Jing *et al. BMC Geriatrics* (2025) 25:150
https://doi.org/10.1186/s12877-025-05798-9

BMC Geriatrics

RESEARCH Open Access

Internet use and healthcare utilization among older adults in China: a nationally representative cross-sectional study

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Abstract

Background Research on whether Internet use is related to older adults' health service use is limited. Hence, this study aimed to empirically examine the associations between Internet use and the different types of healthcare utilization among Chinese older adults and whether there were urban or rural differences.

Methods This study used large-scale nationwide data for Chinese older adults from the 2018 China Longitudinal Aging Social Survey (CLASS). The main explanatory variables were general Internet use and different types of Internet usage, including usage for communication, entertainment, and as instruments. The outcome measures included outpatient and inpatient care utilization, specifically examining the choice of health providers after an illness, the rate of outpatient care utilization after an illness, hospital admission, and the number of hospital admissions in the past two years. Logistic regression, zero-inflated negative binomial regression, and multinomial logistic regression were conducted to assess the associations between Internet use and healthcare utilization. Given the potential urban-rural disparities in Internet use, we applied an interaction term between Internet use and urban-rural status in each model to examine its moderating effects. The potential bias was addressed using the propensity score matching (PSM) method.

Results Compared with older adults who did not use the Internet, Internet users had a lower probability of hospital admission in the past two years (OR: 0.63, 95% CI: 0.55–0.72), fewer hospital admissions (IRR: 0.80, 95% CI: 0.69–0.93), and a higher probability of choosing outpatient care in hospitals after an illness (RRR: 1.22, 95% CI: 1.01–1.47). Using the Internet for communication showed the strongest association with healthcare utilization among different types of Internet use. The urban/rural interaction term was negatively associated with outpatient care utilization but positively associated with inpatient care utilization.

Conclusions This study highlights the important role of the Internet in shaping healthcare utilization, particularly in addressing urban-rural disparities. Implementing Internet-based interventions among older adults is recommended to reduce disparities and improve healthcare access.

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Keywords Healthcare utilization, Internet use, Older adults, Resource substitute and complement, Urban-rural differences

Background

Older adults are in greater demand for healthcare services than younger age groups. Despite variations in their health status, the majority of older adults have at least one chronic condition that necessitates care [1]. Healthcare utilization, as indicated by previous studies, encompassed various aspects such as outpatient visits, inpatient visits, and choice of health providers [2–5]. Adequate access to healthcare is critical for maintaining health and preventing the onset or exacerbation of diseases [6, 7]. Several studies report that older adults showed increased healthcare utilization such as the number and probability of doctor's visits, predominantly in developed countries [2, 8]. This increase was explained by the following reasons: first, the higher prevalence of catastrophic illness and non-communicable diseases (NCDs) among older adults, and the subsequent increased use of inpatient care [9, 10]; second, the decreased opportunity cost of time which could facilitate their healthcare-seeking behaviors [8]. Older adults have a lower ability to pay for healthcare services owing to insufficient income, which is an important barrier to healthcare accessibility [11], particularly outpatient services [12]. Therefore, older adults' healthcare utilization is a crucial public health and policy issue requiring in-depth insights.

In the era of rising life expectancy and an aging population worldwide, the Internet becomes an important part of individuals' daily life, which serves as a powerful tool to increase feelings of self-efficacy [13] and support informed decision-making [14]. Particularly, Internet use contributes to more effective searches for health-related information, improves patient-doctor interactions [15, 16], and provides social support for healthcare utilization [17, 18]. It is also linked to the usage of healthcare, especially among older adults [5, 19, 20]. However, most previous studies were conducted in developed countries where the Internet flourished earlier compared with developing nations [21]. In China, the use of the Internet among older adults has been steadily increasing. According to the Statistical Report on China's Internet Development, the proportion of Internet users aged 60 years and above grew from 4.9% of the total older adult population (8.7 million) in 2010 to 42.0% (110.8 million) in 2020 [22]. With a rapidly aging population and increased prevalence of NCDs in China, it is necessary to evaluate the associations between Internet use and healthcare utilization in China's health delivery system, which could contribute to improving health outcomes for older adults.

Internet use and healthcare utilization

Health information-seeking is embedded in everyday health practices for older adults. Both interpersonal sources (e.g., healthcare providers) and mediated sources (e.g., the Internet) were available for individuals to get access to health information and communication [23]. Traditionally, provider-dominated medical consultations have made it difficult for many patients to obtain sufficient health-related information [24]. In recent decades, a potential shift in the doctor-patient relationship was uncovered, and many started to view the Internet as an important resource for understanding health problems [25, 26]. This shift has improved individuals' engagement with their health and health communication [27], while also boosting their confidence in making informed decisions [28]. There are two pathways through which Internet use can influence healthcare utilization behaviors [29]. Firstly, Internet use directly informs, models, motivatives, and guides personal healthcare utilization. Secondly, Internet use links users to social networks, communication and community settings, which provide incentives and support for desired healthcare utilization. The impact of internet use on healthcare utilization extends beyond health-related online activities. The establishment of social contacts through online platforms could help users to notice and evaluate their symptoms, while social pressure might influence their healthcare-seeking through providing cues to action and shaping health-related beliefs [30].

Research detecting whether Internet use is related to older adults' healthcare utilization is limited, and portrays complex, often inconsistent results [5, 14, 31–33]. Some empirical studies discovered a positive correlation between searching for information online and healthcare utilization [5, 31, 33, 34]. For example, a national survey of Internet users in the USA found that respondents with self-reported stigmatized conditions were significantly more likely to use the Internet for health information [31]. In contrast, some studies found that Internet use was related to lower levels of healthcare utilization. For instance, a randomized controlled trial in the USA reported that using a computer-based health information and support system improved quality of life and led to fewer and shorter hospitalizations [32, 35]. The shorter and relatively inexpensive hospitalization is probably explained by the earlier detection and timely interventions of diseases after searching for health information online. Collectively, relationships between Internet use and multiple sub-dimensions of healthcare utilization among older adults should be further examined.

