RESEARCH

The impact of internet medical service on rural gender inequality in health opportunity: a cross-sectional study

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Abstract

Background The increasing popularity of Internet medical service may have alleviated the gender inequality in health opportunity faced by rural women. However, research to ascertain the association between Internet medical service and gender inequality in health opportunity is scarce. This study explored the impact of Internet medical service on gender inequality in health opportunity among rural women and the underlying mechanisms involved.

Methods A multistage stratified cross-sectional survey was conducted across six counties in three provinces in China, yielding 3,108 responses for a 97.13% response rate. The questionnaire was used to collect information on Internet healthcare use, health status, health behaviors, social activities and personal exercise, chronic disease status, and demographic and socio-economic characteristics of the participants. Based on Roemer's theory of equality of opportunity (EOP), we established a decomposition strategy for the fairness gap between genders, which we used for the measurement of the gender inequality in health opportunity Fixed effects models, propensity score matching (PSM), and least absolute shrinkage and selection operator (LASSO) regression were utilized to explore the impact of Internet medical service on rural gender inequality in health opportunity.

Results On average, rural women experienced a gender health fairness gap of 1.63. Internet medical service significantly mitigated this inequality ($\beta = -0.0602$, $P = 0.0002$), and this finding remained significant across propensity score matching (PSM) and LASSO regression analyses. Mechanistic analysis revealed that human capital positively moderates this effect ($\beta = -0.0510$, $P < 0.01$), while income ($\beta = 0.0370$, $P < 0.001$) and marital status ($\beta = 0.2039$, $P < 0.001$) have negative moderating effects.

Conclusions By focusing on gender inequality in the digital era, this study highlights the mitigating role of Internet medical service on gender inequality in health opportunity in rural areas. This study proposes and validates the mechanisms through which Internet medical service alleviates gender inequality in health opportunity, suggesting that human capital amplifies this effect, while high personal income and marital status attenuate this effect. These findings contribute to understanding how the digital age can narrow gender health opportunity equality, providing support for future interventions aimed at promoting health equity and gender equality.

Keywords Internet medical service, Gender equality, Health opportunity, Human capital, Income, Marital status

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Background

According to data from the Seventh National Population Census of China, women constitute 48.76% of the total population [1], with approximately 250 million women aged 16–70 years engaged in production and business activities in rural areas [2]. Women's health impacts not only their quality of life but also their economic participation and ability to provide for themselves and their families. The complex relationships among health, economic productivity, prosperity prospects, and contributions to economic output are significant [3]. The World Economic Forum estimates that narrowing the health gap could improve women's health conditions, enabling more active participation in the labor market and potentially increasing the GDP per capita by 1.7% [4].

Nevertheless, a substantial body of research has demonstrated that women are at a distinct disadvantage in terms of their health compared to men [5–9]. Lois M [6]. draws a parallel between this phenomenon and an "iceberg on the water," noting that while men's serious illnesses represent only the visible portion of the iceberg that rises to the surface, women's numerous chronic illnesses are akin to the submerged, vast majority that remains hidden. Studies show that women spend 25% more time in poor health than men [4]. Gender theory posits that gender is not merely a biological attribute; rather, it is a socially and culturally constructed role [7]. This discrepancy in health outcomes between genders is a manifestation of gender inequality [8]. The United Nations estimates that less than 1% of women and girls globally live in environments that achieve high levels of female empowerment and gender equality [9]. Furthermore, the 2023 China Global Gender Parity Index (GGPI) indicates that China ranks only 107th, a decline of five places from 2022. Notably, this performance is even worse in rural China [10], where economic conditions are more disadvantaged. Rural women in China encounter a multitude of economic, cultural, and familial obstacles when attempting to access healthcare services. Firstly, rural women are typically less economically independent, relying on family income and lacking independent financial resources. This economic dependence often results in delayed or even abandoned medical care, frequently due to cost considerations [11]. Secondly, educational conditions in rural areas are relatively underdeveloped, with women's educational attainment generally lower than that of men [12]. This contributes to a lack of essential health knowledge and cognitive abilities among many women. The dearth of knowledge among rural women makes it challenging for them to identify and address health issues promptly, thereby increasing their susceptibility to illness. Conversely, the lack of cognitive capacity frequently results in rural women prioritising the wellbeing of their family members over their own healthcare needs. Thirdly [13], the traditional view of women as the primary caregivers within the family unit. A substantial body of research has demonstrated that rural women bear responsibility for a multiplicity of roles [14], including the care of children and the elderly, as well as participation in agricultural production and other economic activities. This multifaceted role presents a significant challenge for rural women in terms of time management and energy allocation. Furthermore, the challenges rural women face with regard to childbearing and nutrition must be acknowledged. Inadequate prenatal nutrition and a dearth of postnatal care have a direct impact on the health of mothers and infants [15]. A considerable number of rural women are deprived of sufficient nutritional assistance during pregnancy and lack the requisite medical attention following childbirth, resulting in heightened health complications. Therefore, the health disadvantages that women in rural China show compared to men are due to gender-specific differences in health resources and health power, which are unjustified gender inequalities in health opportunities.

