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Housing conditions, cooking fuels, and health-related quality of life among rural middle-aged and elderly in northwest China: A ten-year balanced panel study

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ABSTRACT

Objective: To investigate the impacts of improving housing conditions and transitioning to clean cooking fuels on health-related quality of life (HRQOL) among middle-aged and elderly populations in rural China. Methods: Using a 10-year longitudinal follow-up study, we examined changes in housing conditions, cooking fuel use, and HRQOL among 690 Chinese adults aged 45 above in rural areas. HRQOL was assessed using the European Quality of Life-5 Dimensions 3 Levels (EQ-5D-3L) questionnaire. Generalized estimating equations were utilized to analyze correlations between variables. Results: Using four-period balanced panel data of 10 years, there were significant differences in the self-reporting of mobility, self-care, usual activities, pain / discomfort and anxiety / depression in rural middle-aged and elderly people ($p < 0.05$). In terms of the EQ-5D index score and EQ-VAS score, showed a decreasing trend ($p < 0.05$). The housing area, housing material type, utilization of sanitary toilets, separation of housing and kitchen were separated and non-solid fuels used as cooking fuel were significantly associated with high HRQOL ($p < 0.05$). Conclusions: This study found that good housing conditions and the use of non-solid cooking fuel had positive effects on health-related quality of life of middle-aged and elderly people in rural areas of northwest China.

1. Introduction

The aging of the population is an inexorable consequence of demographic transition, and a crucial issue currently confronting human society. With the increase of age, physical function gradually deteriorates. Middle-aged and elderly people are more susceptible to health risks than other groups (Chang et al., 2019). In particular, older residents living in rural areas deserve more attention (Li et al., 2022). China has the largest number of middle-aged and elderly population in the world. Its rapid urbanization process has attracted a large number of young people from rural areas to migrate to cities, resulting in middle-aged and elderly people in rural areas becoming the main left-behind population (Wang et al., 2022). Due to factors such as long-term agricultural activities, physical vulnerability and insufficient protection are common in this group of middle-aged and elderly people (Zhang et al., 2022).

Health-Related Quality of Life (HRQOL) is a widely used subjective health assessment tool, employed to evaluate individuals' subjective impressions of their daily life, physical and mental capabilities, social interactions, and the impact of these aspects on overall well-being (Chen et al., 2020). Research has shown that HRQOL effectively reflects the health-related factors of the elderly and aids in predicting potential disease, disability, and mortality (Jonak et al., 2019; Lapin, 2020). Consequently, information regarding HRQOL is increasingly considered for reinforcing decision-making processes related to available resources (Yao et al., 2023). Housing, as the primary dwelling where individuals spend the majority of their non-working time, exerts profound and enduring effects on personal health and quality of life (Higgs et al., 2023). Simultaneously, it is a key factor contributing to the generation and persistence of health inequalities (Sims et al., 2020; Swope and Hernández, 2019). Studies have indicated that poor housing conditions are independently associated with restricted physical functioning in the

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elderly, resulting in a higher risk of vulnerability (García-Esquinas et al., 2016; Pérez-Hernández et al., 2018). Experiences of insecure housing also foreshadow poorer self-rated physical health and additional chronic diseases (Bhat et al., 2022). Furthermore, studies have shown that improving people's housing conditions can significantly reduce total hospital costs and potentially improve quality of life (Riggs et al., 2021). These studies provide intriguing clues about the relationship between housing conditions and health well-being. Unfortunately, there is a relative lack of long-term examinations of the impact of housing conditions on HRQOL. Investigations into improving living conditions and promoting well-being predominantly originate from economically developed countries. However, research on the influence of housing conditions on HRQOL in rural areas, especially in developing countries like China, remains insufficient. Housing has consistently been one of the most deficient areas in health security for elderly individuals in rural China, particularly in economically underdeveloped regions such as the Northwest.

There are still some rural residential designs in developing countries in which the bedroom may not be separated from the cooking part (Fandiño-Del-Rio et al., 2021). They are experiencing a transition to cooking energy, but around 3 billion people globally still lack access to non-solid cooking fuels such as electricity and natural gas (Deng et al., 2020). In rural China, solid fuels are still used by many people because they are cheaper and more accessible, leading to a sharp rise in indoor air pollution (Fandiño-Del-Rio et al., 2020; Quansah et al., 2017). Research has demonstrated that solid fuel use significantly in the incidence and exacerbation of chronic diseases, and decreased the perception of their own health status compared with those used non-solid fuel (Fatmi and Coggon, 2016; Liu et al., 2018). However, most studies limited to single-stage cross-sectional designs (Deng et al., 2020; Yang et al., 2022). There has been no in-depth discussion on the exact relationship between HRQOL and ambient environmental quality of middle-aged and elderly rural residents. However, the association between housing condition, cooking fuel utilization and HRQOL in middle-aged and older adults is complex, and longitudinal statistical methods can provide deeper insight.