In today's digital age, the Internet serves as a vast source of information, allowing individuals to access a wide range of resources at their convenience. The Internet has also facilitated communication and connectivity among individuals, healthcare providers, and organizations. These avenues of everyday communication play a crucial role in shaping individuals' health-related beliefs, attitudes, and behaviors [36]. There are two theoretical pathways concerning the influence of Internet use on individuals' engagement with healthcare: the resource substitute and complement hypotheses [37, 38]. From a substitution perspective, resource substitution exists when there are multiple resources, making outcomes less dependent on the presence of any specific resource. There may be a substitution between Internet use for health-related activities and offline healthcare utilization, as they could partly serve a similar purpose regarding health-related recommendations, check-up results explanation, anxiety assuagement, etc [34]. The Internet may offer a new option for patients to communicate with doctors online to increase access to health care [39]. Some researchers argued that newer health information sources like the Internet could compete with traditional health communication channels, reducing the authority and trust in health professionals [40]. The information boom, promoted by the rapid Internet growth, provides a relatively inexpensive and easily updated way for consumers to seek health information apart from their physicians [34]. Hence, we proposed the following hypothesis:

H1a: Internet use for health communication is negatively associated with healthcare utilization among older adults.

From a complementary perspective, the Internet may have spillover effects on offline services, generating increased utilization of face-to-face healthcare services. Prior research found that Internet use for health information leads to more frequent physician visits [41]. A thematic analysis suggested that patients' use of Internet health information facilitated doctor-patient communications because patients could share the information that they found on the Internet with health professionals, with an improved willingness to communicate and higher effectiveness of interactions [42]. The complement effects can also be achieved through efforts such as expanding doctors' reputations and underscoring the importance of healthcare-seeking. Patients can get familiar with doctors before going to the hospital using online consultations, facilitating reduced uncertainty and sense of risk, enhanced trust in the doctor, and increased offline healthcare utilization. Moreover, older adults, especially those with multimorbidity and functional impairment, faced multiple barriers encompassing financial and transportation difficulties, and a lack of caregivers or medical escorts [4]. The Internet could provide health-related information and medical consultation for them, thus helping them obtain some healthcare services. Based on this, this study proposed the following hypothesis:

H1b: Internet use for health communication is positively associated with healthcare utilization among older adults.

The substitute or complement of Internet use for health communication relationships may vary across multiple sub-dimensions of healthcare utilization; however, there is very limited evidence regarding this aspect. Thus, it is important to examine the substitute or complement effects of Internet use on the utilization of different sub-dimensions of healthcare services, including inpatient, and outpatient health utilization.

In addition, Increased Internet penetration among older adults has resulted in a shift from analyzing whether the Internet is used to examining how it is used. In developed countries, older adults engage in four primary online activities: communication, entertainment, information, and finance [43]. In particular, older adults who use the Internet for communication have a higher probability of interacting with individuals sharing similar life experiences who are more accessible online [44], thus influencing their healthcare utilization.

Urban-rural differences in the relationship between Internet use and healthcare utilization

Since extensive health information is now available online, inequalities in Internet use might be associated with existing health disparities [45, 46]. Previous studies manifested that the relationship of Internet use with healthcare utilization and health outcomes could vary across subgroups; nevertheless, they report mixed findings [47]. Research identifying the mechanisms of urban-rural disparities in the relationship between Internet use and healthcare utilization is rare. The resource substitute and complement hypotheses can also be adapted to understand these urban-rural differences. The resource substitute effect is particularly relevant in situations where health services are less accessible and populations are economically disadvantaged. In this context, the resource substitute hypothesis suggests that Internet use can serve as a substitute for traditional healthcare services, potentially benefiting older adults in rural areas by bridging the urban-rural healthcare resource gap. On the other hand, the complement hypothesis focuses on the complementary role of the Internet in healthcare utilization, which is expected to be more pronounced among urban older adults. This is because the Internet may complement community-based resources to strengthen their pre-existing advantages. The inconclusiveness regarding this topic underscores the need for further research to better understand urban and rural differences in the relationship between Internet use and healthcare utilization.

Based on the above analysis, this study hypothesizes the following:

H2a: The resource substitute effect of Internet use mainly affects the rural older adults' healthcare utilization.

H2b: The resource complement effect of Internet use mainly affects the urban older adults' healthcare utilization.

Therefore, the present study aimed to empirically examine the associations between Internet use and the different types of healthcare utilization among Chinese older adults and whether there were urban or rural differences.

Methods

Data and sample

We used data from the China Longitudinal Aging Social Survey (CLASS), a large-scale nationwide survey directed by the National Survey Research Center and the Center for Population and Development Studies at the Renmin University of China. The CLASS adopted a stratified multi-stage probabilistic sampling method to construct a nationally representative sample of the aging population. A total of 134 counties were chosen from 28 provinces, autonomous regions, and municipalities of mainland China as the primary sampling units (PSUs). Furthermore, 462 rural villages and urban communities were chosen from the PSUs as the secondary sampling units (SSUs), and 25 older adults aged 60 and older from different households were randomly chosen from each SSU to answer the individual questionnaire. More detailed information regarding the sampling design and data collection procedures is available at http://class.ruc.edu.cn/. Considering that the 2014 wave was not designed to collect information on Internet use, and the 2016 wave did not collect information on outpatient care utilization, this study used the newly available data wave conducted between October and December 2018. A total of 11,511 older adults were invited to participate in the survey, and 11,418 answered all the survey questions. Strict quality control was performed, thereby yielding infrequent missing values in the raw data. In this study, the analytic variables, which are basic variables regarding socio-demographic and socioeconomic features, had no missing values, and none of the 11,418 participants were excluded. Some studies have used this data to demonstrate response rates consistent with this study [48]. The survey collected information regarding basic demographic characteristics, socioeconomic status, health conditions, healthcare utilization, etc.

Measures

Healthcare utilization

This study employed two measures of healthcare utilization. The first measure is outpatient care utilization, including the choice of health providers after an illness (outpatient care in hospitals, outpatient care in primary healthcare facilities, and self-treatment based on the question in the CLASS survey: "Typically, would you seek any outpatient care after an illness?") and the rate of outpatient care utilization after an illness, which can be categorized into two groups: seeking outpatient services in hospitals or primary healthcare facilities, and no. The second is inpatient care utilization, including hospital admission and the number of hospital admissions in the past two years.

Internet use

The main independent variable was older adults' Internet use based on a single question: "Do you use the Internet?" Responses were coded as 0 for non-users and 1 for users. Internet usage types were obtained from the multiple-answer question: "What do you regularly use the Internet for?" We categorized the 11 online activities into three groups: communication (e.g., voice or video chat and text chat), entertainment (e.g., news, blogs, music, radio, videos, and games), and instruments (e.g., shopping, traveling, managing health, investment and financing, as well as learning and training).