In the twenty-first century, advances in information technology and the emergence of the internet have created a new information and media ecosystem, pushing society towards greater network connectivity. This technological progress has made high-quality medical resources more accessible [16]. According to the China Internet Network Information Center (CNNIC), the number of Chinese internet users increased from 854 million (61.2%) in 2019 to 1.079 billion (76.4%) in 2023, with rural internet users increasing from 225 million (16.1%) to 308 million (21.8%) [17].The proportion of female internet users has steadily increased to 49.5% [18]. As of December 2022, the number of users of internet-based medical services in China had reached 363 million, accounting for 34 percent of the total number of Chinese netizens [17]. The COVID-19 pandemic accelerated the digital transformation of daily life and increased access to health resources for vulnerable groups [19]. Studies show that women are more likely than men to use Internet medical service platforms [20] and benefit from online resources [21]. Therefore, investigating whether Internet medical service can reduce gender-based health opportunity inequality among rural women is crucial for advancing gender health equity.

Previous studies have focused more on inequality of health outcomes than inequality of health opportunities in research on gender health disparities, and there have been fewer studies on the relationship between Internet healthcare and inequality of health opportunities for gender, so the research objective of this study is to explore the impact of Internet healthcare on inequality of health

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opportunities for gender in rural areas and to explore the role of Internet healthcare on inequality of health opportunities for gender in terms of the individual, the family and the social mechanism, to further explore gender equality and digital social governance ideas, and to provide a basis for the development of social equity and justice and the realisation of gender equality goals. The study hypothesizes that: (1) there is inequality in health opportunities for rural women in China; (2) Internet medical care can alleviate the inequality in health opportunities faced by rural women; and (3) human capital, marital status, and income play a moderating role in the effect of Internet medical care on this improvement.

Methods

Data sources

This study was conducted from June to October 2023, collecting questionnaire data from three provinces and direct-administered municipalities (Zhejiang, Gansu and Chongqing) and six districts and counties within them. A multistage composite sampling method was employed, with investigators distributing paper questionnaires one-by-one to residents aged 15–70 years within rural households. Out of 3,200 distributed questionnaires, 3,108 were deemed valid, resulting in a 97.13% response rate. 92 samples were excluded because they either refused to be interviewed, did not complete all the questions, or answered too quickly. All surveys were conducted anonymously, solely for research purposes, and with strict confidentiality. The questionnaire mainly includes the usage of internet healthcare, the European Five Dimensions of Health-Related Quality of Life Scale (EQ-5D-3L), the Health Literacy Scale (HLS-SF 9), health behaviors, social activities and personal exercise, chronic disease status, and the demographic and socioeconomic characteristics of the participants. The internal consistency of the questionnaire scales was confirmed with Cronbach's α coefficients ranging from 0.758 to 0.921, indicating high reliability and measurement validity. This study was approved by the ethics committee of Tongji Medical College, Huazhong University of Science and Technology (IORG No: IORG0003571).

Variables

Internet medical service

The fundamental goal of Internet medical service is to enhance the accessibility of quality medical resources. Its most common application involves users accessing health information online [22]; thus, the frequency of Internet medical service information retrieval was used to measure Internet medical service usage status. The response categories were: not used, occasionally, and often.

Measuring health opportunity between genders

Roemer's theory of inequality of opportunity assumed that a person's advantages are determined by both circumstance and effort and defined individuals in the same circumstance as being of the same type; inequality of opportunity was essentially that given a person's level of effort, the advantages he received were equal regardless of the circumstance he was in. For the EOP analysis, Fleurbaey proposed two principles: the reward principle and the compensation principle [23]. The basic idea of the compensation principle was that no matter what the circumstance is, individuals should obtain the same advantages with the same efforts, and inequalities caused by circumstance should be compensated for. Fleurbaey [24] defined the fairness gap under the compensation principle: given an ideal circumstance (c*), the individual advantage under the ideal circumstance is y*, and the fairness gap is the difference between the actual advantage and the advantage under the ideal circumstance (y*-y). This study was based on the compensation principle because the principle emphasizes how to compensate rural women for their disadvantages due to their circumstance (gender), which is more relevant to the topic of this study.

