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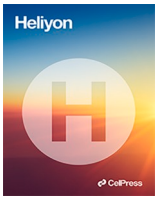

Research article

Socioeconomic inequalities in depressive symptoms in China: The role of social capital

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ABSTRACT

This cohort study used the China Health and Retirement Longitudinal Study (CHARLS, 2015–2018) to investigate the effects of socioeconomic status and social capital to the incidence of depressive symptoms among middle-aged and older individuals in China, incorporating a sample size of 9949 participants. Socioeconomic status, social capital and other explanatory variables were collected in 2015, while depressive symptoms were assessed in 2018. Basic characteristics and social capital measures were compared between urban and rural residents using the chi-square test. Logistic regression was used to explore the relationship between socioeconomic status, social capital and depressive symptoms, and the Karlson, Holm, and Breen (KHB) method was employed to verify the mediating role of social capital. We reported persistent socioeconomic inequalities in depressive symptoms, with rural residents and the illiterate having 1.45 times and 1.34 times higher odds of depression. We ascertained social capital from both the cognitive and structural constructs, where we enriched the measurement of structural social capital from three specific dimensions, i.e., informal interaction, altruism, and formal social participation. We found that both cognitive and structural social capital were associated with lower incidence of depressive symptoms, where informal interaction had the largest effect. The mediation analysis further illustrated that informal interaction contributed most to explain 6 %–12 % of the socioeconomic inequalities in depressive symptoms. These results highlighted the unsatisfied mental wellbeing of the vulnerable older people living in rural areas. The finding suggested that older people may benefit more from personal interactions than formal participations. To fulfill the Health in All vision, government and social organizations should consider how to create opportunities to better integrate the older people into the community.

1. Introduction

Depression has become a global epidemic and one of the main causes of disability worldwide [1], affecting about 280 million people [2] and claiming nearly 800,000 lives each year [3]. Especially after the outbreak of the COVID-19 epidemic, the prevalence of depression, anxiety and other common mental diseases increased by 25 % in the first year alone [4]. Depression disproportionately affects older populations [5,6]. In China, for example, an average of 20 % of the population aged 60 and above were encountering depressive symptoms during 1992–2018 [7]. Prevalence of depression follows the social gradients, where people with lower socioeconomic status (SES), whether measured by educational achievement, wealth or occupation, are more susceptible to experiencing

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depression [8–10]. Except for these individual-level factors, urban-rural residency is also considered as an indicator of SES and an important determinant of depression [11]. However, previous studies reported conflicting findings in different settings for the associations between depression and urban-rural residency from various settings. In many developed countries, the prevalence of depression was nearly 50 % higher amongst urban elderly than the rural ones [12], whilst in most developing countries, including China, older people living in the rural areas had higher prevalence [13,14].

As an upstream determinant of health, social capital is thought to be a predicator of better population health status [15,16], and mental wellbeing [17]. Social capital is an ecological variable and a contextual feature of a community, typically manifested as the degree of citizen participation in the community and the level of trust among community members. Although various taxonomies were suggested, public health literatures normally measured the cognitive and structural dimensions when examining the associations between social capital and populations' mental health [18–20]. Previous studies have found that socioeconomic status was a powerful predictor of social capital [21], and there was a positive correlation between socioeconomic status (household income, educational achievement) and social capital such as social participation and social trust [22].

Prior studies consistently reported negative associations between cognitive social capital and depression, but findings on the relationship between structural social capital and depression were not confirmative [23]. The discrepancies observed in the results could potentially be attributed to the variations in the study design and measurement methods employed for assessing structural social capital [23]. For example, a cross-sectional study conducted among Korean adults aged 65 and older found that structural social capital, measured as social connection, was not associated with depression [24], while another longitudinal study on Mexican older people [25] found that structural social capital, measured as collective action and cooperation, information and communication, empowerment and political action, was negatively associated with depression. In China, findings on the relationship between structural social capital and depression were inconsistent as well [26,27].

Social capital was proposed as a critical factor to improve health equity as manifested in the Health in All initiative [28]. In China, for example, constructing social capital and reducing the socioeconomic inequalities in depression have been endorsed in the Healthy China 2030 strategy under the theme of "Co-construction, Sharing, and Health for All". Previous research suggested that social capital may explain the socioeconomic inequality of depression in theory [29–31]. However, there is a lack of empirical investigations that report on the mediating effects of social capital for the socioeconomic inequalities in depression, for which our systematic search of the literature identified only two papers from Asian countries [27,32]. Both studies were based on cross-sectional designs, which are limited for causal inferences. In addition, the measurement of social capital varied between the studies, leading to inconsistent findings.

Adopting a cohort study design, we explored in this study the socioeconomic inequalities in the incidence of depressive symptoms among middle-aged and older people in China. We assessed participants' exposure to socioeconomic differentials and social capital in 2015 and follow up the occurrence of depressive symptoms in 2018. We enriched the measurement of structural social capital from three dimensions: informal interaction, altruism and formal social participation. By comparing the role of varied dimensions of social capital that mediated the socioeconomic inequalities in depression which were across educational achievement, wealth, and urban-rural settings, respectively, we stressed the importance of informal interaction, and discussed the importance of creating opportunities to better integrate the older people into the community.

