7.56	7.51	12.17	10.77	11.14
	Standard deviation	4.73	3.89	4.02	4.07	4.05	4.10
Married (%)	No	22.89	17.02	17.84	30.89	17.48	20.95
	Yes	77.11	82.98	82.16	69.11	82.52	79.05
	No work	26.82	19.24	20.29	34.65	34.62	34.63
Type of occupation (%)	Non-farm work	39.59	46.94	45.91	64.46	62.85	63.27
	Agricultural work	33.60	33.83	33.79	0.89	2.52	2.10

TABLE 3 Mean and T value test of sons and daughters providing financial support and household care to their parents.

Variable	Sons		Daughters		Difference	*T* test
	Sample size	Mean	Sample size	Mean		
Economic support	9,179	0.282	2,028	0.267	0.015	2.041**
Life care	9,179	0.241	2,028	0.269	−0.028	2.812***

**$p < 0.05$, ***$p < 0.01$.

as education, is scarce, parents prioritize the needs of their sons. On the one hand, there is a certain positive correlation between the years of education and the type of occupation; that is, the more years of education, the higher the probability of engaging in non-farm work. On the other hand, our results show that in urban families, the preference for having boys has decreased.

The comparison of urban and rural areas indicates that the average number of years of education of urban children is 3.63 years higher than that of rural children, indicating that there is still a certain gap in educational resources and educational levels between urban and rural areas. Although children in cities on average' go to school longer, the proportion of children in cities who do not work is greater than the proportion of rural children who are unemployed by 14.34%. On the one hand, this trend may be due to the pressures of the rural pension system; children leave school early to go work and earn money, thus leading to a lower mean for each education period. Moreover, under life pressures and restricted by the lower number of years spent studying, children in rural areas mostly engage in physical labor; thus, their unemployment rate is low. The parents of children in urban areas are highly educated, and most of them have pensions; therefore, they have a certain ability to provide for old age care and reduce the economic burden of their children. In addition, because children in urban areas are relatively highly educated, they are more resistant to engaging in manual work; instead, they seek work in the "knowledge economy." These factors combine to cause the proportion of children who are unemployed to be higher in urban areas than in rural areas.

As shown in Table 3, in rural areas, sons provide significantly more economic support than daughters, but sons provide significantly less homecare than daughters. This finding explains why sons constitute the core of the rural family resource system; this system has not completely collapsed because sons still provide a slightly higher level of economic support. However, daughters care for the elderly and attend to the housework more than sons do, which confirms the "gender role theory"; that is, sons provide for the family materially, while daughters play the role of household carer in the family.

4. Basic regression analysis

4.1. Model setting

Our objective is to determine whether children's gender within the same family results in significant differences in the ways in which they support their parents. We use the fixed effects model for the analysis because this model can use information about multiple children in rural areas to compare the impact of their gender within the same family on the extent to which they contribute to their parents' support and welfare. When the dependent variable is dichotomous, the fixed effects model is as follows:

$$log_{it}(P_{ij}) = log\frac{P_{ij}}{1-P_{ij}} = \sum_{k=0}^{K}\beta_k x_{kj} + \alpha_i$$

where the subscript i denotes the parent and the subscript j denotes the child. P_{ij} is the probability that child j of parent i provides support to his or her parents. x_{kj} is the core explanatory variable for the child's gender, and α_i denotes the fixed coefficient of parent i, the heterogeneity of parent i itself.

Unlike classical logistic regression, the fixed effect model adds the dummy variable of the fixed coefficient of parent i, indicating whether, when both parents are i, there is any difference in children's support behavior. Therefore, through this model, we can more rigorously analyse trends within the same family. Although not for the parents after joining α_i level variables (such as age, marriage, and health), these variables are the same for children within the same family. Therefore, there is no need to control the level variables for parents again.