Therefore, this study conducted a 10-year follow-up survey of the rural middle-aged and elderly population in northwest China. Using balanced panel data, the China's rural middle-aged and elderly people were tracked and investigated four times during a ten-year period to understand the dynamic changes in the health status of the rural middle-aged and elderly people, to analyze the impact of housing size and year, housing material type, toilet type, separation of housing and kitchen, and choice of daily cooking fuel on their HRQOL.

2. Materials and methods

2.1. Data and sampling

This data were mainly obtained from the Improving Health Outcomes through Innovative Payment Systems project jointly conducted by Harvard University, Oxford University, Fudan University and Ningxia Medical University in the United States of America. The baseline survey (2009) and three follow-up visits (2012, 2015, and 2019) were conducted. The survey was conducted in Haiyuan, Yanchi, Pengyang, and Xiji counties of Ningxia using a multi-stage stratified random sampling method. We divided all administrative villages in these four counties into three categories according to their economic level, and then randomly selected 40 % of them as respondents. In each administrative village, we randomly selected 20 to 33 rural residents who had lived there for more than 6 months as respondents. Face-to-face follow-up was conducted by trained research staff to collect data on various aspects of demographic characteristics, family structure, income, consumption, hospitalization and chronic. In addition, detailed information on housing characteristics, type of household cooking fuel use, and HRQOL was available.

In this study, balanced four-phase panel data at the individual level were screened, and all family members of the sample households were investigated. The population who met the following criteria were selected from the database for inclusion in the study: rural residents who participated in all four phases of the survey; aged $\geq$ 45 years old. After excluding invalid and missing information, 690 rural middle-aged and elderly people were included in this study. All participants gave informed written consent, and this study followed the principles of the Helsinki declaration and was approved by the Institutional Review Board of Ningxia Medical University (2021-G152).

2.2. Assessment of housing conditions and household cooking fuel use type

Five factors were extracted from the characteristics of rural built environment in this study, including housing area (Committee, 2018), housing duration (Yang and Fu, 2019), toilet type (Wang et al., 2022; Yang and Fu, 2019), separation between housing and kitchen (Liu et al., 2018), and types of building materials (Dasgupta et al., 2006; Guo et al., 2022), Among them, the housing area was scored by the per capita housing area of the family, which was divided into five grades; The construction time is divided into five grades by reverse scoring method. The types of toilets were divided into flushing toilets and non-flushing toilets. The separation of the house from the kitchen is distinguished by yes or no; The types of building materials are divided into four types: full brick, brick and wood, brick and soil concrete and civil engineering. In addition, we classified cooking fuels into three types: only clean fuels, only solid fuels and both all (Dasgupta et al., 2006). Clean fuels include natural gas, biogas, LPG or electricity, while solid fuels include coal, crop residues, wood, solid charcoal or other fuels. We will consider the role of these factors when analyzing the impact of different variables on HRQOL in rural middle-aged and elderly people.

2.3. Assessment of HRQOL

HRQOL was assessed using the European Quality of Life-5 Dimensions 3 Levels (EQ-5D-3L) questionnaire. The scale comprehensively measures the health status of individuals from the aspects of physical status, psychological status, and social function. This scale contains two main parts, namely the EQ-5D description system and the EQ Visual Analogue Scale (EQ-VAS) (Yao et al., 2021). The EQ-5D description system defines health status at four levels: mobility, self-care ability, usual activities, pain/discomfort, and anxiety/depression. Each level includes three further levels (level 1: no problem, level 2: some problems, and level 3: extreme problems). Health status was defined by combining the levels of each of the five dimensions. (Chen et al., 2020). The EQ-5D-3L health utility value formula based on the preference setting of Chinese rural population was used for calculation (Liu et al., 2022). Utility value = 1–0.053–0.100*MO2 − 0.261*MO3 − 0.104*SC2- 0.224*SC3 − 0.080*UA2 − 0.206*UA3 − 0.101*PD2 − 0.234*PD3 − 0.080*AD2 − 0.189*AD3 − 0.019*N3. MO2, SC2, UA2, PD2, and AD2 represented 1, and the others were 0 when the mobility, self-care ability, daily living ability, pain/discomfort, and anxiety/depression were level 2. MO3, SC3, UA3, PD3, and AD3 represented 1 when mobility, self-care ability, daily activities ability, pain/discomfort, and anxiety/depression were level 3, and others were level 0. N3 term, which equalled to 1 if the health state being valued included at least 1 dimension at level 3, otherwise equalled to 0. The EQ-VAS is a quantitative measure that provides respondents with vertical visual simulations ranging from 0(worst imaginable health state) to 100(best imaginable health state) that report a rating that best describes their self-rated health status (Kang et al., 2018).

2.4. Methods

The data were analyzed with IBM SPSS Statistics (version 24.0). A

descriptive statistical analysis has been conducted on the demographic features, HRQOL, housing conditions, and fuel utilization types of rural inhabitants. Numeric variables were primarily explicated utilizing measures such as means and standard deviations, while categorical variables were evaluated using composition ratios.