Urban-rural status

Urban-rural hukou status (0 = urban, 1 = rural) is a special identifier in China that refers to a household registration status. Older adults with different hukou face different living costs and have different access to government-provided public services and welfare programs. Therefore, this study adopted urban and rural hukou status as the proxy for older adults' urban and rural differences.

Covariates

In the multivariate regressions, we also controlled for the following variables: gender (0 = female, 1 = male), age, education in years, marital status (0 = unmarried, 1 = married), employment status (0 = retired/unemployed, 1 = employed), financial independence (0 = other supports as primary source of livelihood, 1 = personal income as primary source of livelihood), family wealth (0 = not possessing any assets in addition to property, 1 = possessing assets in addition to property), self-reported health (0 = fair/poor health status, 1 = good health status), body mass index (BMI, 0 = BMI not within normal range, 1 = BMI within normal range), number of chronic diseases (totally 23 chronic diseases), activity of daily living (ADL) score (summing nine dummy variables related to specific tasks: dressing, bathing, feeding, taking

medication, urinary continence, bowel continence, toilet use, bed-chair transfer, and moving indoors), and cognition score measured by the Short Portable Mental Health questionnaire with a higher summed score indicating a higher level of cognitive health. We also controlled for local health resources, measured by the number of physicians per 1,000 population, as studies have shown a significant correlation between health resource availability and healthcare utilization [49, 50].

Statistical analyses

We first provided descriptive statistics wherein continuous variables were described as a mean with standard deviation (SD), and categorical ones were described in percentage. The differences in healthcare utilization and Internet use between older adults with urban and rural statuses were analyzed using the chi-square test.

A multinomial logistic regression model was employed to examine the associations between Internet use and the choice of health providers. Logistic regression models were applied to binary categorical dependent variables including outpatient care utilization, and hospital admission. A zero-inflated negative binomial regression model was adopted for count data with overdispersion such as the number of hospital admissions. Along with the fully adjusted models, we conducted some sets of moderating effect analyses. We used the fully adjusted model with an interaction term between Internet use and urban-rural status to examine whether the associations between Internet use and healthcare utilization among older adults were moderated by urban-rural status. We also analyzed the associations between Internet usage types (communication, entertainment, and instrument) and healthcare utilization. Additionally, since Internet use is closely related to personal characteristics (e.g., age, education, socioeconomic status), social support factors (e.g., marital status), and health-related conditions [51–53], the propensity score matching (PSM) method was used to reduce the bias caused by these confounding factors. PSM helps balance the distribution of observed covariates between users and non-users of the Internet, ensuring that any differences in outcomes are more likely to be attributed to Internet use itself rather than to underlying differences in these characteristics [54]. Two-tailed p-values < 0.05 in all analyses were considered statistically significant. All analyses were conducted using Stata Statistical Software, release version 16.0 (Stata Corp. College Station, TX, USA).

Results

Descriptive characteristics of participants

Table 1 shows the healthcare utilization and socioeconomic characteristics of participants. Among the surveyed 11,418 older adults, 4890 (42.8%) and 6528 (57.2%) were from urban and rural areas, respectively. The Internet was used by 18.3% of older adults, with 15.9% using it for communication, 14.6% for entertainment, and 4.0% for instrument, respectively. Rural older adults were less likely to use the Internet compared with their urban counterparts (9.6% vs. 29.9%, $p < 0.001$), and the urban-rural difference was evident across all three Internet usage types (all $p < 0.001$). Nearly half (50.5%) of them used outpatient care after an illness, with 8.5% and 42.0% seeking consultations in hospitals and primary healthcare facilities, respectively. The overall hospital admission rate was 27.5%, and the mean number of hospital admissions was 0.45 for older adults.

Among all participants, 50.2% were male, 69.3% were married, 24.7% were employed, 60.0% were financially independent, and 61.0% had own family wealth. The mean age was 71.8 years, and the mean length of education was 5.5 years. There were 43.8% of older adults rating their health conditions as good, and nearly 70% having a BMI within the normal range. The mean scores of ADL and cognition were 6.7 and 13.2, respectively. The mean number of chronic diseases per person was 1.6, and the mean number of physicians per 1,000 population in areas where older adults reside was 3.2.

The associations between Internet use and healthcare utilization

Table 2 presents the associations between Internet use and healthcare utilization among older adults in China, after controlling for rural or urban status, gender, age, education, marital status, employment status, financial status, self-reported health status, BMI, ADL score, number of chronic diseases, cognition score, and local health human resource. There was no significant relationship between Internet use and outpatient service use after an illness. Moreover, relative to outpatient care in primary healthcare facilities, the probability of choosing outpatient care in hospitals increased by 22% (relative-risk ratio [RRR]: 1.22, 95% CI: 1.01–1.47) for Internet users, whereas that of self-medication did not change insignificantly.

It was also revealed that the probability of hospital admission for older Internet users decreased by 37.0% in the past two years (odds ratio [OR]: 0.63, 95% CI: 0.55–0.72), compared with non-Internet users. The number of hospital admissions for older Internet users decreased by 20% in the past two years (incidence rate ratio [IRR]: 0.80, 95% CI: 0.69–0.93).

The associations between different internet use types and healthcare utilization

Table 3 shows the associations between different Internet use types and healthcare utilization among older adults in China. This closer examination reveals that using the

Table 1 Participants' characteristics

Variables	Overall (*N* = 11418)	Urban (*N* = 4890)	Rural (*N* = 6528)
Healthcare utilization			
Outpatient care utilization	50.50	51.23	49.95
Choice of health providers			
Outpatient care in hospitals	8.47	13.31	4.84
Outpatient care in primary healthcare facilities	42.03	37.91	45.11
Self-medication	49.50	48.77	50.05
Hospital admission	27.47	27.63	27.34
Number of hospital admissions	0.45 (0.94)	0.43 (0.86)	0.46 (1.00)
Internet use			
Total Internet use	18.26	29.88	9.56
Internet usage type			
Communication	15.90	27.51	7.20
Entertainment	14.63	23.56	7.94
Instrument	4.04	7.65	1.33
Covariates			
Male	50.24	48.04	51.88
Age	71.76 (7.37)	71.92 (7.52)	71.64 (7.24)
Education in years	5.50 (4.17)	7.18 (4.04)	4.24 (3.80)
Married	69.32	71.66	67.57
Employed	24.68	8.61	36.72
Financially independent	60.00	77.44	46.94
Has family wealth	61.02	67.71	56.00
Self-reported good health status	43.83	46.91	41.53
BMI within normal range	68.98	63.99	72.72
Number of chronic diseases	1.57 (1.58)	1.67 (1.71)	1.50 (1.48)
ADL score	6.72 (0.98)	6.71 (0.98)	6.72 (0.98)
Cognition score	13.20 (3.35)	13.82 (2.85)	12.74 (3.61)
Local number of physicians per 1,000 population	3.23 (1.46)	4.24 (1.21)	2.47 (1.14)

Note: Descriptive statistics were presented as mean and standard deviation (SD) for continuous data and percentage for categorical data. BMI, body mass index. ADL, activity of daily living.