The first step was to assess the health status of rural residents. The study employed the EQ-5D-3L, a three-level version of the European health-related quality of life index, to generate a composite health score [25]. The EQ-5D-3L is a standardized instrument for measuring health status, widely recognized for its simplicity, ease of use, and high reliability. It covers five dimensions (mobility, self-care, usual activities, pain/discomfort, and anxiety/depression), with three levels within each dimension (1=no problems, 2=some/moderate problems, 3=extreme problems). This study used a health utility value integration system developed by Liu [26], which was based on Chinese population preferences to calculate composite scores.

In this study, the individual advantage is health. Since this study examines gender differences in inequality of health opportunity for rural women, the only circumstance variable (c) is gender (male=1, female=0), and the remaining variables are effort variables (e). Considering that the marginal effects of health inputs are likely to be gender-differentiated, so an interaction term between the two was added to the above model [23]. so the health function can be expressed as:

$$h_i = \alpha + \beta c_i + (\gamma + \lambda c_i)e_i + u_i \tag{1}$$

According to the Roemer partial environmental effect [27], some effort factors are largely affected by circumstance factors and are not completely controllable by individuals. Referring to the method of Fleurabaey et al. [24],

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the effort factors are divided into e^1 (the effort variable affected by the circumstance) and e^2 (the pure effort variable). This study draws on the U.S. Institute of American Institute of Medicine 's definition [28] of group health disparities and Machao's method of dividing effort variables [29, 30], defining e^1 as factors that can affect health while being differentiated by gender, and e^2 as fully reflecting an individual's health preference. The e^1 variables include: human capital, marital status, employment status, income, medical choice, and medical insurance participation. The e^2 Variables included: age, health literacy, health behaviors, exercise frequency, social activity, and chronic disease. Notably, given the right-skewed distribution of income, this study log-transformed income before introducing it into the model to avoid potential heteroskedasticity problems. (see Table 1). Health literacy was measured using

the HLS-SF 9 scale, which is widely utilized in China and consists of nine items focused on healthcare, disease prevention, and health promotion. Respondents rated their understanding on a 4-point scale (1=very difficult, 2=difficult, 3=easy, and 4=very easy). The choice of medical care was assessed by asking respondents, "What kind of medical institution would you choose to go to in the event of an injury or illness within two weeks?" The options provided included three types of institutions: (1) village health center, (2) township health center, and (3) hospital above county level. Medical insurance coverage was evaluated through three questions: (1) Are you currently enrolled in employee medical insurance? (2) Are you currently enrolled in urban and rural basic medical insurance? (3) Are you currently enrolled in commercial medical insurance? Health behaviors were defined in terms of smoking

Table 1 Variable definitions and descriptive analysis (mean (SD))

Variables	Definitions	Total	male(*n* = 1648)	Female(*n* = 1460)
Health outcome	EQ-5D utility value	0.90 (0.18)	0.91 (0.19)	0.90 (0.17)
Internet medical service	0 = Not used 1 = Occasionally 2 = Often	0.33 (0.60)	0.41 (0.66)	0.24 (0.50)
Age	Actual age	55.53 (19.53)	54.30 (20.22)	56.92 (18.62)
Human capital	1 = Never attended school 2 = Elementary school 3 = Middle school 4 = High school and above	2.49 (1.26)	2.71 (1.25)	2.25 (1.23)
Marital status	0 = Unmarried 1 = Married	0.77 (0.42)	0.77 (0.42)	0.77 (0.42)
Employment status	1 = Not working 2 = Working	1.58 (0.49)	1.52 (0.50)	1.64 (0.48)
Income	Actual annual income	20,619.81 (37,647.26)	25,576.59 (46,485.99)	15,024.77 (22,798.18)
Medical choice	1 = Village health centers 2 = Township health centers 3 = Hospitals above county level	1.53 (0.72)	1.53 (0.72)	1.53 (0.71)
Health literacy	Health Literacy Score (1–5)	4.42 (0.83)	4.43 (0.83)	4.40 (0.84)
Urban employee insurance	0 = uninsured 1 = insured	0.11 (0.32)	0.14 (0.35)	0.09 (0.28)
Urban rural resident insurance	0 = uninsured 1 = insured	0.90 (0.30)	0.88 (0.33)	0.92 (0.28)
Commercial insurance	0 = uninsured 1 = insured	0.03 (0.18)	0.04 (0.19)	0.03 (0.17)
Smoking	0 = No smoking 1 = Smoking	0.24 (0.43)	0.43 (0.49)	0.02 (0.16)
Drinking	0 = no alcohol 1 = alcohol	0.22 (0.41)	0.37 (0.48)	0.05 (0.21)
Exercise frequency	Average number of workouts per week in the last 30 days	3.35 (3.53)	3.20 (3.47)	3.51 (3.59)
Social activity	1 = never 2 = once a year 3 = once a month 4 = once a week 5 = once a day	2.23 (1.48)	2.24 (1.45)	2.22 (1.51)
Chronic disease	1 = without chronic disease 2 = with chronic disease	1.10 (0.79)	1.11 (0.79)	1.09 (0.79)