We utilized generalized estimating equations to examine the correlation between rural dwelling conditions, cooking fuel type, and HRQOL. We established three models: Model 1 as the unadjusted model; Model 2 adjusted for age, gender, marital status, education, occupation, and economic level; Model 3, built upon Model 2, further corrected for hospitalization and chronic diseases. Variable assignments was shown in **Table S1**. Models were fitted with unstructured covariance structure and binominal link-function. (Ito and Sugasawa, 2022). The choice of model and matrix structure mainly involved selecting a linear regression model due to the continuous nature of dependent variables (health effect value and EQ-VAS score). The unconstrained correlation structure was chosen for model building (Wang et al., 2010). The QIC criterion and cumulative residuals were employed to assess the job correlation matrix and functional form of covariates (Ito and Sugasawa, 2022; Wang et al., 2010). QIC, representing quasi-likelihood under the independence model criterion, was defined as $-2Q(\beta) + 2$ trace(A-1VMS, R) (Wang et al., 2010). where VIF values were checked for multicollinearity (maximum VIF in this study: 1.246, indicating no multicollinearity) (Kim, 2019).

3. Results

3.1. Housing characteristics and the health of the middle-aged and elderly

3.1.1. Descriptive statistics of the baseline population

In our study, 690 rural middle-aged and elderly were included to assess the association between housing conditions and household cooking fuel use type and HRQOL. Table 1 shows the baseline characteristics of the study population. Among them, the 690 subjects, the average age was 55 years, The oldest was 82 years old, 59.3 % were men and 94.1 % were married, most of them belonged were illiterate (49.9%) or primary school culture (31.0 %). The majority of individuals in this population were engaged in agricultural work, while the average per capita annual income for most families falls within the low-income bracket. As shown in Table 1.

3.1.2. Housing conditions and household cooking fuel type

Table 2 summarized the housing conditions and cooking fuel types used in 690 middle-aged and elderly households over the past decade.

Table 1
Descriptive Statistics of Baseline Demographic Variables among Rural Middle-Aged and Elderly Participants in Northwest China, 2009–2019 (N = 690).

Characteristics		Middle-aged and elderly (n = 690)
		Frequency (%)
Gender	Male	409 (59.3)
	Female	281 (40.7)
Marriage	Married	649 (94.1)
	Other	41 (5.9)
Literacy status	Illiterate	344 (49.9)
	Primary school	214 (31.0)
	Middle school	100 (14.5)
	High school background or above	32 (4.6)
Occupational	Agricultural workers	573 (83.0)
	Other	117 (17.0)
Economic level	Low income	291 (42.2)
	Middle and low income	203 (29.4)
	Middle income	111 (16.1)
	Upper middle income	61 (8.8)
	High income	24 (3.5)

Table 2
Characteristics of Rural Middle-Aged and Elderly Study Participants Based on Housing Conditions and Household Cooking Fuel Types in Northwest China (2009–2019).

Variable		Year 2009 N (%)	Year 2011 N (%)	Year 2015 N (%)	Year 2019 N (%)	*p*
The per capita housing area of households	less than 10 square meters	101 (14.6)	53 (7.7)	51 (7.4)	38 (5.5)	<0.001
	10 ~	225 (32.6)	192 (27.8)	159 (23.0)	132 (19.1)	
	20 ~	138 (20.0)	156 (22.6)	150 (21.7)	154 (22.3)	
	30 ~	92 (13.3)	105 (15.2)	88 (12.8)	107 (15.5)	
	40 ~	134 (19.4)	184 (26.7)	242 (35.1)	259 (37.5)	
The number of years of housing	0 ~	236 (34.2)	215 (31.2)	227 (32.9)	327 (47.4)	<0.001
	10 ~	197 (28.6)	199 (28.8)	200 (29.0)	195 (28.3)	
	20 ~	176 (25.5)	170 (24.6)	153 (22.2)	93 (13.5)	
	30 ~	68 (9.9)	86 (12.5)	84 (12.2)	59 (8.6)	
	40 years and above	13 (1.9)	20 (2.9)	26 (3.8)	16 (2.3)	
Types of building materials	full brick	84 (12.2)	65 (9.4)	108 (15.7)	173 (25.1)	<0.001
	brick wood	172 (25.0)	203 (29.4)	252 (36.5)	267 (38.7)	
	brick soil concrete	162 (23.5)	197 (28.6)	134 (19.4)	143 (20.7)	
	civil engineering	270 (39.2)	225 (32.6)	196 (28.4)	107 (15.5)	
Toilet type	flush toilet	113 (16.4)	106 (15.4)	62 (9.0)	117 (17.0)	<0.001
	non-flush toilet	577 (83.6)	584 (84.6)	628 (91.0)	573 (83.0)	
Separation of housing and kitchen	yes	516 (74.8)	508 (73.6)	477 (69.1)	452 (65.5)	<0.001
	no	174 (25.2)	182 (26.4)	213 (30.9)	238 (34.5)	
Cooking fuel use type	non-solid fuel	8(1.2)	21 (3.0)	52 (7.5)	261 (37.8)	<0.001
	solid fuel	76 (11.0)	84 (12.2)	175 (25.4)	184 (26.7)	
	both clean and solid fuels are used	606 (87.8)	585 (84.8)	463 (67.1)	245 (35.5)	

