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The mediating role of depressive symptoms in the association between social engagement and cognitive functioning among older adults: Evidence from Longitudinal Aging Study in India (LASI)

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Abstract

Objective The present study attempts to determine the mediating role of depressive symptoms in the association between social engagement and cognitive functioning among older individuals, with special attention to sex differences.

Design A cross-sectional large scale survey data was analyzed in this study.

Setting and Participants The present study utilizes the individual-level data from the first wave of the Longitudinal Aging Study in India (LASI) conducted during 2017-19. The sample for the study included 20,084 individuals aged 60 years and above (10,526 men and 9,558 women).

Primary and Secondary outcome measures The primary outcome variable was cognitive functioning which was based on different cognitive measures, including immediate and delayed word recall; orientation related to time, and place; executive functioning based on paper folding and pentagon drawing; arithmetic ability based on serial 7s, computation and backward counting from 20; and object naming.

Results Linear regression results showed that higher levels of social engagements were significantly associated with better cognitive functioning for both men (β= 0.64, p<.001) and women (β= 0.34, p<.001) older adults, after adjusting for sociodemographic factors, lifestyle factors, and chronic conditions. Moreover, greater depressive symptoms significantly reduced the cognitive functioning for both older men and women. KHB method identified a significant mediating effect of depressive symptoms on the relationship between social engagement and cognitive functioning, and the proportional mediation through depressive symptoms was 14.4% and 18.1% for men and women older adults, respectively.

Conclusion The results suggest that a positive association of social engagement with cognitive functioning was partly mediated by depressive symptoms. The findings support the possible benefits of maintaining quality social relations that help coping with depressive symptoms on

cognitive functioning among older adults, which need to be confirmed with future interventional studies.

Keywords: *social engagement, cognitive functioning, depressive symptoms, KHB-method, older adults.*

Strengths and limitations of this study

- The utilization of the national representative sample of older adults is a potential strength of the study
- Mediation analysis explains the mechanism by which social engagement affects cognitive function through a mediator, depressive symptoms
- The social engagements were significantly associated with better cognitive functioning for both men and women older adults
- The association of social engagement with cognitive functioning was partly mediated by depressive symptoms
- The inability to establish the causal relationship between social engagement and cognitive functioning is the limitation of the study

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Background

With the growth of aging population, global challenges in mental health are on the rise. It includes the decline in late-life cognitive abilities which are generally associated with poor quality of life [1], functional disabilities [2], multimorbidity [3], and higher mortality risk [4]. India is currently facing rapid population aging, with an expected increase in the number of individuals aged 60 years and above from 104 million in 2011 to 319 million by 2050 [5]; consequently, the disease burden of cognitive impairment in the country is also expected to increase.

Social engagement is an umbrella concept usually referring to various factors such as social relationships, social and emotional connectedness with other people, and participation in social activities, which provide a sense of belonging, social identity, and fulfilment [6,7]. In the absence of effective pharmacological treatment for persons with cognitive impairment, especially for the long-term benefits, various methods such as improving social engagement and active participation in social activities are considered [8]. Multiple cross-sectional studies investigating the association between social environment and cognition in older adults showed that greater social functioning improves cognitive performances [9,10]. Moreover, several longitudinal studies among older adults have also indicated that greater engagements with relatives [11,12], rich social networks [12,13], and frequent participation in social activities [14] exert protective effects against cognitive decline. Therefore, in the long run, individuals who present trajectories of high and increasing social engagements experience lower levels of cognitive limitation [15].

Several interventional studies reported the protective effects of the improved social behaviours in preventing or delaying dementia among older adults with diagnosed cognitive impairment [16,17]. Most of the available research on social capital and engagement as to enhance cognitive reserve and protect cognitive health has been conducted in developed countries [18–21]. Little is known about the relationship between social engagement and cognitive functioning in developing countries like India, where the cultural and structural context of social engagement differ from developed countries. In India, traditionally, older adults are more

likely to live with their children in multigenerational households where cultural norms emphasize family ties and the virtue of filial piety [22,23], and a higher proportion of older people experience psychological distress and mental illnesses [24–26].

Similarly, depressive disorders are highly prevalent among older adults in low and middle income countries [27–29] and in India in particular [30]. Previously, various studies have found the beneficial effects of greater social engagements (with varying measurements and definitions) against depressive symptoms [31,32]. A cross-sectional study by Jang & Chiriboga (2011) [31] found that a higher level of participation in social activities was associated with a decline in depressive symptoms after controlling for the effects of demographic and health-related factors. Multiple longitudinal studies have also reported similar findings [33–37]. Also, increased participation in social activities and meaningful engagement by older adults may improve their mood, which benefits their emotional functioning and reduces depressive symptoms [38], which is linked to cognitive functioning [39]. According to the 'depression reduction hypothesis', depressive symptoms interferes with cognitive health; therefore, as evident from multiple longitudinal studies, practical strategies to reduce depressive symptoms will possibly improve cognitive functioning [40]. Two facts justify such a hypothesis; first, greater depressive symptoms are related to poor cognitive functioning among older adults [41,42]. Second, depressed older adults who engage in social activities may experience a decline in depressive symptoms and improve cognitive functioning [43]. Furthermore, in multiple cohort studies, cognitively impaired older adults with depressive symptoms were associated with more rapid cognitive decline than those without depression [44,45].

However, it is not clear to what extent social engagement may improve cognitive functioning by minimizing depressive symptoms. There is a dearth of studies in low- and middle-income countries on the association of social engagements and cognitive functioning and the mediating role of depressive symptoms in such association. On the other hand, an effective strategy to prevent or delay cognitive impairment for the aging population could be through increased engagements of older individuals in social activities which may enhance their mental health. Filling this gap, the present study using national-level data of older adults in India, attempts to determine the mediating role of depressive symptoms in the association between social engagement and cognitive functioning among older individuals. Previous research theorized gender as the crucial factor to be considered in understanding the role of social engagement and its positive mental health benefits [46]. Thus, the study also explores the sex difference in

the relationship between social engagement and cognitive functioning and the mediating effects of depressive symptoms. The present study hypothesized that the association between social engagement and cognitive functioning is partially mediated by depressive symptoms (Figure 1).

Methods

Data

The present study utilizes the individual-level data from the first wave of the Longitudinal Aging Study in India (LASI) conducted during 2017-19. LASI is a nationally representative longitudinal survey of more than 72000 older adults aged 45 years and over across all states and union territories of India that provides vital information on the social, physical, psychological, and cognitive health of the Indian aging population. The LASI survey was conducted through a partnership of the International Institute for Population Sciences (IIPS), Harvard T. H. Chan School of Public Health (HSPH), and the University of Southern California (USC). LASI is envisioned to be conducted every two years for the next 25 years. In LASI wave 1, the sample selection is based on a multistage stratified cluster sample design, including a three-stage sampling design in rural areas and a four-stage sampling design in urban areas. LASI survey provided internationally harmonized data that comparable to the United States Health and Retirement Study (HRS) and other HRS-type surveys in other countries, including England (English Longitudinal Study of Ageing) and China (China Health and Retirement Longitudinal Survey). Further, the details of sampling design, survey instruments, and data collection procedures are provided elsewhere [47].

The sample in the main LASI included 31,464 individuals aged 60 years and above. For the present analysis, we have excluded those cases with missing data for any variables of interest (n=7,842). To avoid potential reverse causality, we have excluded 3,390 individuals with poor cognitive functioning (lowest 10th percentile) [48] and 148 individuals with neurological problems such as Alzheimer's disease and dementia. Therefore, the sample for the present study included 20,084 individuals from the LASI survey, and among them 10,526 were men and 9,558 were women.

Measures

Cognitive function

By adopting the Health and Retirement Study (HRS) cognition module, the LASI collected information on measured cognition in various domains – including memory, orientation, executive functioning, arithmetic, and object naming (Table 1). Previously, various studies have established high validity and reliability of these cognitive domains for measuring cognitive impairment among older adults in community settings in the United States [49], China [50], and India [51]. The cognitive functioning in the present study is based on different cognitive measures, including immediate (0–10 points) and delayed word recall (0–10 points); orientation related to time (0-4 points), and place (0-4 points); executive functioning based on paper folding (0-3) and pentagon drawing (0-1); arithmetic ability based on serial 7s (0–5 points), computation (0-2) and backward counting from 20 (0–2 points); and object naming (0-2).

Table 1. Description of domain-wise cognitive measures in LASI, 2017-18

Domain	Measure	Measurement	Range
Memory	Immediate word recall	Interviewer read out a list of 10 words and respondents were asked to repeat the words.	0-10
	Delayed word recall	Respondents were asked to recall the same words read out for immediate recall after some time.	0-10
Orientation	Time	Respondents were asked to state today's date, month and year and day of the week. For each question, the score was 0 or 1. Correct responses received 1 point, incorrect responses received 0. The total score for time was 0-4.	0-4
	Place	Orientation towards place was captured based on place of interview, name of the village, street number/colony name/landmark/neighborhood and name of the district. Each correct response scored 1 point. The total score ranged from 0-4.	0-4
Arithmetic function	Backward counting	Respondents were asked to count backward as quickly as possible from the number 20. The respondents were asked to stop after correctly counting backward from 20 to 11 or from 19 to 10. Correct counting received 2 points: counts with a mistake received 1 point. Those who could not count received 0 points.	0-2
	Serial 7	Respondents were asked to subtract seven from 100 in the first step and asked to continue subtracting seven from the previous number in each subsequent step for five times. Each correct response received 1 point.	0-5
	Computation	This test involved the mathematical operation of division. Respondents were asked to compute the net sale price of a product after considering a discount sale of half of the original price.	0-2
Executive function: 0-4	Executive (paper folding)	This is a three-stage command task. The respondents were instructed to take a piece of paper from the interviewer, turn it over, fold it in half, and give it back to the interviewer. Three points were given if each task was completed successfully.	0-3
	Pentagon	Visio-construction is the ability to coordinate fine motor skills	0-1

	drawing	with visio-spatial abilities, usually by reproducing geometric figures. Respondents were asked to copy two overlapping pentagons and scored 1 point for a correct drawing.	
Object naming: 0-2		The interviewer points to a specific object and asks the respondent to name it. Two objects were pointed out and 1 point was given for each correct response.	0-2
Cognition	Composite cognitive index	Combined score of memory (total word recall), orientation, arithmetic function, executive function, and object naming.	0-43

After adding the scores for each component, the overall score ranged from 0 to 43. Since we exclude those individuals who lie in the lowest 10th percentile in the distribution of cognitive function, and we have obtained a cut-off score of 16 for the lowest 10th percentile [48], the participants with a score of less than 16 were excluded. After re-scaling the cognition scores (subtracting 16 from each individual's score), our final cognition function scores range from 0 to 27, and a higher score indicates better cognitive functioning.

Social Engagements

Following the previous studies [52,53], we have derived social engagement based on five indicators: marital status, living arrangement, availability of confidant, and participation in indoor games, social and cultural functions. Current marital status was set to unmarried (single, widowed, separated, or divorced; coded as 0) versus married (married or living with a partner; coded as 1). Regarding living arrangements, living alone was categorized as 0, and living with extended family is categorized as 1. The availability of a confidant relationship (spouse, son or daughter, grandchildren, or relatives, etc.) was coded as no (0) or yes (1). Two more indicators based on participation in social activities including, playing cards or indoor games and attending social and cultural functions, were included (0 = less than weekly, 1 = weekly or more frequently). A composite index of social engagement was constructed by summing the scores for all five indicators, ranging from 0 to 5. Based on the distribution of the overall composite index, individuals were categorized as having low (0-2 social ties; 27.6 percent), medium (3 ties; 62 percent), or high (4-5 ties; 10.1 percent) levels of social engagement.

Depressive symptoms

The LASI has used an internationally validated 10-item Center for Epidemiological Studies-Depression (CES-D) scale to capture the presence of depressive symptoms in Indian older adults [54,55]. The ten items in CES-D consist of seven negative symptoms (feeling depressed, low energy, trouble concentrating, feeling alone, bothered by things, fear of something, and

everything is an effort) and three positive symptoms (feeling happy, satisfied, and hopeful). The possible responses for these items were: rarely or never (< 1 day), sometimes (1 or 2 days), often (3 or 4 days), and most or all of the time (5-7 days) in a week prior to the interview. For the negative symptoms, rarely or never (< 1 day) and sometimes (1 or 2 days) were scored zero, and often (3 or 4 days) and most or all of the time (5-7 days) categories were scored one. Scoring was reversed for positive symptoms. The overall depressive symptoms score, calculated by adding the scores from ten items, ranges from 0 to 10. A score of four or higher is considered to represent clinically significant symptoms in the 10-item scale [56].

Covariates

After an extensive literature review, potentially related covariates were selected which include socio-demographic characteristics, lifestyle factors, health conditions, and cognitive and social activities. Socio-demographic characteristics were: age (in chronological years); gender (men, women); education (no education, primary, secondary, higher); currently working status (no, yes); residence (rural, urban); religion (Hindu, Muslim, Christian, others); Caste (Scheduled Caste, Scheduled Tribe, Other Backward Class (OBC), others), Region (North, Central, East, Northeast, West, and South), monthly per capita expenditure (MPCE) (poorest, poorer, middle, richer, and richest). The lifestyle factors were: currently smoking (no, yes); currently chewing tobacco (no, yes), alcohol drinking status (never, infrequent non-heavy, frequent non-heavy, heavy episodic drinker), and body mass index (underweight (<18.5 kg/m^2), normal (18.5-24.9 kg/m^2), overweight/obese (>25.0 kg/m^2)). Health conditions include biometric measurement-based hypertension status (normal, pre-hypertensive, high blood pressure), and self-reported conditions such as diabetes, cancer, heart disease, and stroke were coded as no and yes. The older adults were categorized as having normal blood pressure (BP) (Systolic BP <120 mmHg and Diastolic BP<80 mmHg), pre-hypertensive (SBP: 120-139 mmHg and DBP: 80-89 mmHg), and high blood pressure (SBP≥ 140 mmHg and DBP≥ 90 mmHg).

According to the procedure suggested by Dong and Simon [57], we have included the four social participation activities: (1) eat out of the house, (2) go to the park/beach, visit relatives/friends, (3) go out to a movie, and (4) attend political/community group meetings. Based on the frequency of participation, responses were coded as '0' for less than weekly, '1' for weekly or more frequently for these activities.

Statistical analysis

Descriptive statistics (means and percentages) were used to assess the characteristics of the older adults included in the final sample. The analysis procedure in this study follows three procedures. First, linear regression models were employed to determine the association of social engagements and depressive symptoms with cognitive function. Second, correlation analysis and a linear regression model of depressive symptoms on social engagement were conducted. Third, the total effect was divided into direct effects (the association of social engagement with cognitive function controlling for depressive symptoms) and indirect or mediating effects (the association of social engagement with cognitive function through depressive symptoms) using linear regression based on Karlson–Holm–Breen (KHB) method [58,59] for the whole sample, and for men and women subsamples, separately. The KHB method is a recently developed method for assessing mediating effects that allow total effects to be divided into direct and indirect (i.e., mediational) effects for both discrete and continuous variables. Contrary to other decomposition methods, the KHB-method provides unbiased decomposition results [60]. The mediation percentage (the indirect effect divided by the total effect) is interpreted as the percentage of the association explained by the mediator variable. All statistical models were adjusted for various predictors, including age, gender, education, working status, residence, religion, caste, region, body mass index (BMI), monthly per capita expenditure (MPCE), smoking status, chewing tobacco status, alcohol drinking, hypertension, diabetes, cancer, heart disease, and stroke. The statistical analysis was performed using Stata 15.1. A p-value of less than 0.05 was considered statistically significant.

Patient and public involvement

No patient was involved.

Results

Table 2 presents the descriptive information for cognitive function, socio-demographic factors, lifestyle factors, and chronic conditions of older men and women included in the analysis. The mean cognition score of men was higher than that of women (11.0 vs. 7.8). Nearly 86% of older men had at least a medium level of social engagements, while this proportion was 57% for older women. Regarding depressive symptoms score, older women had a slightly higher mean score than older men (2.9 vs. 2.8). On average, men were slightly older than women (68.4 vs. 67.3 years). A higher proportion of older women were uneducated than older men (62.2% vs. 31.7%). Around 44.8% of the older men and 19.5% of women were currently working at the time of the survey. About 32% of older women and 21% of older men were overweight or

obese. A higher proportion of older women in the study compared to men were overweight or obese (32.3% vs. 21.2%). Around 25% of men and only 4% of women were current tobacco smokers, while 24% of men and 15% of women were consuming tobacco by chewing at the time of the survey. Alcohol consumption is way higher among older men than women (31.8% vs. 3.5%). According to measured hypertension status, the prevalence of high blood pressure is slightly higher among older women than men (39.2% vs. 38.1%). According to religion, around three-fourths of both older men and women participants were Hindus. Most of the participants were rural residents (72.1% men vs. 69.2% women).

Table 2. Descriptive statistics for sample characteristics of older adults included in the analysis, by gender, India, (N = 20,084)

	Men		Women		Total	
	n	%	n	%	n	%
Social Engagement						
Low	1,457	13.8	4,085	42.7	5,542	27.6
Medium	7,729	73.4	4,793	50.1	12,522	62.3
High	1,340	12.7	680	7.1	2,020	10.1
Cognition[a]	11.0	5.7	7.8	5.6	9.5	5.9
Depressive symptoms score[a]	2.8	1.6	2.9	1.7	2.8	1.6
Age (years)[a]	68.4	6.8	67.3	6.4	67.9	6.6
Social Activities (0-5)[a]	0.3	0.6	0.2	0.5	0.2	0.5
Education level						
No education	3,337	31.7	5,945	62.2	9,282	46.2
Primary	3,346	31.8	2,220	23.2	5,566	27.7
Secondary	2,500	23.8	988	10.3	3,488	17.4
Higher	1,343	12.8	405	4.2	1,748	8.7
Currently working						
No	5,815	55.2	7,694	80.5	13,509	67.3
Yes	4,711	44.8	1,864	19.5	6,575	32.7
Place of Residence						
Rural	6,978	66.3	5,904	61.8	12,882	64.1
Urban	3,548	33.7	3,654	38.2	7,202	35.9
Religion						
Hindu	7,775	73.9	7,121	74.5	14,896	74.2
Muslim	1,209	11.5	1,010	10.6	2,219	11.0
Christian	1,013	9.6	944	9.9	1,957	9.7
Others[$]	529	5.0	482	5.0	1,011	5.0
Caste						
Scheduled caste	1,749	16.6	1,524	16.0	3,273	16.3
Scheduled tribe	1,667	15.9	1,389	14.6	3,056	15.2
OBC[#]	4,165	39.6	3,785	39.7	7,950	39.6
Others	2,935	27.9	2,839	29.8	5,774	28.8
Regions						
North	1,965	18.7	1,810	18.9	3,775	18.8
Central	1,507	14.3	1,190	12.5	2,697	13.4
East	2,090	19.9	1,701	17.8	3,791	18.9
Northeast	1,248	11.9	1,108	11.6	2,356	11.7
West	1,279	12.2	1,280	13.4	2,559	12.7
South	2,437	23.2	2,469	25.8	4,906	24.4
BMI categories						

Normal	5,934	56.4	4,673	48.9	10,607	52.8
Underweight	2,360	22.4	1,798	18.8	4,158	20.7
Overweight/Obese	2,232	21.2	3,087	32.3	5,319	26.5
MPCE quintile						
Poorest	2,021	19.2	1,831	19.2	3,852	19.2
Poorer	2,114	20.1	1,922	20.1	4,036	20.1
Middle	2,163	20.5	2,003	21.0	4,166	20.7
Richer	2,153	20.5	1,951	20.4	4,104	20.4
Richest	2,075	19.7	1,851	19.4	3,926	19.5
Currently smoking tobacco						
No	7,933	75.4	9,186	96.1	17,119	85.2
Yes	2,593	24.6	372	3.9	2,965	14.8
Currently chewing tobacco						
No	7,981	75.8	8,128	85.0	16,109	80.2
Yes	2,545	24.2	1,430	15.0	3,975	19.8
Drinking Status						
Never	7,180	68.2	9,252	96.8	16,432	81.8
Infrequent non-heavy	2,092	19.9	186	1.9	2,278	11.3
Frequent non-heavy	666	6.3	66	0.7	732	3.6
Heavy episodic drinker	588	5.6	54	0.6	642	3.2
Hypertension Status						
Normal	2,376	22.6	2,171	22.7	4,547	22.6
Pre-hypertensive	4,143	39.4	3,636	38.0	7,779	38.7
High BP	4,007	38.1	3,751	39.2	7,758	38.6
Diabetes						
No	8,792	83.5	7,997	83.7	16,789	83.6
Yes	1,734	16.5	1,561	16.3	3,295	16.4
Cancer						
No	10,456	99.3	9,482	99.2	19,938	99.3
Yes	70	0.7	76	0.8	146	0.7
Heart Disease						
No	9,879	93.9	9,136	95.6	19,015	94.7
Yes	647	6.1	422	4.4	1,069	5.3
Stroke						
No	10,257	97.4	9,410	98.5	19,667	97.9
Yes	269	2.6	148	1.5	417	2.1
Total	**10,526**	**100.0**	**9,558**	**100.0**	**20,084**	**100.0**

Note: [#]Other Backward Classes, [a]Mean and standard deviation; [$]includes Sikh, Buddhist/neo-Buddhist, Jain, Parsi/Zoroastrian and others; BP- Blood Pressure.