Internet for communication was the most significantly associated with healthcare utilization. Specifically, those who used the Internet for communication were more likely to seek outpatient care after an illness (OR: 1.87, 95% CI: 1.56–2.23). Compared to outpatient care in primary healthcare facilities, they had a higher probability of choosing outpatient care in hospitals (RRR: 1.39, 95% CI: 1.05–1.83) and lower odds of opting for self-treatment (RRR: 0.57, 95% CI: 0.47–0.68). Additionally, in terms of inpatient services, Internet use for communication was significantly related to lower odds of hospital admission (OR: 0.54, 95% CI: 0.43–0.67) and fewer hospital admissions (IRR: 0.53, 95% CI: 0.43–0.64).

Moderating effects of urban/rural status on the association between Internet use and healthcare utilization of older adults

By revealing the interaction term of Internet use and urban/rural status, Table 4 further shows moderating effects of urban-rural status on the Internet use-healthcare utilization associations. The results show that the status significantly moderated the associations of Internet use with outpatient care utilization (OR: 0.47, 95% CI: 0.38–0.58), the hospital admission rate in the past two years (OR: 1.53, 95% CI: 1.17–2.00), and the number of hospital admissions (IRR: 1.46, 95% CI: 1.16–1.84). Regarding the choice of health providers after an illness, relative to outpatient care in primary healthcare facilities, the interaction term was significantly and positively related to the probability of self-treatment (RRR: 1.99, 95% CI: 1.59–2.49), whereas insignificantly associated with the odds of choosing outpatient clinics in hospitals after an illness.

Figures 1 and 2 show the predictive outpatient care utilization rate, the predictive rate of hospital admission, and the number of hospital admissions among older adults. We found that urban-rural status had significant moderating effects on the association of Internet use with outpatient and inpatient care utilization of older adults. In particular, Internet users could experience a more significant increase and decrease in outpatient and inpatient care utilization for urban older adults, respectively. Apart

Table 2 Association between internet use and healthcare utilization for older adults

Variables	Outpatient care utilization	Outpatient care in hospitals [a]	Self-medication [a]	Hospital admission	Number of hospital admissions
	OR (95% CI)	RRR (95% CI)	RRR (95% CI)	OR (95% CI)	IRR (95% CI)
Internet use (vs. no)	1.05 (0.94, 1.17)	1.22 (1.01, 1.47) *	1.01 (0.89, 1.13)	0.63 (0.55, 0.72) *	0.80 (0.69, 0.93) *
Covariates					
Rural (vs. urban)	0.95 (0.86, 1.05)	0.49 (0.41, 0.60) *	0.94 (0.85, 1.05)	0.91 (0.80, 1.02)	1.08 (0.96, 1.20)
Male (vs. female)	0.94 (0.87, 1.02)	0.89 (0.76, 1.03)	1.04 (0.96, 1.13)	1.09 (0.99, 1.19)	1.07 (0.98, 1.18)
Age	1.00 (1.00, 1.01)	1.01 (1.00, 1.03) *	1.00 (0.99, 1.01)	1.02 (1.01, 1.03) *	1.00 (1.00, 1.01)
Education in years	0.99 (0.98, 1.00)	1.06 (1.04, 1.08) *	1.02 (1.01, 1.03) *	1.00 (0.98, 1.01)	1.02 (1.00, 1.03) *
Married (vs. unmarried)	1.09 (1.00, 1.19) *	0.97 (0.82, 1.15)	0.91 (0.83, 1.00) *	0.93 (0.84, 1.03)	0.96 (0.87, 1.05)
Employed (vs. retired/unemployed)	0.74 (0.67, 0.81) *	1.05 (0.86, 1.30)	1.36 (1.23, 1.51) *	0.96 (0.85, 1.08)	1.14 (1.01, 1.29) *
Financially independent (vs. family support/ public assistance)	0.93 (0.86, 1.02)	1.08 (0.91, 1.27)	1.08 (0.99, 1.18)	0.94 (0.86, 1.04)	1.08 (0.98, 1.19)
Has family wealth (vs. No family wealth)	0.90 (0.83, 0.97) *	1.40 (1.19, 1.64) *	1.17 (1.08, 1.27) *	1.05 (0.96, 1.15)	1.08 (0.99, 1.19)
Self-reported good health status (vs. fair/poor)	1.18 (1.10, 1.28) *	1.11 (0.95, 1.28)	0.86 (0.79, 0.93) *	0.70 (0.64, 0.77) *	0.83 (0.75, 0.92) *
BMI within normal range (vs. no)	0.83 (0.77, 0.90) *	0.95 (0.82, 1.10)	1.19 (1.09, 1.29) *	0.91 (0.83, 1.00)	1.05 (0.96, 1.16)
Number of chronic diseases	1.08 (1.05, 1.11) *	1.06 (1.02, 1.10) *	0.94 (0.91, 0.96) *	1.40 (1.36, 1.45) *	1.09 (1.06, 1.11) *
ADL score	0.95 (0.91, 0.99) *	0.93 (0.87, 1.00) *	1.04 (0.99, 1.08)	0.81 (0.77, 0.84) *	0.93 (0.90, 0.95) *
Cognition score	0.98 (0.97, 0.99) *	1.01 (0.98, 1.03)	1.02 (1.01, 1.03) *	0.97 (0.96, 0.99) *	0.98 (0.96, 0.99) *
Local number of physicians per 1,000 population	0.96 (0.93, 1.00) *	1.10 (1.04, 1.17) *	1.06 (1.02, 1.10) *	0.99 (0.95, 1.03)	0.99 (0.95, 1.02)

Note: [a] Base outcome: Outpatient care in primary healthcare facilities. OR, odds ratio. CI, confidence interval. RRR, relative-risk ratio. IRR, incidence rate ratio. BMI, body mass index. ADL, activity of daily living. * p-value < 0.05