2. Conceptual framework

As already known, higher socioeconomic status may predict lower risks of depression and higher stock of social capital. Higher stock of social capital, either in the cognitive or the structural dimension, were associated with better mental wellbeing. Prior studies

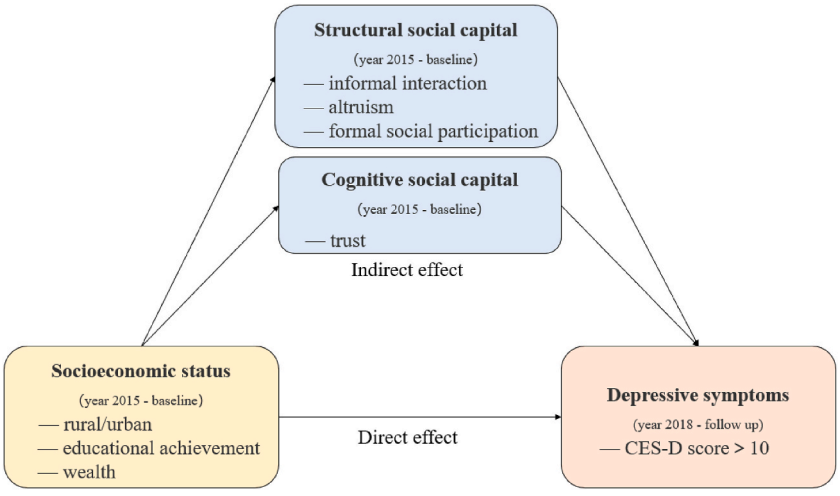


Fig. 1. A conceptual framework that models the mediating effect of social capital in explaining socioeconomic inequalities in depression.

also suggested that social capital may explain the socioeconomic gradient of depression in theory [29–31]. Building upon these theories, we have developed a conceptual framework to provide guidance for this research. As shown in Fig. 1, both socioeconomic status and social capital may have a direct impact on depression. In addition, socioeconomic status may also have an indirect impact on depression through the pathways involving social capital. We proposed three specific research questions: 1) Whether better socioeconomic status, either measured in terms of urban-rural residency, wealth, or educational achievement, were associated with lower incidence of depressive symptoms; 2) Whether higher stock of social capital, either measured in cognitive and structural constructs, were associated with lower incidence of depressive symptoms; And 3) How much could each dimension of social capital explain the socioeconomic inequalities of depressive symptoms across each SES indictor.

3. Methods

3.1. Study design

We designed a cohort study to explore the three questions above. The participants' socioeconomic status in 2015, including urban-rural residency, household wealth, and educational achievement, were measured as exposures. In addition, their social capital was assessed, comprising three dimensions of structural social capital and one dimension of cognitive social capital, also in 2015. These exposures were then associated with the outcomes, that is, being identified as having depressive symptoms after follow-up in 2018 using the CES-D 10 scale.

3.2. Data

We adopted a cohort study design, using two waves of survey from the China Health and Retirement Longitudinal Study (CHARLS), where we recruited all eligible participants from the 2015 survey and followed up their occurrence of depressive symptoms in 2018. The CHARLS is a longitudinal study of Chinese people aged 45 and above, by use of a multistage stratified probability proportion [33].

The CHARLS surveyed 21,098 participants in 2015 from 28 provinces, 150 counties/districts and 450 villages/communities across mainland China. Of the 21,098 participants from 2015, 18,136 participants (excluding 889 died and 2073 lost to follow-up) were successfully followed up in 2018, with a success rate of 85.96 %. We then excluded 814 participants who were less than 45 years of age, and 4974 participants who had already recorded depressive symptoms in 2015. Further excluding 2399 participants who did not respond to the depression scales in the 2018 survey, we finally included 9949 adults aged 45 years and older in this study (Fig. 2).

3.3. Measures

Outcome. The CHARLS assessed depressive symptoms using the ten-item short form of the Center for Epidemiologic Studies Depression Scale (CES-D 10). The CES-D 10 had demonstrated satisfactory psychometric property [34]. Researchers evaluated the reliability and validity of CES-D 10 in a large sample population and found that the Cronbach coefficient of the simplified scale was greater than 0.8 [35]. It recorded a total score range from 0 to 30. In line with the literature, we categorized a participant as having depressive symptoms should he/she reported a total score of no less than 10 [34].

Socioeconomic status. We used three indicators to measure each participant's socioeconomic status separately: urban-rural residency, educational achievement, and household wealth. We defined urban-rural residency based on the observation and verification of observers and the responses of respondents through a question in CHARLS: Was your address in the village or city/town? We categorized participant's educational achievement into three groups: illiterate, primary, and secondary and above. Based on the questionnaire of CHARLS, we included each household's expenses for healthcare, food, education, tourism, transportation, postal and telecommunications, daily necessities, fuel, clothing, heating, furniture, and durable consumer goods. After summing up, the total household expenditure was obtained and distributed to each person based on the number of family members, which was the annual per capita household expenditure. We categorized the participants into quartiles, with Q1 representing the poorest group and Q4 the