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and alcohol consumption. Smoking was measured by identifying whether participants had smoked at the time of the survey, while alcohol consumption referred to any drinking behavior within the past year. Physical exercise was considered as activities consciously performed for fitness, excluding agricultural work or physical labor; participation was categorized as engaging in physical exercise at least three times per week for a minimum of 30 min per session. For the social activity variable, respondents were asked, "In the past year, did you participate in social activities? (e.g. recreational activities such as square dancing, playing cards and chess, volunteer activities, religious activities such as worshipping Buddha and paying homage, etc.)".

To measure the e^1 variables, we convert them to pure effort factors. In different circumstances, individuals located in the same income distribution have the same level of effort, and resources should be allocated based on the relative effort of individuals in the "circumstance" to which they belong [32]. Therefore, this study, based on the processing method of Roemer [33], replaces e_i^1 with the relative ranking (quantile) π_i^1 of the e_i^1 variable within gender. The two can be expressed by the following functional relationship:

$$e_i^1 = a + bc_i + (d + mc_i)\pi_i^1 + \tau_i \qquad (2)$$

When e^1 is a continuous variable such as income, the quantile of the variable in the female sample can be directly calculated. When e^1 is a discrete variable such as medical choice, the propensity value of each sample is first calculated through the logistics model. The quantile of each sample is then converted based on the propensity value. Therefore, Eq. (1) can be transformed into:

$$h_i = \alpha + \beta c_i + (\gamma + \lambda c_i)\pi_i^1 + (\theta + \eta c_i)e_i^2 + u_i \quad (3)$$

According to Eq. (2), assuming that rural men are in an ideal circumstance (c*), the difference between the estimated health counterfactual value and the actual value of the health equity gap between genders in the ideal circumstance is:

$$fg_i = h_i^* - h_i = \widehat{\beta}(1 - c_i) + \widehat{\lambda}(1 - c_i)\pi_i^1 + \widehat{\eta}(1 - c_i)e_i^2 \qquad (4)$$

When $c_i = 0$, the corresponding fg_i is the health equity gap faced by rural women from men, which reflects the inequality of health opportunity for rural women:

$$fg_i = \widehat{\beta} + \widehat{\lambda}\pi_i^1 + \widehat{\eta}e_i^2 \qquad (5)$$

Moderating variables

According to the social determinants of health (SDoH) [34], this study categorizes the sources of gender inequality in health opportunity into three aspects—individual, family and society—and selects moderating variables for each. At the individual level, human capital is closely related to individual health [35] and is most closely related to the digital divide that may be brought about by Internet medical service [36]. Therefore, human capital is chosen as the moderating variable at the individual level, using educational level as a measure, following the approach of Chen et al. [35]. According to traditional gender cultural norms and gender role theory, married and unmarried women differ in terms of family resource allocation and health status [37, 38]. Therefore, marital status is used as a moderating variable at the family level. Last, at the social level, varying incomes imply different socioeconomic statuses, leading to differences in resources and health opportunity from society [39]. Thus, we use income as the moderating variable. (see Table 1).

