BMC Public Health

RESEARCH

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The impact of contracted family doctor services on social adaptability among middle-aged and older adults in rural China: the mediating role of regular health management

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Abstract

Purpose Social adaptability is essential for healthy aging. This study examines how Contracted Family Doctor Services (CFDS) affect social adaptability in rural Chinese middle-aged and older adults, assessing the mediating role of regular health management (RHM).

Methods and materials Using national cross-sectional data from the 2018 China Health and Retirement Longitudinal Study (CHARLS), we analyzed 13,895 community-dwelling adults. We employed generalized linear models (GLM), mediation analysis, and an instrumental variable-based control function approach (IV-CFA) to evaluate causality and control for confounding.

Results Research demonstrated that CFDS participation was significantly associated with enhanced social adaptability ($\beta = 0.204$, $p < 0.01$). RHM partially mediated this relationship, explaining 29.5% of the total effect. Heterogeneity analyses indicated significant associations between CFDS and social adaptability for adults aged 45-60 years ($\beta = 0.250$, $p < 0.01$) and males ($\beta = 0.308$, $p < 0.01$), whereas no significant effects were observed among adults ≥60 years or females.

Conclusions CFDS significantly enhances social adaptability among rural middle-aged and older adults, broadening primary care's impact beyond biomedical domains. RHM mediates 29.5% of this effect. The benefits were particularly pronounced among younger individuals and male subgroups. To sustain CFDS effectiveness, China should maintain 1-3% annual coverage growth while implementing targeted measures: combating social isolation in older adults, screening for perimenopausal comorbidities among women, and strengthening intergenerational care support programs.

Keywords Contracted family doctor services, Middle-aged and older adults, Social adaptability, Regular health management

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Introduction

As gatekeepers designated for primary health, family doctors enhance population health by delivering proactive, continuous care to contracted residents—thereby establishing a foundation for China's primary health care (PHC) reform. Family doctors, formally designated as general practitioners (GPs) or family physicians (FPs) in most healthcare systems, serve as central providers in primary care. Although originating in the United Kingdom during the mid-nineteenth century, China's family doctor model emerged as a policy priority through the 1997 national health reform. This reform prioritized establishing a formalized GP system and standardizing GP training within primary care systems [1]. Building on this groundwork, China formally launched its Contracted Family Doctor Services (CFDS) nationwide in 2016 [2]. Positioned as a core mechanism within China's healthcare system, the CFDS addresses escalating service demands through structured service provision at the community level.

Health constitutes a multidimensional construct encompassing physical, mental, and social well-being. This framework transcends biomedical parameters to operationalize the World Health Organization's (WHO) definition:'a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity [3].'Within this framework, social well-being is operationalized through social adaptability—defined as the proactive adjustment individuals make to changing social environments [4, 5]. In gerontological contexts, social adaptability becomes vital as older adults experience age-related transitions—retirement, widowhood, or physical decline—which necessitate dynamic renegotiation of social roles and environments [6]. Sociologists pioneered this concept [7], examining both maladaptive outcomes (e.g., elevated suicide rates among isolated rural elders) [8, 9] and proactive strategies for navigating late-life challenges [10]. Public health research establishes adaptability as a key determinant of older adults'health, with robust adaptive capacity linked to reduced depression risk and attenuated physical frailty progression [11, 12]. Despite the well-documented relevance to holistic health, research on family doctor systems predominantly focuses on physical and mental health outcomes [13], largely overlooking social adaptability metrics in aging populations.

As early as the 1960s, Hugh recognized family physicians'critical role as frontline healthcare providers [14]. The efficacy of family doctor services in managing physical health conditions is now well-documented. For instance, a Cambridge University study demonstrated that local GP identified dementia in 50% of patients over 75 years old and detected 66% of severe cases through medical records and clinical recall [15]. An Australian randomized controlled trial demonstrated that GP educational interventions significantly improved health behaviors and self-reported health outcomes in elderly patients [16]. A study conducted in China showed that the CFDS significantly improved self-assessed health in people under 65 years of age and had a positive impact on impaired activities of daily living (ADL) and chronic disease control in people over 65 years of age [17]. Furthermore, family doctors'ability to provide continuous and long-term services underpins their strong performance in chronic disease management, which has been widely recognized [18–20]. In addition to its positive effects on physical health, the significance of the family doctor service in terms of mental health has also been verified. A literature review showed that GP involvement in cancer care not only improved patients'physical health but also better identified their psychological issues [21]. A Macau-based study of older adults demonstrated that GP significantly contributed to the early detection and clinical management of psychological disorders [22]. Consistent with these findings, multiple intervention trials confirmed the efficacy of family physician-led services in ameliorating mental health conditions, including depression [23, 24]. Nevertheless, scant empirical evidence exists regarding CFDS and social adaptability correlates. A 2019 cross-sectional survey in Shenzhen, China, revealed a significant association between family physician engagement and enhanced social functioning in post-stroke patients. Specifically, CFDS implementation reduced self-perceived caregiving burden, improved ADL and motor recovery, and potentially facilitated familial relationship maintenance [25]. As a well-documented determinant of healthy aging, social adaptability merits equivalent scholarly attention as physical and mental health dimensions within gerontological research [26].

Existing research frequently overlooks the role of social adaptability in the health benefits of the CFDS. For rural middle-aged and older adults in China—a population disproportionately affected by profound structural inequities (e.g., limited educational access, infrastructural deficits, and geographic isolation) [27, 28]—maintaining robust social adaptability is critically essential. Facing rapid societal transformations like urbanization and the digital divide [29], this group encounters heightened barriers to social integration, with studies indicating approximately 80% experience such challenges [30]. Diminished adaptive capacity exposes them to significant risks, including social isolation, psychological distress, and accelerated declines in health and well-being [31]. We therefore investigate the CFDS impact on social adaptability among this vulnerable population. This study specifically examines this impact through mediation analysis of regular health management (RHM), aiming

to generate evidence-based strategies for targeted CFDS enhancement.