4.2. Basic regression results and analysis

When other variables remain unchanged, the economic support received by parents from their sons is significantly positive at the significance level of 10% (Table 4), which indicates that sons' economic support is significantly greater than daughters'. In contrast, the extent to which sons provide domestic care to their parents is significantly negative at the 1% level (Table 4), indicating that sons play a lesser role than daughters in supporting their parents.

In rural families with both sons and daughters, the sons mainly provide economic support to their parents, while daughters mainly provide household care. The historical principles of traditional rural society in China hold that parents should raise children for security in old age and that "having more children brings more happiness." However, the son-centered support mechanism has changed when it comes to household care, as daughters perform more of this care, and daughters have also begun to participate in activities that support their parents; hence hypothesis 1 is verified. In rural areas, elderly men are generally supported by their sons and daughters-in-law. However, elderly men and daughters-in-law lack a common emotional foundation, and the subtle "old woman daughter-in-law relation" means that daughters-in-law can meet support requirements only to a certain extent. Elderly men's sons, because they have left the area to seek work, often provide economic support and ignore spiritual care. Therefore, elderly people prefer to receive spiritual care from their daughters. Although daughters are less likely to provide financial support to their parents after marriage, their intimate, sensitive feelings and shared experience of having children enable them to better understand their parents' hardships; thus daughters have an advantage over sons and daughters-in-law in terms of providing spiritual support. When parents need care, daughters play an indispensable role of companionship and spiritual comfort. In other words, people's preference for having boys to secure their old age in rural society is not one-sided but is based on both genders' preferences.

5. Mechanism of the effect of children's gender on parental support

According to the above studies, in China's vast rural society, traditional support mechanisms have endured: sons provide "support," but daughters have begun to be involved in providing support to their parents. Hence, we further analyse the differences between urban and rural areas, changes in the socioeconomic status of women and number of children to understand how children support their parents.

5.1. Urban–rural differences

To study differences between urban and rural areas in the ways in which children support their parents, we consider the interaction between urban and rural household registration status and children's gender on the basis of our original model, and the results are shown in Table 5.

The interaction between children's gender and household registration is not significant in terms of how much economic support children provide for their parents' pension or household care, which indicates that there is no significant difference between sons and daughters in supporting their parents in the urbanized countryside. As populations in urban and rural areas have become increasingly more mobile, caring for older people is becoming integrated across urban and rural areas. Hence, children support their parents equally in urban and rural areas. However, some studies have shown significant differences between urban and rural areas in the extent to which children support their parents (44). First, this significant difference is due to the obvious income gap between urban and rural areas, which makes urban children better able than rural children to provide economic support to their parents. Second, different conceptualisations of old-age care lead to certain differences between urban and rural areas in how children support their parents. People in rural areas are relatively conservative and have always adhered to the concept that they should raise children for more security in their old age, resulting in sons being the key to their parents' support in those areas.

TABLE 4 Effects of children's gender structure on intergenerational family support.

Variable	Economic support		Life care	
	Coefficient	Standard error	Coefficient	Standard error
gen	0.105*	0.057	−0.160***	0.058
mar	0.117**	0.057	0.074	0.059
age	−0.035***	0.003	−0.005*	0.003
edu	−0.009*	0.005	−0.001	0.006
nag	−0.046	0.059	0.097	0.064
agr	−0.110	0.068	0.438***	0.070
Constant term	−0.144	0.145	−0.609***	0.145
year	Yes		Yes	
Sample size	11,207		11,207	
Likelihood ratio chi-square	351.697***		464.410***	
R^2	0.027		0.037	

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

TABLE 5 Estimated results of urban–rural differences based on children's gender and level of parental support.

Variable	Economic support		Life care	
	Coefficient	Standard error	Coefficient	Standard error
gen	0.123	0.077	−0.202***	0.077
gen×*huj*	−0.106	0.115	0.072	0.116
huj	−0.155	0.106	−0.149	0.108
mar	0.111*	0.057	0.068	0.060
age	−0.033***	0.003	−0.004	0.003
edu	−0.001	0.006	0.002	0.006
nag	−0.095	0.060	0.080	0.065
agr	−0.214***	0.072	0.398***	0.074
Constant term	−0.168	0.150	−0.577***	0.150
year	Yes		Yes	
Sample size	11,207		11,207	
Likelihood ratio chi-square	373.166***		467.552***	
R^2	0.028		0.037	

*$p < 0.1$, ***$p < 0.01$.