Notably, there has been an increase in the housing acreage available to rural middle-aged and elderly residents. In 2019, there was a significant surge in the percentage of this demographic residing in homes exceeding 40 square meters, reaching 37.5 %. Most housing for this population is relatively new, with less than a decade since construction. The use of full brick or brick wood as primary building materials has notably increased. Although there was a declining trend in segregating bedrooms from culinary spaces, over 65 % of households still have combined sleeping and cooking areas. The use of exclusively non-solid fuels for cooking has risen from 1.2 % in 2009 to 37.8 % in 2019. The use of solid fuels as cooking fuel in 2019 was 26.7%.

3.1.3. Description of HRQOL in rural middle-aged and elderly

Using four-period balanced panel data, we could track ten-year changes in HRQOL among these 690 middle-aged and older adults. As shown in Table 3, there were significant differences in the self-reporting of mobility, self-care, usual activities, pain / discomfort and anxiety /

Table 3
Health Utility Value and EQ-VAS Scores among Rural Middle-Aged and Elderly Participants in Northwest China (2009–2019).

Dimension	Year 2009			Year 2011			Year 2015			Year 2019			*p*
	No N (%)	Some N (%)	Extreme N (%)	No N (%)	Some N (%)	Extreme N (%)	No N (%)	Some N (%)	Extreme N (%)	No N (%)	Some N (%)	Extreme N (%)	
Mobility	561 (81.3)	121 (17.5)	8 (1.2)	591 (85.7)	90 (13.0)	9 (1.3)	529 (76.7)	152 (22.0)	9 (1.3)	517 (74.9)	158 (22.9)	15 (2.2)	<0.001
Self-Care	627 (90.9)	54 (7.8)	9(1.3)	635 (92.0)	48 (7.0)	7 (1.0)	608 (88.1)	74 (10.7)	8 (1.2)	595 (86.2)	79 (11.4)	16 (1.2)	0.008
Usual Activities	551 (79.9)	125 (18.1)	14 (2.0)	595 (86.2)	86 (12.5)	9(1.3)	541 (78.4)	128 (18.6)	21 (3.0)	540 (78.3)	124 (18.0)	26 (3.8)	0.001
Pain/Discomfort	449 (65.1)	219 (31.7)	22 (3.2)	481 (69.7)	192 (27.8)	17 (2.5)	437 (63.3)	235 (34.1)	18 (2.6)	417 (60.4)	241 (34.9)	32 (4.6)	0.007
Anxiety/Depression	513 (74.3)	159 (23.0)	18 (2.6)	557 (80.7)	120 (17.4)	13 (1.9)	591 (85.7)	95 (13.8)	4 (0.6)	533 (77.2)	146 (21.2)	11 (1.6)	<0.001
Utility value	0.83 ± 0.18			0.86 ± 0.16			0.83 ± 0.18			0.81 ± 0.21			0.001
EQ-VAS	67 ± 17			68 ± 17			66 ± 17			62 ± 18			<0.001

depression in the four surveys of rural middle-aged and elderly people ($p < 0.05$). In terms of the EQ-5D index score and EQ-VAS score, showed a decreasing trend ($p < 0.05$).

3.2. Impact of housing condition and cooking fuel choices on HRQOL

Table 4 showed the test results of the EQ-VAS score in the GEE model. The group of the per capita housing area of households is less than 10(vs. 40 ~) middle-aged and elderly people showed significantly lower total EQ-VAS scores ($\beta = -3.156$; 95 % CI: −5.616,−0.697), as well as significantly higher scores for the full brick ($\beta = 2.337$; 95 % CI: 0.436, 4.238), brick and wood ($\beta = 1.879$; 95 % CI: 0.184, 3.573), flush toilet ($\beta = 1.665$; 95 % CI: 0.026, 3.303), separation of bedroom and kitchen ($\beta = 2.872$; 95 % CI: 1.527, 4.217), and both solid and non-solid fuels are used as cooking fuel ($\beta = 1.847$; 95 % CI: 0.320, 3.373) ($p < 0.05$), after adjusting for all confounders.

Table 4
GEE model for EQ-VAS Scores among Rural Middle-Aged and Elderly Participants in Northwest China (2009–2019).