The average cognitive score increased with an increase in the level of social engagement, and it was higher among the non-depressed older adults (9.8 vs. 8.5) (Supplementary; Table S1). Moreover, the prevalence of depressive symptoms decreased with an increase in the level of social engagement. Table 3 presents the results of linear regression of social engagement and depressive symptoms on cognitive function among older adults, adjusted for all the covariates, including socio-demographic factors, lifestyle factors, and chronic conditions. We included the full table in the supplementary material (Table S2). Results suggest that higher levels of social engagement was significantly associated with better cognitive function for older adults (β=

0.90, p<.001), in men (β= 0.90, p<.001) and women (β= 1.13, p<.001). Additionally, greater depressive symptoms significantly reduced the cognitive functioning among both older men (β= -0.31, p<.001) and women (β= -0.28, p<.001). The correlation between social engagement and depressive symptoms was -0.11 (p < .001) (Supplementary; Table S3). The linear regression model demonstrated that higher levels of social engagement was negative associated with depressive symptoms (β = -0.17, p < .001) (Supplementary; Table S4).

Table 3. Linear regression results of social engagement and depressive symptoms on cognitive functioning, by gender, (N = 20,084).

	Men		Women		Total	
	β	**(95% CI)**	**β**	**(95% CI)**	**β**	**(95% CI)**
Social Engagement						
Low®						
Medium	0.64***	(0.38,0.90)	0.34***	(0.15,0.53)	0.49***	(0.34,0.64)
High	0.90***	(0.51,1.28)	1.13***	(0.70,1.56)	0.90***	(0.63,1.18)
Depressive symptoms score	-0.31***	(-0.36,-0.25)	-0.28***	(-0.33,-0.23)	-0.29***	(-0.33,-0.25)
N	**10,526**		**9,558**		**20,084**	
R^2	**0.32**		**0.36**		**0.38**	

Note: Controlled for age, gender, education, working status, social activities, place of residence, religion, caste, region, body mass index (BMI), MPCE, smoking status, chewing tobacco, alcohol status, hypertension, diabetes, cancer, heart disease, and stroke. CI = confidence interval.
* p<0.05, ** p<0.01, *** p<0.001

Table 4 shows the mediation analysis results for the whole sample, the older men and women subsamples. After controlling for all the covariates in the entire sample, the results indicate that depressive symptoms significantly mediated 16.9% of the association between social engagement and cognitive function. In addition, we found significant mediation percentages for older men and women subsamples (14.4% men vs. 18.1% women).

Table 4. The Effect of Social Engagement on cognition mediated by depressive symptoms (the Karlson, Holm, and Breen Method), by gender, (N = 20,084), LASI, 2017-19

	Men		Women		Total	
	β	**(95% CI)**	**β**	**(95% CI)**	**β**	**(95% CI)**
Social Engagements						
Total Effect	0.41***	(0.24,0.57)	0.26***	(0.13,0.39)	0.31***	(0.21,0.42)
Direct effect of social engagement	0.35***	(0.18,0.52)	0.21**	(0.08,0.34)	0.26***	(0.15,0.36)
Indirect effect via depressive symptoms	0.06***	(0.04,0.08)	0.05***	(0.03,0.06)	0.05***	(0.04,0.06)
N	**10,526**		**9,558**		**20,084**	
Conf.-Perc[a]	**14.4%**		**18.1%**		**16.9%**	

Note: Controlled for age, gender, education, working status, social activities, place of residence, religion, caste, region, body mass index (BMI), MPCE, smoking status, chewing tobacco, alcohol status, hypertension, diabetes, cancer, heart disease, and stroke. CI = confidence interval. [a]Confounding percentage.

* p<0.05, ** p<0.01, *** p<0.001

Discussion

The present study examined the direct, indirect, and total effects of social engagement on the cognitive functioning mediated by the depressive symptoms among Indian older adults. We found that a higher level of social engagement was associated with greater cognitive functioning, whereas depressive symptoms mediated 16.9% of the observed association. In addition, gender-based mediation effects were also calculated which were 14.4% and 18.1% for men and women older adults, respectively.

Structural aspects of social network are recommended to be essential to maintain an optimal level of cognitive functioning [61]. As documented, social networks and activity are related concepts and individuals who have a larger social networks tend to take part in more social activities [62]. Similarly, the satisfaction achieved from the social and support networks was observed to lead to better episodic memory performance, and processing speed and global cognition [63]. The main effect hypothesis in the present study is confirmed by the results showing that social engagements are independently associated with a greater level of cognitive functioning. The finding is consistent with previous studies linking the social involvement enhancing the wellbeing and boosting the self-esteem and creating a sense of belonging that result in better cognitive functioning [64–66]. A systematic review reported that although the exact nature of the associations are unclear, different aspects of social relationships such as social activity, social networks and social support and a composite measures of social relationships are associated with cognitive functioning [67].

Although social engagements including the structural support from the spouse and family members are found to enhance cognitive functioning [68–70], the mechanism that mental illnesses adversely mediating the association is less investigated. A recent study found the mediating role of hippocampal volume of brain which is known to be affected by a variety of psychiatric disorders in the association of emotional support with specific cognitive domains [71]. Consistently, the current results showed that depressive symptoms were partial mediators of the social engagement-cognitive functioning relationship. The finding is also in parallel with a recent study conducted in China showing the mediating role of depressive symptoms in the protective effect of frequent exercise on cognitive functioning [72]. Therefore, our results support the previous finding that the protective effect of social relationships is more related to

the aspects of quality and functionality of such relationships than the quantity and structural characteristics [73].

Furthermore, the indirect effect of social engagements on cognitive functioning suggest that social resources can be related to better cognitive functioning through minimizing mental disorders in older adults, indicating that depressive symptoms may serve as an important intervening target and that reversing such illnesses might be related to a greater cognitive functioning. This is similar to an earlier finding that lack of social engagements may be particularly detrimental to late-life cognitive abilities when it is associated with mental illnesses [74]. Earlier meta-analyses and reviews have investigated loneliness, being one of the depressive symptoms, and social isolation together as part of health promotion interventions and suggested that loneliness is often experienced as a part of lack of social engagement and partly attribute to the factors of cognitive declines [75,76], indicating the need for social interventions that promote active participation of older people and help them in maintaining social and structural relationships and coping with age-related stress factors.

The available evidence suggests that there are gender differences in the relationship between social engagement and cognitive functioning. For instance, in developed countries, numerous studies have found that the cognitive performance of older women is as good as or better than that of men [77–79]. By contrast, studies of cognitive abilities in developing countries find older women often perform worse than older men [80,81]. Moreover, earlier studies in India reported a relatively lower cognitive functioning level among older women than men [82,83]. Also, another study suggests that a greater social engagement protects against rapid cognitive decline, particularly among low-educated older women [84]. In addition, social networks were reported as highly influential for women than men in determining better health behaviors related to cognitive maintenance [80]. Consistent with these previous studies, the current analyses have shown that social engagement of older women is strongly associated with better cognitive functioning with greater mediating effects of depressive symptoms compared to older men. Nevertheless, it still needs to be further investigated whether sex differences exist in the association of social engagements mediated by depressive symptoms with cognitive functioning and causally inferred with studies of longitudinal design.

There are several limitations of the present study to be noted. In the analysis, cognitively impaired older adults have been removed to address the reverse causality. However, the possibility of withdrawal of people from social contacts and social activities in the early stages

of pathological changes in cognition cannot be ignored. Therefore, the potential impact of reverse causality cannot be completely ruled out. The composite index of social engagement was generated from the questions which were self-reported. The responses may have been exaggerated or under-reported. However, self-reporting is endorsed as an optimal method to measure how the participants subjectively find themselves having social networks and involved in social activities. On the other hand, exploring the aspect of social engagements that include participating in indoor games for example, as distinct from domains of cognitive activities is questionable, since it is not feasible to completely differentiate social engagement from cognitive engagements. Also many activities have a psychiatric element which may have positive impacts on cognitive processes and a complex confounding effect in the associations of three key variables in our study. Hence, considering the differences in relationships between cognitive domains and the distinct forms of social engagements that also include structural support from marital status and living arrangements, it is important to define social relationships more clearly in future studies to achieve more reliable findings. Besides, in a population with huge proportion of illiterates, the assessment of cognitive functioning with multiple domains might be subject to measurement error which can bias the current findings. Similarly, older women in India who are largely deprived of education and other opportunities including work participation might have resulted in greater gender gap in cognitive functioning observed in our study. Another limitation is the inclusion of only males and females in the study. Since LASI collects the information from males and females only, the inclusion of the other gender was not possible. Finally, the present study was cross-sectional, and thus, a causal relationship between the variables cannot be inferred. Further investigation with longitudinal design is needed to explore the neural mechanisms that underlie the effects of social engagements on cognitive decline. Future research might also consider the impact of technology, internet and social media on social relationships, particularly feelings of social support.

Conclusion

The results suggest that a positive association of social engagement with cognitive functioning was partly mediated by depressive symptoms. The findings support the possible benefits of maintaining quality social relations that help coping with depressive symptoms on cognitive functioning among older adults, which need to be confirmed with future interventional studies. The study also highlights the potential of social engagements independently or with others as an intervention to prevent cognitive impairment among older individuals.

Abbreviations:

MPCE: Monthly Per capita Consumption Expenditure

CES-D: Center for Epidemiological Studies-Depression

KHB: Karlson–Holm–Breen

Declarations

Contributors MK and LKD conceived and designed the research paper. MK analyzed the data. MK and TM contributed agents/materials/analysis tools. MK and TM wrote the manuscript. LKD provides supervision and validation. MK, TM and LKD refined the manuscript. All authors have read and approved the manuscript.

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Competing interest The authors declare that there is no competing interest.

Patient consent for publication Not required.

Ethics approval Not applicable/No human participants included. Therefore, no Ethics Committee or Institutional Board approval is required.

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Data availability statement The study uses secondary data which is available in the private database and accessible on reasonable request through https://www.iipsindia.ac.in/content/lasiwave-i

Consent for publication The administrative permission to access and use the data for the present study was taken from the International Institute for Population Sciences, Mumbai, which conducted the LASI survey.

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Figure Legend:

Figure 1. Framework for mediation analysis

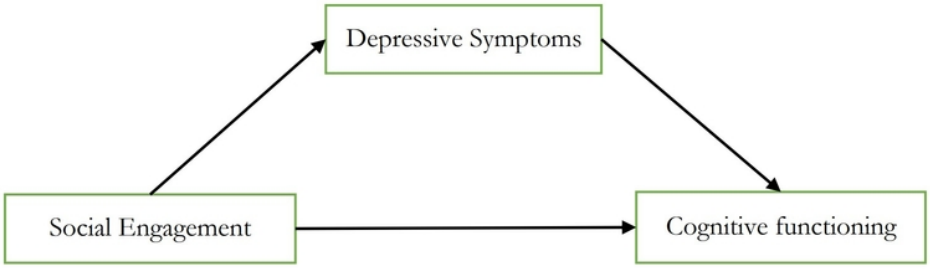

Figure 1. Framework for mediation analysis

68x27mm (300 x 300 DPI)

Supplementary file

Table S1. Descriptive statistics for the cognitive function (0-27) and level of social engagements according to selected variables, (N = 20,084)

			Social engagements					
	Cognitive function (0-27)		*Low (n=5,542)*		*Medium (n=12,522)*		*High (n=2,020)*	
	N	*Mean (sd.)*						
Social Engagements								
Low	5,542	7.7 (5.5)	-	-	-	-	-	-
Medium	12,522	9.9 (5.8)	-	-	-	-	-	-
High	2,020	11.5 (5.8)	-	-	-	-	-	-
Depression[a]								
No	15,132	9.8 (5.9)	3,881	70.0	9,607	76.7	1,644	81.4
Yes	4,952	8.5 (5.6)	1,661	30.0	2,915	23.3	376	18.6
Age (years)								
60-69	13,153	10.0 (5.9)	2,923	52.7	8,829	70.5	1,401	69.4
70-79	5,501	8.8 (5.8)	1,887	34.0	3,075	24.6	539	26.7
80+	1,430	7.4 (5.5)	732	13.2	618	4.9	80	4.0
Social Activities								
0	6,205	7.1 (5.1)	2,004	36.2	3,940	31.5	261	12.9
1	7,222	8.5 (5.4)	2,255	40.7	4,445	35.5	522	25.8
2	4,272	12.0 (5.5)	943	17.0	2,742	21.9	587	29.1
3+	2,385	13.8 (5.5)	340	6.1	1,395	11.1	650	32.2
Education level								
No education	9,282	6.2 (4.5)	3,269	59.0	5,359	42.8	654	32.4
Primary	5,566	10.3 (5.2)	1,400	25.3	3,544	28.3	622	30.8
Secondary	3,488	13.7 (4.7)	646	11.7	2,372	18.9	470	23.3
Higher	1,748	15.9 (4.4)	227	4.1	1,247	10.0	274	13.6
Currently working								
No	13,509	9.3 (5.9)	4,394	79.3	7,829	62.5	1,286	63.7
Yes	6,575	9.8 (5.8)	1,148	20.7	4,693	37.5	734	36.3
Place of Residence								
Rural	12,882	8.3 (5.6)	3,434	62.0	8,284	66.2	1,164	57.6
Urban	7,202	11.5 (5.9)	2,108	38.0	4,238	33.8	856	42.4
Religion								
Hindu	14,896	9.5 (5.9)	4,294	77.5	9,537	76.2	1,065	52.7
Muslim	2,219	9.2 (5.6)	589	10.6	1,266	10.1	364	18.0
Christian	1,957	9.5 (5.7)	423	7.6	1,086	8.7	448	22.2
Others[$]	1,011	9.4 (5.9)	235	4.2	633	5.1	143	7.1
Caste								
Scheduled caste	3,273	8.1 (5.4)	992	17.9	2,082	16.6	199	9.9
Scheduled tribe	3,056	8.2 (5.6)	744	13.5	1,795	14.3	517	25.7
OBC[#]	7,950	9.6 (6)	2,245	40.6	5,077	40.6	628	31.2
Others	5,774	10.8 (5.8)	1,549	28.0	3,556	28.4	669	33.2
Regions								
North	3,775	9.3 (5.7)	928	16.7	2,339	18.7	508	25.1
Central	2,697	8.9 (5.6)	793	14.3	1,728	13.8	176	8.7
East	3,791	9 (5.8)	1,036	18.7	2,532	20.2	223	11.0
Northeast	2,356	9.5 (5.8)	543	9.8	1,332	10.6	481	23.8
West	2,559	9 (5.7)	664	12.0	1,597	12.8	298	14.8
South	4,906	10.4 (6.1)	1,578	28.5	2,994	23.9	334	16.5
BMI categories								
Normal	10,607	9.4 (5.8)	2,790	50.3	6,694	53.5	1,123	55.6
Underweight	4,158	7.4 (5.3)	1,333	24.1	2,553	20.4	272	13.5

Overweight/Obese	5,319	11.2 (5.9)	1,419	25.6	3,275	26.2	625	30.9
MPCE quintile								
Poorest	3,852	8.2 (5.6)	1,183	21.3	2,359	18.8	310	15.3
Poorer	4,036	8.8 (5.7)	1,179	21.3	2,510	20.0	347	17.2
Middle	4,166	9.4 (5.8)	1,115	20.1	2,604	20.8	447	22.1
Richer	4,104	9.8 (5.8)	1,086	19.6	2,604	20.8	414	20.5
Richest	3,926	11.1 (6)	979	17.7	2,445	19.5	502	24.9
Currently smoking tobacco								
No	17,119	9.5 (5.9)	5,020	90.6	10,453	83.5	1,646	81.5
Yes	2,965	9.3 (5.5)	522	9.4	2,069	16.5	374	18.5
Currently chewing tobacco								
No	16,109	9.6 (5.9)	4,467	80.6	9,987	79.8	1,655	81.9
Yes	3,975	8.9 (5.6)	1,075	19.4	2,535	20.2	365	18.1
Drinking Status								
Never	16,432	9.4 (5.9)	4,938	89.1	9,892	79.0	1,602	79.3
Infrequent non-heavy	2,278	10.3 (5.6)	360	6.5	1,622	13.0	296	14.7
Frequent non-heavy	732	9.4 (5.6)	143	2.6	534	4.3	55	2.7
Heavy episodic drinker	642	9.1 (5.5)	101	1.8	474	3.8	67	3.3
Hypertension Status								
Normal	4,547	8.9 (5.6)	1,112	20.1	2,978	23.8	457	22.6
Pre-hypertensive	7,779	9.7 (5.9)	2,022	36.5	4,930	39.4	827	40.9
High BP	7,758	9.6 (5.9)	2,408	43.5	4,614	36.8	736	36.4
Diabetes								
No	16,789	9.1 (5.8)	4,737	85.5	10,383	82.9	1,669	82.6
Yes	3,295	11.1 (5.9)	805	14.5	2,139	17.1	351	17.4
Cancer								
No	19,938	9.5 (5.9)	5,509	99.4	12,430	99.3	1,999	99.0
Yes	146	10.1 (5.8)	33	0.6	92	0.7	21	1.0
Heart Disease								
No	19,015	9.4 (5.9)	5,293	95.5	11,824	94.4	1,898	94.0
Yes	1,069	11.2 (5.8)	249	4.5	698	5.6	122	6.0
Stroke								
No	19,667	9.5 (5.9)	5,450	98.3	12,239	97.7	1,978	97.9
Yes	417	9.3 (5.6)	92	1.7	283	2.3	42	2.1
Total	**20,084**	**9.5 (5.9)**	**5,542**	**100.0**	**12,522**	**100.0**	**2,020**	**100.0**

Note: [a] overall score ranges from zero to 10 and individuals with score of four or more are considered as depressed; [#] Other Backward Classes, [$] includes Sikh, Buddhist/neo-Buddhist, Jain, Parsi/Zoroastrian and others; BP- Blood Pressure.