5.2. Women's status

In general, there is a positive correlation between women's socioeconomic status, the number of years they spend in school and their income level. That is, the more educated women are, the higher their status is in their family and society. Moreover, improvements in women's socioeconomic status will raise their income level and help them provide more economic support to their parents. To study whether the socioeconomic status of daughters has an impact on the ways in which they support their parents, we successively include two cross-terms in the model: gender and non-farm work and gender and years of education.

As shown in Table 6, the effect of the coefficient of the cross-term between children's gender and off-farm work on economic support is significantly negative, indicating that participation in off-farm work significantly increases daughters' economic support to their parents. On the one hand, the reason for this finding may be that off-farm work enhances the income level of daughters, thus laying the economic foundation for them to support their parents. On the other hand, daughters' traditional views change consciously or unconsciously after they engage

TABLE 6 Estimated results of the impact of children's socioeconomic status on parental pension.

Variable	Economic support		Life care	
	Coefficient	Standard error	Coefficient	Standard error
gen	0.240*	0.127	−0.287**	0.122
gen×*nag*	−0.314**	0.128	−0.149	0.130
gen×*edu*	0.001	0.013	0.021	0.013
huj	−0.247***	0.053	−0.092	0.056
mar	0.111*	0.057	0.067	0.060
age	−0.033***	0.003	−0.004*	0.003
edu	−0.002	0.012	−0.015	0.012
nag	0.157	0.119	0.199	0.121
agr	−0.235***	0.072	0.388***	0.075
Constant term	−0.250	0.172	−0.499***	0.168
year	Yes		Yes	
Sample size	11,207		11,207	
Likelihood ratio chi-square	379.660***		469.981***	
R^2	0.029		0.038	

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

TABLE 7 Estimated results of the influence of family size on children's contribution to their parents' care.

Variable	Economic support		Life care	
	Coefficient	Standard error	Coefficient	Standard error
gen	−0.170***	0.063	−0.329***	0.064
gen×*siz*	0.178***	0.018	0.115***	0.019
huj	−0.210***	0.053	−0.074	0.056
mar	0.141**	0.057	0.090	0.060
age	−0.034***	0.003	−0.005*	0.003
edu	0.004	0.006	0.005	0.006
nag	−0.068	0.060	0.093	0.065
agr	−0.203***	0.072	0.405***	0.074
Constant term	−0.133	0.146	−0.607***	0.145
year	Yes		Yes	
Sample size	11,207		11,207	
Likelihood ratio chi-square	467.446***		504.464***	
R^2	0.036		0.040	

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

in off-farm work, laying the sociocultural foundation for them to support their parents. Combined, these two factors make daughters who take part in off-farm work more likely to provide economic support to their parents. Therefore, hypothesis 2 is verified. However, the cross-coefficient that pertains to housework is 0.149, and there are no statistically significant results. When both sons and daughters work in non-farm jobs, their ability to take care of their parents' housework will not be improved. Because time is a scarce resource, extended working hours reduce the ability of sons and daughters to provide support to their parents. In summary, a daughter's family and social status improves when she takes part in non-farm work, and her ability to provide economic support to her parents is enhanced.

Second, the coefficients of the cross-term of children's gender and years of education for economic support and household care are both positive but non-significant. Generally, children's education level is positively correlated with the extent to which they support their parents; that is, children with higher education levels are more likely to provide support. Previous studies have shown that when children have 17 years of education (college), there is no significant difference in the degree of economic support between sons and daughters, and when children have 8 years of education (junior high school), the difference in the support provided by sons and daughters in the form of household care disappears (11). One reason for our results may be that in our sample, only 14% of children have a college education or above, while 86% have an education level that lower than high school. When comparing results across education levels, we find that basic education has little effect on income; thus, the education level of children has little influence on the parents' retirement. This conclusion does not support hypothesis 3.