Data and methods

Data and participants

Data were derived from the 2018 wave of the China Health and Retirement Longitudinal Study (CHARLS), conducted by Peking University (accessible at: https://charls.pku.edu.cn/.). The nationally representative sample covers 28 provincial-level divisions (including provinces, autonomous regions, and municipalities) across 150 counties/districts and 450 communities/villages. CHARLS constitutes a nationally representative survey generating high-quality microdata on Chinese households and individuals aged ≥ 45 years. The 2018 wave introduced novel modules assessing CFDS and Integrated Eldercare and Medical Services (IEMS), enabling robust analysis for this study. Participants comprised community-dwelling adults aged ≥ 45 years. After excluding samples with implausible values, data anomalies, or critical variable missingness (> 30%), the final analytical sample included 13,895 observations. Figure 1 illustrates the process of determining the main research population.

Variables

Independent variable

The independent variable comprised whether the respondent received services from the CFDS and was represented by the answer to the question"Have you ever received paid family doctor services?"The variable was a dummy variable. It was assigned a value of 1 if the respondent had received services from the CFDS and a value of 0 if they had not. More details can be found in Table 1.

Dependent variables

Aligning with Wang and Luo's multidimensional health framework, social adaptability was measured through three core indicators derived from empirical studies: social interaction efficacy, adaptive learning capacity, and social support provision competence [32].

"Social interaction efficacy was measured through a composite index assessing participatory breadth across four domains: engagement in informal friend interactions, participation in recreational activities (Mahjong/chess/card games or community clubs), involvement in structured groups (sports/social clubs), and contributions to community organizations. Each affirmative engagement added 1 point to a summated scale ranging 0–4, where higher scores reflected expanded social

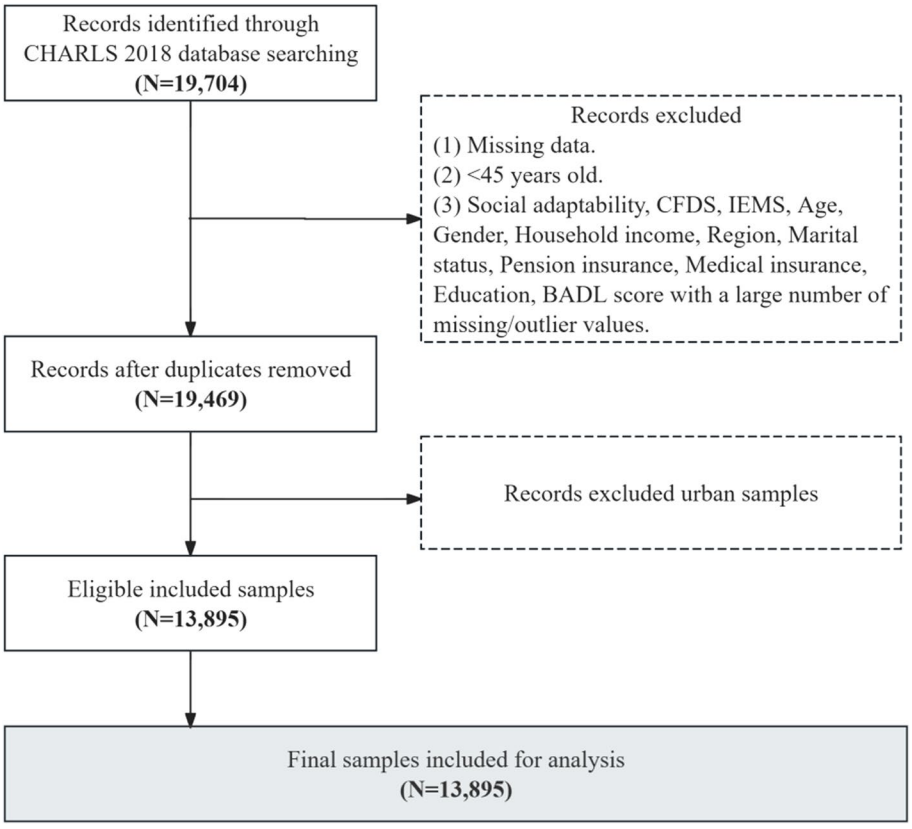

Fig. 1 Flow diagram to illustrate determination of the primary study population

Table 1 Variable assignment table

Variables	Variables assignment	Variable code
Contracted Family Doctor Services	NO = 0, YES = 1	CFDS
social adaptability(point)	Continuous variable	adaptability
Integrated eldercare and medical services	NO = 0, YES = 1	IEMS
Regular health management	NO = 0, YES = 1	RHM
Age(years)	Continuous variable	Age
Gender	Female = 0, Male = 1	Gender
Household income(yuan)	Continuous variable	Income
Region	Eastern region = 0	Region
	Central region = 1	
	Western region = 2	
Marital status	Unmarried = 0, Married = 1	Marital
Pension insurance	NO = 0, YES = 1	P_insurance
Medical insurance	NO = 0, YES = 1	M_insurance
Education(year)	Continuous variable	Education
Basic activities of daily living(point)	Continuous variable	BADL

integration within community contexts."Adaptive learning capacity was derived from a continuous composite scale (0–3), quantifying engagement in three skill-updating domains: educational advancement (attending training courses), financial adaptability (stock investment), and digital integration (Internet utilization). Each participatory instance contributed 1 point to the total score, with higher values signifying greater information acquisition and instrumental skills development essential for contemporary social adaptability. Social support provision competence was assessed via a 3-point additive scale capturing three domains of tangible aid provision: (1) assisting non-cohabiting family/friends/neighbors, (2) undertaking volunteer/charity work, and (3) caring for non-resident ill/disabled adults. Each affirmative engagement contributed 1 point to the summative score (0–3 range), with elevated scores reflecting greater competence in mobilizing instrumental support resources within community networks.

