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Research article

The influence of social participation and depressive symptoms on cognition among middle-aged and older adults

Chen Chen [1], Yu Tian [1], Linghao Ni, Qianjie Xu, Yaoyue Hu [**], Bin Peng [*]

School of Public Health, Chongqing Medical University, Chongqing, 400016, China

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ABSTRACT

Background: The global aging phenomenon has raised concerns about the cognitive abilities of older individuals. This study aimed to explore the relationship between social participation, depressive symptoms, and cognitive function among middle-aged and older adults.

Methods: This study utilized data from the China Longitudinal Study of Health and Retirement (CHARLS) from wave 1 to wave 4. We used linear regression and generalized estimation equations to investigate the correlation between social participation, depressive symptoms, and cognitive function. Moreover, three models were constructed by adjusting covariates, and we used the sobel test and bootstrap method to analyze the mediating effects of depressive symptoms on social activities and cognitive function.

Results: The results of both linear regression and generalized estimation equation showed that social participation had a positive correlation with cognitive function ($P < 0.05$), and the impact of social participation on cognition increased with the number of social activity types. Meanwhile, depressive symptoms had a negative association with cognitive function ($P < 0.05$). Furthermore, there was no interaction between social participation and depressive symptoms on cognitive function. Finally, after adjusting the model, social participation could affect cognitive function by affecting depressive symptoms ($P < 0.05$).

Conclusion: The study emphasizes the mediating role of depressive symptoms in the relationship between social participation and cognitive function. Notably, no interaction was observed between social participation and depressive symptoms. These findings highlight the potential of active social participation in reducing depressive symptoms and enhancing cognitive function in middle-aged and older adults.

1. Introduction

Along with rapid population aging, the prevalence of chronic diseases among older adults has been increasing dramatically, particularly dementia which is estimated to affect half a million people worldwide currently [1,2]. Dementia causes brain function loss and limitations in activities of daily living (ADLs), which places a major financial and caring burden on families and society [3]. In China, the prevalence of dementia is 6.0 % in the population aged 60 and older, and it is expected to grow as the population is aging at

* Corresponding author.
** Corresponding author.
E-mail addresses: yaoyue.hu@cqmu.edu.cn (Y. Hu), pengbin@cqmu.edu.cn (B. Peng).
[1] Joint first authors.

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an exceptionally fast rate [4]. As a result, the annual cost of dementia in China is projected to reach 11.42 billion US dollars by 2030 [5]. Maintaining good cognitive function for as long as possible and preventing cognitive impairment at middle and older ages are therefore becoming more and more important.

Social participation is a key component of active aging, holding significant potential to enhance the cognitive function of older adults with cognitive impairment [6,7]. Social participation refers to individual's direct and indirect involvement in various aspects of social life via diverse ways [8]. Social network theory suggests that social networks can provide cognitive support by promoting social participation [9]. As a behavior of participants in social interactions, social participation can provide individuals with role identity, companionship, and enhanced social awareness [10]. This, in turn, can facilitate cognitive activities such as memory and problem-solving and also mitigate the risk of cognitive decline [10]. Previous cross-sectional studies have reported positive effects of social participation on cognitive function [11,12]. Longitudinal studies have also shown that greater variety and a higher frequency of social participation are associated with better cognitive function [13–15]. However, some studies only found a weak relationship between overall social participation and cognitive performance when confounders were adjusted for [16,17]. The discrepancy in the literature could be attributed to the differences in the study design, the population, and the measurement of social participation and cognitive function between studies. Therefore, cross-sectional and longitudinal studies were necessary to determine the association between social functioning and cognition.

Social network theory not only facilitates social interactions but also provides emotional support. Extensive literature suggests that social participation helps to maintain and even expand an individual's social network size, which in turn helps individuals adapt to old age and changing social roles, reduces subjective feelings of loneliness, and ameliorates depressive symptoms [18,19]. Among depressed individuals, feelings of loneliness in psychological states are associated with having a small social network [20]. A longitudinal study from China reported that low levels of social participation were associated with elevated depressive symptoms in adults aged 50 and beyond [21]. In addition, social participation has been found to play an important role in alleviating depression [22–24]. Cognitive reserve theory explains individual differences in susceptibility to age-related brain changes or pathological changes associated with Alzheimer's disease. Some individuals' bodies can accept these changes and maintain normal function [25,26]. Depressive symptoms, on the other hand, reduce cognitive reserve [27]. Numerous studies have demonstrated that depression increases the risk of cognitive decline [28,29]. Based on the cognitive reserve theory, social engagement will provide mental stimulation through complex communication and interaction with others, which will in turn improve depressive symptoms and increase cognitive reserve [2]. A noteworthy neuropathological study revealed that supportive social participation is related to greater gray matter volume in the posterior insula, middle cingulate gyrus, and hippocampus, while over 10 % and 20 % of the effects of altruistic social participation on hippocampus volume and cingulate gyrus volume, respectively, were mediated by depressive symptoms [30]. Despite the extensive attention given on the association between social participation and cognitive function, the mechanisms linking them remains unclear, for example depression may be a mediator on the pathway [13]. Social participation may affect cognitive function via depression, but there is a lack of formal investigation to quantify the mediation of depression.

This study therefore examined the relationships between social participation, depressive symptoms, and cognitive function among middle-aged and older Chinese adults and further quantified the possible mediating effects of depressive symptoms (the hypothesized direct and indirect pathways are shown in Fig. 1).

2. Materials and methods

2.1. Study sample

The data came from the China Health and Retirement Longitudinal Study (CHARLS). The baseline survey was conducted in 2011 (Wave 1) and collected comprehensive information on socio-demographics, family, health and functioning, health care and insurance, work, retirement, and income for 17,705 participants aged 45 and over from 150 counties in 28 provinces who were recruited using the probability proportional to size (PPS) method. Three follow-up surveys were taken in 2013 (Wave 2), 2015 (Wave 3), and 2018 (Wave 4), respectively. This study used Wave 1 to Wave 4 data. Details can be found elsewhere [31]. All data is publicly available on the Peking University open research data platform.

Participants were excluded if they met the following criteria at Wave 1: (1) brain damage/mental retardation (N = 523); (2) memory-related diseases (e.g., Alzheimer's disease, brain atrophy, and Parkinson's disease, N = 204); (3) emotional, nervous, or psychiatric problems (N = 149); (4) age<45 years (N = 352). Participants who died or lost follow-up in Wave 2 - Wave 4 (N = 5255)

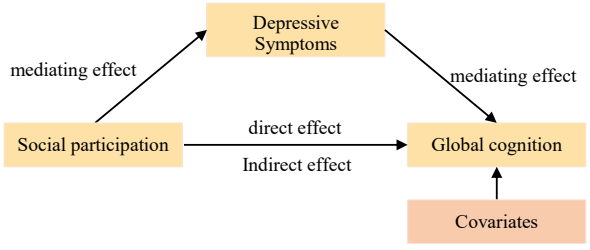

Fig. 1. Hypothesized mediation model.

were excluded. Subsequently, 2121 participants with missing data were excluded, leaving 9101 participants for the cross-sectional study. In the presence of missing data related to education, smoking, vision (distant or near), and hearing status, as well as chronic disease status, we employed imputation by filling in the survey data from the last wave. 75 participants were excluded from Waves 2 through 4 due to missing data on social participation, depressive symptoms, and cognitive assessments on three occasions, finally including 9026 participants for the longitudinal study. After excluding 2044 participants with missing data at Wave 4, a total of 9178 participants were used for the mediation analysis. (The flowchart of the analytic sample is referred to in Fig. 2.)