Table 3 Association between Internet usage type and healthcare utilization for older adults

Variables	Outpatient care utilization	Outpatient care in hospitals [a]	Self-medication [a]	Hospital admission	Number of hospital admissions
	OR (95% CI)	RRR (95% CI)	RRR (95% CI)	OR (95% CI)	IRR (95% CI)
Internet usage type					
Communication (vs. no)	1.87 (1.56, 2.23) *	1.39 (1.05, 1.83) *	0.57 (0.47, 0.68) *	0.54 (0.43, 0.67) *	0.53 (0.43, 0.64) *
Entertainment (vs. no)	0.55 (0.46, 0.66) *	1.01 (0.75, 1.34)	1.81 (1.50, 2.18) *	1.02 (0.82, 1.28)	1.20 (1.00, 1.44)
Instruments (vs. no)	0.98 (0.79, 1.21)	0.79 (0.56, 1.11)	0.97 (0.77, 1.22)	0.94 (0.70, 1.26)	0.92 (0.72, 1.18)
Covariates					
Rural status (vs. urban)	0.95 (0.86, 1.05)	0.49 (0.40, 0.59) *	0.94 (0.85, 1.05)	0.90 (0.80, 1.02)	1.05 (0.94, 1.18)
Male (vs. female)	0.95 (0.88, 1.03)	0.89 (0.77, 1.03)	1.03 (0.95, 1.11)	1.08 (0.99, 1.19)	1.08 (0.99, 1.18)
Age	1.00 (1.00, 1.01)	1.01 (1.00, 1.02) *	1.00 (0.99, 1.01)	1.02 (1.01, 1.02) *	1.00 (1.00, 1.01)
Education in years	0.99 (0.98, 1.00)	1.06 (1.04, 1.09) *	1.02 (1.01, 1.03) *	1.00 (0.98, 1.01)	1.02 (1.01, 1.03) *
Married (vs. unmarried)	1.10 (1.00, 1.20) *	0.97 (0.82, 1.15)	0.91 (0.83, 1.00) *	0.93 (0.84, 1.03)	0.95 (0.86, 1.04)
Employed (vs. retired/unemployed)	0.76 (0.68, 0.83) *	1.06 (0.86, 1.30)	1.33 (1.20, 1.48) *	0.94 (0.83, 1.06)	1.10 (0.97, 1.24)
Financially independent (vs. family support/ public assistance)	0.93 (0.86, 1.01)	1.08 (0.92, 1.28)	1.09 (1.00, 1.19)	0.95 (0.86, 1.05)	1.07 (0.97, 1.18)
Has family wealth (vs. No family wealth)	0.89 (0.82, 0.96) *	1.41 (1.20, 1.65) *	1.19 (1.09, 1.29) *	1.06 (0.97, 1.17)	1.10 (1.01, 1.21) *
Self-reported good health status (vs. fair/poor)	1.20 (1.11, 1.30) *	1.12 (0.96, 1.30)	0.85 (0.78, 0.92) *	0.70 (0.64, 0.77) *	0.83 (0.74, 0.91) *
BMI within normal range (vs. no)	0.84 (0.78, 0.91) *	0.95 (0.82, 1.10)	1.17 (1.08, 1.28) *	0.90 (0.82, 0.99) *	1.06 (0.97, 1.17)
Number of chronic diseases	1.08 (1.06, 1.11) *	1.06 (1.02, 1.11) *	0.94 (0.91, 0.96) *	1.41 (1.37, 1.45) *	1.09 (1.07, 1.12) *
ADL score	0.95 (0.91, 0.99) *	0.93 (0.87, 1.00) *	1.04 (0.99, 1.09)	0.81 (0.77, 0.85) *	0.93 (0.90, 0.95) *
Cognition score	0.98 (0.97, 0.99) *	1.00 (0.98, 1.03)	1.02 (1.01, 1.04) *	0.98 (0.96, 0.99) *	0.98 (0.96, 0.99) *
Local number of physicians per 1,000 population	0.96 (0.92, 0.99) *	1.10 (1.04, 1.17) *	1.07 (1.03, 1.10) *	1.00 (0.96, 1.04)	0.98 (0.95, 1.02)

Note: [a] Base outcome: Outpatient care in primary healthcare facilities. OR, odds ratio. CI, confidence interval. RRR, relative-risk ratio. IRR, incidence rate ratio. BMI, body mass index. ADL, activity of daily living. * p-value < 0.05

Table 4 Moderating effects of Urban-Rural status on the association between internet use and healthcare utilization for older adults