Using the entropy weight method—an objective weighting technique based on information entropy—we calculated weights for the three dimensions (social interaction efficacy, adaptive learning capability, and competence in providing social support). The composite social adaptability score was computed via weighted summation of standardized dimension scores, with weights satisfying $\sum wk = 1$. For intuitive interpretation, the raw composite scores were linearly rescaled to a 0–10 range using min–max normalization, where higher values indicate superior overall adaptive competence (i.e., a score of 10 represents the optimal adaptability level).

Mediating variables

We operationalized RHM as the key mediator variable linking CFDS and elderly social adaptability using a validated dichotomous measure derived from the survey question:"In the past year, did a community/village doctor perform regular blood pressure checks for you?"(affirmative responses indicating service receipt). This indicator constitutes the most fundamental CFDS component mandated by national primary care protocols, serving as the primary nexus converting clinical interventions into social benefits. Its theoretical justification rests on the established biomedical pathway whereby hypertension monitoring enables timely risk mitigation (e.g., reducing dizziness-related fall hazards that impair mobility), thereby maintaining functional capacity essential for sustained social participation. Methodologically, the community-doctor-administered measurement circumvents recall and desirability biases inherent in self-reported health assessments, while its binary operationalization ensures robust causal interpretation within mediation frameworks. Crucially, this approach captures the core implementation mechanism of CFDS—structured physiological surveillance preceding behavioral outcomes—without contamination from psychosocial confounders that might directly influence social adaptability metrics.

Control variables

Control variables were selected to capture demographic and socioeconomic heterogeneity: age, gender, household income, region (categorized as Eastern/Central/Western China), marital status, pension insurance coverage, health insurance participation, educational attainment, and basic activities of daily living (BADL). Standardized measurement protocols for all variables are detailed in Table 1.

Instrumental variable

China's national policy promotes the integration of health and elderly care services [33]. Collaboration with

family doctors represents one of the key models for implementing Integrated Eldercare and Medical Services (IEMS) [34]. This model has been successfully implemented in multiple regions, including Shanghai [35]. In this study, we select the implementation status of IEMS as the instrumental variable. The rollout of IEMS policy exhibits a top-down exogenous nature. Pilot site selection is typically based on macro-level regional planning criteria (such as aging rates and medical resource density), which are unrelated to the social behaviors of individual elderly persons. Furthermore, the IEMS policy mandates collaboration between medical institutions and eldercare facilities, requiring family doctor teams to be regularly stationed in these facilities/communities to provide health management. Its primary policy objectives directly target the improvement of healthcare service linkage (e.g., chronic disease follow-ups, establishment of health records), rather than the construction of social support networks. Manifestations of elderly social adaptability, such as the frequency of participation in community activities or the closeness of neighborhood relationships, are unlikely to be directly altered by the mere presence of an IEMS model. The core pathway of its influence is through promoting CFDS with the elderly, thereby improving their health status, which subsequently indirectly enhances social adaptability capacity. Therefore, IEMS satisfies the exclusion restriction and can serve as a valid instrumental variable for investigating the relationship between CFDS and elderly social adaptability. Naturally, the suitability of this instrumental variable must still be rigorously tested through relevant econometric models.

Following established operational definitions in the literature [2], respondents were classified as IEMS users if they utilized at least one core service (e.g., daycare centers, nursing homes, subsidized community dining, routine health examinations, onsite medical visits, family sickbeds, community nursing, etc.). Table 1 provides complete measurement specifications for all variables.

Methods

Entropy weight method

The Entropy Weight Method (EWM), an objective weighting technique based on information entropy, determines indicator weights by evaluating data dispersion. We applied this widely adopted approach within a multi-indicator evaluation framework to quantify three core competencies. The resulting weights were: social interaction efficacy (0.176), adaptive learning capacity (0.464), and social support provision competence (0.360). The comprehensive social adaptability score was subsequently derived through weighted aggregation of these indicators. Due to space constraints, detailed computational formulas are provided in the additional file 1.

Generalized linear model

Given that the dependent variable data exhibits a pronounced right-skewed distribution and possesses non-negative continuous characteristics, we employed a Generalized Linear Model (GLM) with a Gamma distribution and log link function. The model specification is as follows:

$$ln(E[adaptation_i]) = \beta_0 + \beta CFDS_i + \boldsymbol{X}_i^{\top}\beta_2 \quad (1)$$

where $adaptability_i$ represents individual i's social adaptability, $CFDS_i$ denotes a binary indicator variable (1 = contracted, 0 = not contracted) for family doctor service enrollment, X_i signifies the control variable vector, and β_2 represents the corresponding coefficient vector. Robust standard errors were implemented throughout estimation to mitigate heteroscedasticity concerns. The effects of independent variables are presented as exponentiated coefficients—Incidence Rate Ratios(IRR)—which reflect multiplicative changes in the expected outcome value.

IV-GLM control function approach

To address potential endogeneity concerns in CFDS—such as omitted variables and reverse causality—this study employs an instrumental variable-based control function approach(IV-CFA).

$$CFDS_i = \gamma_0 + \gamma_1 \cdot IEMS_i + \boldsymbol{X}_i^T\gamma_2 + \nu_i \quad (2)$$

This stage aims to predict the endogenous regressor $CFDS_i$ using the exogenous instrument $IEMS_i$, deriving residual estimates $\widehat{v}_1$ that quantify unobserved confounding for subsequent incorporation into the second-stage endogeneity correction. The instrumental variable $IEMS_i$ must satisfy two critical assumptions: the relevance condition ($\gamma_1 = 0$), and the exogeneity condition (Cov ($IEMS_i$, ϵi) = 0).

$$ln\left(E\left[adaptation_i\right]\right) = \delta_0 + \delta_1 \cdot CFDS_i + \boldsymbol{X}_i^T\delta_2 + \delta_3 \cdot \widehat{\nu}_i \quad (3)$$

In this stage, the residual estimates $\widehat{v}_1$ are incorporated into the GLM specification as a control function, where the coefficient δ_1 now represents the net effect of CFDS on social adaptability after correcting for endogeneity.