Variables	β (95 % confidence intervals)		
	Model 1	Model 2	Model 3
The per capita housing area of households (ref = 40 ~)			
0~	−2.005 (−4.673,0.662)	−3.62(−6.208, −1.033) **	−3.156(−5.616, −0.697) *
10~	1.544 (−0.240,3.328)	0.255 (−1.501,2.012)	0.063 (−1.611,1.736)
20~	1.410 (−0.312,3.132)	0.503 (−1.2,2.205)	0.087 (−1.573,1.747)
30~	1.196 (−0.744,3.137)	0.884 (−0.988,2.756)	1.174 (−0.626,2.973)
Age of housing (ref = 40 years and above)			
0~	0.223 (−3.808,4.254)	−2.136 (−6.209,1.938)	−0.917 (−4.664,2.829)
10~	0.934 (−3.070,4.938)	−1.643 (−5.696,2.409)	−0.538 (−4.263,3.187)
20~	1.561 (−2.420,5.541)	−0.709 (−4.735,3.317)	0.359 (−3.316,4.034)
30~	1.3 (−2.961,5.561)	0.053 (−4.332,4.225)	0.724 (−3.251,4.699)
Types of building materials (ref = Civil engineering)			
full brick	1.433 (−0.616,3.512)	2.133 (0.161,4.105) *	2.337 (0.436,4.238) *
brick wood	1.489 (−0.311,3.29)	1.903 (0.141,3.665) *	1.879 (0.184,3.573) *
Brick soil concrete	1.479 (−0.276,3.234)	1.424 (−0.251,3.098)	1.409 (−0.189,3.007)
Toilet type (ref = non-flush toilet)			
flush toilet	1.019 (−0.725,2.764)	1.819 (0.104,3.534) *	1.665 (0.026,3.303) *
Separation of housing and kitchen (ref = no)			
yes	4.349 (2.872,5.826)	3.223 (1.083,4.642) ***	2.872 (1.527,4.217) ***
cooking fuel use type (ref = solid fuels)			
non-solid fuels	−2.632(−4.639, −0.625) *	−0.673 (−2.697,1.352)	0.173 (−1.745,2.091)
both solid and non-solid fuels are used	−0.244 (−1.816,1.329)	1.149 (−0.435,2.733)	1.847 (0.320,3.373) *

Note: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. Model 1: unadjusted model; Model 2: adjusted by age, gender, marital Status, educational background, occupation and economic level only; Model 3: adjusted for hospitalization and chronic disease illness on the basis of model 2.

Table 5 exhibits the test outcomes of the EQ-5D index score in the GEE model. The findings indicated a statistical correlation between housing area, housing material type, and the separation of housing and kitchen from the HRQOL ($p < 0.05$), after adjusting for individual demographic and socioeconomic characteristics such as age, gender, marital status, educational background, occupation, and economic level. Moreover, controlling for the prevalence of chronic diseases and hospitalization revealed statistically significant differences in EQ-5D index scores among rural middle-aged and older adults based on cooking fuel type ($p < 0.05$).

4. Discussion

We conducted tracking and analysis of the living conditions, cooking fuel choices, and HRQOL changes among the elderly in rural northwest China from 2009 to 2019. The research findings reveal that improving the housing conditions and adopting clean fuel for cooking positively influence the HRQOL for elderly individuals in rural areas.

During the period from 2009 to 2019, the average utility index for the elderly in rural northwest China ranged from 0.81 to 0.86. Simultaneously, it is noteworthy that the average utility index measured using the EQ-5D-3L tool designed for the Chinese population is 0.985, surpassing our research findings (Yao et al., 2021). This discrepancy may arise from several factors: firstly, our study focused on the middle-aged and elderly in rural northwest China, exhibiting cultural differences and distinct perspectives on health issues compared to other studied populations. Secondly, the EQ-5D-3L health state utility values we utilized were tailored to the preferences of the rural Chinese population in 2022 (Liu et al., 2022). Lastly, our research results indicate that pain/discomfort is the most commonly reported issue by respondents, consistent with other studies (Huang et al., 2017; Yao et al., 2021).

Furthermore, from 2009 to 2019, the average per capita living space for the elderly in rural northwest China significantly increased, with a continuous surge in the construction of new buildings. At the same time, there was a noticeable shift in housing materials from wood-based structures to constructions made of brick, concrete, or solid brick and stone. However, despite an increase in the proportion of rural elderly households equipped with sanitary toilet facilities, they still constitute a minority. Importantly, over 60 % of this demographic continues to

Table 5
GEE Model for Health Utility Value among Rural Middle-Aged and Elderly Participants in Northwest China (2009–2019).