Data analysis

This study uses a fixed effects model (fixed effects for region) as the baseline model to analyze the impact of Internet medical service on rural gender inequality in health opportunity, and uses propensity score matching (PSM) and least absolute shrinkage and selection operator (LASSO) regression to test the robustness of the results. PSM uses the nearest neighbor matching method to match the association variables to make the samples of men and women as consistent as possible, while LASSO regression quickly compresses the coefficients of non-important explanatory variables to zero, retaining important explanatory variables, and thereby playing a role in variable selection of explanatory variables. Both methods aim to avoid multicollinearity and endogeneity among variables from distorting the regression results during the regression process.

Statistical analysis

Data entry and database creation were conducted using EpiData 4.6, with data analysis and model building performed in R version 4.3.1. Descriptive statistics were employed for all variables, using means and standard deviations. A significance level of $p < 0.05$ was considered statistically significant.

Results

Measurement of health opportunity inequality faced by rural women

The average gender health opportunity fairness gap is 1.63 ± 0.06 ($p < 0.001$). This indicates that replacing rural women with men would on average increase the health

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score by 1.63 units, highlighting a significant gender disparity in health opportunity within the rural context.

Empirical test of internet medical service's impact on gender health opportunity inequality in rural areas

Using a fixed-effects model as the baseline, our analysis quantified the effect of Internet medical service on mitigating gender health opportunity inequality among rural women, as shown in Table 2. Internet medical service was found to significantly alleviate this inequality. The elasticity coefficient of Internet medical service usage was -0.0602 ($P=0.0002$), indicating that increasing the frequency of Internet medical service usage from "never" to "often" reduces the health opportunity inequality faced by rural women by 12.04%.

To assess the robustness of our findings, both propensity score matching (PSM) and LASSO regression methods were employed. Before applying the propensity score matching model, it was essential to verify that the matching satisfied two types of assumptions. The distribution of the propensity score fitting values is shown in Fig. 1. After matching, a significant overlap and coverage area between males and females were evident, indicating that the samples from both groups became quite similar in various aspects, suggesting a good matching effect. Figure 2 shows the trend of the LASSO model prediction mean squared error as a function of the parameter λ, with the model's variable selection effect becoming more pronounced as the logarithmic value increases. When the variable count was eight, the model's mean squared error was kept below the critical point, achieving a balance between prediction accuracy and factor selection. The results from PSM regression (β = -0.0006, $P < 0.01$) and LASSO regression (β = -0.0009, $P < 0.001$) were consistent with the baseline findings, confirming the robustness of the empirical results. This means that Internet medical service plays a significant role in alleviating gendered health opportunity inequality among rural women. (see PSM and LASSO results in additional file 1).

Analysis of the mechanism by which internet medical service alleviates gender health opportunity inequality

The results of the moderating effect analysis are shown in Table 3. First, we address moderating role of human capital. The coefficient for Internet medical service in the baseline model was negative, while the coefficient for the interaction between Internet medical service and human capital was -0.0510 ($P < 0.01$), indicating that human capital plays a positive moderating role in the process of Internet medical service alleviating the health opportunity inequality faced by rural women.

Table 2 Regression results

	Baseline model	PSM	LASSO
Internet medical service	-0.0602**	-0.0760**	-0.0827***
	(0.0222)	(0.0251)	(0.0234)
Age	0.0022*	0.0027**	
	(0.0009)	(0.0010)	
Human capital	0.0962***	0.1739***	0.1015***
	(0.0127)	(0.0144)	(0.0124)
Marital status	0.1475***	0.1423***	
	(0.0352)	(0.0400)	
Employment status	-0.2114***	-0.2209***	0.0118
	(0.0329)	(0.0361)	(0.0310)
Income	-0.0852***	-0.0797***	-0.0000***
	(0.0039)	(0.0044)	(0.0000)
Medical choice	-0.0943***	-0.1051***	-0.1055***
	(0.0189)	(0.0207)	(0.0199)
Health literacy	0.0310+	0.0289+	
	(0.0159)	(0.0174)	
Urban employee insurance	-0.5015***	-0.6319***	-0.6009***
	(0.0619)	(0.0726)	(0.0475)
Urban rural resident insurance	0.0920	0.1636*	
	(0.0622)	(0.0723)	
Commercial insurance	0.4473***	0.5955***	0.3954***
	(0.0726)	(0.0836)	(0.0768)
Smoking	-0.4906***	-0.5555***	
	(0.0356)	(0.0404)	
Drinking	-0.2159***	-0.2213***	-0.5169***
	(0.0369)	(0.0419)	(0.0378)
Exercise frequency	0.0054	0.0062	-0.2415***
	(0.0038)	(0.0043)	(0.0390)
Social activity	0.0010	-0.0023	
	(0.0090)	(0.0099)	
Chronic disease	-0.0012	-0.0064	
	(0.0164)	(0.0175)	
Fixed effects for region	Yes	Yes	Yes
Num	3108	2628	3108
R²	0.325	0.338	0.239

+ $p < 0.1$ * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

This suggests that human capital can further enhance the mitigating effect of Internet medical service.