Mediation effects models

Drawing on the methodology of Preacher et al. [36], we employed a stepwise regression approach to test the mediating effect of RHM in the pathway through which CFDS enhances social adaptability. The empirical models are structured as follows:

$$ln(E[adaptation_i]) = \beta_0 + \beta_1 CFDS_i + X_i^T\beta_2 \quad (4)$$

$$ln(E[RHM_i]) = \alpha_0 + \alpha_1 CFDS_i + X_i^T \alpha_2 \quad (5)$$

$$ln(E[adaptation_i]) = \theta_0 + \theta_1 CFDS_i + \theta_2 HM_i + X_i^T \theta_3 \quad (6)$$

Equation (4) is the total effect model, where β_1 represents the total effect of CFDS on social adaptability. Equation (5) is the mediator path model, where α_1 denotes the effect of CFDS on the mediator variable RHM. Equation (6) is the direct effect model: θ_1 indicates the direct effect of CFDS on social adaptability after controlling for RHM, while θ_2 represents the effect of RHM on social adaptability after controlling for CFDS.

Thus, the indirect effect is $\alpha_1 \times \theta_2$, the direct effect is θ_1, and the total effect $\beta_1 = \theta_1 + \alpha_1 \times \theta_2$. Additionally, in our bootstrap procedure, we generated 1,000 replicated samples through random resampling with replacement, derived the empirical distributions of both indirect and direct effects, and subsequently computed bias-corrected confidence intervals and statistical significance. All data were statistically analyzed using *Stata 16.0* software.

Propensity score matching

Propensity score matching approximates randomized trials by creating matched cohorts balanced on observed covariates, thereby mitigating selection bias in observational studies. Drawing on the classical Rubin causal model for counterfactual analysis, a dichotomous variable *Di* (*Di* = 1 if received CFDS, *Di* = 0 otherwise) was constructed to indicate treatment group assignment. First, covariates x_i were selected—including age, gender, household income, regional division, marital status, pension insurance status, health insurance status, and education level—to satisfy the ignorability assumption. Second, propensity scores were estimated via a Logit model to quantify individual *i*'s probability of receiving CFDS. Subsequently, propensity score matching(PSM) was performed. Among multiple matching approaches—including k-nearest neighbor matching, caliper matching, radius matching with *k-NN* adjustment, and kernel matching—radius matching with *k-NN* adjustment demonstrated optimal performance and was thus selected. Finally, the GLM was re-estimated using the matched sample to test the robustness of the primary model.

Results

Descriptive statistics of the sample

Among the 13,895 samples, the average age was 62.39 years, with females (52.44%) slightly outnumbering males. The average annual income of respondents was RMB 26,256.76 yuan, with the majority being married (84.91%). The proportion of respondents from eastern regions (35.60%) was slightly higher than those from central (30.54%) and western regions (33.86%). Most respondents had pension insurance (88.06%) and medical insurance (96.59%). The average BADL score among respondents was 5.84. Further details are presented in Table 2.

Benchmark regression results

Table 3 presents the GLM regression results for the association between CFDS and social adaptability. Using a Gamma regression model with a log link function and robust standard errors, CFDS showed a significant positive association with the standardized social adaptability score. Specifically, the coefficient for CFDS was $\beta = 0.204$ (robust SE = 0.063, $p < 0.01$), indicating that each additional unit of CFDS was associated with a 0.204-unit increase in the log-transformed expected social adaptability score. Transformed to the original scale, this corresponds to a 22.6% multiplicative increase in the expected score (IRR = 1.226, 95% CI: 1.084–1.387), after adjusting for age, gender, income, region, and health covariates.

Beyond the significant positive association of CFDS with social adaptability, multiple covariates demonstrated notable effects. Older age predicted lower social adaptability scores ($\beta = -0.034$, IRR = 0.967, $p < 0.01$), with each additional year corresponding to a 3.3% reduction in expected scores. Higher log-transformed income was associated with improved adaptability ($\beta = 0.036$, IRR = 1.037, $p < 0.01$), reflecting a 3.7% increase per unit. Residents in central regions showed significantly better adaptability than those in eastern regions ($\beta = 0.116$, IRR = 1.123, $p < 0.01$), representing a 12.3% advantage. Contrastingly, married individuals exhibited reduced scores relative to unmarried counterparts ($\beta = -0.160$, IRR = 0.852, $p < 0.01$), equivalent to a 14.8% decrease. Both education level ($\beta = 0.126$, IRR = 1.134, $p < 0.01$) and BADL($\beta = 0.278$, IRR = 1.321, $p < 0.01$) demonstrated strong positive effects, predicting 13.4% and 32.1% increases per unit respectively. Detailed estimates are provided in Table 3.