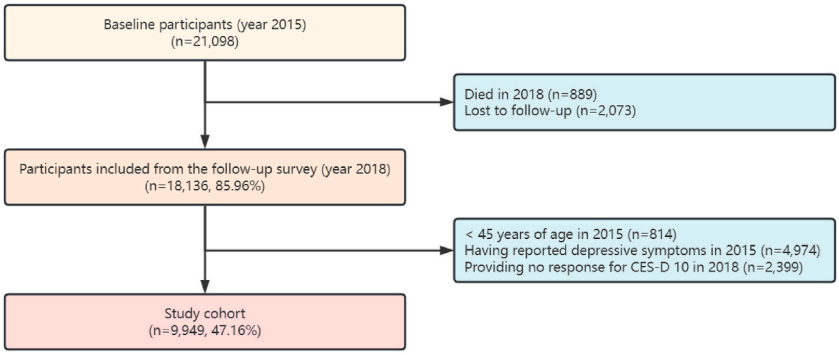


Fig. 2. Flowchart of the participant selection process.

richest. To report on comparative results, we further grouped educational achievement into illiterate and non-illiterate, and wealth into poor (Q1 and Q2) and rich (Q3 and Q4) in the mediation analysis.

Social capital. The cognitive dimension, that is, norms, values, and reciprocity between individuals, was usually measured in the term of social trust; whilst the structural dimension, that is, relationships and networks among individuals, was mostly measured in the term of organizational membership, social participation, social connection and interactions [23]. We defined four dichotomous variables to measure social capital from two distinct constructs: structural social capital and cognitive social capital.

The CHARLS asked whether the participants engaged in any of the eight social activities during the past month before the survey (Table 1). Building on Engbers [36] and Rotenberg [23], we used participation of any of the eight social activities to define three dimensions of structural social capital: informal interaction, altruism and formal social participation. Informal interaction referred to weather the participants be engaged in at least one of these four activities: (1) interacting with friends (2) playing Ma-jong, playing chess, playing cards, or going to community club (3) going to a sport, social, or other kind of club (4) taking part in a community-related organization. Altruism referred to weather the participants be engaged in at least one of these three activities: (1) providing help to family, friends, or neighbors who do not live with you (2) doing voluntary or charity work (3) caring for a sick or disabled adult who does not live with you. And formal social participation referred to weather the participants be engaged in attending an educational or training course.

We measured cognitive social capital based on trust [23]. The CHALRS asked each participant whether he/she having relatives or friends (besides spouse/partner) who would be willing and able to help over a long period of time, should the participant need help for basic daily activities such as eating or dressing. For an answer of yes, we defined the participant to have cognitive social capital, that is, perceived trust to receive others support when he/she needs help.

Other covariates. Building on the literature [37,38], we included the following covariates that might be predictors of depression, in order to control potential covariates: Age (grouped as 45–54 years, 55–64 years, 65–74 years, 75 years or older), sex (males, females), ethnicity (Han majority, other minorities), marital status (married/partnered, single), health insurance coverage (Urban Employee Basic Medical Insurance, Urban-rural Residency Basic Medical Insurance or New Rural Cooperative Medical Scheme, other insurances, without insurances), smoking (yes, no), drinking alcohol (yes, no), and number of chronic conditions (0, 1, 2, 3 and above).

3.4. Statistical analysis

We described the cohorts' basic characteristics, and reported on the proportion of participants having each construct or dimension of social capital. We stratified participants by urban-rural residency and perform Chi square test to compare the differences. We performed logistic regression to examine the association between each SES determinants (urban-rural residency, education and wealth), and each construct/dimension of social capital (informal interaction, altruism, formal social participation, and trust), with the incidence of depressive symptoms in the follow-up period, adjusting for all other potential covariates. We employed the Karlson, Holm, and Breen (KHB) method to estimate the mediating effects of each social capital construct/dimension on the socioeconomic inequalities in depression. The KHB [39] method decomposed the total effects of each SES indicator into two components: direct effects and indirect effects, and then reported on, for each of the SES indicators, the proportion of socioeconomic inequalities in the outcome that were explained by each mediating variable. Since depressive symptom was measured as a dichotomous variable, we specified a logit link function in the KHB model. All analysis was performed using Stata 13.1.

3.5. Subgroup analysis

The dual structure between urban-rural settings in China is prominent, with significant infrastructural, policy, economic and environmental differences [40]. To test whether urban-rural typology would affect the finding, we tested the interaction effects between the urban-rural dummy variable and educational achievement, wealth, and the four dimensions of social capital by including the interaction terms of urban-rural dummy variable with each of the other covariate and testing the joint significance of the interaction terms using Wald test. We further stratified the mediation analysis by urban and rural subgroups, to check whether urban-rural residency would affect the mediating effects of the various social capital construct/dimension on education and wealth related

Table 1
Measure of social capital.

Construct	Dimension	Questions
Structural social capital	**Informal interaction**	Activity 1, interacted with friends
		Activity 2, played Ma-jong, played chess, played cards, or went to community club
		Activity 3, went to a sport, social, or other kind of club
		Activity 4, took part in a community-related organization
	Altruism	Activity 5, provided help to family, friends, or neighbors who do not live with you
		Activity 6, done voluntary or charity work
		Activity 7, cared for a sick or disabled adult who does not live with you
	Formal social participation	Activity 8, attended an educational or training course
Cognitive social capital	**Trust**	Having relatives or friends (besides spouse/partner) who would be willing and able to help over a long period of time, should the participant need help for basic daily activities such as eating or dressing?

inequalities in depression.