Table S2: Linear regression results of social engagement and depression on cognitive functioning, by gender, (N = 20,084), LASI, 2017-19

	Men		Women		Total	
	β	(95% CI)	β	(95% CI)	β	(95% CI)
Social Engagement						
Low®						
Medium	0.64***	(0.38,0.90)	0.34***	(0.15,0.53)	0.49***	(0.34,0.64)
High	0.90***	(0.51,1.28)	1.13***	(0.70,1.56)	0.90***	(0.63,1.18)
Depression score	-0.31***	(-0.36,-0.25)	-0.28***	(-0.33,-0.23)	-0.29***	(-0.33,-0.25)
Social Activities	0.15	(-0.03,0.32)	0.41***	(0.22,0.60)	0.26***	(0.13,0.39)
Age (years)	-0.08***	(-0.09,-0.06)	-0.07***	(-0.08,-0.05)	-0.07***	(-0.08,-0.06)
Gender						
Men®	-	-	-	-		
Women	-	-	-	-	-1.55***	(-1.71,-1.38)
Education level						
No education®						
Primary	3.20***	(2.98,3.43)	3.12***	(2.89,3.36)	3.25***	(3.09,3.41)
Secondary	5.89***	(5.62,6.15)	6.92***	(6.59,7.26)	6.34***	(6.14,6.55)
Higher	6.62***	(6.28,6.95)	8.84***	(8.33,9.35)	7.11***	(6.84,7.38)
Currently working						
No®						
Yes	0.01	(-0.19,0.21)	0.31**	(0.08,0.54)	0.14	(-0.00,0.29)
Place of Residence						
Rural®						
Urban	1.05***	(0.82,1.28)	0.85***	(0.63,1.06)	0.99***	(0.84,1.15)
Religion						
Hindu®						
Muslim	0.38*	(0.07,0.69)	0.01	(-0.30,0.31)	0.21	(-0.01,0.43)
Christian	-0.14	(-0.76,0.48)	0.66*	(0.11,1.21)	0.32	(-0.10,0.74)
Others$	-0.92***	(-1.41,-0.43)	0.68**	(0.20,1.16)	-0.11	(-0.45,0.24)
Caste						
Scheduled caste®						
Scheduled tribe	-0.61**	(-1.02,-0.20)	-0.41*	(-0.81,-0.01)	-0.50***	(-0.79,-0.21)
OBC#	0.35**	(0.10,0.61)	0.48***	(0.23,0.73)	0.41***	(0.23,0.59)
None of them	0.30*	(0.01,0.58)	0.30*	(0.02,0.58)	0.30**	(0.10,0.50)
Region						
North®						
Central	0.56**	(0.22,0.89)	1.43***	(1.11,1.75)	0.99***	(0.76,1.22)
East	0.26	(-0.07,0.59)	1.04***	(0.73,1.36)	0.66***	(0.43,0.88)
Northeast	0.85**	(0.23,1.46)	1.32***	(0.72,1.92)	1.06***	(0.63,1.49)
West	-1.14***	(-1.50,-0.79)	-0.37*	(-0.70,-0.04)	-0.74***	(-0.99,-0.50)
South	0.07	(-0.28,0.42)	1.63***	(1.30,1.96)	0.87***	(0.63,1.11)
BMI categories						
Normal®						
Underweight	-0.82***	(-1.04,-0.60)	-0.87***	(-1.10,-0.64)	-0.85***	(-1.01,-0.69)
Overweight/obese	0.60***	(0.36,0.84)	0.74***	(0.52,0.95)	0.69***	(0.53,0.86)
MPCE quintile						
Poorest®						
Poorer	-0.17	(-0.45,0.11)	0.31*	(0.04,0.57)	0.06	(-0.13,0.26)
Middle	0.12	(-0.16,0.40)	0.48***	(0.22,0.75)	0.28**	(0.09,0.48)
Richer	0.39**	(0.10,0.68)	0.52***	(0.24,0.79)	0.46***	(0.26,0.66)
Richest	0.52**	(0.21,0.83)	0.73***	(0.43,1.02)	0.61***	(0.40,0.83)
Currently smoking tobacco						
No®						

Yes	0.01	(-0.22,0.23)	-0.56*	(-1.06,-0.05)	0.02	(-0.18,0.22)
Currently chewing tobacco						
No®						
Yes	0.07	(-0.15,0.29)	-0.19	(-0.43,0.06)	0.00	(-0.16,0.16)
Drinking Status						
Never®						
Infrequent non-heavy	-0.34**	(-0.58,-0.10)	-0.49	(-1.29,0.31)	-0.29*	(-0.51,-0.06)
Frequent non-heavy	-0.67**	(-1.09,-0.26)	-0.93	(-2.17,0.30)	-0.72***	(-1.10,-0.34)
Heavy episodic drinker	-1.33***	(-1.78,-0.89)	-0.69	(-2.21,0.83)	-1.27***	(-1.68,-0.86)
Hypertension Status						
Normal®						
Pre-hypertensive	0.15	(-0.08,0.38)	0.09	(-0.14,0.32)	0.11	(-0.05,0.27)
High BP	0.36**	(0.12,0.60)	0.01	(-0.22,0.25)	0.18*	(0.01,0.34)
Diabetes						
No®						
Yes	-0.68***	(-0.94,-0.42)	-0.66***	(-0.92,-0.41)	-0.74***	(-0.92,-0.56)
Cancer						
No®						
Yes	0.34	(-0.91,1.58)	-0.16	(-1.27,0.95)	0.19	(-0.64,1.03)
Heart Disease						
No®						
Yes	0.68***	(0.30,1.05)	-0.26	(-0.69,0.17)	0.32*	(0.04,0.60)
Stroke						
No®						
Yes	-0.85**	(-1.43,-0.27)	-0.59	(-1.29,0.10)	-0.77***	(-1.21,-0.32)
Observations	**10,526**		**9,558**		**20,084**	
R^2	**0.34**		**0.39**		**0.41**	

Note: #Other Backward Classes; $includes Sikh, Buddhist/neo-Buddhist, Jain, Parsi/Zoroastrian and others; BP- Blood Pressure.
* p<0.05, ** p<0.01, *** p<0.001

Table S3: Mean, standard deviation, and correlation between social engagement and depression (n=20,084). LASI, 2017-19

Variables	1	2
Depression	-	
Social engagement	-0.11***	-
Mean	2.81	1.78
Standard deviation	1.64	0.67

Note: *p<0.05, **p<0.01, ***p<0.001

Table S4: Linear regression results of social engagement on depression, by gender, (N = 20,084), LASI, 2017-19

	Men		Women		Total	
	β	(95% CI)	β	(95% CI)	β	(95% CI)
Social Engagement	-0.17***	(-0.23,-0.12)	-0.18***	(-0.23,-0.13)	-0.17***	(-0.21,-0.14)
Cognitive function	-0.04***	(-0.04,-0.03)	-0.04***	(-0.05,-0.03)	-0.04***	(-0.04,-0.03)
Social Activities	0.02	(-0.04,0.08)	0.06	(-0.02,0.13)	0.04	(-0.01,0.09)
Age (years)	-0.01**	(-0.01,-0.00)	0.00	(-0.01,0.01)	0.00	(-0.01,0.00)
Gender						
Men®	-	-	-	-		
Women	-	-	-	-	-0.06	(-0.12,0.00)
Education level						
No education®						
Primary	0.04	(-0.04,0.12)	0.00	(-0.09,0.10)	0.02	(-0.05,0.08)
Secondary	0.00	(-0.10,0.09)	0.13	(-0.01,0.27)	0.03	(-0.05,0.11)
Higher	-0.06	(-0.18,0.06)	0.29**	(0.09,0.50)	0.03	(-0.07,0.13)
Currently working						
No®						
Yes	-0.10**	(-0.17,-0.03)	-0.02	(-0.11,0.06)	-0.06*	(-0.11,-0.01)
Place of Residence						
Rural®						
Urban	0.04	(-0.04,0.12)	-0.02	(-0.11,0.06)	0.01	(-0.05,0.07)
Religion						
Hindu®						
Muslim	0.09	(-0.01,0.20)	0.14*	(0.03,0.26)	0.12**	(0.04,0.19)
Christian	-0.41***	(-0.62,-0.20)	0.10	(-0.11,0.31)	-0.14	(-0.28,0.01)
Others[$]	-0.37***	(-0.54,-0.20)	-0.21*	(-0.39,-0.03)	-0.30***	(-0.42,-0.17)
Caste						
Scheduled caste®						
Scheduled tribe	-0.22**	(-0.36,-0.08)	-0.08	(-0.23,0.08)	-0.14**	(-0.24,-0.04)
OBC[#]	-0.22***	(-0.30,-0.13)	-0.03	(-0.12,0.07)	-0.13***	(-0.19,-0.07)
None of them	-0.23***	(-0.33,-0.14)	-0.02	(-0.13,0.09)	-0.13***	(-0.20,-0.06)
Region						
North®						
Central	0.46***	(0.35,0.58)	0.60***	(0.47,0.72)	0.53***	(0.44,0.61)
East	0.08	(-0.03,0.19)	0.03	(-0.09,0.15)	0.05	(-0.03,0.13)
Northeast	-0.20	(-0.40,0.01)	-0.37**	(-0.60,-0.14)	-0.28***	(-0.43,-0.12)
West	-0.56***	(-0.68,-0.44)	-0.58***	(-0.71,-0.46)	-0.57***	(-0.65,-0.48)
South	0.35***	(0.23,0.46)	0.27***	(0.15,0.40)	0.31***	(0.23,0.40)
BMI categories						
Normal®						
Underweight	0.29***	(0.22,0.37)	0.06	(-0.03,0.15)	0.19***	(0.13,0.25)
Overweight/obese	0.05	(-0.03,0.14)	-0.09*	(-0.17,-0.01)	-0.02	(-0.08,0.03)
MPCE quintile						
Poorest®						
Poorer	-0.12*	(-0.21,-0.02)	-0.06	(-0.16,0.04)	-0.09**	(-0.16,-0.02)
Middle	-0.07	(-0.16,0.03)	-0.09	(-0.19,0.01)	-0.08*	(-0.14,-0.01)
Richer	-0.09	(-0.19,0.01)	-0.11	(-0.21,0.00)	-0.10**	(-0.17,-0.03)
Richest	-0.06	(-0.17,0.05)	-0.02	(-0.14,0.09)	-0.04	(-0.12,0.03)
Currently smoking tobacco						
No®						
Yes	0.15***	(0.07,0.22)	0.10	(-0.10,0.29)	0.15***	(0.08,0.23)
Currently chewing tobacco						
No®						
Yes	-0.02	(-0.09,0.06)	0.05	(-0.04,0.15)	0.00	(-0.06,0.06)

Drinking Status						
Never®						
Infrequent non-heavy	-0.17***	(-0.25,-0.08)	0.25	(-0.06,0.55)	-0.13**	(-0.21,-0.05)
Frequent non-heavy	-0.10	(-0.24,0.04)	-0.23	(-0.70,0.24)	-0.11	(-0.24,0.03)
Heavy episodic drinker	0.05	(-0.10,0.20)	0.24	(-0.35,0.82)	0.06	(-0.09,0.21)
Hypertension Status						
Normal®						
Pre-hypertensive	-0.04	(-0.12,0.04)	-0.09*	(-0.17,-0.00)	-0.06*	(-0.12,-0.00)
High BP	-0.04	(-0.12,0.04)	0.03	(-0.06,0.12)	0.00	(-0.06,0.06)
Diabetes						
No®						
Yes	0.10*	(0.02,0.19)	0.01	(-0.09,0.11)	0.06	(-0.00,0.13)
Cancer						
No®						
Yes	0.61**	(0.18,1.03)	-0.52*	(-0.94,-0.09)	0.04	(-0.26,0.34)
Heart Disease						
No®						
Yes	0.09	(-0.04,0.22)	0.16	(-0.00,0.32)	0.12*	(0.02,0.22)
Stroke						
No®						
Yes	0.50***	(0.31,0.70)	0.17	(-0.09,0.44)	0.39***	(0.23,0.55)
Observations	**10,526**		**9,558**		**20,084**	
R^2	**0.10**		**0.08**		**0.08**	

Note: ®reference category; #Other Backward Classes; $includes Sikh, Buddhist/neo-Buddhist, Jain, Parsi/Zoroastrian and others; BP- Blood Pressure.

* p<0.05, ** p<0.01, *** p<0.001

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Recommendation	Page No
Title and abstract	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
	(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2-3
Introduction		
Background/rationale	Explain the scientific background and rationale for the investigation being reported	5-7
Objectives	State specific objectives, including any prespecified hypotheses	6-7
Methods		
Study design	Present key elements of study design early in the paper	7
Setting	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7
Participants	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	7
Variables	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8-10
Data sources/ measurement	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7
Study size	Explain how the study size was arrived at	7
Quantitative variables	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	
Statistical methods	(*a*) Describe all statistical methods, including those used to control for confounding	10-11
	(*b*) Describe any methods used to examine subgroups and interactions	
	(*c*) Explain how missing data were addressed	7
	(*d*) If applicable, describe analytical methods taking account of sampling strategy	
	(*e*) Describe any sensitivity analyses	
Results		
Participants	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	11-12
	(b) Give reasons for non-participation at each stage	
	(c) Consider use of a flow diagram	
Descriptive data	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	11-12
	(b) Indicate number of participants with missing data for each variable of interest	
Outcome data	Report numbers of outcome events or summary measures	12-14
Main results	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	12-14
	(*b*) Report category boundaries when continuous variables were categorized	

	(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion		
Key results	Summarise key results with reference to study objectives	15
Limitations	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	17
Interpretation	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	16-17
Generalisability	Discuss the generalisability (external validity) of the study results	15-17
Other information		
Funding	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	18

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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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)

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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)

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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)

Abstract

Objective: The present study aimed to examine the confounding effects of depressive symptoms and the role of gender in the association between social engagement and cognitive functioning among older Indian adults.

Design: A cross-sectional large scale survey data was analyzed in this study.

Setting and Participants: Data from Longitudinal Aging Study in India (LASI; 2017-19) was used in analysis. The sample included 23,584 individuals aged 60 years and above (11,403 men and 12,181 women).

Primary and Secondary outcome measures: The outcome variable was cognitive functioning which was based on different measures, including immediate and delayed word recall, orientation, executive functioning, arithmetic ability and object naming. Social engagement measure consists of marital status, living arrangement, availability of confidant, and participation in indoor games, and social and cultural functions. Moreover, the Center for Epidemiologic Studies Depression Scale (CES-D) was used to assess depressive symptoms.

Results: Significant gender differences in the mean cognition scores (men: 25.8, women: 21.1; on a scale of 0-43) were observed. Regression results suggests that two-way interactions between social engagement and depressive symptoms were significant after controlling for explanatory factors. Men with high level of social engagements have significantly better cognitive functioning (β=1.12; 95%CI: 0.72-1.53) compared with their counterparts. Also, as compared to men with lower social engagements, women with higher social engagements performs poorly on the cognitive tests (-0.42; 95%CI: -0.95-0.11), however, the result was not significant. Three-way interaction between social engagement, gender, and depressive symptoms were significantly associated with the cognitive functioning and showed a female disadvantage. KHB method identified a significant confounding effect of depressive symptoms on the relationship between social engagement and cognitive functioning.

Conclusion: The positive association of social engagement with cognitive functioning was significantly confounded by depressive symptoms, suggesting the need for maintaining social relations that help improve cognitive functioning among older adults.

Keywords: *social engagement, cognitive functioning, depressive symptoms, KHB-method, older adults.*

Strengths and limitations of this study

- The utilization of the national representative sample of older adults is a potential strength of the study
- KHB analysis explains the mechanism by which social engagement associated with cognitive function through a confounder, depressive symptoms
- The social engagements were significantly associated with better cognitive functioning for both older men and women
- The association of social engagement with cognitive functioning was significantly confounded by depressive symptoms
- The inability to establish the causal relationship between the variables of interest is the limitation of the study

Introduction

With the growth of aging population, global challenges in mental health are on the rise. It includes the decline in late-life cognitive abilities which are generally associated with poor quality of life [1], functional disabilities [2], multimorbidity [3], and higher mortality risk [4]. India is currently facing rapid population aging, with an expected increase in the number of individuals aged 60 years and above from 104 million in 2011 to 319 million by 2050 [5]; consequently, the disease burden of cognitive impairment in the country is also expected to increase.

Social engagement is an umbrella concept usually referring to various factors such as social relationships, social and emotional connectedness with other people, and participation in social activities, which provide a sense of belonging, social identity, and fulfilment [6, 7]. In the absence of effective pharmacological treatment for persons with cognitive impairment, especially for the long-term benefits, various methods such as improving social engagement and active participation in social activities are considered [8]. Multiple cross-sectional studies investigating the association between social environment and cognition in older adults showed that greater social functioning positively associated with cognitive performances [9, 10]. Moreover, several longitudinal studies among older adults have also indicated that greater engagements with relatives [11, 12], rich social networks [12, 13], and frequent participation in social activities [14] exert protective effects against cognitive decline. Therefore, in the long run, individuals who present trajectories of high and increasing social engagements experience lower levels of cognitive limitation [15].

Several interventional studies reported the protective effects of the improved social behaviours in preventing or delaying dementia among older adults with diagnosed cognitive impairment [16, 17]. Most of the available research on social capital and engagement as to enhance cognitive reserve and protect cognitive health has been conducted in developed countries [18–21]. Little is known about the relationship between social engagement and cognitive functioning in developing countries like India, where the cultural and structural context of social engagement differ from developed countries. In India, traditionally, older adults are more likely to live with their children in multigenerational households where cultural norms emphasize family ties and the virtue of filial piety [22, 23], and a higher proportion of older people experience psychological distress and mental illnesses [24–26].

Similarly, depressive disorders are highly prevalent among older adults in low and middle income countries [27–29] and in India in particular [30]. Previously, various studies have found the beneficial effects of greater social engagements (with varying measurements and definitions) against depressive symptoms [31, 32]. A cross-sectional study by Jang & Chiriboga (2011) [31] found that a higher level of participation in social activities was associated with a decline in depressive symptoms after controlling for the effects of demographic and health-related factors. Multiple longitudinal studies have also reported similar findings [33–37]. Also, increased participation in social activities and meaningful engagement by older adults may improve their mood, which benefits their emotional functioning and reduces depressive symptoms [38], which is linked to cognitive functioning [39]. According to the 'depression reduction hypothesis', depressive symptoms interferes with cognitive health; therefore, as evident from multiple longitudinal studies, practical strategies to reduce depressive symptoms will possibly improve cognitive functioning [40]. Two facts justify such a hypothesis; first, greater depressive symptoms are related to poor cognitive functioning among older adults [41, 42]. Second, depressed older adults who engage in social activities may experience a decline in depressive symptoms and improve cognitive functioning [43]. Furthermore, in multiple cohort studies, cognitively impaired older adults with depressive symptoms were associated with more rapid cognitive decline than those without depression [44, 45].

However, it is not clear to what extent social engagement may improve cognitive functioning by minimizing depressive symptoms. There is a dearth of studies in low- and middle-income countries on the association of social engagements and cognitive functioning and the role of depressive symptoms in such association. Filling this gap, the present study using national-level data of older adults in India, aimed to examine the role of the depressive symptoms on the association between social engagement and cognitive functioning (Figure 1). Previous research showed a greater female disadvantage and theorized gender as the crucial factor to be considered in understanding the differences in cognitive functioning in Indian context [46–48]. Also, studies have shown the significant gender differences in the association between social engagement and cognitive functioning [49, 50]. Thus, the study also explored the moderation effects of gender in the relationship between social engagement and cognitive functioning. The present study hypothesized that the association between social engagement and cognitive functioning is significantly confounded by depressive symptoms (Figure 2).

Methods

Data

The present study utilizes the individual-level data from the first wave of the Longitudinal Aging Study in India (LASI) conducted during 2017-19. LASI is a nationally representative longitudinal survey of more than 72000 older adults aged 45 years and over across all states and union territories of India that provides vital information on the social, physical, psychological, and cognitive health of the Indian aging population. The LASI survey was conducted through a partnership of the International Institute for Population Sciences (IIPS), Harvard T. H. Chan School of Public Health (HSPH), and the University of Southern California (USC). LASI is envisioned to be conducted every two years for the next 25 years. In LASI wave 1, the sample selection is based on a multistage stratified cluster sample design, including a three-stage sampling design in rural areas and a four-stage sampling design in urban areas. LASI survey provided internationally harmonized data that comparable to the United States Health and Retirement Study (HRS) and other HRS-type surveys in other countries, including England (English Longitudinal Study of Ageing) and China (China Health and Retirement Longitudinal Survey). Further, the details of sampling design, survey instruments, and data collection procedures are provided elsewhere [51].

In the sampled households, the individual survey schedule includes the biomedical examination administered to each consenting respondent aged 45 and above and their spouses (irrespective of age). The survey agencies authorized to conduct the survey have collected prior consent from all the respondents. Consent forms include the information brochure explaining the purpose of the survey, ways of protecting their privacy, and the safety of the health assessments as part of the ethics protocols. The Indian Council of Medical Research extended the necessary guidelines and ethics approval for undertaking the survey.

The sample in the main LASI included 31,464 individuals aged 60 years and above. For the present analysis, we have excluded those cases with missing data for any variables of interest (n=7,880). Therefore, the sample for the present study included 23,584 individuals from the LASI survey, and among them 11,403 were men and 12,181 were women.

Measures

Cognitive function

By adopting the Health and Retirement Study (HRS) cognition module, the LASI collected information on measured cognition in various domains – including memory, orientation,

executive functioning, arithmetic, and object naming (Table 1). Previously, various studies have established high validity and reliability of these cognitive domains for measuring cognitive impairment among older adults in community settings in the United States [52], China [53], and India [54]. The cognitive functioning in the present study is based on different cognitive measures, including immediate (0–10 points) and delayed word recall (0–10 points); orientation related to time (0-4 points), and place (0-4 points); executive functioning based on paper folding (0-3) and pentagon drawing (0-1); arithmetic ability based on serial 7s (0–5 points), computation (0-2) and backward counting from 20 (0–2 points); and object naming (0-2).

Table 1. Description of domain-wise cognitive measures in LASI, 2017-18

Domain	Measure	Measurement	Range
Memory	Immediate word recall	Interviewer read out a list of 10 words and respondents were asked to repeat the words.	0-10
	Delayed word recall	Respondents were asked to recall the same words read out for immediate recall after some time.	0-10
Orientation	Time	Respondents were asked to state today's date, month and year and day of the week. For each question, the score was 0 or 1. Correct responses received 1 point, incorrect responses received 0. The total score for time was 0-4.	0-4
	Place	Orientation towards place was captured based on place of interview, name of the village, street number/colony name/ landmark/neighborhood and name of the district. Each correct response scored 1 point. The total score ranged from 0-4.	0-4
Arithmetic function	Backward counting	Respondents were asked to count backward as quickly as possible from the number 20. The respondents were asked to stop after correctly counting backward from 20 to 11 or from 19 to 10. Correct counting received 2 points: counts with a mistake received 1 point. Those who could not count received 0 points.	0-2
	Serial 7	Respondents were asked to subtract seven from 100 in the first step and asked to continue subtracting seven from the previous number in each subsequent step for five times. Each correct response received 1 point.	0-5
	Computation	This test involved the mathematical operation of division. Respondents were asked to compute the net sale price of a product after considering a discount sale of half of the original price.	0-2
Executive function: 0-4	Executive (paper folding)	This is a three-stage command task. The respondents were instructed to take a piece of paper from the interviewer, turn it over, fold it in half, and give it back to the interviewer. Three points were given if each task was completed successfully.	0-3
	Pentagon drawing	Visio-construction is the ability to coordinate fine motor skills with visio-spatial abilities, usually by reproducing geometric figures. Respondents were asked to copy two overlapping pentagons and scored 1 point for a correct drawing.	0-1

Object naming: 0-2		The interviewer points to a specific object and asks the respondent to name it. Two objects were pointed out and 1 point was given for each correct response.	0-2
Cognition	Composite cognitive index	Combined score of memory (total word recall), orientation, arithmetic function, executive function, and object naming.	0-43

After adding the scores for each component, the overall score ranged from 0 to 43, and a higher score indicates better cognitive functioning.