5.3. Number of children

The number of children has a certain impact on their support of their parents. Therefore, the cross-term between the gender of children and the number of children in a family is included in the analytical model. The result of the cross-term represents the impact of the number of children in a family on the ways in which these children support their parents.

As shown in Table 7, the coefficients of the interaction terms between children's gender and the number of children in a family are both positive and significant at the 1% level in terms of economic support and household care, indicating that in families with many children, sons play a relatively greater role in providing economic support and household care to their parents. The reason may be that in rural areas, people generally believe that it is "legitimate" and in line with tradition for sons to support their parents, so there is a greater expectation that sons will support their parents. Since people in rural areas believe that raising children provides security for their old age, it is not surprising that within the same family, sons provide more financial support and household care to their parents. After they marry, daughters are considered to be "spilt water." Parents expect little from daughters in terms of support because after marriage, daughters, along with their husbands, mostly serve their in-laws. If married women provide financial support to their parents and take care of housework for them, it is bound to cause dissatisfaction among their in-laws and conflict that is not conducive to family harmony. In addition, in rural families in which there are many children, children compete to show how much they support their parents, playing an exemplary role to improve the overall level of support they provide. However, when sons provide more economic and housework care, some daughters may be "free riders" and reduce the financial support and household care that they provide to their parents. The results show that in families with many children, sons provide more financial support and housework than daughters. Therefore, hypothesis 4 is supported.

6. Tests for robustness and endogeneity

6.1. Robustness tests

To test the robustness of our results, we used the propensity score matching (PSM) method to retest the above model. The PSM method can alleviate the problem of biased estimation caused by the incorrect setting of functional forms by reducing the dependence on functional forms. The scores shown in Table 8 tend to match the balance to the test results. The absolute value of the standard deviation of all matching variables is $<10\%$. The characteristics of the experimental group and control group are similar and match after matching the t value, and there are basically no significant variables. After matching the experimental group and control group, there is no significant difference in the balance after the data match. A total of 8,421 samples are obtained by the PSM method.

The coefficient signs and significance of the core explanatory variables in each model in Table 9 are basically consistent with the basic regression results, indicating that the estimation results of this study have a certain robustness. Among them, the coefficients of the interaction terms between children's gender and urban and rural household registration based on economic support and household care are −0.135 and 0.031, respectively, which are not significant (column 2 and column 3 of Table 8). This result indicates that there is no significant difference between the level of support sons and daughters provide to their parents in the urbanized countryside, which is consistent with the results of the basic regression. To verify whether socioeconomic status affects the ways in which children support their parents, two interaction terms are added successively: children's gender and off-farm work and gender and children's years of education. The results show (column 4 and column 5 of Table 8) that the interaction term between sons and off-farm work is significantly negative at the 5% level. This result indicates that daughters' participation in off-farm work significantly increases the amount of economic support they provide to their parents, but the interaction term between gender and off-farm work is not significant in terms of household care, indicating that, once they participate in off-farm work, neither sons nor daughters provide more domestic care to their parents. This result is consistent with the results of the basic regression. The cross-terms of sons and years of education are not significant in terms of economic support and household care, which

TABLE 8 PSM balance test.