4. Results

4.1. Cohort characteristics

There were 9949 individuals included in the cohorts, among which 43 (0.4 %) participants lacked information for household wealth. Table 2 presented the cohorts' basic characteristics in 2015 and the incidence of depressive symptoms in 2018, stratified by participants' urban-rural residency. There were 57.6 % (5737/9949) participants living in rural areas. Fig. 3 showed that 25.9 % (2579/9948) participants reported depressive symptoms in 2018, including 1697 living in rural areas and 882 living in urban areas, with an incidence rate of 29.6 % and 20.9 %, respectively ($p < 0.001$).

The cohort presented varied basic characteristics across urban-rural settings. More rural residents (26.7 %) were in the lowest wealth quartile, comparing to a proportion of 13.7 % for their urban counterparts ($p < 0.001$). And 17.8 % of the participants were illiterate, with the proportion being 11.3 % for the urban residents and 22.6 % for the rural one ($p < 0.001$). Despite the differences in

Table 2
Cohorts' basic characteristics in 2015 and incidence of depressive symptoms in 2018, by urban and rural residency.

Basic Characteristics	Overall		Urban		Rural	
	(n = 9949)		(n = 4212)		(n = 5737)	
	n	%	n	%	n	%
Educational achievement						
Illiterate	1774	17.8	478	11.3	1296	22.6
Primary school	4027	40.5	1433	34.0	2594	45.2
Secondary school and above	4148	41.7	2301	54.6	1847	32.2
Household wealth[a]						
Q1 poorest	2108	21.2	577	13.7	1531	26.7
Q2	2452	24.6	852	20.2	1600	27.9
Q3	2604	26.2	1221	29.0	1383	24.1
Q4 richest	2742	27.6	1534	36.4	1208	21.1
Age groups						
45–54 years	3943	39.6	1608	38.2	2335	40.7
55–64 years	3452	34.7	1480	35.1	1972	34.4
65–74 years	2030	20.4	855	20.3	1175	20.5
75 years and above	524	5.3	269	6.4	255	4.4
Sex						
Female	4625	46.5	2043	48.5	2582	45.0
Male	5324	53.5	2169	51.5	3155	55.0
Ethnicity						
Other minorities	724	7.3	266	6.3	458	8.0
Han major	9225	92.7	3946	93.7	5279	92.0
Marital status						
Married or partnered	9090	91.4	3823	90.8	5267	91.8
Single or others	859	8.6	389	9.2	470	8.2
Health insurance coverage						
UEBMI[b]	1586	15.9	1319	31.3	267	4.7
URBMI or NRCMS[c]	7986	80.3	2632	62.5	5354	93.3
Other insurances	272	2.7	213	5.1	59	1.0
Without insurances	105	1.1	48	1.1	57	1.0
Smoke						
No	9094	91.4	3782	89.8	5312	92.6
Yes	855	8.6	430	10.2	425	7.4
Drinking alcohol						
No	5280	53.1	2244	53.3	3036	52.9
Yes	4669	46.9	1968	46.7	2701	47.1
Number of chronic conditions						
0	5375	54.0	2318	55.0	3057	53.3
1	2563	25.8	1000	23.7	1563	27.2
2	1283	12.9	561	13.3	722	12.6
3 and above	728	7.3	333	7.9	395	6.9
Depressive symptoms (year 2018)						
No	7370	74.1	3330	79.1	4040	70.4
Yes	2579	25.9	882	20.9	1697	29.6

Note.
p-Value reports Chi-square tests for all categorical variables.
[a] There were 43 (0.4 %) participants missing information for household wealth.
[b] UEBMI: Urban Employee Basic Medical Insurance.
[c] URBMI or NRCMS: Urban Resident Basic Medical Insurance or New Rural Cooperative Medical Scheme.

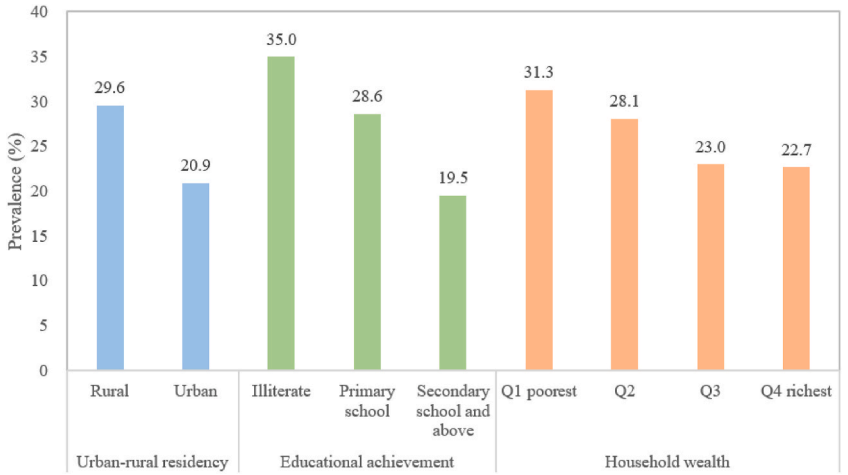


Fig. 3. Prevalence of depressive symptoms by urban-rural residency, educational achievement and wealth.

socioeconomic differentials, urban-rural disparities were also found for age, sex, ethnicity, health insurance coverage, smoking, and number of chronic conditions ($p < 0.001$).