Social Engagements

Following the previous studies [55, 56], we have derived social engagement based on five indicators: marital status, living arrangement, availability of confidant, and participation in indoor games, social and cultural functions. Current marital status was set to unmarried (single, widowed, separated, or divorced; coded as 0) versus married (married or living with a partner; coded as 1). Regarding current living arrangements, living alone was categorized as 0, and living with extended family is categorized as 1. The availability of a current confidant relationship (spouse, son or daughter, grandchildren, or relatives, etc.) was coded as no (0) or yes (1). Two more indicators based on participation in social activities including, playing cards or indoor games and attending social and cultural functions, were included (0 = less than weekly, 1 = weekly or more frequently). A composite index of social engagement was constructed by summing the scores for all five indicators, ranging from 0 to 5. Based on the distribution of the overall composite index, individuals were categorized as having low (0-2 social ties; 27.6 percent), medium (3 ties; 62 percent), or high (4-5 ties; 10.1 percent) levels of social engagement.

Depressive symptoms

The LASI has used an internationally validated 10-item Center for Epidemiological Studies-Depression (CES-D) scale to capture the presence of depressive symptoms in Indian older adults [57, 58]. The ten items in CES-D consist of seven negative symptoms (feeling depressed, low energy, trouble concentrating, feeling alone, bothered by things, fear of something, and everything is an effort) and three positive symptoms (feeling happy, satisfied, and hopeful). The possible responses for these items were: rarely or never (< 1 day), sometimes (1 or 2 days), often (3 or 4 days), and most or all of the time (5-7 days) in a week prior to the interview. For the negative symptoms, rarely or never (< 1 day) and sometimes (1 or 2 days) were scored zero, and often (3 or 4 days) and most or all of the time (5-7 days) categories were scored one.

Scoring was reversed for positive symptoms. The overall depressive symptoms score, calculated by adding the scores from ten items, ranges from 0 to 10. A score of four or higher is considered to represent clinically significant symptoms in the 10-item scale [59].

Covariates

After an extensive literature review, potentially related covariates were selected which include socio-demographic characteristics, lifestyle factors, health conditions, and cognitive and social activities. Socio-demographic characteristics were: age (in chronological years); gender (men, women); education (no education, primary, secondary, higher); currently working status (no, yes); residence (rural, urban); religion (Hindu, Muslim, Christian, others); and Region (North, Central, East, Northeast, West, and South), monthly per capita expenditure (MPCE) (poorest, poorer, middle, richer, and richest). The lifestyle factors were currently smoking (no, yes); currently consuming smokeless tobacco (no, yes), alcohol drinking (never, infrequent non-heavy, frequent non-heavy, heavy episodic drinker), and body mass index (underweight (<18.5 kg/m^2), normal (18.5-24.9 kg/m^2), overweight/obese (>25.0 kg/m^2)). Health conditions include biometric measurement-based hypertension status (normal, pre-hypertensive, high blood pressure), and self-reported conditions such as diabetes, cancer, heart disease, and stroke were coded as no and yes. The older adults were categorized as having normal blood pressure (BP) (Systolic BP <120 mmHg and Diastolic BP<80 mmHg), pre-hypertensive (SBP: 120-139 mmHg and DBP: 80-89 mmHg), and high blood pressure (SBP≥ 140 mmHg and DBP≥ 90 mmHg).

The 'caste' of the household is reported by the head of the household, and it is generally grouped as four categories: Scheduled Caste (SC), Schedules Tribes (ST), Other Backward Class (OBC), and general class. Scheduled caste and scheduled tribe are considered as among the most deprived and socioeconomically disadvantaged groups in India. The individuals in the general class represent the hierarchically higher social status in India. On the other hand, although, Other Backward Class (OBC) is an educationally, economically, and socially backward group, but, hierarchically, this group is considered as in better social position than SC and ST category [60].

According to the procedure suggested by Dong and Simon [61], we included four social participation activities: (1) eat out of the house, (2) go to the park/beach, visit relatives/friends, (3) go out to a movie, and (4) attend political/community group meetings. Based on the

frequency of participation, responses were coded as '0' for less than weekly, '1' for weekly or more frequently for these activities.

Statistical analysis

Descriptive statistics (means and percentages) were used to present the characteristics of the older adults included in the final sample. We used t-test to assess the gender differences in the mean cognition score according to various covariates. Moreover, linear regression models were employed to determine the association of two-way interaction of social engagements and depressive symptoms, and social engagement and gender with cognitive function. Also, linear regression models were used to assess the association of three-way interaction of social engagement, gender, and depressive symptoms with cognitive functioning. We conducted a correlation analysis and a linear regression analysis of depressive symptoms on social engagement. The total effect was divided into direct effects (the association of social engagement with cognitive function controlling for depressive symptoms) and indirect effects (the association of social engagement with cognitive function through depressive symptoms) using linear regression based on Karlson–Holm–Breen (KHB) method [62, 63] for the whole sample. The KHB method is a recently developed method for assessing the confounding effects that allow total effects to be divided into direct and indirect effects for both discrete and continuous variables. Contrary to other decomposition methods, the KHB-method provides unbiased decomposition results [64]. The confounding percentage (the indirect effect divided by the total effect) is interpreted as the percentage of the association explained by the confounder variable. All statistical models were adjusted for various predictors, including age, gender, education, working status, residence, religion, caste, region, body mass index (BMI), monthly per capita expenditure (MPCE), smoking status, consuming smokeless tobacco, alcohol drinking, hypertension, diabetes, cancer, heart disease, and stroke. The statistical analysis was performed using Stata 15.1. We incorporated the complex design of the survey data used in the study. Stata's survey command (svyset) was used to incorporate the complex design of LASI, and adjusted for sampling weight, clustering, and stratification in the sampling design. A p-value of less than 0.05 was considered statistically significant.

Patient and public involvement

No patient or public involvement.

Results

Table 2 presents the descriptive information for cognitive function, socio-demographic factors, lifestyle factors, and chronic conditions of older men and women included in the analysis. The mean cognition score of men was higher than that of women (25.9 vs. 21.3). Nearly 85% of older men had at least a medium level of social engagements, while this proportion was 53% for older women. Regarding depressive symptoms score, older women had a slightly higher mean score than older men (3.0 vs. 2.8). On average, men were slightly older than women (68.7 vs. 68.2 years). A higher proportion of older women were uneducated than older men (68.7% vs. 35.1%). Around 44.0% of the older men and 19.3% of women were currently working at the time of the survey. A higher proportion of older women were overweight or obese than men (28.6% vs. 20.2%). Around 25% of men and only 4% of women were current tobacco smokers, while 24% of men and 16% of women were consuming smokeless tobacco at the time of the survey. Alcohol consumption is much higher among older men than women (32.4% vs. 4.4%). According to measured hypertension status, the prevalence of high blood pressure was slightly higher among older women than men (39.9% vs. 37.9%). According to religion, around three-fourths of both older men and women participants were Hindus. Most of the participants were rural residents (67.7% men vs. 65.8% women).

Table 2. Descriptive statistics for sample characteristics of older adults included in the analysis, by gender, India, (N = 23,584)

	Men		Women		Total	
	n	%	n	%	n	%
Social Engagement						
Low	1,681	14.7	5,720	47.0	7,401	31.4
Medium	8,347	73.2	5,705	46.8	14,052	59.6
High	1,375	12.1	756	6.2	2,131	9.0
Cognition[a]	25.9	6.7	21.3	7.0	23.5	7.3
Depressive symptoms score[a]	2.8	1.6	3.0	1.7	2.9	1.7
Age (years)[a]	68.7	7.1	68.2	7.2	68.5	7.1
Social Activities (0-5)[a]	0.3	0.6	0.2	0.5	0.2	0.5
Education level						
No education	4,005	35.1	8,364	68.7	12,369	52.4
Primary	3,505	30.7	2,404	19.7	5,909	25.1
Secondary	2,537	22.2	1,006	8.3	3,543	15.0
Higher	1,356	11.9	407	3.3	1,763	7.5
Currently working						
No	6,383	56.0	9,830	80.7	16,213	68.7
Yes	5,020	44.0	2,351	19.3	7,371	31.3
Place of Residence						
Rural	7,719	67.7	8,018	65.8	15,737	66.7
Urban	3,684	32.3	4,163	34.2	7,847	33.3
Religion						

Hindu	8,405	73.7	9,009	74.0	17,414	73.8
Muslim	1,265	11.1	1,311	10.8	2,576	10.9
Christian	1,154	10.1	1,256	10.3	2,410	10.2
Others[$]	579	5.1	605	5.0	1,184	5.0
Caste						
Scheduled caste	1,921	16.8	2,032	16.7	3,953	16.8
Scheduled tribe	1,975	17.3	2,159	17.7	4,134	17.5
OBC[#]	4,428	38.8	4,681	38.4	9,109	38.6
Others	3,079	27.0	3,309	27.2	6,388	27.1
Regions						
North	2,104	18.5	2,291	18.8	4,395	18.6
Central	1,588	13.9	1,531	12.6	3,119	13.2
East	2,276	20.0	2,246	18.4	4,522	19.2
Northeast	1,399	12.3	1,466	12.0	2,865	12.1
West	1,409	12.4	1,666	13.7	3,075	13.0
South	2,627	23.0	2,981	24.5	5,608	23.8
BMI categories						
Normal	6,406	56.2	5,961	48.9	12,367	52.4
Underweight	2,698	23.7	2,738	22.5	5,436	23.0
Overweight/Obese	2,299	20.2	3,482	28.6	5,781	24.5
MPCE quintile						
Poorest	2,283	20.0	2,544	20.9	4,827	20.5
Poorer	2,318	20.3	2,543	20.9	4,861	20.6
Middle	2,334	20.5	2,528	20.8	4,862	20.6
Richer	2,283	20.0	2,364	19.4	4,647	19.7
Richest	2,185	19.2	2,202	18.1	4,387	18.6
Currently smoking tobacco						
No	8,570	75.2	11,640	95.6	20,210	85.7
Yes	2,833	24.8	541	4.4	3,374	14.3
Currently consuming smokeless tobacco						
No	8,638	75.8	10,233	84.0	18,871	80.0
Yes	2,765	24.2	1,948	16.0	4,713	20.0
Drinking Status						
Never	7,718	67.7	11,650	95.6	19,368	82.1
Infrequent non-heavy	2,269	19.9	299	2.5	2,568	10.9
Frequent non-heavy	748	6.6	122	1.0	870	3.7
Heavy episodic drinker	668	5.9	110	0.9	778	3.3
Hypertension Status						
Normal	2,612	22.9	2,774	22.8	5,386	22.8
Pre-hypertensive	4,465	39.2	4,550	37.4	9,015	38.2
High BP	4,326	37.9	4,857	39.9	9,183	38.9
Diabetes						
No	9,599	84.2	10,388	85.3	19,987	84.7
Yes	1,804	15.8	1,793	14.7	3,597	15.3
Cancer						
No	11,332	99.4	12,088	99.2	23,420	99.3
Yes	71	0.6	93	0.8	164	0.7
Heart Disease						
No	10,721	94.0	11,678	95.9	22,399	95.0
Yes	682	6.0	503	4.1	1,185	5.0
Stroke						

No	11,091	97.3	11,978	98.3	23,069	97.8
Yes	312	2.7	203	1.7	515	2.2
Total	**11,403**	**100.0**	**12,181**	**100.0**	**23,584**	**100.0**

Note: [#]Other Backward Classes, [a]Mean and standard deviation; [$]includes Sikh, Buddhist/neo-Buddhist, Jain, Parsi/Zoroastrian and others; BP- Blood Pressure.

The average cognitive score increased with an increase in the level of social engagement, and it was higher among the non-depressed older adults (24.0 vs. 22.1) (Supplementary; Table S1). Moreover, the prevalence of depressive symptoms decreased with an increase in the level of social engagement.

Table 3. Gender comparison of the mean cognition score (0-43) according to background characteristics in older adults, India, (N = 23,584)

	Men	Women	Difference	p-value[1]
Social Engagement				
Low	23.7	19.7	4.0	<0.001
Medium	26.0	22.3	3.7	<0.001
High	27.6	24.2	3.4	<0.001
Age groups				
60-69	26.6	22.2	4.4	<0.001
70-79	24.9	19.9	5.0	<0.001
80+	23.3	18.2	5.1	<0.001
Social activities				
0	23.1	18.7	4.4	<0.001
1	25.3	21.3	4.0	<0.001
2	28.8	25.1	3.7	<0.001
3+	30	28.2	1.8	<0.001
Education level				
No education	21.5	19.0	2.5	<0.001
Primary	26.1	24.5	1.6	<0.001
Secondary	29.7	29.6	0.1	0.203
Higher	31.0	31.9	-0.9	<0.001
Currently working				
No	25.7	21.2	4.5	<0.001
Yes	26.0	20.8	5.2	<0.001
Place of Residence				
Rural	24.7	19.8	4.9	<0.001
Urban	28.7	24.4	4.3	<0.001
Religion				
Hindu	25.9	21.2	4.7	<0.001
Muslim	25.9	20.5	5.4	<0.001
Christian	24.6	21.8	2.8	<0.001
Others[$]	24.3	21.2	3.1	<0.001
Caste				
Scheduled caste	24.1	19.4	4.7	<0.001
Scheduled tribe	22.2	17.8	4.4	<0.001
OBC[#]	26.2	21.7	4.5	<0.001
Others	27.4	22.4	5.0	<0.001
Regions				

North	25.4	20.0	5.4	<0.001
Central	25.9	20.8	5.1	<0.001
East	25.4	20.2	5.2	<0.001
Northeast	26.5	21.3	5.2	<0.001
West	25.7	21.0	4.7	<0.001
South	26.3	23.2	3.1	<0.001
BMI categories				
Normal	26.0	20.8	5.2	<0.001
Underweight	23.3	18.2	5.1	<0.001
Overweight/Obese	28.7	24.5	4.2	<0.001
MPCE quintile				
Poorest	24.2	19.6	4.6	<0.001
Poorer	24.9	20.3	4.6	<0.001
Middle	26.4	21.7	4.7	<0.001
Richer	26.3	21.9	4.4	<0.001
Richest	27.4	22.7	4.7	<0.001
Currently smoking tobacco				
No	26.1	21.2	4.9	<0.001
Yes	24.7	18.1	6.6	<0.001
Currently consuming smokeless tobacco				
No	26.1	21.4	4.7	<0.001
Yes	25.0	19.5	5.5	<0.001
Drinking Status				
Never	26.2	21.2	5.0	<0.001
Infrequent non-heavy	25.4	18.9	6.5	<0.001
Frequent non-heavy	23.5	16.7	6.8	<0.001
Heavy episodic drinker	22.9	15.7	7.2	<0.001
Hypertension Status				
Normal	24.7	20.6	4.1	<0.001
Pre-hypertensive	26.1	21.6	4.5	<0.001
High BP	26.2	20.9	5.3	<0.001
Diabetes				
No	25.5	20.8	4.7	<0.001
Yes	27.7	23.3	4.4	<0.001
Cancer				
No	25.8	21.1	4.7	<0.001
Yes	27.8	22.4	5.4	<0.001
Heart Disease				
No	25.7	21.1	4.6	<0.001
Yes	27.7	22.5	5.2	<0.001
Stroke				
No	25.8	21.1	4.7	<0.001
Yes	24.3	19.4	4.9	<0.001
Total	25.8	21.1	4.7	<0.001

Note: [1]Based on two sample t-test.
[#]Other Backward Classes; [$]includes Sikh, Buddhist/neo-Buddhist, Jain, Parsi/Zoroastrian and others; BP- Blood Pressure.

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Table 3 presents the gender differences in the mean cognition score according to various covariates. Results suggest a significant gender difference in the cognitive performance (difference=4.7; p<0.001). Men had significantly greater mean cognition score than women irrespective of age, education, working status, number of social activities, residence, obesity status, MPCE quintiles, tobacco and alcohol use, and morbidity status. Table 4 shows the linear regression results for the two-way interactions of social engagement and depressive symptoms, and social engagement and gender, and three-way interaction of the social engagement, gender, and depressive symptoms. The two-way interaction between social engagement and depressive symptoms were significant after controlling for various explanatory factors, including socio-demographic factors, lifestyle factors, and chronic conditions. The whole table is provided in the supplementary material (Table S2). In Table 4, the interaction between social engagement and gender suggests that men with high level of social engagements have significantly better cognitive functioning (β=1.12; 95%CI: 0.72-1.53) compared with men with low level of social engagements. On the other hand, women with high level of social engagement performs poorly on the cognitive tests (-0.42; 95%CI: -0.95-0.11) than the men with lower social engagements, however, the result was not significant. Also, three-way interaction between social engagement, gender, and depressive symptoms were significantly associated with the cognitive functioning and showed a female disadvantage. The correlation between social engagement and depressive symptoms was -0.12 (p<.001) (Supplementary; Table S3). The linear regression model demonstrated that higher levels of social engagement was significantly negatively associated with depressive symptoms (β = -0.18, p<.001) (Supplementary; Table S4).

Table 5 shows the KHB analysis results for the whole sample. After controlling for all the covariates in the entire sample, the results indicate that depressive symptoms significantly confounded 14.4% of the association between social engagement and cognitive function.

Table 4. Linear regression results of interaction of social engagement and depressive symptoms on cognitive functioning, by gender, (N = 23,584).

	Total	
	β	**(95% CI)**
Social engagements # Depressive symptoms		
Low + depressive symptoms	-0.61***	(-0.66, -0.56)
Medium + depressive symptoms	-0.28***	(-0.33, -0.23)
High + depressive symptoms	-0.10*	(-0.20, -0.01)
Social engagements # Gender		
Low + Men		
Low + Women	-2.32***	(-2.62, -2.03)
Medium + Men	0.78***	(0.51, 1.05)
Medium + Women	-1.27***	(-1.57, -0.97)
High + Men	1.12***	(0.72, 1.53)

High + Women	-0.42	(-0.95, 0.11)
Social engagements # Gender # Depressive symptoms		
Low + Men + depressive symptoms	-0.24***	(-0.31, -0.16)
Low + Women + depressive symptoms	-0.75***	(-0.80, -0.70)
Medium + Men + depressive symptoms	-0.07**	(-0.12, -0.02)
Medium + Women + depressive symptoms	-0.55***	(-0.60, -0.49)
High + Men + depressive symptoms	0.07	(-0.05, 0.18)
High + Women + depressive symptoms	-0.35***	(-0.50, -0.20)

Note: Controlled for age, gender, education, working status, social activities, place of residence, religion, caste, region, body mass index (BMI), MPCE, smoking status, consuming smokeless tobacco, alcohol status, hypertension, diabetes, cancer, heart disease, and stroke. CI = confidence interval.
* p<0.05, ** p<0.01, *** p<0.001

Table 5. The Effect of Social Engagement on cognition confounded by depressive symptoms (the Karlson, Holm, and Breen Method), by gender, (N = 23,584), LASI, 2017-19

	β	**(95% CI)**
Social Engagements		
Total Effect	0.52***	(0.40,0.63)
Direct effect of social engagement	0.44***	(0.33,0.55)
Indirect effect via depressive symptoms	0.07***	(0.06,0.09)
N	**23,584**	
Conf.-Perc[a]	**14.40%**	

Note: Controlled for age, gender, education, working status, social activities, place of residence, religion, caste, region, body mass index (BMI), MPCE, smoking status, consuming smokeless tobacco, alcohol status, hypertension, diabetes, cancer, heart disease, and stroke. CI = confidence interval. [a]Confounding percentage.
* p<0.05, ** p<0.01, *** p<0.001

Discussion

The COVID-19 pandemic has called for international attention on the importance of social relationships/social engagement/social inclusion in terms of supporting the physical, emotional and cognitive health of older adults [65, 66]. Evidence suggests significant correlations exist between engaging in social activities with enhanced cognitive function outcomes [10, 50]. However, depression and other mental illnesses may lead to reduced social networks and activities that result in cognitive decline among older adults is little explored. The present study examined the direct, indirect, and total effects of social engagement on the cognitive functioning confounded by the effects of depressive symptoms among older adults in India. We found that a higher level of social engagement was associated with greater cognitive functioning, whereas depressive symptoms confounded 16.9% of the observed association. In addition, gender-based moderation effects were also examined which were found significant with female disadvantages.