Analysis of heterogeneity

Table 4 presents heterogeneity analysis examining differential effects of CFDS across subpopulations. Significant effect variations were observed: Among relatively younger adults (45–60 years), CFDS showed a strong positive impact on social adaptability ($\beta = 0.250$, $p < 0.01$). Conversely, for older adults (≥ 60 years), the association was non-significant ($\beta = 0.125$, $p = 0.174$). Striking gender disparities emerged: CFDS significantly benefited males ($\beta = 0.308$, $p < 0.01$) but not females ($\beta = 0.061$, $p = 0.534$). All models included full covariates (age, gender, income, etc.) with better fit for younger adults (AIC = 1.87) versus older groups (AIC = 0.43). The empirical evidence confirms that CFDS significantly enhances social adaptability among middle-aged individuals (45–60 years) and male

Table 2 Basic characteristics of the sample

Variables	Total ($n=13,895$)	Non-contracted ($n=1,3248$)	Contracted ($n=647$)	*P/t*
Adaptability				< 0.001
Mean ± S.D	0.70 ± 1.08	0.69 ± 1.06	0.89 ± 1.37	
Age (years)				0.0683
Mean ± S.D	62.39 ± 10.07	62.36 ± 10.06	63.11 ± 10.30	
Gender				0.003
Female	7,286 (52.44)	6,984 (52.72)	302 (46.68)	
Male	6,609 (47.56)	6,264 (47.28)	345 (53.52)	
Ln (Income)				0.0752
Mean ± S.D	8.09 ± 3.54	8.08 ± 3.55	8.32 ± 3.40	
Area				0.809
East	4,947 (35.60)	4,720 (35.63)	227 (35.09)	
Centre	4,243 (30.54)	4,038 (30.48)	205 (31.68)	
West	4,705 (33.86)	4,490 (33.89)	215 (33.23)	
Marital Status				0.390
Unmarried	2,097 (15.09)	2,007 (15.15)	90 (13.91)	
Married	11,798 (84.91)	11,241 (84.85)	557 (86.09)	
P_insurance				0.001
No	1,659 (11.94)	1,609 (12.15)	50 (7.73)	
Yes	12,236 (88.06)	11,639 (87.85)	597 (92.27)	
M_insurance				0.025
No	474 (3.41)	462 (3.49)	12 (1.85)	
Yes	13,421 (96.59)	12,786 (96.51)	635 (98.15)	
Education				0.000
Mean ± S.D	3.03 ± 1.74	3.01 ± 1.74	3.41 ± 1.84	
BADL				0.0705
Mean ± S.D	5.84 ± 0.70	5.85 ± 0.69	5.78 ± 0.88	
IEMS				0.000
No	12,309 (88.59)	11,801 (89.08)	508 (78.52)	
Yes	1,586 (11.41)	1,447 (10.92)	139 (21.48)	
RHM				0.000
No	9,784 (83.09)	9,378 (83.61)	406 (72.63)	
Yes	1,991 (16.91)	1,838 (16.39)	153 (27.37)	

(1) The Pearson Chi-square test is used for categorical variables, and the t-test is used for continuous variables. (2) Due to the presence of numerous zero and extreme values in the household income variable, it was log-transformed

populations, while not reaching statistical significance in other demographic groups.

Analysis of mediating effect

Mediation analysis revealed that RHM partially explains the positive effect of CFDS on social adaptability. As shown in Table 5: The total effect of CFDS was significant ($\beta = 0.204$, $p < 0.01$, 95% CI [0.087, 0.320]). CFDS strongly predicted RHM adoption (mediator pathway: $\beta = 0.614$, $p < 0.01$). When both CFDS and RHM were included, direct effects remained significant ($\beta = 0.192$, $p < 0.01$, 95% CI [0.075, 0.309]), while RHM itself showed a positive impact ($\beta = 0.098$, $p < 0.05$). Bootstrap results (1,000 reps) confirmed a significant indirect effect of 0.060 (95% CI [0.010, 0.110], $p < 0.05$), accounting for 29.5% of the total effect. This demonstrates that RHM acts as a partial mediator in the CFDS-adaptability relationship, explaining nearly one-third of the overall benefit.

Endogeneity analysis

To address potential endogeneity bias in CFDS estimates, we implemented an instrumental variable generalized linear model (IV-GLM) with control function approach, utilizing the IEMS as an instrumental variable. Results presented in Table 6 confirm the instrument's validity, demonstrating that IEMS strongly predicted CFDS adoption ($\beta = 0.048$, $p < 0.01$) with an F-statistic of 40.44—significantly exceeding the critical threshold of 10 and thereby rejecting weak instrument concerns. After endogeneity correction, the CFDS coefficient increased substantially to $\beta = 0.434$ ($p < 0.01$, robust SE = 0.092), suggesting that baseline estimates may have underestimated the true treatment effect. Notably, the positive coefficient direction remains consistent with our primary GLM results, further reinforcing the robustness of CFDS benefits. The model fit improved substantially (AIC decreased from 1.87 to 1.00), supporting the control function

Table 3 GLM regression results of CFDS on social adaptability

Variables	Social adaptability			
	Coefficient/*β*	**Std. Error**	**IRR**	**95% CI**
CFDS	**0.204*****	**0.063**	**1.226*****	[1.084, 1.387]
Age	−0.034***	0.002	0.967***	[0.964, 0.970]
Gender (Female=0)	−0.039	0.029	0.961	[0.908, 1.018]
Ln (Income)	0.036***	0.004	1.037***	[1.028, 1.046]
Central region (Eastern region=0)	0.116***	0.031	1.123***	[1.056, 1.194]
Western region (Eastern region=0)	0.043	0.033	1.044	[0.979, 1.114]
Marital Status (Unmarried=0)	−0.160***	0.043	0.852***	[0.783, 0.928]
P_insurance (NO=0)	0.003	0.043	1.003	[0.922, 1.091]
M_insurance (NO=0)	−0.126	0.093	0.882	[0.736, 1.058]
Education	0.126***	0.009	1.134***	[1.115, 1.153]
BADL	0.278***	0.043	1.321***	[1.213, 1.438]
Cos	−0.491	0.306	0.612	[0.336, 1.114]
N	13,895			
Residual df	13,883			

(1) Gamma GLM with log-link reports *β* coefficients (additive effects on log-mean) and IRR (multiplicative mean effects, e.g., IRR=1.2=20% increase). (2) Robust SEs correct for heteroskedasticity. (3) Statistical significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4 Results of heterogeneity analysis