4.2. Stock of social capital

Table 3 described the stock of social capital in four distinct dimensions, stratified by urban-rural settings. The descriptive results by wealth and educational achievement showed similar patterns (Supplementary Tables 1 and 2). A total of 5516 (55.4 %) participants possessed structural social capital, i.e., participating in at least one listed social activity, whilst 6729 (67.6 %) participants possessed social trust, i.e., cognitive social capital. Within the construct of structural social capital, informal interaction (51.0 %) was more common than formal social participation (1.3 %). Comparing to the urban residents (60.5 %), rural residents (51.8 %) reported lower stock of structural social capital (Fig. 4a), with informal interaction activity taking the largest urban to rural difference (10.5 %, $p < 0.001$). However, no evidence was found for urban-rural differences in the construct of cognitive social capital (Fig. 4b).

4.3. The association between SES, social capital and depressive symptoms

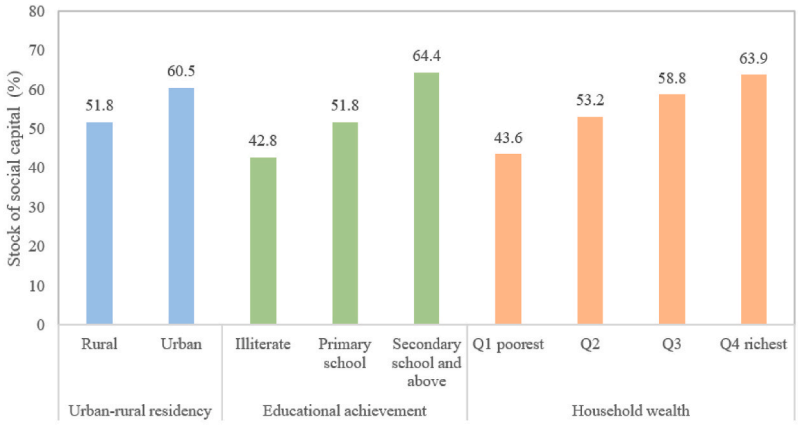
Table 4 showed the factors associated with depressive symptoms, focusing on the role of SES and social capital. All SES indicators (urban-rural residency, educational achievement and household wealth) were negatively associated with the incidence of depressive symptom in the follow-up period, taking similar scales across differentials. For example, urban residents had 37 % lower odds (OR = 0.63, 95%CI: 0.57 to 0.69) of experiencing depressive symptoms than the rural residents; people with higher education had lower odds than the illiterate (OR = 0.45, 95%CI: 0.40 to 0.51), and the richest group had 35 % lower odds than the poorest group (OR = 0.65, 95%CI: 0.57 to 0.73). Socioeconomic inequalities in the incidence of depressive symptoms persisted in the adjusted model. For example, the urban to rural aOR was 0.69 (95%CI: 0.62 to 0.76) after adjusting for age, marital status, health insurance coverage, smoking, drinking alcohol and number of chronic conditions.

Both structural and cognitive social capital in 2015 were negatively associated with the incidence of depressive symptoms in the follow-up period in the adjusted analysis (Table 4). The effects of cognitive social capital were larger (aOR = 0.71, 95%CI: 0.64 to 0.79) than structural social capital (aOR = 0.87, 95%CI: 0.79 to 0.95). Within the structural social capital construct, only the effects of

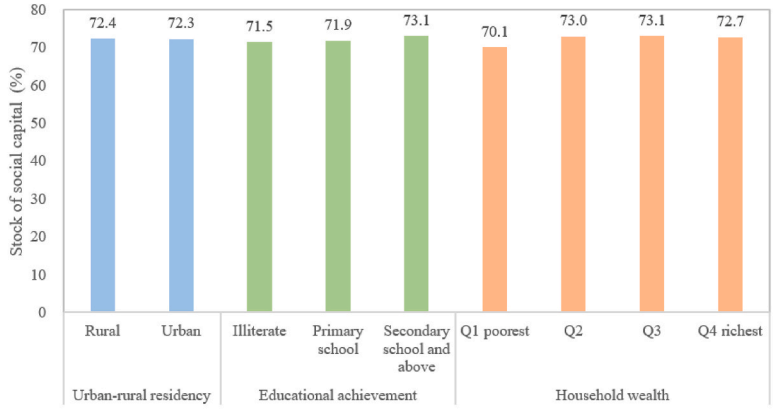
Table 3
Cohorts' basic stock of social capital, by urban and rural residency.