Variables	β (95 % confidence intervals)		
	Model 1	Model 2	Model 3
The per capita housing area of households (ref = 40 ~)			
0~	−0.026(−0.047,-0.005) *	−0.035(−0.056,-0.015) **	−0.032(−0.053,-0.011) **
10~	−0.003 (−0.013,0.007)	−0.010 (−0.020,0.000) *	−0.010(−0.019,-0.001) *
20~	−0.005 (−0.016,0.006)	−0.009 (−0.020,0.001)	−0.011 (−0.021,0.000) *
30~	0.002 (−0.009,0.012)	−0.001 (−0.011,0.009)	0.000 (−0.010,0.010)
Age of housing (ref = 40 years and above)			
0~	0.024 (−0.009,0.057)	0.008 (−0.025,0.041)	0.016 (−0.015,0.047)
10~	0.024 (−0.008,0.057)	0.007 (−0.026,0.040)	0.015 (−0.017,0.047)
20~	0.029 (−0.004,0.062)	0.013 (−0.020,0.046)	0.020 (−0.011,0.052)
30~	0.009 (−0.025,0.044)	0.001 (−0.034,0.035)	0.007 (−0.026,0.040)
Types of building materials (ref = Civil engineering)			
full brick	0.000 (−0.015,0.014)	0.004 (−0.010,0.018)	0.005 (−0.008,0.018)
brick wood	0.011 (−0.002,0.024)	0.012 (0.000,0.025) *	0.012 (0.000,0.024) *
Brick soil concrete	0.009 (−0.003,0.021)	0.009 (−0.002,0.021)	0.009 (−0.002,0.020)
Toilet type (ref = non-flush toilet)			
flush toilet	−0.002 (−0.013,0.009)	0.003 (−0.008,0.014)	0.002 (−0.009,0.012)
Separation of housing and kitchen (ref = no)			
yes	0.029 (0.017,0.041) ***	0.020 (0.009,0.031) **	0.018 (0.007,0.028) **
cooking fuel use type (ref = solid fuels)			
non-solid fuels	0.001 (−0.010,0.013)	0.010 (−0.001,0.021)	0.014 (0.003,0.025) *
both solid and non-solid fuels are used	−0.002 (−0.012,0.009)	0.004 (−0.005,0.014)	0.007 (−0.003,0.016)

Note: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. Model 1: unadjusted model; Model 2: adjusted by age, gender, marital Status, educational background, occupation and economic level only; Model 3: adjusted for hospitalization and chronic disease illness on the basis of model 2.

reside in households where the kitchen and bedroom are not separated. We find that, despite the diversification of energy consumption, traditional solid fuels remain the primary energy source in rural areas of northwest China, either used alone or in combination, consistent with previous research results (Liu et al., 2018; Shen et al., 2022). This further underscores the need to promote the transition of rural household energy towards clean cooking fuels (Ma et al., 2021).

Enhancing the housing conditions for the elderly in rural areas, particularly by adopting clean energy for cooking, can actively promote their HRQOL. This conclusion aligns with prior research, which also emphasizes the importance of providing suitable and supportive housing environments and living spaces in improving the physical activity levels of the elderly (Meghani et al., 2023). Additionally, the study further reveals that using solid fuels, compared to non-solid fuels, significantly increases the likelihood of the elderly developing chronic diseases while diminishing their self-assessed health status (Liu et al., 2018). Our research unveils that a per capita housing area below 10 square meters has a detrimental impact on the HRQOL for the rural elderly. On the other hand, housing constructed with all brick or a mixture of brick and wood materials has a positive impact. The results further indicate that living conditions such as a lack of sanitary toilets, separated bedrooms and kitchens negatively affect HRQOL, consistent with previous research results (Antunes et al., 2023; Fang et al., 2019). These findings provide additional evidence, emphasizing the significance of improving housing conditions and environments for the rural elderly in maintaining and enhancing their HRQOL.

Therefore, to effectively support this demographic, coordination is needed between public health and housing policies (Swope and Hernández, 2019). Based on the current status of rural housing construction and the health-related needs of elderly families, public health professionals should collaborate with housing architects to formulate basic standards and technical guidance (Jacobs, 2011) (Swope and Hernández, 2019). Simultaneously, raising awareness among rural elderly residents about the importance of separating housing and kitchen spaces and encouraging them to undertake toilet hygiene reforms would not only contribute to enhancing their overall quality of life but also promote the development of age-friendly housing (Fang et al., 2019; Wei et al., 2023). To mitigate the health hazards of using solid fuels, it is necessary to promote clean energy. Considering the geographical climate, resource conditions, and limited technical knowledge of the rural elderly in northwest China, many households face limitations in adopting clean energy. Hence, providing clean energy technology support tailored to specific regional requirements and subsidies is crucial (Quansah et al., 2017). Additionally, the government should prioritize establishing rural energy service stations and strengthen public services related to rural energy (Ma et al., 2021).

Finally, there are certain limitations inherent in this study. In rural areas of developing countries, the working and living environments of disadvantaged groups often overlap and lack clear delineation; however, we have not gathered sufficient information to conduct a relevant analysis on this aspect. Nevertheless, our current investigation is based on longitudinal data aimed at comprehending the fluctuations in housing conditions and household cooking fuel preferences among middle-aged and elderly individuals residing in China's rural regions over a decade-long period. Moreover, our objective is to scrutinize the enduring impacts of housing conditions and household cooking fuel choices on HRQOL. The insights gained from this study will facilitate conducting similar research in other communities.

5. Conclusion

In conclusion, the study revealed that the HRQOL of middle-aged and elderly people in rural northwest China showed a downward trend from 2009 to 2019. In addition, pain/discomfort was the most commonly reported problem among respondents. Our research showed that the housing area, housing material type, utilization of sanitary toilets, separation of housing and kitchen were separated and non-solid fuels used as cooking fuel were significantly associated with high HRQOL. The findings aid relevant departments in focusing on rural housing environments and the utilization of clean cooking fuels from a public health perspective, enhancing HRQOL for the rural middle-aged and elderly population in China.