Structural aspects of social network are recommended to be essential to maintain an optimal level of cognitive functioning [67]. As documented, social networks and activity are related concepts and individuals who have a larger social networks tend to take part in more social activities [68]. Similarly, the satisfaction achieved from the social and support networks was observed to lead to better episodic memory performance, and processing speed and global cognition [69]. The main effect hypothesis in the present study is confirmed by the results showing that social engagements are independently associated with a greater level of cognitive functioning. The finding is consistent with previous studies linking the social involvement enhancing the wellbeing and boosting the self-esteem and creating a sense of belonging that result in better cognitive functioning [70–72]. A systematic review reported that although the exact nature of the associations are unclear, different aspects of social relationships such as social activity, social networks and social support and a composite measures of social relationships are associated with cognitive functioning [73]. Thus, social engagement interventions should be prioritized in public policy to help older adults optimize their cognitive health, regardless of underlying mechanisms.

Although social engagements including the structural support from the spouse and family members are found to enhance cognitive functioning [74–76], the role of mental illnesses adversely affecting the association is less investigated. A recent study found the mediating role of hippocampal volume of brain which is known to be affected by a variety of psychiatric disorders in the association of emotional support with specific cognitive domains [77]. Consistently, the current results showed that depressive symptom was significant confounder in the social engagement-cognitive functioning relationship. The finding is also in parallel with a recent study conducted in China showing the mediating role of depressive symptoms in the protective effect of frequent exercise on cognitive functioning [78]. Therefore, our results support the previous finding that the protective effect of social relationships is more related to the aspects of quality and functionality of such relationships than the quantity and structural characteristics [79]. Furthermore, the indirect effect of social engagements on cognitive functioning suggest that social resources can be related to better cognitive functioning through minimizing mental disorders in older adults, indicating that depressive symptoms may serve as an important intervening target and that reversing such illnesses might be related to a greater cognitive functioning. This is similar to an earlier finding that lack of social engagements may be particularly detrimental to late-life cognitive abilities when it is associated with mental illnesses [80]. Earlier meta-analyses and reviews have investigated loneliness, being one of the

depressive symptoms, and social isolation together as part of health promotion interventions and suggested that loneliness is often experienced as a part of lack of social engagement and partly attribute to the factors of cognitive declines [81, 82], indicating the need for social interventions that promote active participation of older people and help them in maintaining social and structural relationships and coping with age-related stress factors.

The available evidence suggests that there are gender differences in the relationship between social engagement and cognitive functioning. For instance, in developed countries, numerous studies have found that the cognitive performance of older women is as good as or better than that of men [83–85]. By contrast, studies of cognitive abilities in developing countries find older women often perform worse than older men [86, 87]. Moreover, earlier studies in India reported a relatively lower cognitive functioning level among older women than men [46, 47]. In line with the previous literature, the current findings suggest a significant female disadvantage in cognitive function among older Indian adults and call for special attention with regard to public policy frameworks, clinical practice and future research.

On the other hand, studies suggest that a greater social engagement protects against rapid cognitive decline, particularly among low-educated older women [88]. In addition, social networks were reported as highly influential for women than men in determining better health behaviors related to cognitive maintenance [86]. Consistent with these previous studies, the current analyses have shown that social engagement of older women is strongly associated with better cognitive functioning with greater moderation effects of depressive symptoms compared to older men. Nevertheless, it still needs to be further investigated whether gender differences exist in the association of social engagements confounded by depressive symptoms with cognitive functioning and causally inferred with studies of longitudinal design.

There are several limitations of the present study to be noted. The composite index of social engagement was generated from the questions which were self-reported. The responses may have been exaggerated or under-reported. However, self-reporting is endorsed as an optimal method to measure how the participants subjectively find themselves having social networks and involved in social activities. On the other hand, exploring the aspect of social engagements that include participating in indoor games for example, as distinct from domains of cognitive activities is questionable, since it is not feasible to completely differentiate social engagement from cognitive engagements. Also many activities have a psychiatric element which may have positive impacts on cognitive processes and a complex confounding effect in the associations

of three key variables in our study. Hence, considering the differences in relationships between cognitive domains and the distinct forms of social engagements that also include structural support from marital status and living arrangements, it is important to define social relationships more clearly in future studies to achieve more reliable findings.

Besides, in a population with huge proportion of illiterates, the assessment of cognitive functioning with multiple domains might be subject to measurement error which can bias the current findings. Similarly, older women in India who are largely deprived of education and other opportunities including work participation might have resulted in greater gender gap in cognitive functioning observed in our study. Another limitation is the inclusion of only men and women in the study. Since LASI collects the information from men and women only, the inclusion of the other gender was not possible. Finally, the present study was cross-sectional, and thus, a causal relationship between the variables cannot be inferred. Further investigation with longitudinal design is needed to explore the neural mechanisms that underlie the effects of social engagements on cognitive decline. Future research might also consider the impact of technology, internet and social media on social relationships, particularly feelings of social support.

Conclusion

The positive association of social engagement with cognitive functioning was significantly confounded by depressive symptoms, suggesting the need for maintaining social relations that help improve cognitive functioning among older adults. This needs to be confirmed with future longitudinal and interventional studies. The study also highlights the potential of social engagements independently or with others as an intervention to prevent cognitive impairment among older individuals, especially among women.

Abbreviations:

MPCE: Monthly Per capita Consumption Expenditure

CES-D: Center for Epidemiological Studies-Depression

KHB: Karlson–Holm–Breen

Declarations

Contributors: MK and LKD conceived and designed the research paper. MK analyzed the data. MK and TM contributed agents/materials/analysis tools. MK and TM wrote the

manuscript. LKD provides supervision and validation. MK, TM and LKD refined the manuscript. All authors have read and approved the manuscript.

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Data availability statement: The study uses secondary data which is available in the private database and accessible on reasonable request through

https://www.iipsindia.ac.in/content/lasiwave-i

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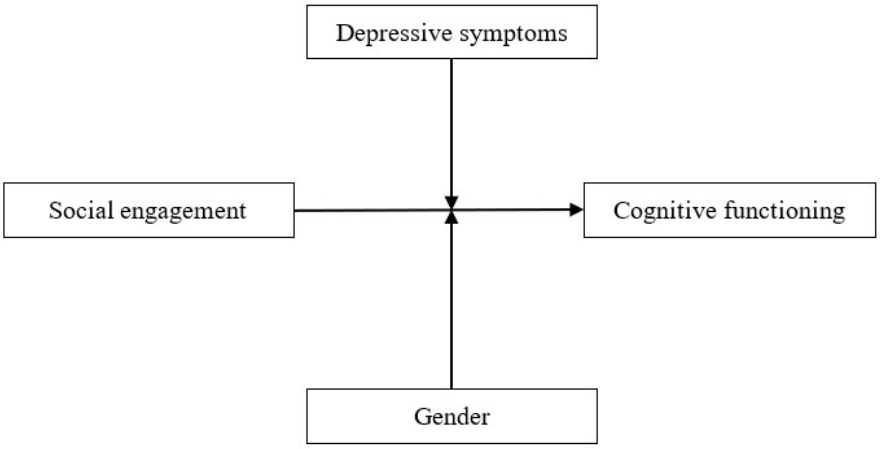
Figure Legend:

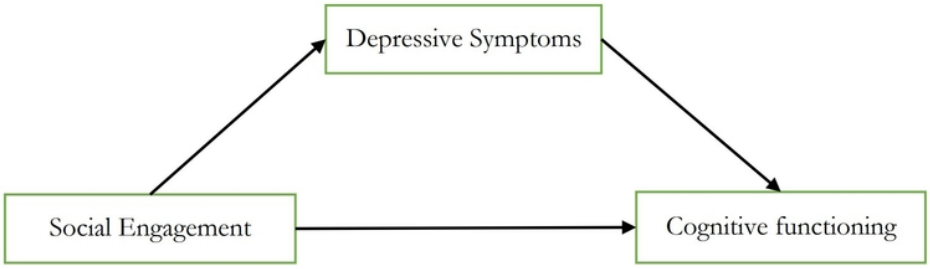
Figure 1. Moderation effects of gender and depressive symptoms on association between social engagement and cognitive functioning.

Figure 2. Confounding effects of depressive symptoms on association between social engagement and cognitive functioning



Moderation effects of gender and depressive symptoms on association between social engagement and cognitive functioning.

163x85mm (120 x 120 DPI)



Confounding effects of depressive symptoms on association between social engagement and cognitive functioning

68x27mm (300 x 300 DPI)

Supplementary file

Table S1. Descriptive statistics for the cognitive function (0-43) and level of social engagements according to selected variables, (N = 23,584), LASI, 2017-19

	Cognitive function (0-43)		*Low (n=7,401)*		*Medium (n=14,052)*		*High (n=2,131)*	
	N	*Mean (sd.)*						
Social Engagements								
Low	7,401	20.7 (7.1)	-	-	-	-	-	-
Medium	14,052	24.5 (7)	-	-	-	-	-	-
High	2,131	26.8 (6.6)	-	-	-	-	-	-
Depression[a]								
No	17,432	24 (7.2)	5,022	67.9	10,683	76.0	1,727	81.0
Yes	6,152	22.1 (7.2)	2,379	32.1	3,369	24.0	404	19.0
Age (years)								
60-69	14,691	24.6 (6.9)	3,512	47.5	9,721	69.2	1,458	68.4
70-79	6,735	22.5 (7.2)	2,624	35.5	3,529	25.1	582	27.3
80+	2,158	19.3 (7.5)	1265	17.1	802	5.7	91	4.3
Social Activities								
0	8,235	20.4 (6.7)	3,133	42.3	4,808	34.2	294	13.8
1	8,380	22.9 (6.6)	2,849	38.5	4,968	35.4	563	26.4
2	4,522	27.2 (6.4)	1065	14.4	2,855	20.3	602	28.2
3+	2,447	29.4 (6)	354	4.8	1,421	10.1	672	31.5
Education level								
No education	12,369	19.7 (6)	4,946	66.8	6,683	47.6	740	34.7
Primary	5,909	25.5 (6)	1,559	21.1	3,707	26.4	643	30.2
Secondary	3,543	29.5 (5.1)	663	9.0	2,405	17.1	475	22.3
Higher	1,763	31.8 (4.6)	233	3.1	1,257	8.9	273	12.8
Currently working								
No	16,213	23.1 (7.4)	5,986	80.9	8,862	63.1	1,365	64.1
Yes	7,371	24.3 (6.9)	1,415	19.1	5,190	36.9	766	35.9
Place of Residence								
Rural	15,737	22.1 (7)	4,915	66.4	9,570	68.1	1,252	58.8
Urban	7,847	26.3 (7)	2,486	33.6	4,482	31.9	879	41.2
Religion								
Hindu	17,414	23.6 (7.2)	5,652	76.4	10,634	75.7	1,128	52.9
Muslim	2,576	23.3 (7)	789	10.7	1,407	10.0	380	17.8
Christian	2,410	22.9 (7.7)	645	8.7	1,293	9.2	472	22.1
Others[$]	1,184	23.5 (7.2)	315	4.3	718	5.1	151	7.1
Caste								
Scheduled caste	3,953	22.1 (6.7)	1356	18.3	2,384	17.0	213	10.0
Scheduled tribe	4,134	21 (7.5)	1257	17.0	2,310	16.4	567	26.6
OBC[#]	9,109	24 (7.1)	2,895	39.1	5,556	39.5	658	30.9
Others	6,388	25.4 (7)	1,893	25.6	3,802	27.1	693	32.5
Regions								
North	4,395	23.5 (7.1)	1237	16.7	2,617	18.6	541	25.4
Central	3,119	23.2 (6.7)	1019	13.8	1,913	13.6	187	8.8
East	4,522	23 (7.2)	1,434	19.4	2,857	20.3	231	10.8
Northeast	2,865	23.1 (7.6)	796	10.8	1,567	11.2	502	23.6
West	3,075	22.9 (7.2)	928	12.5	1,825	13.0	322	15.1
South	5,608	24.7 (7.5)	1,987	26.8	3,273	23.3	348	16.3
BMI categories								
Normal	12,367	23.6 (7.1)	3,674	49.6	7,511	53.5	1,182	55.5
Underweight	5,436	20.7 (6.9)	2,051	27.7	3,080	21.9	305	14.3

Overweight/Obese	5,781	26.1 (7)	1,676	22.6	3,461	24.6	644	30.2
MPCE quintile								
Poorest	4,827	21.8 (7.1)	1,695	22.9	2,795	19.9	337	15.8
Poorer	4,861	22.7 (7.1)	1,614	21.8	2,873	20.4	374	17.6
Middle	4,862	23.6 (7.1)	1,478	20.0	2,909	20.7	475	22.3
Richer	4,647	24.3 (7.1)	1,389	18.8	2,832	20.2	426	20.0
Richest	4,387	25.6 (7.3)	1225	16.6	2,643	18.8	519	24.4
Currently smoking tobacco								
No	20,210	23.5 (7.3)	6,719	90.8	11,747	83.6	1,744	81.8
Yes	3,374	23.7 (6.7)	682	9.2	2,305	16.4	387	18.2
Currently chewing tobacco								
No	18,871	23.7 (7.3)	5,930	80.1	11,198	79.7	1,743	81.8
Yes	4,713	22.9 (6.9)	1,471	19.9	2,854	20.3	388	18.2
Drinking Status								
Never	19,368	23.4 (7.3)	6,573	88.8	11,099	79.0	1,696	79.6
Infrequent non-heavy	2,568	24.8 (6.9)	484	6.5	1,781	12.7	303	14.2
Frequent non-heavy	870	23.3 (7.2)	191	2.6	617	4.4	62	2.9
Heavy episodic drinker	778	22.9 (7.1)	153	2.1	555	3.9	70	3.3
Hypertension Status								
Normal	5,386	22.9 (7)	1,512	20.4	3,386	24.1	488	22.9
Pre-hypertensive	9,015	23.9 (7.2)	2,644	35.7	5,505	39.2	866	40.6
High BP	9,183	23.5 (7.4)	3,245	43.8	5,161	36.7	777	36.5
Diabetes								
No	19,987	23.1 (7.2)	6,436	87.0	11,782	83.8	1,769	83.0
Yes	3,597	25.9 (7)	965	13.0	2,270	16.2	362	17.0
Cancer								
No	23,420	23.5 (7.3)	7,355	99.4	13,955	99.3	2,110	99.0
Yes	164	24.5 (7.2)	46	0.6	97	0.7	21	1.0
Heart Disease								
No	22,399	23.4 (7.3)	7,096	95.9	13,300	94.6	2,003	94.0
Yes	1,185	25.8 (7)	305	4.1	752	5.4	128	6.0
Stroke								
No	23,069	23.5 (7.3)	7,258	98.1	13,726	97.7	2,085	97.8
Yes	515	23 (7.2)	143	1.9	326	2.3	46	2.2
Total	**23,584**	**23.5 (7.3)**	**7,401**	**100.0**	**14,052**	**100.0**	**2,131**	**100.0**

Note: [a] overall score ranges from zero to 10 and individuals with score of four or more are considered as depressed; [#] Other Backward Classes, [$] includes Sikh, Buddhist/neo-Buddhist, Jain, Parsi/Zoroastrian and others; BP- Blood Pressure.

Note: *p<0.05, **p<0.01, ***p<0.001

Table S2. Linear regression results of interaction of social engagement and depressive symptoms on cognitive functioning, by gender, (N = 23,584).

	Men		**Women**		**Total**	
	β	**(95% CI)**	**β**	**(95% CI)**	**β**	**(95% CI)**
Social engagements # Depressive symptoms						
Low + depressive symptoms	-0.53***	(-0.62,-0.45)	-0.49***	(-0.55,-0.43)	-0.61***	(-0.66,-0.56)
Medium + depressive symptoms	-0.33***	(-0.40,-0.27)	-0.32***	(-0.39,-0.26)	-0.28***	(-0.33,-0.23)
High + depressive symptoms	-0.19**	(-0.31,-0.07)	-0.16*	(-0.32,-0.01)	-0.10*	(-0.20,-0.01)

Social Activities	0.26**	(0.07,0.44)	0.76***	(0.55,0.97)	0.48***	(0.33,0.62)
Age (years)	-0.11***	(-0.13,-0.10)	-0.15***	(-0.17,-0.14)	-0.11***	(-0.12,-0.10)
Education level						
No education®						
Primary	4.06***	(3.82,4.30)	4.23***	(3.96,4.50)	4.82***	(4.64,4.99)
Secondary	6.92***	(6.63,7.21)	8.12***	(7.73,8.52)	8.27***	(8.05,8.49)
Higher	7.61***	(7.24,7.97)	9.99***	(9.39,10.59)	9.28***	(8.99,9.56)
Currently working						
No®						
Yes	0.31**	(0.10,0.52)	0.59***	(0.35,0.84)	0.87***	(0.71,1.03)
Place of Residence						
Rural®						
Urban	1.28***	(1.03,1.53)	1.26***	(1.02,1.50)	1.16***	(0.99,1.34)
Religion						
Hindu®						
Muslim	0.72***	(0.38,1.06)	-0.38*	(-0.70,-0.05)	0.37**	(0.13,0.60)
Christian	-0.63	(-1.27,0.00)	0.06	(-0.51,0.63)	-0.26	(-0.70,0.17)
Others$	-0.65*	(-1.18,-0.13)	0.41	(-0.10,0.91)	0.13	(-0.24,0.49)
Caste						
Scheduled caste®						
Scheduled tribe	-1.36***	(-1.78,-0.94)	-1.15***	(-1.55,-0.76)	-1.40***	(-1.69,-1.11)
OBC#	0.46**	(0.18,0.73)	0.74***	(0.48,1.00)	0.58***	(0.39,0.77)
None of them	0.40*	(0.10,0.71)	0.66***	(0.36,0.95)	0.44***	(0.23,0.66)
Region						
North®						
Central	1.17***	(0.81,1.53)	1.81***	(1.47,2.15)	1.58***	(1.33,1.83)
East	0.43*	(0.08,0.78)	0.96***	(0.63,1.29)	0.69***	(0.45,0.93)
Northeast	1.10***	(0.45,1.76)	1.10***	(0.47,1.72)	0.87***	(0.41,1.33)
West	-1.13***	(-1.51,-0.76)	-0.57**	(-0.92,-0.23)	-0.93***	(-1.19,-0.67)
South	0.27	(-0.10,0.64)	1.82***	(1.47,2.16)	1.11***	(0.85,1.36)
BMI categories						
Normal®						
Underweight	-0.93***	(-1.17,-0.70)	-1.19***	(-1.42,-0.96)	-1.07***	(-1.24,-0.91)
Overweight/obese	0.76***	(0.50,1.02)	1.00***	(0.76,1.24)	0.77***	(0.59,0.95)
MPCE quintile						
Poorest®						
Poorer	0.03	(-0.27,0.32)	0.15	(-0.12,0.43)	0.10	(-0.11,0.30)
Middle	0.39*	(0.09,0.69)	0.60***	(0.32,0.88)	0.38***	(0.17,0.59)
Richer	0.73***	(0.42,1.04)	0.70***	(0.40,0.99)	0.65***	(0.43,0.87)
Richest	0.79***	(0.45,1.12)	0.72***	(0.41,1.04)	0.63***	(0.40,0.87)
Currently smoking tobacco						
No®						
Yes	0.25*	(0.00,0.49)	-0.53*	(-1.03,-0.03)	0.84***	(0.63,1.05)
Currently chewing tobacco						
No®						
Yes	0.10	(-0.14,0.33)	-0.23	(-0.49,0.02)	0.25**	(0.07,0.42)
Drinking Status						
Never®						
Infrequent non-heavy	-0.32*	(-0.58,-0.06)	-0.41	(-1.21,0.38)	0.39**	(0.15,0.64)
Frequent non-heavy	-1.14***	(-1.58,-0.70)	-2.44***	(-3.55,-1.33)	-0.69***	(-1.09,-0.29)
Heavy episodic drinker	-1.74***	(-2.21,-1.28)	-2.56***	(-3.77,-1.36)	-1.22***	(-1.65,-0.78)
Hypertension Status						
Normal®						
Pre-hypertensive	0.25*	(0.00,0.50)	0.21	(-0.03,0.46)	0.20*	(0.03,0.38)
High BP	0.37**	(0.11,0.63)	0.00	(-0.24,0.25)	0.10	(-0.08,0.28)

Diabetes						
No®						
Yes	-0.59***	(-0.87,-0.30)	-0.47**	(-0.76,-0.18)	-0.52***	(-0.73,-0.32)
Cancer						
No®						
Yes	0.81	(-0.57,2.20)	-0.34	(-1.55,0.87)	0.19	(-0.74,1.12)
Heart Disease						
No®						
Yes	0.81***	(0.40,1.22)	0.24	(-0.24,0.71)	0.75***	(0.43,1.06)
Stroke						
No®						
Yes	-1.55***	(-2.14,-0.96)	-1.41***	(-2.11,-0.71)	-1.33***	(-1.79,-0.87)
N	11,403		12,181		23,584	
R2	0.39		0.42		0.45	