Social capital	Overall (n = 9949)		Urban (n = 4212)		Rural (n = 5737)		*p*-Value
	n	%	n	%	n	%	
Structural social capital	5516	55.4	2546	60.5	2970	51.8	<0.001
Informal interaction	5070	51.0	2401	57.0	2669	46.5	<0.001
Altruism	2006	20.2	885	21.0	1121	19.5	0.071
Formal social participation	127	1.3	86	2.0	41	0.7	<0.001
Cognitive social capital (Trust)	6729	67.6	2815	66.8	3914	68.2	0.898

Note.
We defined a participant having each construct/dimension of social capital should he/she engaged in at least one activity within this construct/dimension.
p-Value reports Chi-square tests for all categorical variables.



a Stock of structural social capital by urban-rural residency, educational achievement and wealth



b Stock of cognitive social capital by urban-rural residency, educational achievement and wealth

Fig. 4. (a) Stock of structural social capital by urban-rural residency, educational achievement and wealth (b) Stock of cognitive social capital by urban-rural residency, educational achievement and wealth.

informal interaction persisted in the adjusted analysis (aOR = 0.84, 95%CI: 0.76 to 0.92).

4.4. Mediation analysis

Table 5 showed the results of the mediation analysis, reporting the total, direct and indirect effects, and the proportion of total effects mediated, for each social capital dimension, along the pathway how each SES differential takes an impact. Only informal interaction within the construct of structural social capital showed evidence of mediating effects in explaining the socioeconomic inequalities in the incidence of depressive symptoms. Informal interaction could explain 6.17 % of the urban-rural differences (with a direct effect of 0.425 and an indirect effect of 0.028), 11.24 % of education related inequalities and 11.78 % of wealth related inequalities in depressive symptoms. However, cognitive social capital showed no evidence in mediating the socioeconomic inequalities in depressive symptoms either for urban-rural residency, educational achievement or household wealth related inequalities ($p = 0.455$, 0.362, and 0.321).

4.5. Subgroup analysis

Results of Wald test showed that all the interaction effects between the urban-rural dummy variable and educational achievement, wealth, and the four dimensions of social capital were not significant (Supplementary Table 4). The subgroup analysis that compared the mediating effects of social capital to education and wealth related inequalities in depressive symptoms by urban-rural settings reported similar findings (Supplementary Tables 5 and 6).

Table 4
Associations between socioeconomic status, social capital and depressive symptoms.

Independent variables	Unadjusted model			Adjusted model		
	OR	95 % CI	*p*-Value	aOR	95 % CI	*p*-Value
Socioeconomic status						
Urban-rural residency						
Rural	ref.			ref.		
Urban	**0.63**	**(0.57, 0.69)**	**<0.001**	**0.69**	**(0.62, 0.76)**	**<0.001**
Educational achievement						
Illiterate	ref.			ref.		
Primary school	**0.74**	**(0.66, 0.84)**	**<0.001**	**0.85**	**(0.75, 0.97)**	**0.013**
Secondary school and above	**0.45**	**(0.40, 0.51)**	**<0.001**	**0.58**	**(0.51, 0.67)**	**<0.001**
Household wealth						
Q1 poorest	ref.			ref.		
Q2	**0.86**	**(0.75, 0.97)**	**0.018**	0.89	(0.78, 1.01)	0.081
Q3	**0.66**	**(0.58, 0.75)**	**<0.001**	**0.72**	**(0.63, 0.83)**	**<0.001**
Q4 richest	**0.65**	**(0.57, 0.73)**	**<0.001**	**0.75**	**(0.65, 0.85)**	**<0.001**
Social capital						
Structural social capital						
Yes	**0.83**	**(0.76, 0.91)**	**<0.001**	**0.87**	**(0.79, 0.95)**	**0.002**
No	ref.			ref.		
Informal interaction						
Yes	**0.81**	**(0.74,0.89)**	**<0.001**	**0.84**	**(0.76,0.92)**	**<0.001**
No	ref.			ref.		
Altruism						
Yes	**0.88**	**(0.78,0.98)**	**0.023**	0.96	(0.85,1.08)	0.475
No	ref.			ref.		
Formal participation						
Yes	**0.50**	**(0.31,0.81)**	**0.005**	0.64	(0.39,1.04)	0.072
No	ref.			ref.		
Cognitive social capital (Trust)						
Yes	**0.73**	**(0.66,0.80)**	**<0.001**	**0.71**	**(0.64, 0.79)**	**<0.001**
No	ref.			ref.		

Note.
Logistic regressions were performed to report on the odds ratios (ORs). The adjusted model reported aORs that additionally control for age, marital status, health insurance, smoking, drinking alcohol and number of chronic conditions.

5. Discussion

Using the data from CHARLS, we explored the longitudinal effects of socioeconomic status and social capital on the incidence of depressive symptoms. We reported persistent socioeconomic inequalities in depression, irrespective of how socioeconomic status were measured. We measured social capital from two constructs and four distinct dimensions: informal interaction, altruism, formal social participation, and trust. We found that both cognitive social capital and structural social capital were associated with lower incidence of depressive symptoms, where informal interaction took the largest effect within the construct of structural social capital. The mediation analysis further illustrated that informal interaction took the single most important medicating effect that explains 6%–12 % of the inequalities in depressive symptoms related to each socioeconomic determinant.