2.2. Cognitive function

Cognitive function was measured from Wave 1 to Wave 4 and included two parts of episodic memory and mental status. Episodic memory (0–20 points) was assessed via immediate word recall (requiring participants to recall ten words immediately after the interviewer finished reading, 0–10 points) and delayed word recall (recalling the same ten words a few minutes later, 0–10 points). The mental status (0–11 points) was evaluated by time orientation (naming the month, day, year, week, and season, 0–5 points), serial 7s (subtracting 7 from 100 five times consecutively, 0–5 points), and drawing (redrawing an overlapped pentagon, 0–1 point). Global cognition was the sum of episodic memory and mental intactness (0–31 points), with higher scores indicating better cognitive function. Both the reliability and the validity of these tests have been well documented [32].

2.3. Social participation

Social participation was measured from Wave 1 to Wave 4. Participants reported taking part in social activities over the past month, including whether they (1) interacted with friends; (2) played Ma-jong, chess, or cards, or went to community club; (3) provided help to family, friends, or neighbors who did not live with the participant and did not pay for the help; (4) went to a sport, social, or other kinds of club; (5) took part in a community-related organization; (6) did voluntary or charity work; (7) cared for a sick or disabled adult who did not live with the participant and did not pay for the help; (8) attended an educational or training course; (9) did stock investment; (10) used the Internet; and (11) engaged in other activities. The total number of social activities in which the participant took part was calculated and further categorized into three groups (0, 1, and ≥2) [13].

2.4. Depressive symptoms

Depressive symptoms were measured from Wave 1 to Wave 4, using the Chinese version of the 10-item Center for Epidemiological

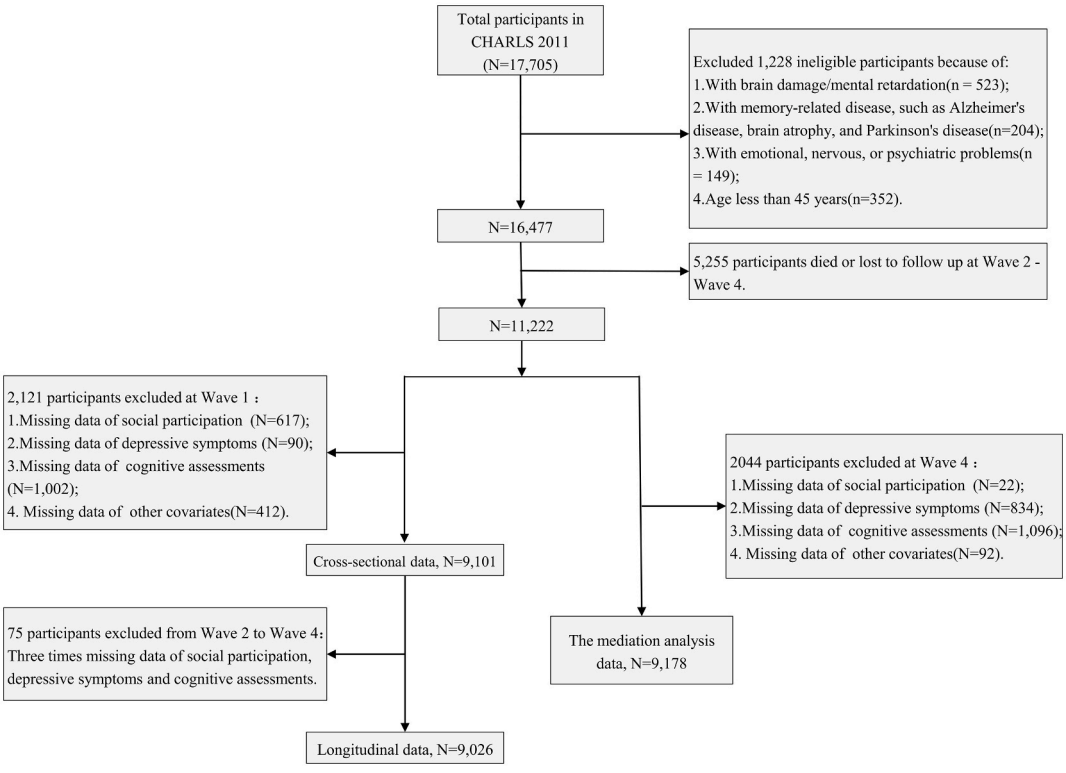

Fig. 2. Flowchart of analytic sample.

Studies Depression Scale (CES-D-10) [33,34]. CES-D-10 has demonstrated good validity and reliability in Charls, with a Cronbach's α coefficient of 0.78–0.79 [33]. Participants were asked to report in the past week how they (1) felt bothered by things, (2) had trouble keeping their mind on what they were doing, (3) felt depressed, (4) felt everything they did was an effort, (5) felt hopeful about the future, (6) felt fearful, (7) had restless sleep, (8) felt happy, (9) felt lonely, and (10) felt unable to get going. Each item has a response on a Likert scale ranging from "Rarely or none of the time (<1 day)" to "Most or all of the time (5–7 days)". The total score of CES-D-10 ranged from 0 to 30, with higher scores indicating more depressive symptoms. A cut-off point of 12 was used to define probable depression, as validated in a previous study [24].

2.5. Covariates

Covariates were selected based on previous research [35–37] and measured at Wave 1 - Wave 4. Socio-demographic characteristics included age, gender, marital status (single/partnered), residence (urban/rural), and education (illiterate, primary school, lower secondary school, upper secondary school, and higher). Health behaviors covered current smoking (yes/no), alcohol drinking (yes/no), sleep duration (≤6, 6< sleep duration ≤8, >8 h), and daytime napping (≤30, 30 < daytime napping ≤60, 60 < daytime napping ≤90, >90 min). Health conditions consisted of distant vision (poor/good), near vision (poor/good), hearing (poor/good), hypertension (yes/no), dyslipidemia (yes/no), diabetes (yes/no), chronic lung diseases (yes/no), liver disease (yes/no), heart disease (yes/no), and stroke (yes/no). Details were provided in Supplementary Table 1.