Second, there is a moderating role of marital status. The coefficient for the interaction between Internet medical service and marital status was 0.2039 ($P < 0.001$), indicating a negative moderating effect of marital status on the mitigation of health opportunity inequality through Internet medical service. This means that the mitigating effect of Internet medical service on gendered health opportunity inequality is more significant among unmarried individuals compared to married ones.
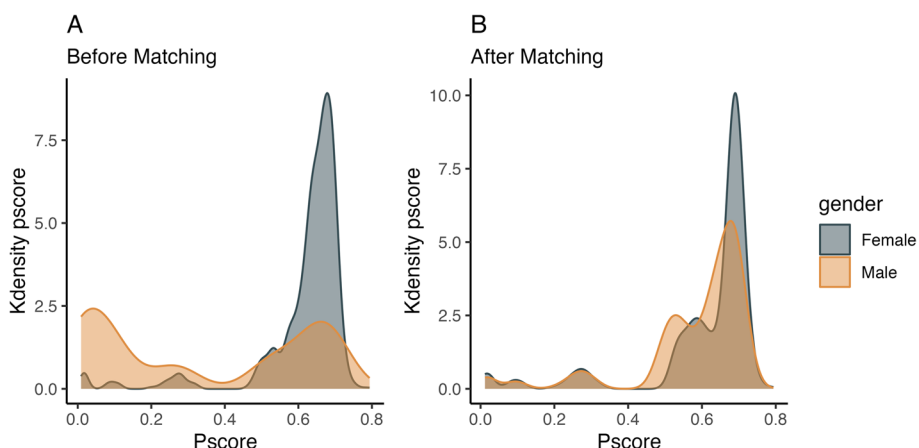
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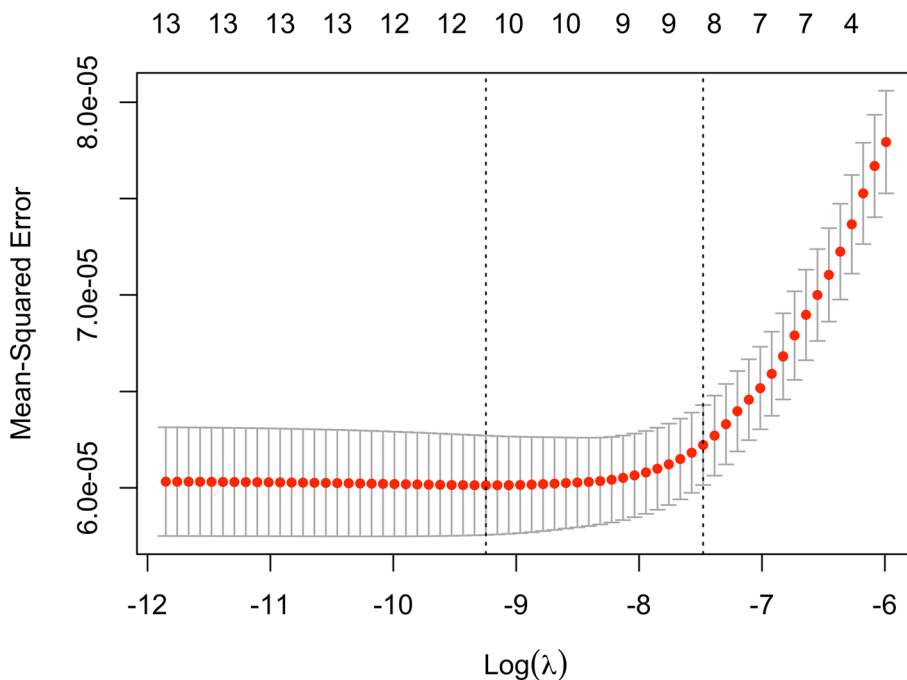**Fig. 1** Kernel density plot before matching (Left) and after matching (Right)

Fig. 2 LASSO variable selection diagram

The third one is the moderating role of income. The coefficient for the interaction between Internet medical service and personal economic status was 0.0370 ($P < 0.001$), showing that personal economic status negatively moderates the process by which Internet medical service alleviates health opportunity inequality for rural women. Thus, the alleviating effect of Internet medical service on health opportunity inequality is more pronounced among those with lower incomes.