The findings of persistent education and wealth related inequalities in depression corroborated data from other countries, and China as well [32][41–45]. Based on a cohort design, our data also confirmed the protective role of cognitive social capital for depression. We contributed to the literature by specify three distinct dimensions of structural social capital, where we found that informal interaction took larger effects than altruism and formal social participation. Such findings were in line with prior data on the role of social participation activities such as mahjong and physical exercise in protecting mental wellbeing [46]. We only found two previous research that quantified the mediating effects of social capital in explaining socioeconomic inequalities in depression. Xin and Ren found that cognitive and structural social capital could explain 14.3 % and 3.8 % of the educational related inequalities in depression amongst Chinese older people [27]. Whilst data from Korean older people showed that cognitive social capital, measured as reciprocity, could explain about 10.2 % of the wealth related inequalities in depression [32]. These two studies were all based on cross-sectional data. We therefore enriched the literature by providing evidence from cohort design and ascertaining more dimensions of structural social capital.

Windsor's study indicated that low socioeconomic status, such as poor education or income, may undermine community cohesion, social trust and reciprocity, leading to reduced resistance to stress and eventually affecting mental wellbeing [31]. However, we did not find evidence of socioeconomic differences in cognitive social capital, which helped to explain why trust offers no mediating effects in explaining the socioeconomic inequalities in depression in our case. Importantly, our data showed strong protecting effects of structural social capital for depression, with the dimension of informal interaction taking the single most important role. Whenever using urban-rural residency, household wealth or educational achievement as the SES indicator, we found that informal interaction mediates about 6%–12 % of the socioeconomic inequalities in depressive symptoms. We found that only 1.3 % participants were engaged in formal social participation, in line with the literature that formal social participations and institutions played a weak role in

Table 5
Mediation analysis for the role of each dimension of social capital on socioeconomic inequalities in the incidence of depressive symptoms.

Social participation	Total effect			Direct effect			Indirect effect			Mediated (%)
	β_1	95 % CI	*p*-Value	β_2	95 % CI	*p*-Value	β_3	95 % CI	*p*-Value	
Urban-rural residency										
Structural Social capital	0.452	(0.355,0.550)	<0.001	0.430	(0.333,0.528)	<0.001	0.022	(0.011,0.033)	<0.001	**4.90**
Informal interaction	0.453	(0.356,0.550)	<0.001	0.425	(0.327,0.523)	<0.001	0.028	(0.015,0.041)	<0.001	**6.17**
Altruism	0.451	(0.354,0.549)	<0.001	0.450	(0.353,0.547)	<0.001	0.001	(-0.001,0.004)	0.303	0.33
Formal social participation	0.452	(0.355,0.549)	<0.001	0.447	(0.350,0.544)	<0.001	0.005	(-0.001,0.012)	0.092	1.20
Cognitive social capital (Trust)	0.455	(0.354,0.556)	<0.001	0.454	(0.353,0.555)	<0.001	0.001	(-0.005,0.007)	0.755	0.22
Educational achievement										
Structural Social capital	0.359	(0.240,0.479)	<0.001	0.326	(0.206,0.447)	<0.001	0.033	(0.017,0.049)	<0.001	**9.17**
Informal interaction	0.360	(0.240,0.479)	<0.001	0.319	(0.199,0.440)	<0.001	0.040	(0.023,0.058)	<0.001	**11.24**
Altruism	0.359	(0.239,0.477)	<0.001	0.355	(0.235,0.474)	<0.001	0.003	(-0.002,0.009)	0.274	0.88
Formal social participation	0.358	(0.239,0.478)	<0.001	0.355	(0.235,0.474)	<0.001	0.003	(-0.000,0.007)	0.073	0.92
Cognitive social capital (Trust)	0.362	(0.239,0.485)	<0.001	0.358	(0.235,0.481)	<0.001	0.004	(-0.004,0.012)	0.362	1.07
Household wealth										
Structural Social capital	0.300	(0.190,0.408)	<0.001	0.267	(0.158,0.377)	<0.001	0.031	(0.017,0.046)	<0.001	**10.53**
Informal interaction	0.299	(0.190,0.374)	<0.001	0.264	(0.155,0.374)	<0.001	0.035	(0.020,0.050)	<0.001	**11.78**
Altruism	0.297	(0.189,0.406)	<0.001	0.294	(0.185,0.403)	<0.001	0.004	(-0.004,0.012)	0.341	1.27
Formal social participation	0.298	(0.186,0.407)	<0.001	0.294	(0.186,0.403)	<0.001	0.003	(-0.000,0.007)	0.079	1.13
Cognitive social capital (Trust)	0.321	(0.225,0.418)	<0.001	0.317	(0.220,0.414)	<0.001	0.004	(-0.002,0.011)	0.164	1.36

Note: KHB methods were performed to decompose the total effects of each SES on incidence of depressive symptoms into direct effects and indirect effects. Logistic regressions were performed which additionally adjusted for age, marital status, health insurance, smoking, drinking alcohol and number of chronic conditions. Indirect effects reflect the contribution of each social capita dimension to the socioeconomic inequalities related to urban-rural residence, educational achievement, and wealth, respectively. We define each SES differential as a dichotomous variable, i.e. rural vs urban, illiterate vs non-illiterate, and poor vs rich (Q1-Q2 vs Q3-Q4).