2.6. Statistical analysis

We used the *t*-test and ANOVA to test the differences between social participation groups and between depression groups for continuous variables and employed the Chi-square test for categorical variables. The cross-sectional associations of social participation and depressive symptoms with cognitive function were analyzed using a linear regression with stepwise adjustment of covariates. Model 1 was unadjusted. Model 2 was adjusted for age, gender, residence, marital status, and education. Model 3 was additionally adjusted for smoking, drinking, sleep duration, daytime napping, distant vision, near vision, hearing, hypertension, dyslipidemia,

Table 1
Sample characteristics of participants at baseline.

	Total sample	Social participation			*p*	Depressive Symptoms		*p*
		0	1	≥2		Non-depressed	Depressed	
N(%)	9101 (100)	4471(49.1)	3042(33.4)	1588(17.4)	–	7129(78.3)	1972(21.7)	–
Age (mean ± SD, years)	58.3 ± 8.7	58.7 ± 8.5	58.4 ± 9.0	56.7 ± 8.5	<0.001	58 ± 8.8	59.2 ± 8.5	<0.001
Male, N(%)	4269(46.9)	2060(46.1)	1374(45.2)	835(52.6)	<0.001	3596(50.4)	673(34.1)	<0.001
Partnered, N(%)	8187(90.0)	4021(89.9)	2714(89.2)	1452(91.4)	0.058	6524(91.5)	1663(84.3)	<0.001
Rural, N(%)	752(8.3)	251(5.6)	257(8.4)	244(15.4)	<0.001	671(9.4)	81(4.1)	<0.001
Education level, N(%)					<0.001			<0.001
Illiterate	2343(25.7)	1331(29.8)	771(25.3)	241(15.2)		1649(23.1)	694(35.2)	
Primary school	3711(40.8)	1865(41.7)	1275(41.9)	571(36.0)		2836(39.8)	875(44.4)	
Lower secondary school	1979(21.7)	914(20.4)	646(21.2)	419(26.4)		1681(23.6)	298(15.1)	
Upper secondary school and higher	1068(11.7)	361(8.1)	350(11.5)	357(22.5)		963(13.5)	105(5.3)	
Smoking, N(%)	2794(30.7)	1329(29.7)	898(29.5)	567(35.7)	<0.001	2296(32.2)	498(25.3)	<0.001
Drinking, N(%)	2341(25.7)	1070(23.9)	765(25.1)	506(31.9)	<0.001	1953(27.4)	388(19.7)	<0.001
Sleep duration, N(%)					0.001			<0.001
≤6 h	4485(49.3)	2319(51.9)	1446(47.5)	720(45.3)		4485(49.3)	3174(44.5)	
(6 h, 8 h]	3870(42.5)	1772(39.6)	1341(44.1)	757(47.7)		3870(42.5)	3336(46.8)	
> 8 h	746(8.2)	380(8.5)	255(8.4)	111(7.0)		746(8.2)	619(8.7)	
Daytime napping, N(%)					0.079			<0.001
≤ 30min	5840(64.2)	2927(65.5)	1936(63.6)	977(61.5)		5840(64.2)	4489(63.0)	
(30min, 60min]	1976(21.7)	921(20.6)	670(22)	385(24.2)		1976(21.7)	1580(22.2)	
(60min, 90min]	290(3.2)	135(3.0)	104(3.4)	51(3.2)		290(3.2)	241(3.4)	
≥90min	995(10.9)	488(10.9)	332(10.9)	175(11.0)		995(10.9)	819(11.5)	
Poor distant vision, N(%)	5561(61.1)	2838(63.5)	1838(60.4)	885(55.7)	0.001	4040(56.7)	1521(77.1)	<0.001
Poor near vision, N(%)	6033(66.3)	3051(68.2)	1989(65.4)	993(62.5)	<0.001	4510(63.3)	1523(77.2)	<0.001
Poor hearing, N(%)	4903(53.9)	2535(56.7)	1603(52.7)	765(48.2)	<0.001	3535(49.6)	1368(69.4)	<0.001
Hypertension, N(%)	2112(23.2)	987(22.1)	744(24.5)	381(24.0)	0.040	1595(22.4)	517(26.2)	0.010
Dyslipidemia, N(%)	834(9.2)	329(7.4)	289(9.5)	216(13.6)	<0.001	629(8.8)	205(10.4)	0.032
Diabetes, N(%)	501(5.5)	222(5)	170(5.6)	109(6.9)	0.017	374(5.2)	127(6.4)	0.040
Chronic lung diseases, N(%)	836(9.2)	428(9.6)	277(9.1)	131(8.2)	0.287	541(7.6)	295(15.0)	<0.001
Liver disease, N(%)	344(3.8)	149(3.3)	131(4.3)	64(4.0)	0.080	241(3.4)	103(5.2)	<0.001
Heart disease, N(%)	1009(11.1)	470(10.5)	345(11.3)	194(12.2)	0.153	684(9.6)	325(16.5)	<0.001
Stroke, N(%)	135(1.5)	63(1.4)	50(1.6)	22(1.4)	0.668	86(1.2)	49(2.5)	<0.001
Cognitive function scores (Z-scores, mean ± SD)								
Global cognition	0.0 ± 1.0	−0.2 ± 1.0	0.1 ± 1.0	0.4 ± 0.9	<0.001	0.1 ± 1.0	−0.4 ± 0.9	<0.001
Episodic memory Mental	0.0 ± 1.0	−0.2 ± 1.0	0.1 ± 1.0	0.3 ± 1.0	<0.001	0.1 ± 1.0	−0.3 ± 0.9	<0.001
Mental status	0.0 ± 1.0	−0.2 ± 1.0	0.0 ± 1.0	0.4 ± 0.9	<0.001	0.1 ± 1.0	−0.4 ± 1.0	<0.001

diabetes, chronic lung diseases, liver disease, heart disease, and stroke on the basis of Model 2.

The generalized estimating equation (GEE) is a valuable approach for analyzing longitudinal data with only two repeated measurements, as it is effective in managing potential correlation between observations, thereby enabling more precise estimation of parameters and extrapolation of results. Therefore, GEE was applied to analyze the longitudinal associations of social participation and depressive symptoms with cognitive function, as well as the interaction between social participation and depressive symptoms.

The sobel test relies on the assumption of data normality, while the bootstrap method estimates a parameter's distribution by repeatedly selecting random samples from the original dataset and conducting statistical analyses on each sample, eliminating the need for specific data distribution assumptions [38]. We employed wave 4 data to explore the association between social participation and cognitive function mediated by depressive symptoms, using the sobel test with a bootstrapping of 1000 times [38]. The ratio of the mediating effect is equal to the indirect effect over the total effect. Different models were estimated with the adjustment of various covariates, and the specific steps were the same as in cross-sectional analysis.