Discussion

This study, from the perspective of inequality in health opportunity, demonstrates the existence of gender health inequality in rural China and how Internet medical service significantly mitigates this health opportunity inequality. This study further validates the mechanisms through which Internet medical service alleviates gender-based health opportunity inequality at the individual, family, and social levels.

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Table 3 Analysis of the mechanisms by which internet medical service alleviates rural health opportunity inequality

	Equation 1	Equation 2	Equation 3
Internet medical service × human capital	-0.0510**		
	(0.0167)		
Internet medical service × marital status		0.2039***	
		(0.0537)	
Internet medical service × income			0.0370***
			(0.0056)
Human capital	0.1149***	0.0995***	0.0977***
	(0.0141)	(0.0127)	(0.0126)
Marital status	0.1434***	0.0887*	0.1389***
	(0.0352)	(0.0384)	(0.0350)
Income	-0.0853***	-0.0854***	-0.0948***
	(0.0039)	(0.0039)	(0.0042)

Control variables include employment status, medical choice, medical insurance participation, health literacy, health behavior, exercise frequency, social activity status, and chronic disease

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

Our findings confirm that Internet medical service can reduce the gendered health opportunity inequality in rural areas. The diminishing effect is attributed to the transformation of the traditional industrial society's power structure in the internet society, where the flow of information and resources evolves [40]. Internet technology democratizes and networks information distribution [41], presenting diverse health knowledge and medical information to the public in a highly affordable manner, thus facilitating the democratization of medical information [42]. With the rapid development of Internet medical service, the overflow of information helps alleviate the asymmetry between doctors and patients, potentially influencing public health judgement and cognitive structures [43], enhancing disease prevention and health management abilities, and, consequently, improving health literacy and levels [44]. The internet medical service revolutionizes the traditional face-to-face medical service model, addressing the limitations of geographical distribution, economic, and medical standards in providing equitable, continuous health services throughout the life cycle. It enables patients to reduce non-medical costs such as accommodation and transportation, thus improving the economic accessibility of medical resources and mitigating the negative impact of income inequality on medical care access. Studies have shown a 6.19% reduction in individual medical expenditures due to internet medical information overflow [45]. Moreover, digital technology can be effective in promoting women's health empowerment [46, 47]. The convenient and cross-regional nature of Internet medical service enhances the economic accessibility, timeliness, and geographical

reach of quality medical services, helping to dismantle the social stigma surrounding women's medical care and encouraging them to seek medical and other health services, thus freeing rural women from traditional constraints [48]. Internet resources previously inaccessible due to gender barriers become available, thereby easing gender health opportunity inequality.

Our results indicate that human capital plays a positive moderating role in the process through which internet medical care reduces gendered health opportunity inequality. Human capital, as an intangible productive resource,has a positive impact on individual health [49]. On the other hand, it can directly affect the possibility and frequency of Internet medical use and greatly determine the probability of individual acceptance of the health promotion function of Internet medical [50], so that people with high human capital can gain more in the process of Internet medical mitigation of gender health inequality of opportunity. For rural women, higher levels of human capital usually reflect higher socioeconomic status, more comprehensive and faster network coverage in the area of residence, more openness to gender roles, and greater acceptability of Internet healthcare [51]. Rural women with high human capital are then more likely to cross the access and skill gaps of Internet use, and gain more benefits from it.

This study also revealed that marriage plays a negative moderating role in narrowing gender inequality in health opportunity through Internet healthcare. This implies that married women in rural areas have difficulty in sharing the benefits of Internet medical service. This is due to the persistence of unequal health power between males

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and females within the households in rural areas. Social gender norms have expectations of male and female behavior [52], and the theory of gendered division of household labor suggests that in the male-dominated, female-dominated gender division of labor model, men in the household are defined as breadwinners, while women are defined as homemakers and educators [13]. Women have long been in a situation where their socioeconomic status is lower than that of men, and resources and power within the family are tilted in favour of men. Women's autonomy in health decision-making and ability to access health resources are subject to many limitations [53], and they are a disadvantaged group in terms of access to health opportunity. On the other hand, in terms of access to and use of Internet healthcare, marital status may affect an individual's perception of health issues and health decision-making patterns [54], making married women more inclined to seek traditional healthcare services or rely on the advice of family members rather than use Internet healthcare resources [55].