Author contributions

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

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Ethics approval

The study was conducted in accordance with the Declaration of

Helsinki, and the protocol was approved by the Ethics Committee of Ningxia Medical University (2021-G152).

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

CRediT authorship contribution statement

Kexin Chen: Data curation, Formal analysis, Investigation, Writing – original draft. **Wenlong Wang:** Conceptualization, Investigation, Writing – original draft. **Jiangwei Qiu:** Data curation, Investigation. **Wenqin Guo:** Data curation, Investigation. **Jiancai Du:** Data curation, Investigation. **Baokai Gao:** Data curation, Investigation. **Zhaoyan Hu:** Data curation, Investigation. **Hui Qiao:** Research idea and Design.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

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References

Antunes, M.C., Zardeto, H.N., Pscheidt, S.L., Custódio, G., Mello, D.N., Giehl, M.W.C., 2023. Built environment and its association with self-rated health in Brazilian elderly: National Health Survey 2013. Cien. Saude Colet 28, 3137–3148.

Bhat, A.C., Almeida, D.M., Fenelon, A., Santos-Lozada, A.R., 2022. A longitudinal analysis of the relationship between housing insecurity and physical health among midlife and aging adults in the United States. SSM Popul. Health 18, 101128.

Chang, A.Y., Skirbekk, V.F., Tyrovolas, S., Kassebaum, N.J., Dieleman, J.L., 2019. Measuring population ageing: an analysis of the Global Burden of Disease Study 2017. Lancet Public Health 4, e159–e167.

Chen, C., Liu, G.G., Shi, Q.L., Sun, Y., Zhang, H., Wang, M.J., Jia, H.P., Zhao, Y.L., Yao, Y., 2020. Health-related quality of life and associated factors among oldest-old in China. J. Nutr. Health Aging 24, 330–338.

Dasgupta, S., Huq, M., Khaliquzzaman, M., Pandey, K., Wheeler, D., 2006. Indoor air quality for poor families: new evidence from Bangladesh. Indoor Air 16, 426–444.

Deng, Y., Gao, Q., Yang, D., Hua, H., Wang, N., Ou, F., Liu, R., Wu, B., Liu, Y., 2020. Association between biomass fuel use and risk of hypertension among Chinese older people: A cohort study. Environ. Int. 138, 105620.

Fandiño-Del-Rio, M., Kephart, J.L., Williams, K.N., Moulton, L.H., Steenland, K., Checkley, W., Koehler, K., 2020. Household air pollution exposure and associations with household characteristics among biomass cookstove users in Puno, Peru. Environ. Res. 191, 110028.

Fandiño-Del-Rio, M., Kephart, J.L., Williams, K.N., Malpartida, G., Boyd Barr, D., Steenland, K., Koehler, K., Checkley, W., 2021. Household air pollution and blood markers of inflammation: A cross-sectional analysis. Indoor Air 31, 1509–1521.

Fang, M., Mirutse, G., Guo, L., Ma, X., 2019. Role of socioeconomic status and housing conditions in geriatric depression in rural China: a cross-sectional study. BMJ Open 9, e024046.

Fatmi, Z., Coggon, D., 2016. Coronary heart disease and household air pollution from use of solid fuel: a systematic review. Br. Med. Bull. 118, 91–109.

García-Esquinas, E., Pérez-Hernández, B., Guallar-Castillón, P., Banegas, J.R., Ayuso-Mateos, J.L., Rodríguez-Artalejo, F., 2016. Housing conditions and limitations in physical function among older adults. J. Epidemiol. Community Health 70, 954–960.

Guo, W., Du, J., Chen, K., Wang, W., Gao, B., Hu, Z., Qiao, H., 2022. The mediation path of physical multimorbidity on the vulnerability to health-related poverty of rural aging families in Ningxia, China: A cross-sectional survey. Front. Public Health 10, 993977.

Higgs, C., Lowe, M., Hooper, P., Mavoa, S., Arundel, J., Gunn, L., Simons, K., Giles-Corti, B., 2023. Policy relevant health related liveability indicator datasets for addresses in Australia's 21 largest cities. Sci. Data 10, 113.

Huang, W., Yu, H., Liu, C., Liu, G., Wu, Q., Zhou, J., Zhang, X., Zhao, X., Shi, L., et al., 2017. Assessing health-related quality of life of chinese adults in heilongjiang using EQ-5D-3L. Int. J. Environ Res. Public Health 14.

Ito, T., Sugasawa, S., 2022. Grouped generalized estimating equations for longitudinal data analysis. Biometrics.

Jacobs, D.E., 2011. Environmental health disparities in housing. Am. J. Public Health 101 (Suppl 1), S115–S122.

Jonak, C., Porkert, S., Oerlemans, S., Papadavid, E., Molloy, K., Lehner-Baumgartner, E., Cozzio, A., Efficace, F., Scarisbrick, J., 2019. Health-related quality of life in cutaneous lymphomas: past, present and future. Acta Derm. Venereol. 99, 640–666.