We conducted three sensitivity analyses to assess the robustness of our findings. Firstly, we identified influential social participation items one by one to repeat the main analysis. Secondly, recognizing that the effects of social participation and depression on cognitive function could vary by age and gender [13,39], we repeated the main analysis stratified by age and gender. Third, to investigate the influence of missing data, we applied multiple imputation to estimate baseline data for the 2121 excluded participants, resulting in five imputed datasets, from which combined values with 95 % confidence intervals were calculated.

All statistical analyses were performed with SPSS 25 (Armonk, NY: IBM Corp) and Stata 17 (College Station, TX: StataCorp LLC), and $P < 0.05$ was taken as statistically significant.

3. Results

3.1. Sample characteristics

The baseline characteristics of participants (N = 9101) are provided in Table 1. A total of 4630 (50.9 %) participants reported engaging in social participation in the past month, while 78.3 % of them were not depressed. The majority of participants were partnered (90.0 %) and received primary school education (40.8 %). Few lived in rural areas (8.3 %). More than a quarter of participants reported smoking and drinking alcohol, while most participants slept for 8 h or less at night and 64.2 % napped for 30 min or less during the day. Over half of the participants reported having vision and hearing problems. Hypertension was the most prevalent disease (23.2 %). Most characteristics differed between social participation groups and between depression groups. Notably, global

Table 2
Cross-sectional associations between social participation, depressive symptoms, and cognitive function at baseline.

	Global cognition		Episodic memory		Mental status	
	β (95 % CI)	*p*	β (95 % CI)	*p*	β (95 % CI)	*p*
Model 1						
Social participation						
0	Ref		Ref		Ref	
1	0.25(0.20,0.29)	<0.001	0.22(0.17,0.26)	<0.001	0.19(0.14,0.23)	<0.001
≥2	0.60(0.55,0.66)	<0.001	0.48(0.42,0.53)	<0.001	0.52(0.47,0.58)	<0.001
Depressive symptoms						
Non-depressed	Ref		Ref		Ref	
Depressed	−0.53(-0.58,-0.48)	<0.001	−0.38(-0.43,-0.33)	<0.001	−0.50(-0.55,-0.45)	<0.001
Model 2						
Social participation						
0	Ref		Ref		Ref	
1	0.18(0.14,0.22)	<0.001	0.17(0.13,0.21)	<0.001	0.13(0.09,0.16)	<0.001
≥2	0.32(0.28,0.37)	<0.001	0.28(0.22,0.33)	<0.001	0.26(0.21,0.31)	<0.001
Depressive symptoms						
Non-depressed	Ref		Ref		Ref	
Depressed	−0.31(-0.35,-0.27)	<0.001	−0.25(-0.29,-0.20)	<0.001	−0.27(-0.32,-0.23)	<0.001
Model 3						
Social participation						
0	Ref		Ref		Ref	
1	0.17(0.13,0.21)	<0.001	0.16(0.12,0.21)	<0.001	0.12(0.08,0.16)	<0.001
≥2	0.31(0.26,0.36)	<0.001	0.27(0.21,0.32)	<0.001	0.25(0.20,0.30)	<0.001
Depressive symptoms						
Non-depressed	Ref		Ref		Ref	
Depressed	−0.29(-0.33,-0.24)	<0.001	−0.23(-0.28,-0.18)	<0.001	−0.25(-0.29,-0.21)	<0.001

Model 1 without any adjustment.
Model 2 adjusted for age, gender, residence, marital status, and education.
Model 3 additionally adjusted for smoking, drinking, sleep duration, daytime napping, distant vision, near vision, hearing, hypertension, dyslipidemia, diabetes, chronic lung diseases, liver disease, heart disease, and stroke.
Ref, referred to reference group.
CI, confidence interval.

cognition, episodic memory, and mental status scores increased with more varieties of social participation, and non-depressed participants scored significantly higher on cognitive function than depressed counterparts. Participants were finally included in the analysis, and those excluded due to missing data are shown in Supplementary Table S2.

3.2. Cross-sectional associations between social participation, depressive symptoms, and cognitive function

Social participation was positively associated with global cognition, episodic memory, and mental status at baseline in all three models (Table 2). The more types of social participation in which the participants engaged, the higher their global cognition (Model 3, 1: β = 0.17, 95 % CI: 0.13 to 0.21; ≥2: β = 0.31, 95 % CI: 0.26 to 0.36), with similar results found for episodic memory and mental states. Depressive symptoms were negatively associated with global cognition (Model 3, β = −0.29, 95 % CI: 0.33 to −0.24), episodic memory, and mental status in all three models. Moreover, mental status (Model 3: β = −0.25, 95 % CI: 0.29 to −0.21) was more affected by depressive symptoms than episodic memory (β = −0.23, 95 % CI: 0.28 to −0.18).

3.3. Longitudinal associations between social participation, depressive symptoms, and global cognition

A similar positive association between social participation and cognition was found using longitudinal data (Table 3). Participants who engaged in two or more social activities (β = 0.26, 95 % CI: 0.23 to 0.929) had 0.13 points higher global cognition compared to those who participated in only one social activity (β = 0.13, 95 % CI: 0.10 to 0.15). Depressed participants had 0.24 points lower global cognition than non-depressed participants (β = −0.24, 95 % CI: 0.030 to −0.19). Episodic memory and mental status had similar results. No interaction was found between social participation and depressive symptoms on global cognition (p = 0.469), episodic memory (p = 0.336) and mental status (p = 0.455).

3.4. Mediation of depressive symptoms

Table 4 and Fig. 3 present the results of the mediation analysis. After controlling for covariates, all three models exhibited that depressive symptoms were mediators of the association between social participation and global cognition. In Model 3, social participation remained associated with global cognition (β = 0.164, 95%CI: 0.143 to 0.185) even after taking depressive symptoms into account as a mediator. The indirect effect of social participation on global cognition via depressive symptoms accounted for 5.5 % of the total effect.

3.5. Sensitivity analysis

After analyzing the influence of social participation items one by one on cognitive function, we observed a positive association between six specific social participation (interacting with friends, voluntary activities, playing mah-jong, sports or social clubs, community organizations, and the internet) and cognitive enhancement, especially playing mahjong and internet usage. Interestingly, volunteer activities displayed no significant influence on mental status. Furthermore, each social participation (except for volunteer activities) where depressive symptoms acted as a mediator remained linked to global cognition (Supplementary Table S3 - Table S5).

Secondly, by stratifying the data by age and sex, we found similar results to the main analysis. Nevertheless, in contrast to participants under 65, diverse social participation had a more significant cognitive boosting effect on participants aged 65 years or older, accompanied by an increased mediating role of depression and a more substantial adverse impact of depressive symptoms on global cognition (Supplementary Table S6 - Table S8).

Thirdly, the combined estimates derived from the estimation dataset did not exhibit statistically significant deviations from the estimates in the primary analysis (Supplementary Table S9).

Table 3
Longitudinal associations between social participation, depressive symptoms, and cognition.