Note: # Other Backward Classes, $ includes Sikh, Buddhist/neo-Buddhist, Jain, Parsi/Zoroastrian and others; BP- Blood Pressure.
Note: *p<0.05, **p<0.01, ***p<0.001

Table S3. Mean, standard deviation, and correlation between social engagement and depression (n=23,584). LASI, 2017-19

Variables	1	2
Depression	-	
Social engagement	-0.12***	-
Mean	2.97	1.69
Standard deviation	1.68	0.67

Note: *p<0.05, **p<0.01, ***p<0.001

Table S4. Linear regression results of social engagement on depressive symptoms, by gender, (N = 23,584), LASI, 2017-19

	Men		**Women**		**Total**	
	β	**(95% CI)**	**β**	**(95% CI)**	**β**	**(95% CI)**
Social Engagement	-0.16***	(-0.22,-0.11)	-0.21***	(-0.25,-0.16)	-0.18***	(-0.22,-0.15)
Cognitive function	-0.03***	(-0.04,-0.03)	-0.04***	(-0.05,-0.04)	-0.04***	(-0.04,-0.03)
Social Activities	0.01	(-0.04,0.07)	0.06	(-0.01,0.13)	0.04	(-0.00,0.08)
Age (years)	-0.01**	(-0.01,-0.00)	0.00	(-0.00,0.00)	0.00	(-0.01,0.00)
Gender						
Men®	-	-	-	-		
Women	-	-	-	-	-0.06*	(-0.12,-0.00)
Education level						
No education®						
Primary	0.00	(-0.08,0.08)	-0.01	(-0.10,0.08)	-0.01	(-0.06,0.05)
Secondary	-0.03	(-0.13,0.06)	0.15*	(0.02,0.29)	0.03	(-0.05,0.10)
Higher	-0.08	(-0.20,0.04)	0.33**	(0.13,0.53)	0.03	(-0.07,0.13)
Currently working						
No®						
Yes	-0.10**	(-0.16,-0.03)	-0.04	(-0.11,0.04)	-0.06*	(-0.11,-0.01)
Place of Residence						
Rural®						
Urban	0.03	(-0.04,0.11)	-0.02	(-0.09,0.06)	0.01	(-0.04,0.06)
Religion						

Hindu®						
Muslim	0.10	(-0.00,0.20)	0.13*	(0.03,0.24)	0.12**	(0.05,0.19)
Christian	-0.41***	(-0.60,-0.21)	0.07	(-0.12,0.25)	-0.14*	(-0.28,-0.01)
Others$	-0.41***	(-0.57,-0.25)	-0.18*	(-0.34,-0.01)	-0.29***	(-0.40,-0.18)
Caste						
Scheduled caste®						
Scheduled tribe	-0.27***	(-0.40,-0.14)	-0.03	(-0.15,0.10)	-0.14**	(-0.23,-0.05)
OBC#	-0.25***	(-0.33,-0.16)	-0.05	(-0.13,0.03)	-0.15***	(-0.21,-0.09)
None of them	-0.23***	(-0.33,-0.14)	-0.07	(-0.16,0.03)	-0.15***	(-0.21,-0.08)
Region						
North®						
Central	0.46***	(0.35,0.57)	0.60***	(0.49,0.71)	0.53***	(0.45,0.61)
East	0.07	(-0.03,0.18)	0.08	(-0.03,0.18)	0.08*	(0.00,0.15)
Northeast	-0.15	(-0.35,0.05)	-0.37***	(-0.57,-0.17)	-0.27***	(-0.41,-0.13)
West	-0.55***	(-0.67,-0.44)	-0.60***	(-0.71,-0.48)	-0.57***	(-0.65,-0.49)
South	0.35***	(0.23,0.46)	0.25***	(0.13,0.36)	0.30***	(0.22,0.38)
BMI categories						
Normal®						
Underweight	0.29***	(0.22,0.36)	0.07	(-0.01,0.14)	0.18***	(0.13,0.23)
Overweight/obese	0.05	(-0.03,0.14)	-0.08*	(-0.16,-0.00)	-0.02	(-0.08,0.03)
MPCE quintile						
Poorest®						
Poorer	-0.09	(-0.18,0.01)	-0.10*	(-0.19,-0.02)	-0.09**	(-0.16,-0.03)
Middle	-0.06	(-0.16,0.03)	-0.10*	(-0.19,-0.01)	-0.08*	(-0.14,-0.02)
Richer	-0.07	(-0.16,0.03)	-0.10*	(-0.19,-0.00)	-0.08*	(-0.15,-0.02)
Richest	-0.05	(-0.15,0.06)	-0.02	(-0.12,0.08)	-0.03	(-0.11,0.04)
Currently smoking tobacco						
No®						
Yes	0.14***	(0.07,0.22)	0.03	(-0.13,0.20)	0.15***	(0.08,0.21)
Currently chewing tobacco						
No®						
Yes	-0.01	(-0.08,0.07)	0.07	(-0.02,0.15)	0.02	(-0.04,0.07)
Drinking Status						
Never®						
Infrequent non-heavy	-0.15***	(-0.23,-0.07)	0.05	(-0.20,0.31)	-0.12**	(-0.20,-0.05)
Frequent non-heavy	-0.22**	(-0.35,-0.08)	-0.41*	(-0.77,-0.06)	-0.24***	(-0.37,-0.12)
Heavy episodic drinker	-0.05	(-0.20,0.09)	-0.15	(-0.54,0.24)	-0.07	(-0.20,0.07)
Hypertension Status						
Normal®						
Pre-hypertensive	-0.04	(-0.12,0.03)	-0.09*	(-0.17,-0.01)	-0.07*	(-0.12,-0.01)
High BP	-0.04	(-0.12,0.04)	0.02	(-0.06,0.09)	-0.01	(-0.07,0.05)
Diabetes						
No®						
Yes	0.10*	(0.02,0.19)	0.02	(-0.08,0.11)	0.06	(-0.00,0.13)
Cancer						
No®						
Yes	0.59**	(0.17,1.01)	-0.36	(-0.75,0.03)	0.06	(-0.23,0.35)
Heart Disease						
No®						
Yes	0.11	(-0.01,0.24)	0.17*	(0.01,0.32)	0.14**	(0.04,0.24)
Stroke						
No®						
Yes	0.56***	(0.38,0.74)	0.31**	(0.09,0.54)	0.46***	(0.32,0.61)
N	11,403		12,181		23,584	

R^2	0.10	0.09	0.09

Note: # Other Backward Classes, $ includes Sikh, Buddhist/neo-Buddhist, Jain, Parsi/Zoroastrian and others; BP- Blood Pressure.
Note: *p<0.05, **p<0.01, ***p<0.001

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Recommendation	Page No
Title and abstract	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
	(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2-3
Introduction		
Background/rationale	Explain the scientific background and rationale for the investigation being reported	5-6
Objectives	State specific objectives, including any prespecified hypotheses	6
Methods		
Study design	Present key elements of study design early in the paper	7
Setting	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7
Participants	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	7
Variables	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-10
Data sources/ measurement	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7
Study size	Explain how the study size was arrived at	7
Quantitative variables	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	
Statistical methods	(*a*) Describe all statistical methods, including those used to control for confounding	11
	(*b*) Describe any methods used to examine subgroups and interactions	
	(*c*) Explain how missing data were addressed	7
	(*d*) If applicable, describe analytical methods taking account of sampling strategy	
	(*e*) Describe any sensitivity analyses	
Results		
Participants	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	11
	(b) Give reasons for non-participation at each stage	
	(c) Consider use of a flow diagram	
Descriptive data	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	12
	(b) Indicate number of participants with missing data for each variable of interest	
Outcome data	Report numbers of outcome events or summary measures	12-16
Main results	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	12-16
	(*b*) Report category boundaries when continuous variables were categorized	

	(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion		
Key results	Summarise key results with reference to study objectives	17
Limitations	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	20
Interpretation	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	17-20
Generalisability	Discuss the generalisability (external validity) of the study results	17-20
Other information		
Funding	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	21

*Give information separately for exposed and unexposed groups.

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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)

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Abstract

Objective: The present study aimed to examine the confounding effects of depressive symptoms and the role of gender in the association between social engagement and cognitive functioning among older Indian adults.

Design: Large-scale, cross-sectional survey data was analyzed.

Setting and participants: Data from Longitudinal Aging Study in India (2017-19) were used in the analysis. The sample included 23,584 individuals aged 60 years and above (11,403 men and 12,181 women).

Outcome measures: The outcome variable was cognitive functioning, which was based on various measures including immediate and delayed word recall, orientation, executive functioning, arithmetic ability and object naming. Social engagement measure consists of marital status, living arrangement, availability of confidant, and participation in indoor games, and social and cultural functions. The Center for Epidemiologic Studies Depression Scale was used to assess depressive symptoms.

Results: Significant gender differences in mean cognition scores (men: 25.8, women: 21.1; on a scale of 0-43) were observed. Two-way stratification between social engagement and depressive symptoms was significantly associated with cognitive functioning after controlling for selected explanatory factors. Older men with low level of social engagements had significantly poor cognitive functioning (β=-1.12; 95%CI: -1.53, -0.72) compared with men with high level of social engagements. On the other hand, women with higher level of social engagement performed poorly on cognitive tests (-1.54; 95%CI: -2.11, -0.98) compared with men with higher social engagements. Three-way stratification between social engagement, gender, and depressive symptoms suggests that social engagement's buffering effects are lower in women than in men. Karlson–Holm–Breen method identified significant confounding effect of depressive symptoms on the relationship between social engagement and cognitive functioning.

Conclusion: The positive association of social engagement with cognitive functioning was significantly confounded by depressive symptoms, suggesting the need for maintaining social relations that help improve mental health and cognitive functioning among older adults.

Keywords: *social engagement, cognitive functioning, depressive symptoms, KHB-method, older adults.*

Strengths and limitations of this study

- The study utilized data of large, nationally representative sample of older adults.
- Internationally validated scales of cognition and depressive symptoms were used.
- In a sample with large proportion of illiterate people, assessment of cognitive functioning might be subject to measurement error.
- The inability to establish a causal relationship between the variables of interest is the main limitation of the study.

Introduction

With the growth of aging population, global challenges in mental health are on the rise. It includes the decline in late-life cognitive abilities which are generally associated with poor quality of life [1], functional disabilities [2], multimorbidity [3], and higher mortality risk [4]. India is currently facing rapid population aging, with an expected increase in the number of individuals aged 60 years and above from 104 million in 2011 to 319 million by 2050 [5]; consequently, the disease burden of cognitive impairment in the country is also expected to increase.

Social engagement is an umbrella concept usually referring to various factors such as social relationships, social and emotional connectedness with other people, and participation in social activities, which provide a sense of belonging, social identity, and fulfilment [6, 7]. In the absence of effective pharmacological treatment for persons with cognitive impairment, especially for the long-term benefits, various methods such as improving social engagement and active participation in social activities are considered [8]. Multiple cross-sectional studies investigating the association between social environment and cognition in older adults showed that greater social functioning positively associated with cognitive performances [9, 10]. Moreover, several longitudinal studies among older adults have also indicated that greater engagements with relatives [11, 12], rich social networks [12, 13], and frequent participation in social activities [14] exert protective effects against cognitive decline. Therefore, in the long run, individuals who present trajectories of high and increasing social engagements experience lower levels of cognitive limitation [15].

Several interventional studies reported the protective effects of the improved social behaviours in preventing or delaying dementia among older adults with diagnosed cognitive impairment [16, 17]. Most of the available research on social capital and engagement as to enhance cognitive reserve and protect cognitive health has been conducted in developed countries [18–21]. Little is known about the relationship between social engagement and cognitive functioning in developing countries like India, where the cultural and structural context of social engagement differ from developed countries. In India, traditionally, older adults are more likely to live with their children in multigenerational households where cultural norms emphasize family ties and the virtue of filial piety [22, 23], and a higher proportion of older people experience psychological distress and mental illnesses [24–26].

Similarly, depressive disorders are highly prevalent among older adults in low- and middle income countries (LMICs) [27–29] and in India in particular [30]. Previously, various studies have found the beneficial effects of greater social engagements (with varying measurements and definitions) against depressive symptoms [31, 32]. A cross-sectional study by Jang & Chiriboga (2011) [31] found that a higher level of participation in social activities was associated with a decline in depressive symptoms after controlling for the effects of demographic and health-related factors. Multiple longitudinal studies have also reported similar findings [33–37]. Also, increased participation in social activities and meaningful engagement by older adults may improve their mood, which benefits their emotional functioning and reduces depressive symptoms [38], which is linked to cognitive functioning [39]. According to the 'depression reduction hypothesis', depressive symptoms interferes with cognitive health; therefore, as evident from multiple longitudinal studies, practical strategies to reduce depressive symptoms will possibly improve cognitive functioning [40]. Two facts justify such a hypothesis; first, greater depressive symptoms are related to poor cognitive functioning among older adults [41, 42]. Second, depressed older adults who engage in social activities may experience a decline in depressive symptoms and improve cognitive functioning [43]. Furthermore, in multiple cohort studies, cognitively impaired older adults with depressive symptoms were associated with more rapid cognitive decline than those without depression [44, 45].

However, it is not clear to what extent social engagement may improve cognitive functioning by minimizing depressive symptoms. There is a dearth of studies in LMICs on the association of social engagements and cognitive functioning and the role of depressive symptoms in such association. Filling this gap, the present study using national-level data of older adults in India, aimed to examine the role of the depressive symptoms on the association between social engagement and cognitive functioning (Figure 1). Previous research showed a greater female disadvantage and theorized gender as the crucial factor to be considered in understanding the differences in cognitive functioning in Indian context [46–48]. Also, studies have shown the significant gender differences in the association between social engagement and cognitive functioning [49, 50]. Thus, the study also explored the moderation effects of gender in the relationship between social engagement and cognitive functioning. The present study hypothesized that the association between social engagement and cognitive functioning is significantly confounded by depressive symptoms (Figure 2).

Methods

Data

The present study utilized the individual-level data from the first wave of the Longitudinal Aging Study in India (LASI) conducted during 2017-19. LASI is a nationally representative longitudinal survey of more than 72000 adults aged 45 years and over and their spouses regardless of age across all states and union territories of India that provides vital information on the social, physical, psychological, and cognitive health of the Indian aging population. The LASI survey was conducted through a partnership of the International Institute for Population Sciences (IIPS), Harvard T. H. Chan School of Public Health (HSPH), and the University of Southern California (USC). In LASI wave 1, the sample selection is based on a multistage stratified cluster sample design, including a three-stage sampling design in rural areas and a four-stage sampling design in urban areas. LASI survey provided internationally harmonized data that comparable to the United States Health and Retirement Study (HRS) and other HRS-type surveys in other countries, including England (English Longitudinal Study of Ageing) and China (China Health and Retirement Longitudinal Survey). Further, the details of sampling design, survey instruments, and data collection procedures are provided elsewhere [51].

In the sampled households, the individual survey schedule includes the biomedical examination administered to each consenting respondent aged 45 and above and their spouses (irrespective of age). The survey agencies authorized to conduct the survey have collected prior consent from all the respondents. Consent forms include the information brochure explaining the purpose of the survey, ways of protecting their privacy, and the safety of the health assessments as part of the ethics protocols. The Indian Council of Medical Research extended the necessary guidelines and ethics approval for undertaking the survey.

The sample in the main LASI survey data included 31,464 individuals aged 60 years and above. For the present analysis, we have excluded those cases with missing data for any variable of interest (n=7,880). Therefore, the sample for the present study included 23,584 individuals aged 60 years and above from the LASI survey, and among them 11,403 were men and 12,181 were women.

Measures

Cognitive function

By adopting the Health and Retirement Study (HRS) cognition module, the LASI collected information on measured cognition in various domains – including memory, orientation,

executive functioning, arithmetic, and object naming (Table 1). Previously, various studies have established high validity and reliability of these cognitive domains for measuring cognitive impairment among older adults in community settings in the United States [52], China [53], and India [54]. The cognitive functioning in the present study is based on different cognitive measures, including immediate (0–10 points) and delayed word recall (0–10 points); orientation related to time (0-4 points), and place (0-4 points); executive functioning based on paper folding (0-3) and pentagon drawing (0-1); arithmetic ability based on serial 7s (0–5 points), computation (0-2) and backward counting from 20 (0–2 points); and object naming (0-2).

Table 1. Description of domain-wise cognitive measures in LASI, 2017-18

Domain	Measure	Measurement	Range
Memory	Immediate word recall	Interviewer read out a list of 10 words and respondents were asked to repeat the words.	0-10
	Delayed word recall	Respondents were asked to recall the same words read out for immediate recall after some time.	0-10
Orientation	Time	Respondents were asked to state today's date, month and year and day of the week. For each question, the score was 0 or 1. Correct responses received 1 point, incorrect responses received 0. The total score for time was 0-4.	0-4
	Place	Orientation towards place was captured based on place of interview, name of the village, street number/colony name/ landmark/neighborhood and name of the district. Each correct response scored 1 point. The total score ranged from 0-4.	0-4
Arithmetic function	Backward counting	Respondents were asked to count backward as quickly as possible from the number 20. The respondents were asked to stop after correctly counting backward from 20 to 11 or from 19 to 10. Correct counting received 2 points: counts with a mistake received 1 point. Those who could not count received 0 points.	0-2
	Serial 7	Respondents were asked to subtract seven from 100 in the first step and asked to continue subtracting seven from the previous number in each subsequent step for five times. Each correct response received 1 point.	0-5
	Computation	This test involved the mathematical operation of division. Respondents were asked to compute the net sale price of a product after considering a discount sale of half of the original price.	0-2
Executive function: 0-4	Executive (paper folding)	This is a three-stage command task. The respondents were instructed to take a piece of paper from the interviewer, turn it over, fold it in half, and give it back to the interviewer. Three points were given if each task was completed successfully.	0-3
	Pentagon drawing	Visio-construction is the ability to coordinate fine motor skills with visio-spatial abilities, usually by reproducing geometric figures. Respondents were asked to copy two overlapping pentagons and scored 1 point for a correct drawing.	0-1

Object naming: 0-2		The interviewer points to a specific object and asks the respondent to name it. Two objects were pointed out and 1 point was given for each correct response.	0-2
Cognition	Composite cognitive index	Combined score of memory (total word recall), orientation, arithmetic function, executive function, and object naming.	0-43

After adding the scores for each component, the overall score ranged from 0 to 43, and a higher score indicates better cognitive functioning.

Social engagements

Following the previous studies [55, 56], we have derived social engagement based on five indicators: marital status, living arrangement, availability of confidant, and participation in indoor games, social and cultural functions. Current marital status was set to unmarried (single, widowed, separated, or divorced; coded as 0) versus married (married or living with a partner; coded as 1). Regarding current living arrangements, living alone was categorized as 0, and living with extended family is categorized as 1. The availability of a current confidant relationship (spouse, son or daughter, grandchildren, or relatives, etc.) was coded as no (0) or yes (1). Two more indicators based on participation in social activities including, playing cards or indoor games and attending social and cultural functions, were included (0 = several times a month/at least once a month/rarely/once in a year/never/not relevant, 1 = daily/several times a week/less than weekly). A composite index of social engagement was constructed by summing the scores for all five indicators, ranging from 0 to 5. Based on the distribution of the overall composite index, individuals were categorized as having low (0-2 social ties; 27.6 percent), medium (3 ties; 62 percent), or high (4-5 ties; 10.1 percent) levels of social engagement.

Depressive symptoms

The LASI has used an internationally validated 10-item Center for Epidemiological Studies-Depression (CES-D) scale to capture the presence of depressive symptoms in Indian older adults [57, 58]. The ten items in CES-D consist of seven negative symptoms (feeling depressed, low energy, trouble concentrating, feeling alone, bothered by things, fear of something, and everything is an effort) and three positive symptoms (feeling happy, satisfied, and hopeful). The possible responses for these items were: rarely or never (< 1 day), sometimes (1 or 2 days), often (3 or 4 days), and most or all of the time (5-7 days) in a week prior to the interview. For the negative symptoms, rarely or never (< 1 day) and sometimes (1 or 2 days) were scored zero,

and often (3 or 4 days) and most or all of the time (5-7 days) categories were scored one. Scoring was reversed for positive symptoms. The overall depressive symptoms score, calculated by adding the scores from ten items, ranges from 0 to 10. A score of four or higher is considered to represent clinically significant symptoms in the 10-item scale [59].