China's social structure [47]. In fact, informal social participation, such as playing Ma-jong or square dance was observed to be more common among older Chinese [46]. These informal interactions provided additional opportunities for social support, social networking, and social participation. Social support from peers might buffer the negative effects of stress [48,49]. Social networking positively influenced older people [50] by giving them opportunity to fulfill their personal expectations, increase self-esteem and sense of purpose, and dampen stress-related neuroendocrine responses [30]. While social participation might help strengthen the social ties between older people to obtain more economic or cultural resources [51]. To improve equity of mental health, our finding therefore suggested that the government should create opportunities for residents to organize or engage in social activities on their own by strengthening activity planning, venue support, and other supportive measures. Social networking positively influenced older people by giving them the opportunity to fulfill their personal expectations, increased self-esteem and sense of purpose, and dampened stress-related neuroendocrine responses [30]. While social participation might help strengthen the social ties between older people to obtain more economic or cultural resources [51]. To improve equity of mental health, our finding therefore suggested that the government should create opportunities for residents to organize or engage in social activities on their own by strengthening activity planning, venue support, and other supportive measures. For example, strengthening public transportation construction can facilitate residents' travel and help them establish close connections with family and friends.

A recent systematic review on urban-rural disparities for depression reported conflicting findings in different settings across countries among the older people [12]. In the developed world, depressive disorders were more prevailed in the urban areas, especially in large cities; whilst the developing world presented reverse epidemic patterns in general [14]. The higher incidence of depressive symptoms in rural China, as we reported, corroborate data from the other developing countries, and China as well [40,46]. In developed countries, rural residents also had access to mental health care services. However, urban residents were more susceptible to sleep disruption due to excessive exposure to artificial light at night, thereby increasing the risk of depression [12]. However, Enormous urban-rural disparities existed in China's health systems, policies and environment [52–54]. Weaker infrastructure and less convenient traffic disproportionately affected the rural areas [12,55]. Mental health services concentrated in urban areas, health insurance is more generous to the urban residents, the rural vulnerable are therefore less likely to receive adequate care when in needs [56,57]. In addition, evidence was emerging that many rural older Chinese were suffering empty-nests as urbanization rapidly processes, which also undermined rural elder's opportunities for social connection. As our data showed, 49 % rural older people were less likely to participate in four informal social activities. Indeed, the stronger association between urban-rural residency and incidence of depressive symptoms, as compare to the effects of household wealth and educational achievement, suggested that urban-rural division might be a more fundamental social determinant of health in China's specific case.

5.1. Strength and limitations

This study was based on a cohort design, providing solid evidence and also informing policy interventions. We enriched the measurement of structural social capital and highlight the role of informal interaction that explains the socioeconomic gradients in depression. However, there were several important limitations. First, 2073 (9.8 %) participants lost to follow up for the CES-D. Compared to the 9949 cohorts included, more of these participants lived in urban areas (19.2 % higher, $p < 0.001$) and are poorer (7.1 % higher, $p < 0.001$) (Supplementary Table 3), which may lead to the underestimation of the incidence of depressive symptoms in our case. Therefore, it needed to be cautious when interpreting our results across the country. Second, we excluded 4974 (23.6 %) participants who had already recorded depressive symptoms in 2015, which would also lower the rates of depression and may lead to an overestimation of the social capital effect on depressive symptoms. However, we reported a incidence of 25.9 %, higher than the results reported by Tang et al. in their 2021 review [7]. These findings were consistent with previous data that the CHARLS tend to report higher prevalence of depressive symptoms using CES-D [7]. Third, questions to define cognitive social capital were limited in CHARLS. There were previous studies using trust in parents, friends, and strangers to define trust, as well as a common definition of cognitive social capital based on feelings of belonging, trust, and willingness to provided help to others. However, due to the limitation in CHARLS, our research can only select trust measured by one question to define cognitive social capital. Future work is warranted to better explore the definition of trust and cognitive social capital. Besides, the CES-D 10 scale we used had limitations in defining depression, as it is only a screening scale and has no diagnostic value.

6. Conclusion

Our data highlighted the unsatisfied mental wellbeing of the vulnerable older people with low income, low educational achievement, and who lives in the rural areas. The single important protecting effect of informal interaction suggested a deliberate thinking on how to make change. Older people seemed rely more on personal interactions instead of formal participations, collective activities such as training, course, clubs and sports are more likely to track attention and helped the seniors to increase their interaction with partners and reduce loneliness, especially for those with relatively low socioeconomic status. To promote the Health in All Policies, government and social organizations should consider more on how to intervene on the environment and create more opportunities that encourage the older people to connect and better able to integrate into the community [58].

Data availability statement

CHARLS is a survey project hosted by the National Development Research Institute of Peking University and executed by the China Social Science Survey Center. It is a major project funded by the National Natural Science Foundation of China. CHARLS is publicly available data that can be applied for by anyone in need, with website link attached (http://charls.pku.edu.cn/). However, CHARLS requires the applicant to sign an agreement and not directly share data with the outside world. Any user with a need should directly apply to CHARLS. If the publication requires the provision of raw data, it is available to apply to CHARLS, and meanwhile, we will also provide all code of Stata involved in the data analysis and processing process.

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CRediT authorship contribution statement

Xixi Fu: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Shunzhuang Peng:** Methodology, Data curation, Conceptualization. **Xing Lin Feng:** Writing – review & editing, Supervision, Methodology, Funding acquisition, Conceptualization.

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.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e24918.

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