	Global cognition		Episodic memory		Mental status	
	β(95 % CI)	p	β(95 % CI)	p	β(95 % CI)	p
Social participation						
0	Ref	Ref		Ref		Ref
1	0.13(0.10,0.15)	<0.001	0.11(0.08,0.13)	<0.001	0.11(0.08,0.13)	<0.001
≥2	0.26(0.23,0.29)	<0.001	0.25(0.22,0.28)	<0.001	0.18(0.16,0.21)	<0.001
Depressive symptoms						
Non-depressed		Ref		Ref		Ref
Depressed	−0.24(-0.29,-0.19)	<0.001	−0.23(-0.28,-0.17)	<0.001	−0.19(-0.24,-0.14)	<0.001
Social participation[a] Depressive Symptoms		0.469		0.336		0.455

Adjusted for age, gender, residence, marital status, education, smoking, drinking, sleep duration, daytime napping, distant vision, near vision, hearing, hypertension, dyslipidemia, diabetes, chronic lung diseases, liver disease, heart disease, and stroke.
CI, confidence interval.
[a] , interaction.

Table 4
Direct and indirect effect between social participation and global cognition mediated by depressive symptoms.

	Model 1		Model 2		Model 3	
	β(95 % CI)	*p*	β(95 % CI)	*p*	β(95 % CI)	*p*
Total effect	0.307(0.282,0.332)	<0.001	0.176(0.155,0.196)	<0.001	0.164(0.143,0.185)	<0.001
Direct effect	0.287(0.262,0.311)	<0.001	0.165(0.145,0.186)	<0.001	0.155(0.135,0.176)	<0.001
Indirect effect via depressive symptoms	0.020(0.015,0.025)	<0.001	0.011(0.007,0.014)	<0.001	0.009(0.006,0.012)	<0.001
pMe	6.5 %		6.3 %		5.5 %	

Model 1 was a crude model.
Model 2 adjusted for age, gender, residence, marital status, and education.
Model 3 additionally adjusted for smoking, drinking, sleep duration, daytime napping, distant vision, near vision, hearing, hypertension, dyslipidemia, diabetes, chronic lung diseases, liver disease, heart disease, and stroke.
CI, confidence interval.
pMe (proportion of mediating effects), which is the proportion of indirect effects to total effects.

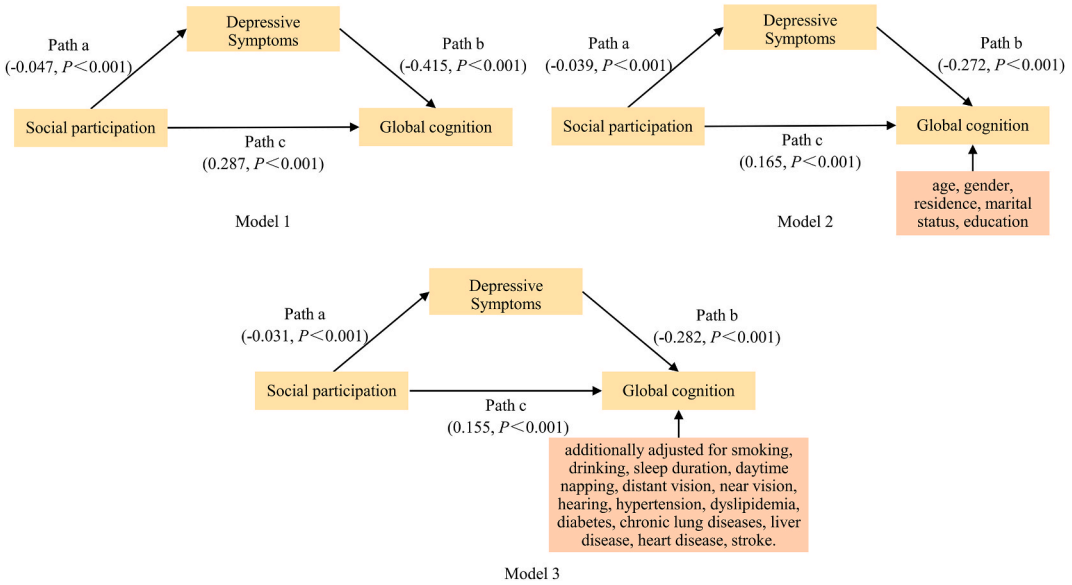

Fig. 3. Mediation of depressive symptoms on the pathway between social participation and global cognition.. (Model 1 was a simple model. Model 2 adjusted for age, gender, residence, marital status, and education. Model 3 additionally adjusted for smoking, drinking, sleep duration, daytime napping, distant vision, near vision, hearing, hypertension, dyslipidemia, diabetes, chronic lung diseases, liver disease, heart disease, and stroke. Path a = exposure predicting mediator; path b = mediator predicting outcome; path c = exposure predicting outcome, i.e., direct effect; indirect effect = path a multiplied by path b.)

4. Discussion

Our study found that social participation was positively associated with cognitive function, with participants engaging in more types of social activities having better cognitive function. Depressed participants had worse cognition. We did not find any interaction between social participation and depressive symptoms on global cognition. Approximately 5.5 % of the effect of social participation on global cognition was mediated by depressive symptoms.

Our findings suggested that social participation is crucial to achieving active aging and enhancing cognitive function. In our study, 50.9 % of middle-aged and older adults engaged in social participation, which was consistent with previous studies [40]. This phenomenon may be due to the formal introduction of the concept of "active aging" by the WHO [41]. Social participation, as one of the three pillars of active aging, creates opportunities for older adults to reintegrate into society, transforming the socioeconomic pressure of aging into a driving force for sustainable development [42]. Meanwhile, dementia has become a significant public health challenge in aging societies, including China, with approximately 15 million older people suffering from dementia. This number is expected to reach 29 million by 2050 [4]. Several studies have found no association between social participation and the risk of incident dementia [43,44]. Our findings are in line with most studies that support a positive effect of social participation on cognitive function, suggesting that participation in social activities may help prevent cognitive decline and the development of dementia in middle-aged and older adults [11,12,45]. Additionally, we found that the more types of social participation an individual engaged in, the better their cognitive function, which echoed findings from previous research that participating in a variety of social activities could provide

greater cognitive benefits [13–15]. Therefore, older adults' social participation can not only prevent dementia but also alleviate a series of aging issues, such as social and health care, in the long run. Furthermore, it was crucial support for elder adults to continue socializing through a high-quality life in their later years.