Variable	Unmatched Matched	Mean Treated	Mean Control	% Bias	% Reduction |bias|	T test t	T test p>|t|
huj	*U*	0.31528	0.49803	−37.9		−15.8	0.000
	M	0.30698	0.30668	0.1	99.8	0.04	0.970
mar	*U*	0.8283	0.73126	23.6		10.14	0.000
	M	0.89399	0.89108	0.7	97	0.54	0.590
age	*U*	41.149	38.602	27.7		11.66	0.000
	M	40.151	40.198	−0.5	98.2	−0.36	0.718
edu	*U*	8.57	9.6933	−24.1		−10.46	0.000
	M	8.7862	8.8172	−0.7	97.2	−0.44	0.659
nag	*U*	0.51956	0.51972	0		−0.01	0.989
	M	0.54718	0.54894	−0.4	−948.8	−0.2	0.838
agr	*U*	0.23957	0.17308	16.5		6.48	0.000
	M	0.2514	0.2511	0.1	99.5	0.04	0.968

further indicates that the level of children's education has little influence on the support provided to their parents. To study the robustness of family size on the ways in which children support their parents, we add the interaction term between children's gender and family size and use the propensity matching score PSM method to conduct a fixed-effect regression. The results (column 6 and column 7 in Table 8) show that for families with many children, the coefficients of sons on economic support and household care are 0.196 and 0.103, respectively, and both are significant at the 1% level, indicating that the larger the family, the more financial support and household care son provide compared to daughters, which is consistent with the results of the basic model.

6.2. Endogeneity test

The endogenous problem between the core dependent variable and the independent variable must be avoided. According to the research methods of other scholars (45), the variable lags behind one period and is related to the current period. However, because the unobservable variable is determined in advance, the lag period of this variable is not related to the current disturbance term; thus, the subsequent period of the variable can effectively become a tool variable of the current period. In this study, the independent variable that lags one period is a tool variable. Table 10 shows the estimated results using the tool variables. First, tool variables were used to check whether there were endogenous variables present, and the effectiveness of the tool variables was evaluated. The results show that the endogenous test statistics reject the original hypothesis at the level of 1%, indicating that the endogeneity of the independent variable is significant; thus, the regression of the results using tool variables is more accurate. The test results of weak instrumental variables are all >10, indicating the absence of weak instrumental variable concerns. The above tests show that the tool variables selected in this paper are appropriate. The study found that sons have a positive but not significant impact on parents' economic support; son's life care for parents is significantly negative at the level of 5%, indicating that the daughter plays a significant role in parental life care.

7. Discussion

Our research not only contributes to an in-depth understanding of the changes taking place in China's rural family pension strategies but also has implications for policy in today's aging China. First, the tradition in rural areas of raising children to gain security in old age has led parents to prefer having boys. However, studies have shown that daughters are playing an increasingly important role in supporting their parents, especially because they perform housework. Will this change lessen the preference for boys in rural families? How will this change affect the gender imbalance in rural areas? These questions are worth further academic attention.

Second, in this research, we select rural families with many children, thus avoiding the influence of individual parental differences on children's support behavior, which is consistent with the reality of most families with many children in rural China. Studies have shown that the larger the family, the more financial support sons provide; that is, when there are fewer children, daughters provide more support to their parents. This result is valid mainly when resources are scarce; hence,

TABLE 9 Robustness estimation results for the effect of children's gender role on the ways in which they support their parents.

Variable	Differences between urban and rural areas		Socioeconomic status		Number of children	
	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error
gen	0.105 (0.081)	−0.180** (0.081)	0.250* (0.139)	−0.288** (0.135)	−0.221*** (−3.207)	−0.306*** (−4.368)
gen×*huj*	−0.135 (0.123)	0.031 (0.126)				
gen×*nag*			−0.285** (0.140)	−0.085 (0.145)		
gen×*edu*			−0.004 (0.015)	0.018 (0.015)		
gen×*siz*					0.196*** (9.040)	0.103*** (4.566)
huj	−0.117 (0.113)	−0.115 (0.116)	−0.227*** (0.063)	−0.092 (0.067)	−0.184*** (-2.887)	−0.074 (−1.095)
mar	0.097 (0.076)	0.056 (0.080)	0.096 (0.076)	0.057 (0.080)	0.128∗ (1.687)	0.073 (0.912)
age	−0.032*** (0.004)	−0.003 (0.004)	−0.031*** (0.004)	−0.003 (0.004)	−0.033*** (−9.030)	−0.004 (−1.061)
edu	−0.001 (0.007)	−0.003 (0.008)	0.001 (0.013)	−0.016 (0.013)	0.003 (0.343)	−0.002 (−0.273)
nag	−0.105 (0.073)	0.182** (0.080)	0.110 (0.129)	0.245* (0.133)	−0.070 (−0.959)	0.198** (2.480)
agr	−0.199** (0.086)	0.494*** (0.090)	−0.226*** (0.086)	0.490*** (0.091)	−0.192** (−2.234)	0.498*** (5.533)
Constant term	−0.229 (0.188)	−0.649*** (0.190)	−0.327 (0.206)	−0.567*** (0.205)	−0.182 (−0.982)	−0.656*** (−3.511)
year	Yes	Yes	Yes	Yes	Yes	Yes
Sample size	8,421	8,421	8,421	8,421	8,421	8,421
Likelihood ratio chi-square	266.691	390.330	271.716	391.737	346.618	410.872
R^2	0.027	0.041	0.027	0.041	0.035	0.043