Variables	Outpatient care utilization	Outpatient care in hospitals [a]	Self-medication [a]	Hospital admission	Number of hospital admissions
	OR (95% CI)	RRR (95% CI)	RRR (95% CI)	OR (95% CI)	IRR (95% CI)
Internet use (vs. no)	1.38 (1.21, 1.58) *	1.17 (0.95, 1.44)	0.77 (0.67, 0.89) *	0.54 (0.46, 0.64) *	0.69 (0.58, 0.82) *
Internet use * rural	0.47 (0.38, 0.58) *	0.84 (0.53, 1.35)	1.99 (1.59, 2.49) *	1.53 (1.17, 2.00) *	1.46 (1.16, 1.84) *
Rural (vs. urban)	1.06 (0.96, 1.18)	0.51 (0.41, 0.62) *	0.85 (0.76, 0.95) *	0.86 (0.76, 0.98) *	1.04 (0.92, 1.16)
Covariates					
Male (vs. female)	0.95 (0.88, 1.02)	0.89 (0.76, 1.03)	1.04 (0.95, 1.12)	1.08 (0.99, 1.19)	1.08 (0.98, 1.18)
Age	1.00 (1.00, 1.01)	1.01 (1.00, 1.03) *	1.00 (0.99, 1.01)	1.02 (1.01, 1.03) *	1.00 (1.00, 1.01)
Education in years	0.99 (0.98, 1.00)	1.06 (1.04, 1.08) *	1.02 (1.01, 1.03) *	1.00 (0.98, 1.01)	1.02 (1.00, 1.03) *
Married (vs. unmarried)	1.10 (1.00, 1.20) *	0.97 (0.82, 1.15)	0.91 (0.83, 1.00) *	0.93 (0.84, 1.03)	0.96 (0.87, 1.05)
Employed (vs. retired/unemployed)	0.77 (0.70, 0.85) *	1.06 (0.86, 1.31)	1.32 (1.19, 1.46) *	0.94 (0.83, 1.05)	1.13 (1.00, 1.27)
Financially independent (vs. family support/ public assistance)	0.93 (0.86, 1.02)	1.08 (0.91, 1.28)	1.09 (0.99, 1.19)	0.94 (0.86, 1.04)	1.07 (0.97, 1.18)
Has family wealth (vs. No family wealth)	0.89 (0.82, 0.97) *	1.40 (1.19, 1.65) *	1.18 (1.08, 1.28) *	1.05 (0.96, 1.16)	1.09 (0.99, 1.19)
Self-reported good health status (vs. fair/poor)	1.18 (1.09, 1.28) *	1.11 (0.95, 1.28)	0.86 (0.79, 0.93) *	0.70 (0.64, 0.77) *	0.83 (0.75, 0.92) *
BMI within normal range (vs. no)	0.84 (0.78, 0.91) *	0.95 (0.82, 1.11)	1.18 (1.08, 1.28) *	0.91 (0.82, 1.00) *	1.06 (0.97, 1.16)
Number of chronic diseases	1.08 (1.05, 1.11) *	1.06 (1.02, 1.11) *	0.94 (0.91, 0.96) *	1.41 (1.36, 1.45) *	1.09 (1.07, 1.12) *
ADL score	0.95 (0.91, 0.99) *	0.93 (0.87, 1.00) *	1.04 (1.00, 1.09)	0.81 (0.77, 0.85) *	0.93 (0.90, 0.95) *
Cognition score	0.98 (0.97, 0.99) *	1.01 (0.98, 1.03)	1.02 (1.01, 1.03) *	0.97 (0.96, 0.99) *	0.98 (0.96, 0.99) *
Local number of physicians per 1,000 population	0.96 (0.93, 1.00) *	1.10 (1.04, 1.17) *	1.06 (1.02, 1.09) *	0.99 (0.95, 1.03)	0.98 (0.94, 1.02)

Note: [a] Base outcome: Outpatient care in primary healthcare facilities. OR, odds ratio. CI, confidence interval. RRR, relative-risk ratio. IRR, incidence rate ratio. BMI, body mass index. ADL, activity of daily living. * p-value < 0.05

from inpatient care, rural Internet users also showed a significant reduction in outpatient care utilization.

Additional analysis

Table 5 shows the ATT for healthcare utilization among older Internet users and non-users after PSM. Table S1 presents the logit Model predicting the associations between control variables and Internet use. We found a decrease in the standardized percentage of bias of almost all covariates after matching (See Figure S1). Moreover, the majority of participants were on support in the analysis (See Figure S2). Hence, only a few samples would be lost when matching.

Three matching methods were adopted to realize post-randomization of data, including one-to-four, four-nearest neighbors, and kernel matching. As shown in Table 5, after matching, the hospital admission rate significantly decreased for Internet uses in the past two years along with the number of hospital admissions. Moreover, there was no significant change in outpatient care utilization after an illness in the past year after matching.

Discussion

This study is one of the few studies that investigated Internet use along with multiple sub-dimensions of healthcare utilization in China. The findings indicated the relationships between Internet use and healthcare utilization among older adults. Specifically, compared with Internet non-users, older Internet users had a higher probability of choosing hospitals for outpatient care after an illness, as well as a decreased likelihood and fewer instances of hospital admissions. When examining different types of Internet usage, similar relationships were found between Internet use for communication and healthcare utilization. The interaction term of Internet use and urban-rural status indicated a significantly stronger correlation between Internet use and outpatient care utilization, hospital admission, and the number of hospital admissions among urban older adults. Internet use had a substitutive effect on outpatient and inpatient services for rural older adults, while in urban areas it complemented outpatient services and simultaneously led to a substitutive effect on inpatient services.

In light of this, Internet use may reduce inpatient care utilization and increase the probability of choosing outpatient care in hospitals, which was explained by the resource substitute effect of Internet use [37, 38]; thus, H1a was partly supported, especially for inpatient care utilization, while inconsistent with H1b. Previous studies showed that Internet use cannot help in eliminating the monopoly of knowledge about serious or complicated diseases; hence, the use of high-level hospital services may not be significantly reduced [55]. However, this study yielded contrary findings, which can be explained by several mechanisms. First, older adults often experience declining income and increased economic