Our findings were consistent with previous studies demonstrating that middle-aged and older adults with depressive symptoms have worse cognitive function than those without depression [46,47]. This is linked to changes in brain structure and function observed in depressed individuals compared to their non-depressed counterparts [48,49]. This may be due to the fact that depressed individuals may become preoccupied with negative emotions, which consume cognitive resources, making it difficult for them to maintain objectivity about their condition [50]. In addition, our study found that social participation was associated with a reduced risk of depressive symptoms. A longitudinal study from Canada showed that social participation could modulate emotional states and generate positive self-evaluations, thus promoting mental health [51]. Furthermore, a Mendelian randomization study reported that social activity serves as a protective factor against depression, even among individuals with high genetic susceptibility [52]. Thus, social participation might assist middle-aged and older adults in obtaining emotional support, reducing depressive symptoms, and maintaining good cognitive function.

This study found that depression plays a mediating role in the relationship between social participation and cognitive function. A recent neuroimage analysis method study revealed that depressive symptoms mediated more than 10 % and 20 % of the effects of altruistic social engagement on hippocampal volume and cingulate gyrus volume, respectively [30]. A cross-sectional study in India also showed the mediating effect of depressive symptoms on cognitive function in social engagement [53]. Our research results support the previous findings. The present study confirms that social engagement may affect cognition through depression by formally investigating the quantitative mediators of depression. The indirect effects through depressive symptoms accounted for 5.5 % of the total impact of social engagement on cognitive functioning. Although the indirect effects are relatively small, this implies that social engagement contributes to improving cognitive functioning to some extent by reducing depressive symptoms [54]. Therefore, mental health interventions and support can play a key role in promoting cognitive health [55]. At the same time, individualized treatment may be even more important for individuals whose depressive symptoms mediate the relationship between social engagement and cognitive functioning. For instance, a physician or psychotherapist may use interventions tailored to the individual to reduce depressive symptoms, thus contributing to improved cognitive functioning. Nevertheless, we did not find any interaction between social participation and depressive symptoms on cognitive function, suggesting that both increased social participation and lower levels of depression were important for improving cognitive function in older adults. These findings provided valuable empirical evidence for the promotion of social participation among the middle-aged and older Chinese population and have policy implications for public health.

Previous research has explored the correlation between social participation and cognitive function using various grouping methods [56]. Employing these diverse approaches aids in achieving accurate research results. Nonetheless, this study primarily emphasized the diversity of social participation while neglecting its frequency and quality. Further research is required to offer a more comprehensive comprehension of the association between social participation and cognitive function. Secondly, this study did not detect gender discrepancies in the impact of social participation on cognition, consistent with previous research [13]. With advancing age, the significance of social participation in cognitive function becomes increasingly prominent. This phenomenon may be attributed to the higher susceptibility of older adults to social isolation. Active social engagement offers cognitive stimulation, emotional support, and safeguards physical and mental well-being, thereby exerting a more substantial positive influence on cognitive function. Owing to incomplete data in the statistics, approximately 19.0 % of participants were excluded at the baseline, possibly introducing selection bias. Compared to included participants, those excluded subjects significantly had lower education, higher cigarette smoking habits, poorer vision, higher prevalence of depressive symptoms, and poorer cognitive function, which meant that excluded subjects were relatively unhealthy. Both smoking and poor vision may prompt participants to actively reduce their social participation, possibly due to personal reasons or the fear of social rejection. Consequently, among participants with these characteristics, lower social participation, higher depressive symptoms, and poorer cognitive function are more prevalent. Meanwhile, possessing these features may strengthen the observed associations, leading to an underestimation of the mediating role of depressive symptoms in the relationship between social participation and cognitive function, i.e., reduced pMe. This could potentially impact the overall study results. It is noteworthy that we conducted a sensitivity analysis using multiple imputations to further support our research conclusions. This indicated that, even in the presence of selection bias, our conclusions remained robust.

5. Strengths and limitations

To our best knowledge, this study was the first large-scale longitudinal study that quantified the mediation of depressive symptoms on the association between social participation and cognitive function in middle-aged and older Chinese adults. Despite the modest effect size observed for the mediating variable, our results could still inform the design and analysis of subsequent research endeavors, such as the incorporation of moderating variables to bolster model comprehensiveness. Secondly, we examined both the cross-sectional and longitudinal associations of social participation, depressive symptoms and cognitive function, using data from a nationally representative sample.

Nonetheless, we acknowledge that this study also has several limitations. First and foremost, exposure and mediation were measured simultaneously, and reverse causation was possible. Furthermore, reliance on self-reported social participation may introduce response bias and distort the associations. Simultaneously, the frequency and quality of social participation were significant factors influencing cognitive function. However, this study solely addressed the diversity of social participation. Third, the CHARLS respondents were followed up every 2 years with face-to-face computer-assisted personal interview (CAPI), but the cognitive

measurement method was telephone interview, which might bring some bias to the results. Finally, this study's use of complete data without interpolating missing data raised the possibility of biased results.

6. Conclusions

Overall, this study found that social participation was positively associated with cognitive function in middle-aged and older Chinese adults, and a small part of the effect was mediated by depressive symptoms. Given the ample sample size, the study had robust statistical power to detect associations. Therefore, our findings carried significant implications for both practice and policy. For example, middle-aged and elderly individuals who actively participate in diverse social activities may ameliorate depressive symptoms and enhance cognitive functioning. Interventions targeting on enhancing social participation and reducing depressive symptoms would be beneficial for middle-aged and older adults to maintain good cognitive function as long as possible and prevent dementia.

Ethical statement

This study involves no data collected from human subjects. We only make use of the publicly available de-identified sample. This paper performed secondary data analysis on survey data which have obtained ethical approval before being fielded and are publicly available.

Role of the funding source

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Data accessibility statement

The data used in this study came from the CHARLS database. CHARLS data can be obtained at http://opendata.pku.edu.cn/dataverse/CHARLS.

CRediT authorship contribution statement

Chen Chen: Writing – review & editing, Writing – original draft, Software, Formal analysis, Data curation. **Yu Tian:** Writing – review & editing, Writing – original draft, Data curation. **Linghao Ni:** Writing – review & editing, Methodology. **Qianjie Xu:** Writing – review & editing. **Yaoyue Hu:** Writing – review & editing, Project administration. **Bin Peng:** Writing – review & editing, Supervision.

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.e24110.

References

[1] N. Chowdhary, et al., Reducing the risk of cognitive decline and dementia: WHO recommendations, Front. Neurol. 12 (2021) 765584, https://doi.org/10.3389/fneur.2021.765584.
[2] L. Fratiglioni, H.X. Wang, K. Ericsson, M. Maytan, B. Winblad, Influence of social network on occurrence of dementia: a community-based longitudinal study, Lancet (London, England) 355 (1315–9) (2000), https://doi.org/10.1016/s0140-6736(00)02113-9, 9212.
[3] U. Lucca, et al., Incidence of dementia in the oldest-old and its relationship with age: the Monzino 80-plus population-based study, Alzheimers Dement 16 (2020) 472–481, https://doi.org/10.1016/j.jalz.2019.09.083, 3.
[4] Y.T. Wu, et al., The changing prevalence and incidence of dementia over time - current evidence, Nat. Rev. Neurol. 13 (2017) 327–339, https://doi.org/10.1038/nrneurol.2017.63, 6.
[5] J. Xu, J. Wang, A. Wimo, L. Fratiglioni, C. Qiu, The economic burden of dementia in China, 1990-2030: implications for health policy, Bull. World Health Organ. 95 (2017) 18–26, https://doi.org/10.2471/BLT.15.167726, 1.
[6] K.J. Bourassa, M. Memel, C. Woolverton, D.A. Sbarra, Social participation predicts cognitive functioning in aging adults over time: comparisons with physical health, depression, and physical activity, Aging Ment. Health 21 (2017) 133–146, https://doi.org/10.1080/13607863.2015.1081152, 2.