Standard error in parentheses; $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

daughters make a passive choice, leading to more material and spiritual support for elderly individuals. However, as the birth rate continues to decline and the rural population continues to age, causing an increasing number of rural families to have only one child, the burden of family pension will further increase. The adjustment of the number of children in rural families alone is not a long-term solution to the problem of rural family old-age care. New models of old-age care, such as rural home care and community care, can not only meet the needs of elderly people in rural areas but also reduce children's burden of caring for elderly parents.

Finally, we consider the role of children's gender in the level of financial support they provide to their parents based on two factors, but due to limitations in the data, this paper has the following deficiencies. First, only in 2010 did the data show how far children live from their parents, and distance greatly affects children's level of support to their parents. Generally, children living close to their parents provide more support. Moreover, we do not consider daughters-in-law and their husbands in the family support system. In rural areas, married daughters traditionally join their husbands' families and, together with their husbands, are required to serve their in-laws, and sons-in-law, to a certain extent, participate in supporting their parents.

TABLE 10 Test results of instrumental variables of children's parental support behavior.

Variable	Economic support	Life care
L_gen	0.002 (0.031)	−0.081**(0.030)
Control variable	Yes	Yes
Weak identification test	1,812.762	1,812.762
Underidentification test	1,521.650	1,521.650

Standard error in parentheses, $^{**}p < 0.05$.

However, because the data do not investigate the support provided by daughters-in-law and sons-in-law, it is difficult to distinguish the share of support provided by daughters and sons-in-law and sons and daughters-in-law. Therefore, the family support system needs to be further explored.

8. Conclusion

Based on the fourth set of panel data of the Chinese Family Tracking Survey (CFPS), we investigate the differences in the ways in which children support their parents and the mechanisms that influence this support in rural families from the perspectives of economic support and life care. We find that in rural areas, sons mainly provide economic support, while daughters mainly provide life care, thus forming a gender division of labor in rural areas. There is no significant difference between sons and daughters in rural areas and urban areas. Children's education level is positively related to the level of support they provide to their parents, but our regression results are not significant. With the increase in off-farm job opportunities, daughters provide more financial support to their parents but reduce the time they spend on housework for them. With the increase in the number of children in a family, daughters may free-ride, allowing others to support their parents, and their share of support decreases, while sons provide relatively more in terms of both economic support and household care. Our research shows that although the traditional son-centered support system in China has not completely disintegrated, it has changed significantly. In general, changes in the size of the population and improvements in women's status are important factors in explaining the changes taking place in the rural family support model.

This work provides three potential contributions. First, different from thought research regarding intergenerational relationships in a whole model, this article focuses on the role identity of internal subjects in a family and shows the characteristics of the individual in the family, which is conducive to theoretically explore tension in intergenerational relationships. Studying individuals and families helps explain contemporary China's model of rural family generation ethics and intergenerational solidarity (46). Most scholars believe that the function of rural family pension has been weakened; however, this study finds that the family pension model with children supporting the elderly as the core still occupies a very important position in rural areas. Different from previous studies, this paper finds that there is exclusion and substitution in economic support and life care provided by children in rural elderly populations. The probability of the rural elderly receiving economic support and life care from their children is relatively low. This finding is in line with the reality that the spatial distance between children and parents increases abruptly due to the transfer of the young and middle-aged rural labor force and the decreased opportunity for children to live with the elderly due to the transformation of the rural family core (47).