Covariates

After an extensive literature review, potentially related covariates were selected which include socio-demographic characteristics, lifestyle factors, health conditions, and cognitive and social activities. Socio-demographic characteristics were: age (in chronological years); gender (men, women); education (no education, primary, secondary, higher); currently working status (no, yes); residence (rural, urban); religion (Hindu, Muslim, Christian, others); and Region (North, Central, East, Northeast, West, and South), monthly per capita expenditure (MPCE) (poorest, poorer, middle, richer, and richest). The lifestyle factors were currently smoking (no, yes); currently consuming smokeless tobacco (no, yes), alcohol drinking (never, infrequent non-heavy, frequent non-heavy, heavy episodic drinker), and body mass index (BMI) (underweight (<18.5 kg/m^2), normal (18.5-24.9 kg/m^2), overweight/obese (>25.0 kg/m^2)). Health conditions include biometric measurement-based hypertension status (normal, pre-hypertensive, high blood pressure), and self-reported conditions such as diabetes, cancer, heart disease, and stroke were coded as no and yes. The older adults were categorized as having normal blood pressure (BP) (Systolic BP <120 mmHg and Diastolic BP<80 mmHg), pre-hypertensive (SBP: 120-139 mmHg and DBP: 80-89 mmHg), and high blood pressure (SBP≥ 140 mmHg and DBP≥ 90 mmHg).

The 'caste' of the household is reported by the head of the household, and it is generally grouped as four categories: Scheduled Caste (SC), Schedules Tribes (ST), Other Backward Class (OBC), and other than SC/ST/OBC. SC and ST are considered as among the most deprived and socioeconomically disadvantaged groups in India. The individuals in the general class represent the hierarchically higher social status in India. On the other hand, although, OBC is an educationally, economically, and socially backward group, but, hierarchically, this group is considered as in better social position than SC and ST category [60].

According to the procedure suggested by Dong and Simon [61], we included four social participation activities: (1) eat out of the house, (2) go to the park/beach, visit relatives/friends, (3) go out to a movie, and (4) attend political/community group meetings. Based on the frequency of participation, responses were coded as '1' for daily/several times a week/less than

weekly, and '0' for several times a month/at least once a month/rarely/once in a year/never/not relevant for these activities.

Statistical analysis

Descriptive statistics (means and percentages) were used to present the characteristics of the older adults included in the final sample. Two sample test for difference of mean/ proportion was used to assess the gender differences in the reporting of cognition score. Moreover, linear regression models were employed to determine the association of two-way stratification of social engagements and depressive symptoms, and social engagement and gender, and gender and depressive symptoms with cognitive function. Also, linear regression models were used to assess the association of three-way stratification of social engagement, gender, and depressive symptoms with cognitive functioning. We conducted a correlation analysis and a linear regression analysis of depressive symptoms on social engagement. The total effect was divided into direct effects (the association of social engagement with cognitive function controlling for depressive symptoms) and indirect effects (the association of social engagement with cognitive function through depressive symptoms) using linear regression based on Karlson–Holm–Breen (KHB) method [62–64] for the whole sample. The KHB method is a recently developed method for assessing the confounding effects that allow total effects to be divided into direct and indirect effects for both discrete and continuous variables. Contrary to other decomposition methods, the KHB-method provides unbiased decomposition results [65]. The confounding percentage (the indirect effect divided by the total effect) is interpreted as the percentage of the association explained by the confounder variable. All statistical models were adjusted for various predictors, including age, gender, education, working status, residence, religion, caste, region, BMI, MPCE, smoking status, consuming smokeless tobacco, alcohol drinking, hypertension, diabetes, cancer, heart disease, and stroke. The statistical analysis was performed using Stata 15.1. We incorporated the complex design of the survey data used in the study. Stata's survey command (*svyset*) was used to incorporate the complex design of LASI, and adjusted for sampling weight, clustering, and stratification in the sampling design. The data set do not contain the information of stratum and so, place of residence (rural/urban) is considered as two different strata. A p-value of less than 0.05 was considered statistically significant.

Patient and public involvement

None.

Results

Table 2 presents the descriptive information for cognitive function, socio-demographic factors, lifestyle factors, and chronic conditions of older men and women included in the analysis. The mean cognition score of men was higher than that of women (25.9 vs. 21.3). Nearly 85% of older men had at least a medium level of social engagements, while this proportion was 53% for older women. Regarding depressive symptoms score, older women had a slightly higher mean score than older men (3.0 vs. 2.8). On average, men were slightly older than women (68.7 vs. 68.2 years). A higher proportion of older women were uneducated than older men (68.7% vs. 35.1%). Around 44.0% of the older men and 19.3% of women were currently working at the time of the survey. A higher proportion of older women were overweight or obese than men (28.6% vs. 20.2%). Around 25% of men and only 4% of women were current tobacco smokers, while 24% of men and 16% of women were consuming smokeless tobacco at the time of the survey. Alcohol consumption is much higher among older men than women (32.4% vs. 4.4%). According to measured hypertension status, the prevalence of high blood pressure was slightly higher among older women than men (39.9% vs. 37.9%). According to religion, around three-fourths of both older men and women participants were Hindus. Most of the participants were rural residents (67.7% men vs. 65.8% women). Table 2 also shows the gender comparison across all the selected variable for the sample. The results indicate the significant gender differences in the social engagement, cognitive functioning, depressive symptoms, age, social activities, educational status, work status, residence, BMI, current use of tobacco use, heart disease and stroke.

Table 2. Descriptive statistics for sample characteristics of older adults included in the analysis, by gender, India (N = 23,584)

	Men		Women		Difference (%)	p-value for difference
	n	%	n	%		
Social engagement						
Low	1,681	14.7	5,720	47.0	-32.3	<0.001
Medium	8,347	73.2	5,705	46.8	26.4	<0.001
High	1,375	12.1	756	6.2	5.9	<0.001
Cognition[a]	25.9	6.7	21.3	7.0	4.6	<0.001[†]
Depressive symptoms score[a]	2.8	1.6	3.0	1.7	-0.2	<0.001[†]
Age (years)[a]	68.7	7.1	68.2	7.2	0.5	<0.001[†]
Social Activities (0-5)[a]	0.3	0.6	0.2	0.5	0.1	<0.001[†]
Education level						
No education	4,005	35.1	8,364	68.7	-33.6	<0.001
Primary	3,505	30.7	2,404	19.7	11.0	<0.001
Secondary	2,537	22.2	1,006	8.3	13.9	<0.001
Higher	1,356	11.9	407	3.3	8.6	<0.001
Currently working						
No	6,383	56.0	9,830	80.7	-24.7	<0.001
Yes	5,020	44.0	2,351	19.3	24.7	<0.001
Place of residence						
Rural	7,719	67.7	8,018	65.8	1.9	0.002
Urban	3,684	32.3	4,163	34.2	-1.9	0.002

Religion						
Hindu	8,405	73.7	9,009	74.0	-0.3	0.662
Muslim	1,265	11.1	1,311	10.8	0.3	0.416
Christian	1,154	10.1	1,256	10.3	-0.2	0.628
Others[$]	579	5.1	605	5.0	0.1	0.697
Caste						
Scheduled caste	1,921	16.8	2,032	16.7	0.1	0.735
Scheduled tribe	1,975	17.3	2,159	17.7	-0.4	0.414
OBC[#]	4,428	38.8	4,681	38.4	0.4	0.525
Others	3,079	27.0	3,309	27.2	-0.2	0.778
Regions						
North	2,104	18.5	2,291	18.8	-0.3	0.482
Central	1,588	13.9	1,531	12.6	1.3	0.002
East	2,276	20.0	2,246	18.4	1.6	0.003
Northeast	1,399	12.3	1,466	12.0	0.3	0.583
West	1,409	12.4	1,666	13.7	-1.3	0.003
South	2,627	23.0	2,981	24.5	-1.5	0.010
BMI categories						
Normal	6,406	56.2	5,961	48.9	7.3	<0.001
Underweight	2,698	23.7	2,738	22.5	1.2	0.031
Overweight/Obese	2,299	20.2	3,482	28.6	-8.4	<0.001
MPCE quintile						
Poorest	2,283	20.0	2,544	20.9	-0.9	0.100
Poorer	2,318	20.3	2,543	20.9	-0.6	0.297
Middle	2,334	20.5	2,528	20.8	-0.3	0.588
Richer	2,283	20.0	2,364	19.4	0.6	0.236
Richest	2,185	19.2	2,202	18.1	1.1	0.033
Currently smoking tobacco						
No	8,570	75.2	11,640	95.6	-20.4	<0.001
Yes	2,833	24.8	541	4.4	20.4	<0.001
Currently consuming smokeless tobacco						
No	8,638	75.8	10,233	84.0	-8.2	<0.001
Yes	2,765	24.2	1,948	16.0	8.2	<0.001
Drinking status						
Never	7,718	67.7	11,650	95.6	-27.9	<0.001
Infrequent non-heavy	2,269	19.9	299	2.5	17.4	<0.001
Frequent non-heavy	748	6.6	122	1.0	5.6	<0.001
Heavy episodic drinker	668	5.9	110	0.9	5.0	0.193
Hypertension Status						
Normal	2,612	22.9	2,774	22.8	0.1	0.808
Pre-hypertensive	4,465	39.2	4,550	37.4	1.8	0.004
High BP	4,326	37.9	4,857	39.9	-2.0	0.002
Diabetes						
No	9,599	84.2	10,388	85.3	-1.1	0.019
Yes	1,804	15.8	1,793	14.7	1.1	0.019
Cancer						
No	11,332	99.4	12,088	99.2	0.2	0.193
Yes	71	0.6	93	0.8	-0.2	0.193
Heart disease						
No	10,721	94.0	11,678	95.9	-1.9	<0.001
Yes	682	6.0	503	4.1	1.9	<0.001
Stroke						
No	11,091	97.3	11,978	98.3	-1.0	<0.001
Yes	312	2.7	203	1.7	1.0	<0.001
Total	11,403	100	12,181	100		

Note. [#]Other Backward Classes, [a]Mean and standard deviation; [$]includes Sikh, Buddhist/neo-Buddhist, Jain, Parsi/Zoroastrian and others; BP- Blood Pressure.

The average cognitive score increased with an increase in the level of social engagement, and it was higher among the non-depressed older adults (24.0 vs. 22.1) (Supplementary; Table S1). Moreover, the prevalence of depressive symptoms decreased with an increase in the level of social engagement.

Table 3. Gender comparison of the mean cognition score (0-43) according to background characteristics in older adults, India (N = 23,584)

	Men	Women	Difference	p-value for difference[1]
Social engagement				
Low	23.7	19.7	4.0	<0.001
Medium	26.0	22.3	3.7	<0.001
High	27.6	24.2	3.4	<0.001
Age groups				
60-69	26.6	22.2	4.4	<0.001
70-79	24.9	19.9	5.0	<0.001
80+	23.3	18.2	5.1	<0.001
Social activities				
0	23.1	18.7	4.4	<0.001
1	25.3	21.3	4.0	<0.001
2	28.8	25.1	3.7	<0.001
3+	30	28.2	1.8	<0.001
Education level				
No education	21.5	19.0	2.5	<0.001
Primary	26.1	24.5	1.6	<0.001
Secondary	29.7	29.6	0.1	0.203
Higher	31.0	31.9	-0.9	<0.001
Currently working				
No	25.7	21.2	4.5	<0.001
Yes	26.0	20.8	5.2	<0.001
Place of residence				
Rural	24.7	19.8	4.9	<0.001
Urban	28.7	24.4	4.3	<0.001
Religion				
Hindu	25.9	21.2	4.7	<0.001
Muslim	25.9	20.5	5.4	<0.001
Christian	24.6	21.8	2.8	<0.001
Others[$]	24.3	21.2	3.1	<0.001
Caste				
Scheduled caste	24.1	19.4	4.7	<0.001
Scheduled tribe	22.2	17.8	4.4	<0.001
OBC[#]	26.2	21.7	4.5	<0.001
Others	27.4	22.4	5.0	<0.001
Regions				
North	25.4	20.0	5.4	<0.001
Central	25.9	20.8	5.1	<0.001
East	25.4	20.2	5.2	<0.001
Northeast	26.5	21.3	5.2	<0.001
West	25.7	21.0	4.7	<0.001
South	26.3	23.2	3.1	<0.001

BMI categories				
Normal	26.0	20.8	5.2	<0.001
Underweight	23.3	18.2	5.1	<0.001
Overweight/Obese	28.7	24.5	4.2	<0.001
MPCE quintile				
Poorest	24.2	19.6	4.6	<0.001
Poorer	24.9	20.3	4.6	<0.001
Middle	26.4	21.7	4.7	<0.001
Richer	26.3	21.9	4.4	<0.001
Richest	27.4	22.7	4.7	<0.001
Currently smoking tobacco				
No	26.1	21.2	4.9	<0.001
Yes	24.7	18.1	6.6	<0.001
Currently consuming smokeless tobacco				
No	26.1	21.4	4.7	<0.001
Yes	25.0	19.5	5.5	<0.001
Drinking status				
Never	26.2	21.2	5.0	<0.001
Infrequent non-heavy	25.4	18.9	6.5	<0.001
Frequent non-heavy	23.5	16.7	6.8	<0.001
Heavy episodic drinker	22.9	15.7	7.2	<0.001
Hypertension status				
Normal	24.7	20.6	4.1	<0.001
Pre-hypertensive	26.1	21.6	4.5	<0.001
High BP	26.2	20.9	5.3	<0.001
Diabetes				
No	25.5	20.8	4.7	<0.001
Yes	27.7	23.3	4.4	<0.001
Cancer				
No	25.8	21.1	4.7	<0.001
Yes	27.8	22.4	5.4	<0.001
Heart disease				
No	25.7	21.1	4.6	<0.001
Yes	27.7	22.5	5.2	<0.001
Stroke				
No	25.8	21.1	4.7	<0.001
Yes	24.3	19.4	4.9	<0.001
Total	25.8	21.1	4.7	<0.001

Note: [1]Based on two sample t-test.
[#]Other Backward Classes; [$]includes Sikh, Buddhist/neo-Buddhist, Jain, Parsi/Zoroastrian and others; BP- Blood Pressure.

Table 3 presents the gender differences in the mean cognition score according to selected covariates. Results suggest a significant gender difference in the cognitive performance (difference=4.7; p<0.001). Men had significantly greater mean cognition score than women irrespective of age, working status, number of social activities, residence, obesity status, MPCE

quintiles, tobacco and alcohol use, and morbidity status. With regard to education, women with higher education had significantly greater mean cognitive score than men.

Table 4. Linear regression results of stratifications of social engagement, gender, and depressive symptoms on cognitive functioning (N = 23,584)

	β	(95% CI)
Social engagements # Depressive symptoms		
Low + depressive symptoms	-0.61***	(-0.66, -0.56)
Medium + depressive symptoms	-0.28***	(-0.33, -0.23)
High + depressive symptoms	-0.10*	(-0.20, -0.01)
Social engagements # Gender		
Low + Men	-1.12***	(-1.53, -0.72)
Low + Women	-3.45***	(-3.81, -3.08)
Medium + Men	-0.35*	(-0.68, -0.01)
Medium + Women	-2.39***	(-2.75, -2.03)
High + Men®		
High + Women	-1.54***	(-2.11, -0.98)
Gender # Depressive symptoms		
Men + depressive symptoms	-0.10***	(-0.15, -0.05)
Women + depressive symptoms	-0.66***	(-0.70, -0.61)
Social engagements # Gender # Depressive symptoms		
Low + Men + depressive symptoms	-0.24***	(-0.31, -0.16)
Low + Women + depressive symptoms	-0.75***	(-0.80, -0.70)
Medium + Men + depressive symptoms	-0.07**	(-0.12, -0.02)
Medium + Women + depressive symptoms	-0.55***	(-0.60, -0.49)
High + Men + depressive symptoms	0.07	(-0.05, 0.18)
High + Women + depressive symptoms	-0.35***	(-0.50, -0.20)

Note: Controlled variables were age, gender, education, working status, social activities, place of residence, religion, caste, region, body mass index (BMI), MPCE, smoking status, consuming smokeless tobacco, alcohol status, hypertension, diabetes, cancer, heart disease, and stroke. CI = confidence interval; ® - reference category.
* p<0.05, ** p<0.01, *** p<0.001

Table 4 shows the linear regression results for the two-way stratifications of social engagement and depressive symptoms, and social engagement and gender, and, gender and depressive symptoms, and three-way stratification of the social engagement, gender, and depressive symptoms on the cognitive functioning after adjusting the selected explanatory variables including socio-demographic, lifestyle, and chronic conditions. Two-way stratification of social engagements and depressive symptoms depicts the estimated effects of the depressive symptoms on cognitive functioning for all levels of social engagement. The negative relationship between depressive symptoms and cognitive score significantly reduces with higher level of social engagement. Furthermore, the two-way stratification of social engagement and gender suggests that men with low level of social engagements had significantly poor cognitive functioning (β=-1.12; 95%CI: -1.53,-0.72) compared with men

with high level of social engagements. On the other hand, women with higher level of social engagement performed poorly on cognitive tests (β=-1.54; 95%CI: -2.11,-0.98) than men with higher social engagements. The two-way stratification of the gender and depressive symptoms suggests that the magnitude of negative relationship between depressive symptoms and cognitive functioning is higher in women than in men. The results corresponding to three-way stratification between social engagement, gender, and depressive symptoms portrays that social engagement's buffering effects are lower in women than men. The complete table with all the covariates is provided in the supplementary material (Table S2).

Table 5. Linear regression results of stratifications of gender and education on cognitive functioning in older adults, LASI, 2017-18 (N = 23,584)

	β	(95% CI)
Gender # Education		
Men # No education®		
Men # Primary	3.95***	(3.71,4.19)
Men # Secondary	6.73***	(6.46,7.01)
Men # Higher	7.24***	(6.90,7.57)
Women # No education	-2.60***	(-2.82,-2.39)
Women # Primary	1.80***	(1.49,2.10)
Women # Secondary	5.86***	(5.45,6.27)
Women # Higher	7.67***	(7.06,8.28)

Note: Controlled for age, social engagements, depressive symptoms working status, social activities, place of residence, religion, caste, region, body mass index (BMI), MPCE, smoking status, consuming smokeless tobacco, alcohol status, hypertension, diabetes, cancer, heart disease, and stroke. CI = confidence interval; ® - reference category.
* p<0.05, ** p<0.01, *** p<0.001

Table 5 presents the regression results for two-way stratification of gender and educational status on the cognitive functioning after controlling for selected covariates. The results indicate that men with higher education significantly better cognition than men with no education (β=7.24; 95% CI: 6.90, 7.57). Women with no education had poor cognitive performance than men with no education (β=-2.60; 95% CI: -2.82, -2.39). The complete table including all the covariates adjusted in the analysis, is provided in supplementary material (Table S3). The correlation between social engagement and depressive symptoms was -0.12 (p<.001) (Supplementary; Table S4).

The linear regression model demonstrated that higher levels of social engagement was significantly negatively associated with depressive symptoms (β=-0.18, p<.001) (Supplementary; Table S4). Table 6 shows the results obtained from KHB analysis for the

sample under study. After controlling the selected covariates, results indicate that depressive symptoms significantly confounded 14.4% of the association between social engagement and cognitive function.

Table 6. Effect of social engagement on cognition confounded by depressive symptoms (Karlson–Holm–Breen method), by gender, LASI, 2017-19 (N = 23,584)

	β	(95% CI)
Social Engagements		
Total Effect	0.52***	(0.40,0.63)
Direct effect of social engagement	0.44***	(0.33,0.55)
Indirect effect via depressive symptoms	0.07***	(0.06,0.09)
N	**23,584**	
Conf.-Perc[a]	**14.40%**	

Note: Controlled variables were age, gender, education, working status, social activities, place of residence, religion, caste, region, body mass index (BMI), MPCE, smoking status, consuming smokeless tobacco, alcohol status, hypertension, diabetes, cancer, heart disease, and stroke. CI = confidence interval. [a]Confounding percentage.
* p<0.05, ** p<0.01, *** p<0.001

Discussion

The COVID-19 pandemic has called for international attention on the importance of social relationships/ social engagement/ social inclusion in terms of supporting the physical, emotional and cognitive health of older adults [66, 67]. Evidence suggests significant correlations exist between engaging in social activities with enhanced cognitive outcomes [10, 50]. However, depression and other mental illnesses that may lead to reduced social networks and activities resulting in cognitive decline among older adults are little explored, especially in LMICs. The present study examined the direct, indirect, and total effects of social engagement on cognitive functioning confounded by depressive symptoms among older adults in India. We found that a higher level of social engagement was associated with greater cognitive functioning, whereas depressive symptoms confounded 14.4% of the observed association. In addition, gender-based moderation effects were also examined which were found significant with female disadvantages.