[7] World Health Organization's (WHO), Ageing and health, Available: https://ww-w.who.int/news-room/fact-sheets/detail/ageing-and-health, 2022.
[8] T.R. Prohaska, L.A. Anderson, R.H. Binstock, Public health for an aging society, Aust. N. Z. J. Publ. Health 37 (2013) 1, https://doi.org/10.1111/1753-6405.12021.
[9] Y. Nie, et al., Social networks and cognitive function in older adults: findings from the HAPIEE study, BMC Geriatr. 21 (1) (2021) 570, https://doi.org/10.1186/s12877-021-02531-0.
[10] S. Costa-Cordella, C. Arevalo-Romero, F.J. Parada, A. Rossi, Social support and cognition: a systematic review, Front. Psychol. 12 (2021) 637060, https://doi.org/10.3389/fpsyg.2021.637060.
[11] C. Fu, Z. Li, Z. Mao, Association between social activities and cognitive function among the elderly in China: a cross-sectional study, Int. J. Environ. Res. Publ. Health 15 (2018) 2, https://doi.org/10.3390/ijerph15020231.
[12] L.C. Lam, et al., Intellectual and physical activities, but not social activities, are associated with better global cognition: a multi-site evaluation of the cognition and lifestyle activity study for seniors in Asia (CLASSA), Age Ageing 44 (5) (2015) 835–840, https://doi.org/10.1093/ageing/afv099.
[13] Y. Zhou, et al., Association between social participation and cognitive function among middle- and old-aged Chinese: a fixed-effects analysis, J Glob Health 10 (2) (2020) 020801, https://doi.org/10.7189/jogh.10.020801.
[14] Y. Lou, et al., Association of social participation and psychological resilience with adverse cognitive outcomes among older Chinese adults: a national longitudinal study, J. Affect. Disord. 327 (2023) 54–63, https://doi.org/10.1016/j.jad.2023.01.112.
[15] Z. Fan, X. Lv, L. Tu, M. Zhang, X. Yu, H. Wang, Reduced social activities and networks, but not social support, are associated with cognitive decline among older Chinese adults: a prospective study, Soc. Sci. Med. 289 (2021) 114423, https://doi.org/10.1016/j.socscimed.2021.114423.
[16] X. Su, X. Huang, Y. Jin, S. Wan, Z. Han, The relationship of individual social activity and cognitive function of community Chinese elderly: a cross-sectional study, Neuropsychiatr. Dis. Treat. 14 (2018) 2149–2157, https://doi.org/10.2147/ndt.S160036.
[17] H. Iwasa, Y. Yoshida, I. Kai, T. Suzuki, H. Kim, H. Yoshida, Leisure activities and cognitive function in elderly community-dwelling individuals in Japan: a 5-year prospective cohort study, J. Psychosom. Res. 72 (2) (2012) 159–164, https://doi.org/10.1016/j.jpsychore-s.2011.10.002.
[18] W.J. Chopik, The benefits of social technology use among older adults are mediated by reduced loneliness, Cyberpsychol., Behav. Soc. Netw. 19 (9) (2016) 551–556, https://doi.org/10.1089/cyber.2016.0151.
[19] Z.I. Santini, et al., The moderating role of social network size in the temporal association between formal social participation and mental health: a longitudinal analysis using two consecutive waves of the Survey of Health, Ageing and Retirement in Europe (SHARE), Soc. Psychiatr. Psychiatr. Epidemiol. 56 (3) (2021) 417–428, https://doi.org/10.1007/s00127-020-01961-2.
[20] J. Domènech-Abella, et al., Loneliness and depression in the elderly: the role of social network, Soc. Psychiatr. Psychiatr. Epidemiol. 52 (4) (2017) 381–390, https://doi.org/10.1007/s00127-017-1339-3.
[21] Z. Feng, T. van den Broek, O. Perra, J.M. Cramm, A.P. Nieboer, Longitudinal health behaviour patterns among adults aged ≥50 years in China and their associations with trajectories of depressive symptoms, Aging Ment. Health (2022) 1–10, https://doi.org/10.1080/13607863.2022.2149694.
[22] J. Wang, et al., Effects of social participation and its diversity, frequency, and type on depression in middle-aged and older persons: evidence from China, Front. Psychiatr. 13 (2022) 825460, https://doi.org/10.3389/fpsyt.2022.825460.
[23] Y. Ni, J.Y. Tein, M. Zhang, Y. Yang, G. Wu, Changes in depression among older adults in China: a latent transition analysis, J. Affect. Disord. 209 (2017) 3–9, https://doi.org/10.1016/j.jad.2016.11.004.
[24] Z.C. Ruoxi Wang, Yongjie Zhou, Lining Shen, Zhiguo Zhang, Xiang Wu, Melancholy or mahjong? Diversity, frequency, type, and rural-urban divideof social participation and depression in middle- and old-aged Chinese: afixed-effects analysis, Soc. Sci. Med. 238 (2019) 112518, https://doi.org/10.1016/j.socscimed.2019.112518, 2019.
[25] Y. Stern, Cognitive reserve in ageing and Alzheimer's disease, Lancet Neurol. 11 (2012) 1006–1012, https://doi.org/10.1016/s1474-4422(12)70191-6, 11.
[26] Y. Stern, What is cognitive reserve? Theory and research application of the reserve concept, J. Int. Neuropsychol. Soc. : JINS 8 (3) (2002) 448–460.
[27] S. Wang, D.G. Blazer, Depression and cognition in the elderly, Annu. Rev. Clin. Psychol. 11 (2015) 331–360, https://doi.org/10.1146/annurev-clinpsy-032814-112828.
[28] L.M. McDermott, K.P. Ebmeier, A meta-analysis of depression severity and cognitive function, J. Affect. Disord. 119 (1–8) (2009) 1–3, https://doi.org/10.1016/j.jad.2009.04.022.
[29] M. Semkovska, et al., Cognitive function following a major depressive episode: a systematic review and meta-analysis, Lancet Psychiatr. 6 (10) (2019) 851–861, https://doi.org/10.1016/s2215-0366(19)30291-3.
[30] Y. Liu, et al., Altruistic social activity, depressive symptoms, and brain regional gray matter volume: voxel-based morphometry analysis from 8,695 old adults, J Gerontol A Biol Sci Med Sci 77 (2022) 1789–1797, https://doi.org/10.1093/gerona/glac093, 9.
[31] Y. Zhao, Y. Hu, J.P. Smith, J. Strauss, G. Yang, Cohort profile: the China health and retirement longitudinal study (CHARLS), Int. J. Epidemiol. 43 (2014) 61–68, https://doi.org/10.1093/ije/dys203, 1.
[32] Y. Ma, L. Liang, F. Zheng, L. Shi, B. Zhong, W. Xie, Association between sleep duration and cognitive decline, JAMA Netw. Open 3 (9) (2020) e2013573, https://doi.org/10.1001/jamanetworkopen.2020.13573.
[33] K.W. Boey, Cross-validation of a short form of the CES-D in Chinese elderly, Int. J. Geriatr. Psychiatr. 14 (1999) 608–617, https://doi.org/10.1002/(sici)1099-1166, 8.
[34] H. Chen, A.C. Mui, Factorial validity of the center for epidemiologic studies depression scale short form in older population in China, International psychogeriatrics 26 (1) (2014) 49–57, https://doi.org/10.1017/s1041610213001701.
[35] G. Livingston, et al., Dementia prevention, intervention, and care: 2020 report of the Lancet Commission, Lancet (London, England) 396 (2020) 413–446, https://doi.org/10.1016/S0140-6736(20)30367-6, 10248.
[36] Y. Shang, L. Widman, H. Hagström, Nonalcoholic fatty liver disease and risk of dementia: a population-based cohort study, Neurology 99 (2022) e574–e582, https://doi.org/10.1212/wnl.0000000000200853, 6.
[37] P.L. Lutsey, et al., Impaired lung function, lung disease, and risk of incident dementia, Am. J. Respir. Crit. Care Med. 199 (2019) 1385–1396, https://doi.org/10.1164/rccm.201807-1220OC, 11.
[38] Z. Wen, B. Ye, Analyses of mediating effects: the development of methods and models, Adv. Psychol. Sci. 22 (5) (2014) 731, https://doi.org/10.3724/SP.J.1042.2014.00731.
[39] C.-L. Li, H.-C. Hsu, Cognitive function and associated factors among older people in Taiwan: age and sex differences, Arch. Gerontol. Geriatr. 60 (2015) 196–200, 1.
[40] W. Pothisiri, P.M.M. Vicerra, Cognitive function, co-residence, and social participation among older persons in Thailand, Soc. Sci. J. (2021) 1–14, https://doi.org/10.1080/036233-19.2020.1851076.
[41] World Health Organization's (WHO), Second world assembly on ageing, Available: https://www.un.org/en/conferences/ageing/madrid2002, 2002.
[42] Y. Yang, Y. Meng, P. Dong, Health, security and participation: a structural relationship modeling among the three pillars of active ageing in China, Int. J. Environ. Res. Publ. Health 17 (7255) (2020) 19, https://doi.org/10.3390/ijerph17197255.
[43] P. Almeida-Meza, A. Steptoe, D. Cadar, Is engagement in intellectual and social leisure activities protective against dementia risk? Evidence from the English longitudinal study of ageing, J. Alzheimers Dis. 80 (2021) 555–565, https://doi.org/10.3233/JAD-200952, 2.
[44] S. Floud, et al., Cognitive and social activities and long-term dementia risk: the prospective UK Million Women Study, Lancet Public Health 6 (2) (2021) e116–e123, https://doi.org/10.1016/S2468-2667(20)30284-X.
[45] B.D. James, R.S. Wilson, L.L. Barnes, D.A. Bennett, Late-life social activity and cognitive decline in old age, J. Int. Neuropsychol. Soc. : JINS. 17 (6) (2011) 998–1005, https://doi.org/10.1017/s1355617711000531.
[46] T.M. Liew, Depression, subjective cognitive decline, and the risk of neurocognitive disorders, Alzheimer's Res. Ther. 11 (1) (2019), https://doi.org/10.1186/s13195-019-0527-7, 70.