Variables	Social adaptability			
	Relatively younger adults group (45–60 years)	**Older adults group (≥ 60 years)**	**Female**	**Male**
CFDS(NO = 0)	**0.250***** (0.078)	0.125 (0.092)	0.061 (0.098)	**0.308***** (0.091)
Control variables	Controlled	Controlled	Controlled	Controlled
Cos	−2.646*** (0.474)	−3.007*** (0.322)	−3.077*** (0.357)	−3.544*** (0.424)
N	5,783	8,112	7,286	6,609
AIC	1.8705	0.4289	0.9286	1.2703

(1) All estimates are derived from GLM. (2) Statistical significance: *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$. (3) All specified control variables (age, gender, income, etc.) are included. (4) Goodness-of-fit: Model fit is assessed using the Akaike Information Criterion (AIC), with lower values indicating better fit

specification. While empirical evidence supports IEMS's statistical validity, we acknowledge possible alternative influence pathways beyond the CFDS mechanism. For instance, community eldercare facilities may enhance seniors'social networks independently of family doctor services. Concurrently, policy-driven health awareness initiatives (e.g., regular health screenings) could improve mental health outcomes alongside the CFDS framework.

Robustness test of benchmark regression

Robustness was further substantiated through propensity score matching (PSM) using caliper-based 3-nearest neighbor matching, where the caliper width was set at 0.25 standard deviations of the propensity score (actual caliper value = 0.0819, k = 3). Figure 2 demonstrates that after matching, biases in all covariates except one were substantially reduced (largely falling within the acceptable range of ± 10%), indicating PSM effectively minimized systematic differences between the treatment and control groups.

As evidenced in Table 7, GLM estimates derived from the balanced matched sample ($n = 13{,}825$) demonstrated exceptional congruence with baseline findings: The CFDS treatment effect remained statistically robust ($\beta = 0.203$, $p = 0.001$; IRR = 1.226, 95% CI [1.083, 1.386]), with all key covariates exhibiting coefficient variations below 0.5% ($|\Delta\beta| < 0.003$ for CFDS, age, income, education, and BADL) while maintaining identical directionality and significance patterns across all control variables. This methodological stability—reinforced by absolute standardized differences falling below the 0.10 threshold post-matching—provides empirical confirmation that our core inferences withstand selection bias concerns.

Table 5 Results of mediation effect analysis

Variables	Total effect	Mediator model	Direct effect	Bootstrap result (1,000 reps)
RHM (NO = 0)			**0.098**** **(0.038)**	
CFDS (NO = 0)	**0.204***** **(0.063)**	**0.614***** **(0.102)**	**0.192***** **(0.062)**	
Control variables	Controlled	Controlled	Controlled	
Cos	−0.491 (0.308)	−4.369*** (0.412)	−0.954* (0.992)	
Indirect effect (a × b)				0.060 (0.026)** [0.010–0.110]
Direct effect (c')				0.192 (0.062)*** [0.075–0.309]
Total effect (c)				0.203 (0.063)*** [0.087–0.320]
Mediation Proportion				29.5%
N	11,775			

(1) The coefficient estimates reflect the pathway effects of CFDS on social adaptability. Robust standard errors are reported in parentheses. (2) Bootstrap results for mediation effects (indirect/direct/total) are derived from 1,000 replications, with 95% confidence intervals shown in brackets. (3) The mediation proportion (29.5%) quantifies the indirect effect's contribution to the total effect (0.0601/0.2037). (4) Statistical significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. (5) All specified control variables (age, gender, income, etc.) are included

Table 6 Results of the endogeneity analysis

Variables	CFDS(NO = 0)	Social adaptability
CFDS(NO = 0)		**0.434***** **(0.092)**
IEMS(NO = 0)	**0.048***** **(0.008)**	
Control variables	Controlled	Controlled
Cos	0.018 (0.027)	−0.450 (0.308)
Weak instrumental variable test	40.44	
R_squared/AIC	0.092	1.005

(1) Endogeneity control: Analysis employs the IV-GLM control function approach with IEMS as the instrumental variable for CFDS. (2) Statistical significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. (3) Control variables: All covariates included in both stages. (4)Robustness: Standard errors reported in parentheses

Discussion

This study found that CFDS significantly improved social adaptability in rural middle-aged and older Chinese adults. Using the IV-CFA, we confirmed this robust causal relationship. The benefits were particularly strong among adults aged 45–60 years and male subgroups. Critically, RHM mediated approximately 30% of CFDS's total effect. As noted in the Introduction, while existing research predominantly focuses on the physical and mental health effects of CFDS, this study contributes to emerging evidence by examining its impact on social adaptability, a dimension rarely addressed in prior studies.

Regular blood pressure(BP) monitoring as a proxy for RHM demonstrates a significant mediating link between CFDS and enhanced social adaptability (indirect effect = 0.060, 95% CI: 0.010–0.110), with hypertension control preserving functional capacity to reduce disability barriers [37]. Clinical interactions during monitoring concurrently function as socialization training, boosting adaptability—aligning with Chen's observed 15% social confidence gain from rural clinic engagement [38]. Bandura's self-efficacy theory elucidates this process [39]: CFDS first builds health self-efficacy through physician support (verbal persuasion) and BP control achievements (mastery experiences), increasing RHM adherence ($\beta = 0.614$, $p < 0.001$). This efficacy reservoir subsequently transfers to social domains via three channels: (a) improved physical capacity enabling participation; (b) generalized confidence from health successes; and (c) expanded support networks through continuous patient-doctor relationships. Our analysis identified regular BP monitoring (as the operational proxy for RHM) as a significant mediator. However, the interpretation of this mediation effect must be contextualized within a key measurement limitation. While regular BP monitoring is a vital and accessible component of chronic disease management—particularly hypertension, which is highly prevalent among middle-aged and older adults in rural China—it remains a primary focus of family doctor