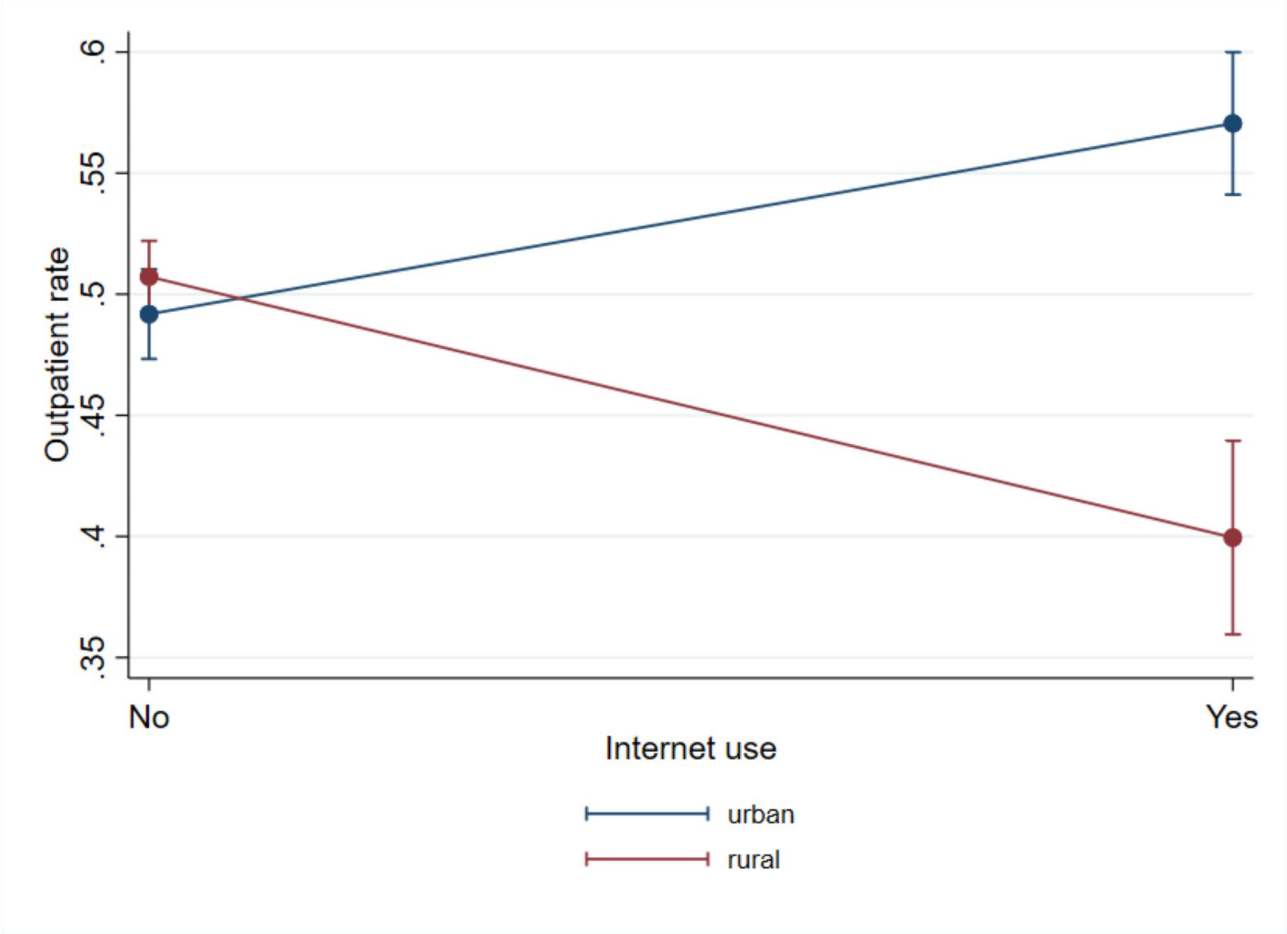

Fig. 1 The interaction effect of Internet use and urban-rural status on outpatient care utilization

burden after diseases [4], resulting in limited economic resources. Consequently, cost-saving becomes a driving force for the resource substitute effect, particularly for more expensive inpatient services. Second, although the Internet would not necessarily decrease outpatient care utilization brought by the substitute effect, our results showed that relative to outpatient care in primary healthcare facilities, the probability of choosing outpatient care in hospitals after an illness increased, and timely outpatient visits may reduce the need for subsequent hospital admissions [56–58]. Furthermore, the reduced number of hospital admissions and increased preference for outpatient care in hospitals among older Internet users are good indicators for the sound development of a healthcare system, regardless of the substitute effect of outpatient care utilization or Internet use.

Besides, the Internet acts as a powerful tool for effectively disseminating information to populations with limited access to healthcare professionals [59], and there is a positive correlation between Internet usage for communication and healthcare utilization. Therefore, it is important to leverage the potential of Internet communication platforms to improve healthcare accessibility and promote informed decision-making. In this sense, implementing Internet-related interventions among older adults, particularly rural older adults, such as Internet popularization, training on communication platforms and electronic devices, or proper interface design for older adults, might be conducive to helping them achieve better access to care and reducing urban and rural disparities in healthcare and health consequences.

Research on urban-rural differences concerning the associations between Internet use and healthcare utilization is in the nascent stage, despite its importance as urban-rural disparities significantly affect access to healthcare, and Internet use may play a different role in each setting. In this study, further urban-rural differences analyses examining potential gaps were performed, revealing that urban-rural status had significant moderating effects on the relationships between Internet use and outpatient or inpatient care utilization, but differences existed regarding service type. The moderating effect was consistent for both outpatient and inpatient care utilization among rural older adults, indicating a negative