[47] D.J. Vinkers, J. Gussekloo, M.L. Stek, R.G. Westendorp, R.C. van der Mast, Temporal relation between depression and cognitive impairment in old age: prospective population based study, J. Alzheimers Dis. 329 (2004), https://doi.org/10.1136/bmj.38216.604664.DE, 881, 7471.
[48] A. Hammar, E.H. Ronold, G.A. Rekkedal, Cognitive impairment and neurocognitive profiles in major depression-A clinical perspective, Front. Psychiatr. 13 (2022) 764374.
[49] S. Invernizzi, I. Simoes Loureiro, K.G. Kandana Arachchige, L. Lefebvre, Late-life depression, cognitive impairment, and relationship with Alzheimer's disease, Dement. Geriatr. Cogn. Disord 50 (2021) 414–424, https://doi.org/10.1159/000519453, 5.
[50] D.M. Mackie, L.T. Worth, Processing deficits and the mediation of positive affect in persuasion, J. Pers. Soc. Psychol. 57 (1) (1989) 27–40, https://doi.org/10.1037//0022-3514.57.1.27.
[51] J. Sibalija, M.Y. Savundranayagam, J.B. Orange, M. Kloseck, Social support, social participation, & depression among caregivers and non-caregivers in Canada: a population health perspective, Aging Ment. Health 24 (5) (2020) 765–773, https://doi.org/10.1080/13607863.2018.1-544223.
[52] K.W. Choi, et al., An exposure-wide and mendelian randomization approach to identifying modifiable factors for the prevention of depression, Am. J. Psychiatr. 177 (2020) 944–954, https://doi.org/10.1176/appi.ajp.2020.19111158, 10.
[53] M. Kumar, T. Muhammad, L.K. Dwivedi, Assessing the role of depressive symptoms in the association between social engagement and cognitive functioning among older adults: analysis of cross-sectional data from the Longitudinal Aging Study in India (LASI), BMJ Open 12 (10) (2022) e063336, https://doi.org/10.1136/bmjopen-2022-063336.
[54] R. Yang, et al., Loneliness as a mediator of the impact of social isolation on cognitive functioning of Chinese older adults, Age Ageing 49 (2020) 599–604, https://doi.org/10.1093/ageing-/afaa020, 4.
[55] M. Farhang, C. Miranda-Castillo, M. Rubio, G. Furtado, Impact of mind-body interventions in older adults with mild cognitive impairment: a systematic review, International psychogeriatrics 31 (2019) 643–666, https://doi.org/10.1017/s1041610218002302, 5.
[56] S. Kanamori, et al., Social participation and mortality according to company size of the longest-held job among older men in Japan: a 6-year follow-up study from the JAGES, J. Occup. Health 63 (1) (2021) e12216, https://doi.org/10.1002/1348-9585.12216.