Kang, S.H., Ju, Y.J., Yoon, H.J., Lee, S.A., Kim, W., Park, E.C., 2018. The relationship between catastrophic health expenditure and health-related quality of life. Int. J. Equity Health 17, 166.

Kim, J.H., 2019. Multicollinearity and misleading statistical results. Korean J. Anesthesiol. 72, 558–569.

Lapin, B.R., 2020. Considerations for reporting and reviewing studies including health-related quality of life. Chest 158, S49–S56.

Li, H., Zeng, Y., Gan, L., Tuersun, Y., Yang, J., Liu, J., Chen, J., 2022. Urban-rural disparities in the healthy ageing trajectory in China: a population-based study. BMC Public Health 22, 1406.

Liu, G.G., Guan, H., Jin, X., Zhang, H., Vortherms, S.A., Wu, H., 2022. Rural population's preferences matter: a value set for the EQ-5D-3L health states for China's rural population. Health Qual. Life Outcomes 20, 14.

Liu, J., Hou, B., Ma, X.W., Liao, H., 2018. Solid fuel use for cooking and its health effects on the elderly in rural China. Environ. Sci. Pollut. Res. Int. 25, 3669–3680.

Ma, X., Wang, M., Chen, D., Li, C., 2021. Energy choice in rural household cooking and heating: influencing factors and transformation patterns. Environ. Sci. Pollut. Res. Int. 28, 36727–36741.

Meghani, N.A.A., Hudson, J., Stratton, G., Mullins, J., 2023. Optimising older adults' home spaces to enhance their physical activity level: an exploratory qualitative study protocol. BMJ Open 13, e066940.

Pérez-Hernández, B., Lopez-García, E., Graciani, A., Ayuso-Mateos, J.L., Rodríguez-Artalejo, F., García-Esquinas, E., 2018. Housing conditions and risk of physical function limitations: a prospective study of community-dwelling older adults. J. Public Health (oxf) 40, e252–e259.

Quansah, R., Semple, S., Ochieng, C.A., Juvekar, S., Armah, F.A., Luginaah, I., Emina, J., 2017. Effectiveness of interventions to reduce household air pollution and/or improve health in homes using solid fuel in low-and-middle income countries: A systematic review and meta-analysis. Environ. Int. 103, 73–90.

Riggs, L., Keall, M., Howden-Chapman, P., Baker, M.G., 2021. Environmental burden of disease from unsafe and substandard housing, New Zealand, 2010–2017. Bull. World Health Organ 99, 259–270.

Shen, G., Xiong, R., Tian, Y., Luo, Z., Jiangtulu, B., Meng, W., Du, W., Meng, J., Chen, Y., et al., 2022. Substantial transition to clean household energy mix in rural China. Natl. Sci. Rev. 9 nwac050.

Sims, M., Kershaw, K.N., Breathett, K., Jackson, E.A., Lewis, L.M., Mujahid, M.S., Suglia, S.F., 2020. Importance of housing and cardiovascular health and well-being: a scientific statement from the American Heart Association. Circ. Cardiovasc. Qual. Outcomes 13, e000089.

Swope, C.B., Hernández, D., 2019. Housing as a determinant of health equity: A conceptual model. Soc. Sci. Med. 243, 112571.

Wang, Q., Cao, H., Zhang, S., 2022. Trends of and factors associated with access to residential toilets among the middle-aged and elderly in rural China from 2011 to 2018. BMC Public Health 22, 421.

Wang, S., Qian, L., Carroll, R.J., 2010. Generalized empirical likelihood methods for analyzing longitudinal data. Biometrika 97, 79–93.

Wei, K., Wang, W., Fahad, S., 2023. Spatial and temporal characteristics of rural livability and its influencing factors: implications for the development of rural revitalization strategy. Environ. Sci. Pollut. Res. Int.

Yang, Z., Fu, Y., 2019. Physical attributes of housing and elderly health: a new dynamic perspective. Int. J. Environ. Res. Public Health 16.

Yang, Y., Liu, Y., Peng, L., Zhang, S., Yuan, C., Li, W., Liu, Z., Ma, Y., 2022. Cooking or heating with solid fuels increased the all-cause mortality risk among mid-aged and elderly People in China. Environ. Health 21, 91.

Yao, Q., Zhang, X., Wu, Y., Liu, C., 2023. Decomposing income-related inequality in health-related quality of life in mainland China: a national cross-sectional study. BMJ Glob Health 8.

Yao, Q., Liu, C., Zhang, Y., Xu, L., 2021. Population norms for the EQ-5D-3L in China derived from the 2013 National Health Services Survey. J. Glob. Health 11, 08001.

Zhang, Y., Sun, Y., Xie, M., Chen, Y., Cao, S., 2022. Health shocks, basic medical insurance and common prosperity: Based on the analysis of rural middle-aged and elderly groups. Front. Public Health 10, 1014351.