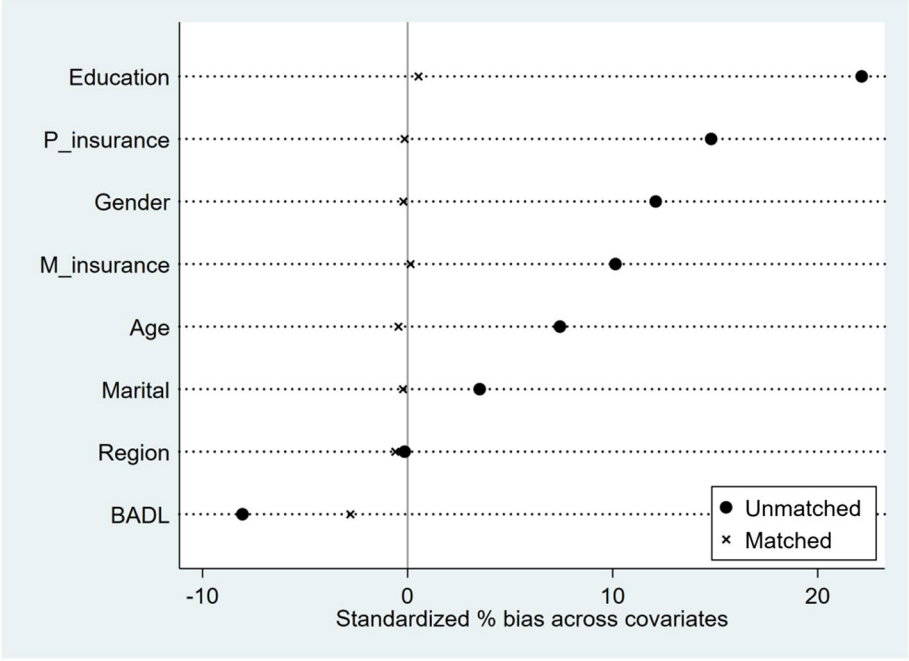

Fig. 2 Standardized percent bias of covariates before and after PSM

Table 7 GLM coefficients with PSM

Variables	Social adaptability				
	Coefficient/*β*	**Std. Error**	**IRR**	**95% CI**	***p***
CFDS	0.203	0.063	1.226	[1.083, 1.386]	0.001
Age	−0.034	0.002	0.967	[0.964, 0.970]	0.000
Gender (Female = 0)	−0.037	0.029	0.964	[0.911, 1.020]	0.205
Ln (Income)	0.036	0.004	1.036	[1.028, 1.045]	0.000
Central region (Eastern region = 0)	0.114	0.031	1.120	[1.054, 1.191]	0.000
Western region (Eastern region = 0)	0.040	0.033	1.041	[0.976, 1.110]	0.219
Marital Status (Unmarried = 0)	−0.167	0.043	0.847	[0.778, 0.922]	0.000
P_insurance (NO = 0)	−0.012	0.043	0.989	[0.909, 1.075]	0.788
M_insurance (NO = 0)	−0.199	0.097	0.820	[0.678, 0.991]	0.040
Education	0.126	0.009	1.134	[1.115, 1.153]	0.000
BADL	0.278	0.043	1.321	[1.215, 1.437]	0.000
Cos	−0.382	0.305	0.683	[0.375, 1.242]	0.211
N	13,825				
Residual df	13,813				

PSM was performed using caliper-based 3-nearest neighbor matching (k = 3) within a caliper width of 0.0819. The caliper was defined as 0.25 standard deviations of the propensity score logit. Matching was conducted without replacement, and common support was enforced

services. Nevertheless, its use as the sole proxy for RHM warrants discussion. RHM encompasses a diverse set of health-seeking and self-management behaviors beyond BP monitoring, such as: regular check-ups for other chronic conditions (e.g., diabetes, hyperlipidemia); timely vaccination; medication adherence; lifestyle modifications (diet, exercise, smoking cessation); management of health records; and proactive communication with healthcare providers. Focusing only on BP monitoring provides an incomplete picture of an individual's engagement in their overall health management routine. It potentially overlooks significant aspects of proactive and preventive health behaviors that RHM entails. Consequently, our analysis cannot illuminate which specific aspects of RHM (driven by family doctor services) are most crucial for enhancing social adaptability.

Nevertheless, as the most observable core component of RHM, the identified mediating effect of BP monitoring provides critical preliminary evidence: health management behaviors—particularly structured clinical interactions—serve as conduits linking family doctor contracts to social adaptability. This underscores RHM's value as a viable pathway and warrants future investigations using multidimensional measures (e.g., integrating medication adherence and preventive screenings) to elucidate comprehensive transmission mechanisms.

Our heterogeneity analysis reveals critical differential impacts of CFDS on social adaptability, underscoring the intervention's context-dependent efficacy. The significantly stronger effect among younger adults (45–60 years: $\beta = 0.250$, $p < 0.01$) versus older cohorts (≥ 60 years: $\beta = 0.125$, ns) may reflect life-stage disparities in health plasticity and social roles: Younger individuals likely possess greater capacity to translate health management gains into social reintegration, whereas age-related comorbidities and entrenched social isolation in older groups may buffer CFDS benefits—consistent with CHARLS findings on functional limitations exacerbating with age [40].