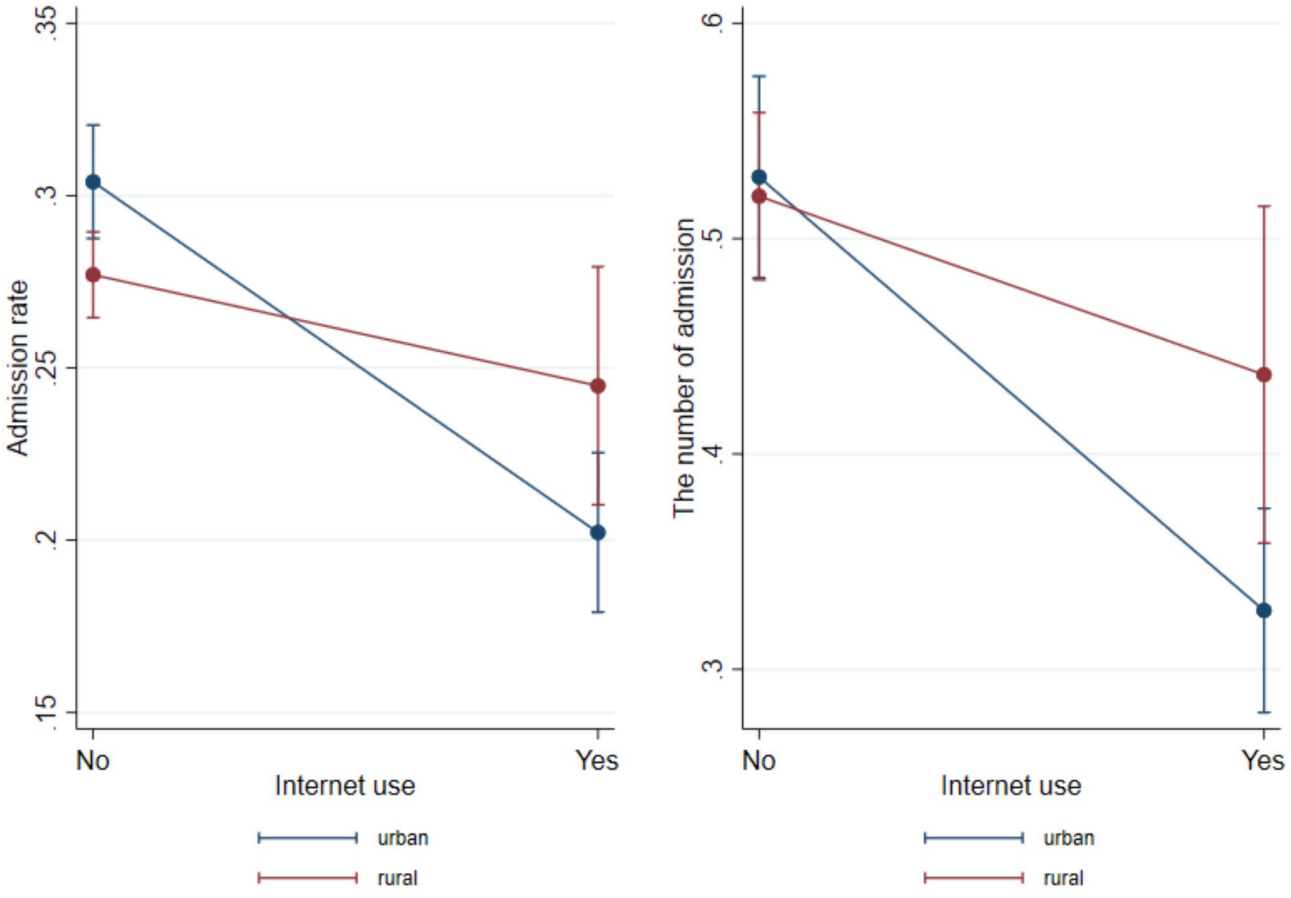

Fig. 2 The interaction effect of Internet use and urban-rural status on inpatient care utilization

Table 5 Associations between internet use and health service utilization using different matching methods

Variables	Matching methods	Treated	Control	ATT	SE	T-value
Outpatient care utilization	One-to-one nearest-neighbor matching	0.495	0.517	-0.022	0.023	-0.98
	One-to-four nearest-neighbor matching	0.495	0.496	-0.001	0.019	-0.05
	Kernel matching	0.495	0.506	-0.011	0.017	-0.63
Hospital admission	One-to-one nearest-neighbor matching	0.188	0.242	-0.054 *	0.019	-2.80
	One-to-four nearest-neighbor matching	0.188	0.242	-0.054 *	0.016	-3.38
	Kernel matching	0.188	0.254	-0.065 *	0.015	-4.32
Number of hospital admissions	One-to-one nearest-neighbor matching	0.292	0.405	-0.113 *	0.039	-2.87
	One-to-four nearest-neighbor matching	0.292	0.385	-0.093 *	0.033	-2.81
	Kernel matching	0.292	0.397	-0.105 *	0.031	-3.37

Note: * p-value < 0.05

association between Internet use and healthcare utilization. This finding provides support for H2a. However, the effect was inconsistent for outpatient and inpatient care utilization among urban adults, as Internet use was found to promote outpatient care and reduce inpatient care, which partly supports H2b. The complement effect of Internet use on outpatient care utilization among urban older adults may be attributed to the persistent disparities in health resources between urban and rural regions over an extended period [60, 61]. Identifying these disparities can provide insights into how healthcare interventions or digital health strategies can be tailored to bridge gaps and improve healthcare access and outcomes in both areas.

This study systematically revealed the complex effects of Internet use on the utilization of different types of health services, and the Internet can neither completely replace nor compensate for all types of services due to

the inherent interplay of substitutability and complementarity among various service types. In fact, attempts to compensate for certain services may inadvertently lead to increased substitution of other services. Therefore, it is crucial to take into account the comprehensive landscape of service types, which represents a significant contribution of our study compared to previous research. We also shed light on urban-rural disparities, which have not been addressed in existing literature. Internet use may generate more benefits by reducing inpatient care utilization among urban older adults given the potential effects of preventive measures and early treatment in outpatient care [5, 37, 55]. Such benefits can contribute to the transformation of urban healthcare delivery system, alleviate the economic burden of diseases, and ease the pressure of hospital admissions in cities. In contrast, rural Internet users were less likely and frequently to utilize healthcare services. Although previous literature has indicated that the Internet can help reduce health inequalities by addressing certain barriers associated with accessing traditional healthcare [31], based on the findings of this study, it is imperative to carefully examine the role of the Internet in facilitating healthcare utilization, with particular attention to urban-rural disparities.

This study also has a few limitations. First, self-reported responses may be subjected to recall bias, and we tried to minimize it by asking about participants' conditions in the past one or two years and conducting a face-to-face survey so that interviewees were more cautious regarding their answers. Second, in this cross-sectional survey, regression was performed only to show statistical correlations rather than inherent causal relations. Moreover, a causal relationship between Internet use and healthcare service use cannot be inferred due to the nature of the study. Despite these limitations, the nationally representative sample was large, with a diverse sociodemographic population, offering good generalizability for older adults in China.

Conclusions

In conclusion, this study revealed negative relationships between Internet use and healthcare utilization, especially for hospital admissions. Besides, Internet users tended to seek outpatient visits in hospitals which may hamper the need for inpatient services. A more detailed look at urban and rural status revealed that the resource substitution effect exists in Internet use and healthcare utilization among rural older adults, while it complemented outpatient services and simultaneously led to a substitutive effect on inpatient services for urban older adults. Therefore, it is imperative to carefully examine the role of the Internet in facilitating healthcare utilization, with particular attention to urban-rural disparities.

Supplementary information

The online version contains supplementary material available at https://doi.org/10.1186/s12877-025-05798-9.

Supplementary Material 1

Acknowledgements
The authors would like to thank all participants and staff of the China Longitudinal Aging Social Survey (CLASS).

Author contributions
RJ and LL conceptualized and designed the study, RJ and XL conducted statistical analysis and wrote the original draft. LL and HW assisted with writing/editing. All authors gave final approval of the version to be published.

Funding
This work was supported by grants from the Beijing Municipal Social Science Foundation (grant number: 23SRC025). The study sponsor has no role in study design, data analysis and interpretation of data, the writing of manuscript, or the decision to submit the paper for publication.

Data availability
The dataset generated and/or analyzed during the current study is available in the China Longitudinal Aging Social Survey, CLASS, this can be found in CLASS website at http://class.ruc.edu.cn/. Additionally, the datasets used and/or analyzed during the current study available from the first author and corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
In this study, all the procedures involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration as well as its later amendments or comparable ethical standards. This study does not contain any procedures involving animals performed by any of the authors. Individual informed consent was obtained from all the participants involved in this study, and the Institutional Review Board of the Renmin University of China approved all study protocols.

Consent for publication
Not applicable. The manuscript contains neither identifiable information nor images of participants. This paper has not been published elsewhere nor is under consideration for publication. All authors agree to submit the manuscript and to transfer copyright to the publisher, if the manuscript is accepted.

Competing interests
The authors declare no competing interests.

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Received: 29 June 2024 / Accepted: 17 February 2025
Published online: 05 March 2025

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