Second, families are classified more carefully here according to the number of children, family size and gender of children to fully show the heterogeneity and complexity of intergenerational relationships and old-age care models in rural families with different structural types. In the multi-child family supporting the elderly shown in this paper, daughters may demonstrate free-riding behaviors in terms of parental support, and their input in parental support is reduced, while sons play a relatively large role in both economic support and household care. Women provide emotional support and do not fully consider the economic ideal of the initiative to pay, reflecting the unique role of women in the family pension. In spite of reduced conventions in rural households, China's rural system is still not similar to the western individual framework, and families still follow traditional Chinese family roles. Sons remain in a dual system of ethics and moral emotion regarding specific financial responsibilities, representing intergenerational ethics and solidarity that differ substantially from western ideals. The change in family social status leads to different pension modes. With the improvement of women's social and economic status and the rationalization trend of "daughter pension" in public opinion and ethics, daughters gradually increase parental economic support and life care, and this support is considered altruistic with the concept of filial piety and gratitude. Sons are more likely to follow the traditional norms in rural areas. Supporting their parents is a reflection of following the traditional theory of filial piety and fulfilling their responsibility to support (48, 49).

Third, the discussion of the above issues has refined the description of rural family pension resources in China, which has certain reference significance for improving rural pension policies and actively dealing with the aging population. With the change in rural fertility concepts, the trend of the family core is enhanced. As for how to increase rural elderly care, the authors believe that the government, the market and the family multi-dimensional main body should coordinate and assistant in a complementary manner (46). Based on the trend of increasing intergenerational support provided by rural daughters to their parents, social gender preferences should be changed from a preference for sons to a social consensus that "adopted daughters can also protect their old age." Finally, the government needs to increase the financial expenditure and resource input for rural elderly care through policies that provide public services and prioritize the groups with weak rural elderly care resources.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

SY: conceptualization. WY: methodology, data curation, and writing—original draft preparation. ZJ: formal analysis, writing—review and editing, and supervision. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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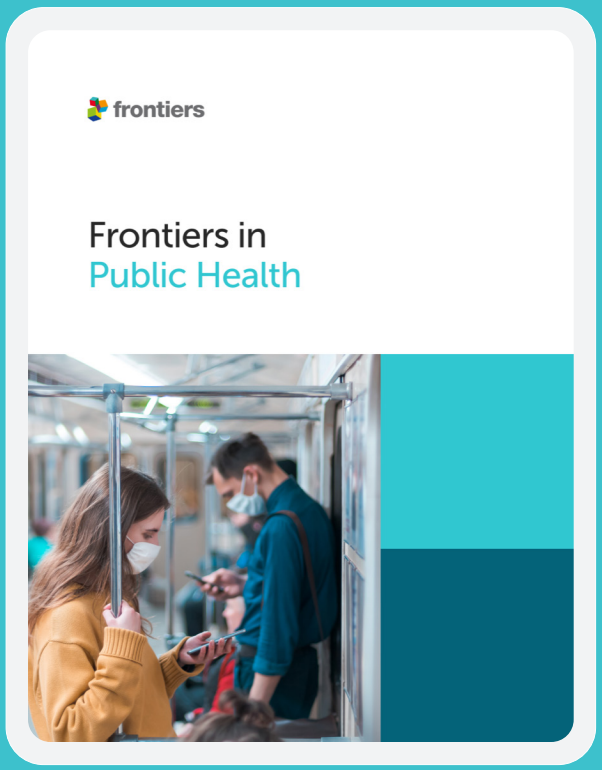

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