Similarly, the stark gender gap (Male: $\beta = 0.308$, $p < 0.01$; Female: $\beta = 0.061$, ns) suggests structural barriers rooted in gendered healthcare dynamics. For males, CFDS potentially overcomes healthcare avoidance behaviors prevalent in rural China—where traditional masculinity norms discourage medical help-seeking [41]. By delivering services directly to households, CFDS bridges this accessibility gap, converting passive recipients into active health participants [42]. Conversely, the null effect among females signals systemic service deficiencies: Current CFDS protocols under-prioritize women's high-burden conditions (e.g., depression prevalence is 68% higher in rural women vs. men) [43] and ignore time constraints from disproportionate caregiving duties [44]. Compounding this, current social adaptability metrics exhibit systematic gender bias, prioritizing structured communal engagement while undervaluing relational contributions—a domain where women demonstrate pronounced strengths. This methodological gap calls for developing gender-sensitive instruments in future research.

To enhance social adaptability among rural middle-aged and older adults through CFDS, the country should continue expanding CFDS coverage nationally—targeting an annual growth rate of 1–3%, with priority given to western regions where current coverage remains below 40% [45]. Concurrently, health monitoring must be upgraded by replacing basic check-ups with integrated socio-health profiles that link physical metrics (e.g., BP control) to social engagement records, while implementing digital social prescriptions (e.g., weekly intergenerational activities) to strengthen health management's mediator role. Precision interventions should include: bundling physician enrollment with community services (fitness/education) for adults ≥ 60 to reduce isolation; integrating menopausal health screening (osteoporosis, cardiovascular risks, depression) into mobile clinics for rural women, supplemented by monthly"Menopause Care Days"at village centers; and synchronizing elderly chronic disease management with child health monitoring (nutrition/vaccination) to optimize resource efficiency.

This study demonstrates how CFDS enhance social adaptability in rural China. By extending services beyond disease-centered treatment, CFDS applies the WHO's holistic health framework of"complete physical, mental and social well-being."However, four limitations require attention. First, due to CHARLS survey intervals and CFDS's recent nationwide launch (2016), our findings reflect only intermediate-term effects (≤ 3 years of exposure). Second, the low CFDS adoption rate (4.65%) may cause selection bias. Although we used propensity score matching, unmeasured factors—such as differences in health-seeking motivation or family support—could still affect results. Third, current social adaptability measures may not fully capture rural aging experiences due to potential cultural or gender biases. For example: stock investment questions are less relevant in subsistence economies, and Mahjong participation metrics overlook female seniors'activities. Fourth, while BP monitoring aligns with hypertension management priorities in rural elders, it fails to reflect the full scope of RHM. This narrow measure misses critical components such as multi-disease screenings, vaccination adherence, and lifestyle modifications, potentially limiting the observed mediation effect. To advance beyond these constraints, future studies should: (1) establish longitudinal cohorts tracking CFDS impacts over ≥ 5 years; (2) employ mixed-methods designs integrating community interviews to dissect adoption barriers; (3) co-create culturally responsive social adaptability metrics with rural elders through participatory workshops—particularly centering women's lived experiences; and (4) develop multidimensional RHM indices synthesizing chronic disease screenings, preventive care documentation, and patient self-management diaries.

Conclusion

CFDS significantly enhances social adaptability among rural middle-aged and older adults ($\beta = 0.203$, $p < 0.01$), extending primary care benefits beyond biomedical domains. RHM (proxied by BP monitoring) mediates 29.5% of this effect ($\beta = 0.060$, 95% CI [0.010, 0.110]). Striking heterogeneity exists—younger adults ($\beta = 0.250$) and males ($\beta = 0.308$) benefit substantially more than elders (ns) and females (ns). To maximize CFDS'societal

impact, China must sustain annual coverage expansion (1–3 percentage points) while deploying demographically precision-targeted interventions: clinic-community bundles to counter age-related isolation for older adults, life-stage-timed perimenopausal comorbidity screening for rural women, and intergenerational responsibility synchronization to resolve caregiving-derived time poverty.

Abbreviations

ADL	Activities of Daily Living
BADL	Basic Activities of Daily Living
BP	Blood Pressure
CFDS	Contracted Family Doctor Services
CHARLS	China Health and Retirement Longitudinal Study
EWM	Entropy Weight Method
FP	Family Physicians
GLM	Generalized Linear Models
GP	General Practitioners
IRR	Incidence Rate Ratios
IEMS	Integrated Eldercare and Medical Services
IV-CFA	Instrumental Variable-based Control Function Approach
PHC	Primary Health Care
PSM	Propensity Score Matching
RHM	Regular Health Management
WHO	World Health Organization

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12889-025-24392-7.

Additional file 1. The mathematical expression formula of the EWM. The mathematical expression for calculating the weights of each part of the dependent variable using the entropy weight method

Additional file 2. China Health and Retirement Longitudinal Study Wave 4 (2018) Questionnaire. This survey constitutes a national longitudinal study comprehensively capturing multisource data on health, economic status, family dynamics, and social participation among individuals aged 45 and above in China

Acknowledgements
We would like to acknowledge the CHARLS team for providing the data.

Clinical trial number
Not applicable.

Authors' contributions
FY participated in the study design, data analysis and interpretation, and was the primary person responsible for drafting the manuscript. MS contributed to study design, data analysis, and reviews. TZ conceived of the study design, participated in data analysis, and revision. WZ, ZL and HL participated in revision. All authors read and approved the final manuscript.

Funding
This study was supported by the National Natural Science Foundation of China (Grant No. 72204128 & 72164031), the Natural Science Foundation of Inner Mongolia Autonomous Region (Distinguished Youth Grant No. 2025YQ041), and the Joint Research Fund of Inner Mongolia Medical Academy (Major Project Grant No. 2023GLLH0042).

Data availability
The Data were derived from the CHARLS. Researchers who want to use these data can visit https://charls.pku.edu.cn/.

Declarations

Ethics approval and consent to participate
The ethics review board of Peking University approved the CHARLS study (approval number IRB00001052-11015). Informed consent was obtained, and the data were anonymized for analysis.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Received: 28 April 2025 / Accepted: 11 August 2025
Published online: 06 October 2025

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