This study revealed that income plays a negative moderating role in the process of reducing gender inequality in health opportunity through Internet medical service, in other words, lower-income women benefit more from Internet medical service in reducing gender inequality in health opportunity. This is because Internet healthcare promotes the diffusion of quality healthcare resources, and greatly reduces the economic, transportation and time costs for low-income women to access quality healthcare resources. It has been proven that the poor people usually have less access to offline healthcare than the affluent ones [56]. Moreover, grassroots women's and children's organizations are on the decline, the gender sensitivity of the grassroots public health system in the countryside has been drastically decreased [57], which makes it even more difficult for low-income women in the rural areas to have access to offline high-quality healthcare resources [58]. Perspectives from the psychological theory of social class emphasize that an individual's perceptions and attitudes are influenced by one's economic status [59]. Individuals with higher incomes tend to travel to offline hospitals for medical treatment, which can have a crowding out effect on Internet healthcare [60]. Rural women with low incomes are more likely to seek medical treatment on the Internet than in hospitals due to economic costs, transportation costs, and time costs [15], so Internet healthcare has a greater effect on alleviating their unequal health opportunity.

There are also some limitations to this study. First, the study is a cross-sectional study, and it is not possible to explain cause-and-effect relationships between variables. Longitudinal studies, such as cohort studies, may be helpful for this purpose. In addition, our study explored the impact of the Internet medical service on gender inequality in health opportunity in rural areas, and there are many unexplored factors. It is hoped that the future research can explore more mediating or moderating variables and enrich the mechanism of action. At last, there may be recall bias in questionnaire surveys. Participants may forget or misremember certain information, which could affect the accuracy of their responses.

The findings of this study have significant implications for various target audiences. For rural women, the results demonstrate that internet healthcare can reduce the health opportunity gap with men, enhancing their confidence in digital health services and encouraging them to utilize these resources to improve their health and quality of life. Internet healthcare providers are urged to consider gender and socioeconomic differences in designing services to better address the specific needs of rural women, thereby increasing service effectiveness and acceptability. Additionally, the study highlights the need for regulatory agencies and policymakers to focus on health disparities faced by rural women in their public health policies, advocating for the inclusion of gender considerations to promote more inclusive and targeted interventions.

Conclusion

Based on Roemer's theory of equality of opportunity, this paper examines the impact of Internet medical service on rural women's health inequality of opportunity and analyzes the mechanism in terms of both women's socioeconomic status and household power distribution. It is found that: firstly, rural women face unequal health opportunity with a health equity gap value of 1.67, and secondly, rural women can benefit from Internet medical service, thus reducing the health equity gap with men. The regression results remain robust after counterfactual causal inference by the propensity score matching method and the use of LASSO regression to solve the multicollinearity problem. Third, female human capital amplifies the role of Internet medical service in mitigating gender health opportunity inequality, while high personal economic income and being married weaken this effect.

Abbreviations
GGPI   China Global Gender Parity Index
CNNIC   China Internet Network Information Center
EQ-5D-3L   The European Five Dimensions of Health-Related Quality of Life Scale
HLS-SF 9   The Health Literacy Scale
PSM   Propensity Score Matching
LASSO   Least Absolute Shrinkage and Selection Operator

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Supplementary Information

Authors' contributions
Jingjing Jia wrote the body of the manuscript and plotted all the graphs. Changli Jia was responsible for data management and statistical analysis. PanPan Ren, Mengyao Chen, Jinglin Xu were responsible for data collection and thesis revision. Xiang Zhang was responsible for overseeing the progress of the study and coordinating the researcher recruitment and data collection process. and all authors agreed to submit the final manuscript for publication.

Data availability
The datasets generated and/or analysed during the current study are available from the investigation of the research funded by the National Natural Science Foundation of China(Grant No. 72074084),but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from corresponding author on reasonable request and with permission of the project principal.

Declarations

Ethics approval and consent to participate
The study was approved by the Ethics Committee of Tongji Medical College of Huazhong University of Science and Technology (IORG No. IORG0003571). Informed consent was obtained from all subjects prior to the investigation and there were no human subjects in the study. All methods were performed in accordance with relevant guidelines and regulations.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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