Structural aspects of social network are recommended to be essential to maintain an optimal level of cognitive functioning [68]. As documented, social networks and activity are related concepts and individuals who have a larger social networks tend to take part in more social activities [69]. Similarly, the satisfaction achieved from the social and support networks was observed to lead to better episodic memory performance, and processing speed and global

cognition [70]. The main effect hypothesis in the present study is confirmed by the results showing that social engagements are independently associated with a greater level of cognitive functioning. The finding is consistent with previous studies linking the social involvement enhancing the wellbeing and boosting the self-esteem and creating a sense of belonging that result in better cognitive functioning [71–73]. A systematic review reported that although the exact nature of the associations are unclear, different aspects of social relationships such as social activity, social networks and social support and composite measures of social relationships are associated with cognitive functioning [74]. Thus, social engagement interventions should be prioritized in public policy to help older adults optimize their cognitive health, regardless of underlying mechanisms.

Although social engagements including the structural support from the spouse and family members are found to enhance cognitive functioning [75–77], the role of mental illnesses adversely affecting the association is less investigated. A recent study found the mediating role of hippocampal volume of brain which is known to be affected by a variety of psychiatric disorders in the association of emotional support with specific cognitive domains [78]. Consistently, the current results showed that depressive symptom was significant confounder in the social engagement-cognitive functioning relationship. The finding is also in parallel with a recent study conducted in China showing the mediating role of depressive symptoms in the protective effect of frequent exercise on cognitive functioning [79]. Therefore, our results support the previous finding that the protective effect of social relationships is more related to the aspects of quality and functionality of such relationships than the quantity and structural characteristics [80]. Furthermore, the indirect effect of social engagements on cognitive functioning suggest that social resources can be related to better cognitive functioning through minimizing mental disorders in older adults, indicating that depressive symptoms may serve as an important intervening target and that reversing such illnesses might be related to a greater cognitive functioning. This is similar to an earlier finding that lack of social engagements may be particularly detrimental to late-life cognitive abilities when it is associated with mental illnesses [81]. Earlier meta-analyses and reviews have investigated loneliness, being one of the depressive symptoms, and social isolation together as part of health promotion interventions and suggested that loneliness is often experienced as a part of lack of social engagement and partly attribute to the factors of cognitive declines [82, 83]. This indicates the need for social interventions that promote active participation of older people and help them in maintaining social and structural relationships and coping with age-related stress factors.

The available evidence suggests that there are gender differences in the relationship between social engagement and cognitive functioning. For instance, in developed countries, numerous studies have found that the cognitive performance of older women is as good as or better than that of men [84–86]. In contrast, studies of cognitive abilities in developing countries find older women often perform worse than older men [87, 88]. Moreover, earlier studies in India reported a relatively lower cognitive functioning level among older women than men [46–48, 89]. In line with the previous literature, the current findings suggest a significant female disadvantage in cognitive function among older Indian adults and call for special attention with regard to public policy frameworks, clinical practice and future research.

On the other hand, studies suggest that a greater social engagement protects against rapid cognitive decline, particularly among low-educated older women [90]. In addition, social networks were reported as highly influential for women than men in determining better health behaviours related to cognitive maintenance [87]. In contrast to these studies, our findings suggest a greater buffering effects of the social engagements on cognitive functioning in men than in women. Nevertheless, it still needs to be further investigated whether gender differences exist in the association of social engagements confounded by depressive symptoms with cognitive functioning using longitudinal design.

There are several limitations of the present study to be noted. The composite index of social engagement was generated from the questions which were self-reported. The responses may have been exaggerated or under-reported. However, self-reporting is endorsed as an optimal method to measure how the participants subjectively find themselves having social networks and involved in social activities. On the other hand, exploring the aspect of social engagements that include participating in indoor games for example, as distinct from domains of cognitive activities is questionable, since it is not feasible to completely differentiate social engagement from cognitive engagements. Also, many activities have a psychiatric element which may have positive impacts on cognitive processes and a complex confounding effect in the associations of three key variables in our study. Hence, considering the differences in relationships between cognitive domains and the distinct forms of social engagements that also include structural support from marital status and living arrangements, it is important to define social relationships more clearly in future studies to achieve more reliable findings.

Besides, in a population with huge proportion of illiterate people, the assessment of cognitive functioning with multiple domains might be subject to measurement error which can create

bias in the current findings. Similarly, older women in India who are largely deprived of education and other opportunities including work participation might have resulted in greater gender gap in cognitive functioning observed in our study. Finally, the present study was cross-sectional, and thus, a causal relationship between the variables cannot be inferred. Further investigation with longitudinal design is needed to explore the neural mechanisms that underlie the effects of social engagements on cognitive decline. Future research might also consider the impact of technology, internet and social media on social relationships, particularly feelings of social support.

Conclusion

The positive association of social engagement with cognitive functioning was significantly confounded by depressive symptoms, suggesting the need for maintaining social relations that help improve cognitive functioning among older adults. This needs to be confirmed with future longitudinal and interventional studies. The study also highlights the potential of social engagements independently or with others as an intervention to prevent cognitive impairment among older individuals, especially among women.

Abbreviations:

MPCE: Monthly Per capita Consumption Expenditure

CES-D: Center for Epidemiological Studies-Depression

KHB: Karlson–Holm–Breen

Declarations

Contributors: MK and LKD conceived and designed the research paper. MK analyzed the data. MK and TM contributed agents/materials/analysis tools. MK and TM wrote the manuscript. LKD provides supervision and validation. MK, TM and LKD refined the manuscript. All authors have read and approved the manuscript.

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Figure title:

Figure 1. Conceptual framework of the study

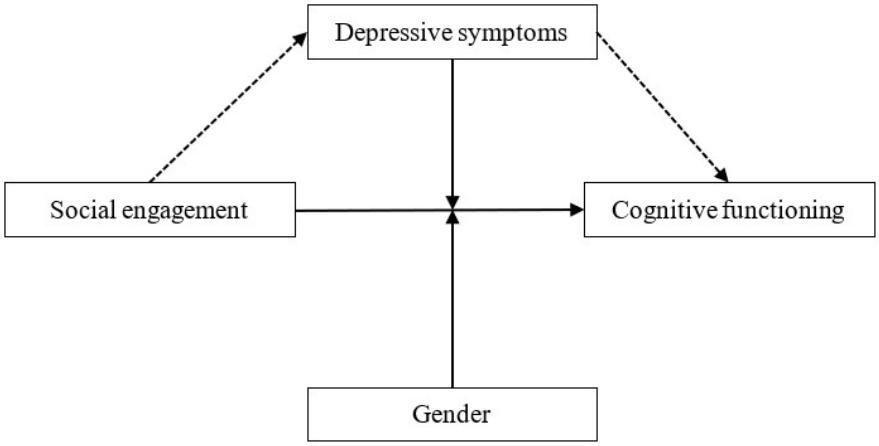

Figure 1. Conceptual framework of the study.

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Supplementary file

Table S1. Descriptive statistics for the cognitive function (0-43) and level of social engagements according to selected variables, (N = 23,584), LASI, 2017-19

	Cognitive function (0-43)		*Low (n=7,401)*		*Medium (n=14,052)*		*High (n=2,131)*	
	N	*Mean (sd.)*						
Social Engagements								
Low	7,401	20.7 (7.1)	-	-	-	-	-	-
Medium	14,052	24.5 (7)	-	-	-	-	-	-
High	2,131	26.8 (6.6)	-	-	-	-	-	-
Depression[a]								
No	17,432	24 (7.2)	5,022	67.9	10,683	76.0	1,727	81.0
Yes	6,152	22.1 (7.2)	2,379	32.1	3,369	24.0	404	19.0
Age (years)								
60-69	14,691	24.6 (6.9)	3,512	47.5	9,721	69.2	1,458	68.4
70-79	6,735	22.5 (7.2)	2,624	35.5	3,529	25.1	582	27.3
80+	2,158	19.3 (7.5)	1265	17.1	802	5.7	91	4.3
Social Activities								
0	8,235	20.4 (6.7)	3,133	42.3	4,808	34.2	294	13.8
1	8,380	22.9 (6.6)	2,849	38.5	4,968	35.4	563	26.4
2	4,522	27.2 (6.4)	1065	14.4	2,855	20.3	602	28.2
3+	2,447	29.4 (6)	354	4.8	1,421	10.1	672	31.5
Education level								
No education	12,369	19.7 (6)	4,946	66.8	6,683	47.6	740	34.7
Primary	5,909	25.5 (6)	1,559	21.1	3,707	26.4	643	30.2
Secondary	3,543	29.5 (5.1)	663	9.0	2,405	17.1	475	22.3
Higher	1,763	31.8 (4.6)	233	3.1	1,257	8.9	273	12.8
Currently working								
No	16,213	23.1 (7.4)	5,986	80.9	8,862	63.1	1,365	64.1
Yes	7,371	24.3 (6.9)	1,415	19.1	5,190	36.9	766	35.9
Place of Residence								
Rural	15,737	22.1 (7)	4,915	66.4	9,570	68.1	1,252	58.8
Urban	7,847	26.3 (7)	2,486	33.6	4,482	31.9	879	41.2
Religion								
Hindu	17,414	23.6 (7.2)	5,652	76.4	10,634	75.7	1,128	52.9
Muslim	2,576	23.3 (7)	789	10.7	1,407	10.0	380	17.8
Christian	2,410	22.9 (7.7)	645	8.7	1,293	9.2	472	22.1
Others[$]	1,184	23.5 (7.2)	315	4.3	718	5.1	151	7.1
Caste								
Scheduled caste	3,953	22.1 (6.7)	1356	18.3	2,384	17.0	213	10.0
Scheduled tribe	4,134	21 (7.5)	1257	17.0	2,310	16.4	567	26.6
OBC[#]	9,109	24 (7.1)	2,895	39.1	5,556	39.5	658	30.9
Others	6,388	25.4 (7)	1,893	25.6	3,802	27.1	693	32.5
Regions								
North	4,395	23.5 (7.1)	1237	16.7	2,617	18.6	541	25.4
Central	3,119	23.2 (6.7)	1019	13.8	1,913	13.6	187	8.8
East	4,522	23 (7.2)	1,434	19.4	2,857	20.3	231	10.8
Northeast	2,865	23.1 (7.6)	796	10.8	1,567	11.2	502	23.6
West	3,075	22.9 (7.2)	928	12.5	1,825	13.0	322	15.1
South	5,608	24.7 (7.5)	1,987	26.8	3,273	23.3	348	16.3
BMI categories								
Normal	12,367	23.6 (7.1)	3,674	49.6	7,511	53.5	1,182	55.5
Underweight	5,436	20.7 (6.9)	2,051	27.7	3,080	21.9	305	14.3

Overweight/Obese	5,781	26.1 (7)	1,676	22.6	3,461	24.6	644	30.2
MPCE quintile								
Poorest	4,827	21.8 (7.1)	1,695	22.9	2,795	19.9	337	15.8
Poorer	4,861	22.7 (7.1)	1,614	21.8	2,873	20.4	374	17.6
Middle	4,862	23.6 (7.1)	1,478	20.0	2,909	20.7	475	22.3
Richer	4,647	24.3 (7.1)	1,389	18.8	2,832	20.2	426	20.0
Richest	4,387	25.6 (7.3)	1225	16.6	2,643	18.8	519	24.4
Currently smoking tobacco								
No	20,210	23.5 (7.3)	6,719	90.8	11,747	83.6	1,744	81.8
Yes	3,374	23.7 (6.7)	682	9.2	2,305	16.4	387	18.2
Currently chewing tobacco								
No	18,871	23.7 (7.3)	5,930	80.1	11,198	79.7	1,743	81.8
Yes	4,713	22.9 (6.9)	1,471	19.9	2,854	20.3	388	18.2
Drinking Status								
Never	19,368	23.4 (7.3)	6,573	88.8	11,099	79.0	1,696	79.6
Infrequent non-heavy	2,568	24.8 (6.9)	484	6.5	1,781	12.7	303	14.2
Frequent non-heavy	870	23.3 (7.2)	191	2.6	617	4.4	62	2.9
Heavy episodic drinker	778	22.9 (7.1)	153	2.1	555	3.9	70	3.3
Hypertension Status								
Normal	5,386	22.9 (7)	1,512	20.4	3,386	24.1	488	22.9
Pre-hypertensive	9,015	23.9 (7.2)	2,644	35.7	5,505	39.2	866	40.6
High BP	9,183	23.5 (7.4)	3,245	43.8	5,161	36.7	777	36.5
Diabetes								
No	19,987	23.1 (7.2)	6,436	87.0	11,782	83.8	1,769	83.0
Yes	3,597	25.9 (7)	965	13.0	2,270	16.2	362	17.0
Cancer								
No	23,420	23.5 (7.3)	7,355	99.4	13,955	99.3	2,110	99.0
Yes	164	24.5 (7.2)	46	0.6	97	0.7	21	1.0
Heart Disease								
No	22,399	23.4 (7.3)	7,096	95.9	13,300	94.6	2,003	94.0
Yes	1,185	25.8 (7)	305	4.1	752	5.4	128	6.0
Stroke								
No	23,069	23.5 (7.3)	7,258	98.1	13,726	97.7	2,085	97.8
Yes	515	23 (7.2)	143	1.9	326	2.3	46	2.2
Total	**23,584**	**23.5 (7.3)**	**7,401**	**100.0**	**14,052**	**100.0**	**2,131**	**100.0**

Note: [a] overall score ranges from zero to 10 and individuals with score of four or more are considered as depressed; [#] Other Backward Classes, [$] includes Sikh, Buddhist/neo-Buddhist, Jain, Parsi/Zoroastrian and others; BP- Blood Pressure.

Note: *p<0.05, **p<0.01, ***p<0.001

Table S2. Linear regression results of stratifications of social engagement, gender, and depressive symptoms on cognitive functioning, by gender, (N = 23,584).

	β	(95% CI)	β	(95% CI)	β	(95% CI)	β	(95% CI)
Social engagements # Depressive symptoms								
Low + depressive symptoms	-0.61***	(-0.66,-0.56)	-	-	-	-	-	-
Medium + depressive symptoms	-0.28***	(-0.33,-0.23)	-	-	-	-	-	-
High + depressive symptoms	-0.10*	(-0.20,-0.01)	-	-	-	-	-	-
Social engagements # Gender					-	-	-	-
Low + Men®	-	-	-1.12***	(-1.53,-0.72)	-	-	-	-
Low + Women	-	-	-3.45***	(-3.81,-3.08)	-	-	-	-
Medium + Men	-	-	-0.35*	(-0.68,-0.01)	-	-	-	-
Medium + Women	-	-	-2.39***	(-2.75,-2.03)	-	-	-	-
High + Men	-	-			-	-	-	-
High + Women	-	-	-1.54***	(-2.11,-0.98)	-	-	-	-
Gender # Depressive symptoms	-	-	-	-	-	-	-	-
Men + depressive symptoms	-	-	-	-	-0.10***	(-0.15,-0.05)	-	-
Women + depressive symptoms	-	-	-	-	-0.66***	(-0.70,-0.61)	-	-
Social engagements # Gender # Depressive symptoms							-	-
Low + Men + depressive symptoms	-	-	-	-	-	-	-0.24***	(-0.31,-0.16)
Low + Women + depressive symptoms	-	-	-	-	-	-	-0.75***	(-0.80,-0.70)
Medium + Men + depressive symptoms	-	-	-	-	-	-	-0.07**	(-0.12,-0.02)
Medium + Women + depressive symptoms	-	-	-	-	-	-	-0.55***	(-0.60,-0.49)
High + Men + depressive symptoms	-	-	-	-	-	-	0.07	(-0.05,0.18)
High + Women + depressive symptoms	-	-	-	-	-	-	-0.35***	(-0.50,-0.20)
Social Activities	0.48***	(0.33,0.62)	0.43***	(0.28,0.57)	0.57***	(0.43,0.71)	0.48***	(0.34,0.63)
Age (years)	-0.11***	(-0.12,-0.10)	-0.13***	(-0.14,-0.12)	-0.14***	(-0.15,-0.13)	-0.13***	(-0.14,-0.12)
Education level								
No education®								
Primary	4.82***	(4.64,4.99)	4.31***	(4.13,4.49)	4.47***	(4.29,4.65)	4.45***	(4.27,4.63)
Secondary	8.27***	(8.05,8.49)	7.49***	(7.26,7.72)	7.78***	(7.56,8.01)	7.76***	(7.53,7.98)
Higher	9.28***	(8.99,9.56)	8.09***	(7.79,8.39)	8.57***	(8.28,8.87)	8.54***	(8.25,8.84)
Currently working								
No®								
Yes	0.87***	(0.71,1.03)	0.42***	(0.26,0.58)	0.59***	(0.43,0.75)	0.58***	(0.43,0.74)
Place of Residence								

Rural®								
Urban	1.16***	(0.99,1.34)	1.37***	(1.20,1.55)	1.25***	(1.08,1.42)	1.26***	(1.09,1.43)
Religion								
Hindu®								
Muslim	0.37**	(0.13,0.60)	0.1	(-0.13,0.34)	0.26*	(0.03,0.50)	0.24*	(0.00,0.47)
Christian	-0.26	(-0.70,0.17)	-0.15	(-0.59,0.28)	-0.11	(-0.54,0.32)	-0.16	(-0.59,0.27)
Others$	0.13	(-0.24,0.49)	0.07	(-0.30,0.44)	0.06	(-0.30,0.43)	0.05	(-0.31,0.42)
Caste								
Scheduled caste®								
Scheduled tribe	-1.40***	(-1.69,-1.11)	-1.24***	(-1.52,-0.95)	-1.28***	(-1.57,-0.99)	-1.29***	(-1.57,-1.00)
OBC#	0.58***	(0.39,0.77)	0.65***	(0.46,0.84)	0.64***	(0.45,0.83)	0.62***	(0.43,0.81)
None of them	0.44***	(0.23,0.66)	0.59***	(0.38,0.81)	0.54***	(0.32,0.75)	0.52***	(0.31,0.74)
Region								
North®								
Central	1.58***	(1.33,1.83)	1.36***	(1.12,1.61)	1.52***	(1.27,1.77)	1.55***	(1.30,1.79)
East	0.69***	(0.45,0.93)	0.73***	(0.48,0.97)	0.70***	(0.46,0.94)	0.72***	(0.48,0.96)
Northeast	0.87***	(0.41,1.33)	1.21***	(0.75,1.67)	0.92***	(0.46,1.38)	0.97***	(0.52,1.43)
West	-0.93***	(-1.19,-0.67)	-0.61***	(-0.86,-0.35)	-0.91***	(-1.17,-0.65)	-0.86***	(-1.12,-0.61)
South	1.11***	(0.85,1.36)	1.07***	(0.82,1.33)	1.02***	(0.76,1.27)	1.10***	(0.84,1.35)
BMI categories								
Normal®								
Underweight	-1.07***	(-1.24,-0.91)	-1.15***	(-1.31,-0.98)	-1.14***	(-1.31,-0.97)	-1.11***	(-1.28,-0.95)
Overweight/obese	0.77***	(0.59,0.95)	0.98***	(0.80,1.16)	0.90***	(0.72,1.08)	0.87***	(0.69,1.05)
MPCE quintile								
Poorest®								
Poorer	0.10	(-0.11,0.30)	0.15	(-0.06,0.35)	0.08	(-0.12,0.29)	0.09	(-0.11,0.30)
Middle	0.38***	(0.17,0.59)	0.50***	(0.30,0.71)	0.48***	(0.27,0.68)	0.44***	(0.24,0.65)
Richer	0.65***	(0.43,0.87)	0.79***	(0.57,1.00)	0.73***	(0.51,0.94)	0.71***	(0.49,0.93)
Richest	0.63***	(0.40,0.87)	0.78***	(0.55,1.02)	0.76***	(0.52,0.99)	0.72***	(0.49,0.95)
Currently smoking tobacco								
No®								
Yes	0.84***	(0.63,1.05)	0.16	(-0.05,0.38)	0.38***	(0.16,0.59)	0.39***	(0.17,0.60)
Currently chewing tobacco								
No®								
Yes	0.25**	(0.07,0.42)	0.00	(-0.18,0.17)	0.06	(-0.11,0.23)	0.08	(-0.09,0.26)

Drinking Status								
Never®								
Infrequent non-heavy	0.39**	(0.15,0.64)	-0.27*	(-0.52,-0.03)	-0.04	(-0.28,0.20)	-0.02	(-0.26,0.22)
Frequent non-heavy	-0.69***	(-1.09,-0.29)	-1.31***	(-1.72,-0.90)	-1.13***	(-1.53,-0.72)	-1.11***	(-1.51,-0.71)
Heavy episodic drinker	-1.22***	(-1.65,-0.78)	-1.85***	(-2.29,-1.42)	-1.63***	(-2.06,-1.20)	-1.63***	(-2.06,-1.20)
Hypertension Status								
Normal®								
Pre-hypertensive	0.20*	(0.03,0.38)	0.22*	(0.04,0.39)	0.16	(-0.01,0.34)	0.19*	(0.01,0.36)
High BP	0.10	(-0.08,0.28)	0.14	(-0.04,0.32)	0.07	(-0.11,0.25)	0.12	(-0.05,0.30)
Diabetes								
No®								
Yes	-0.52***	(-0.73,-0.32)	-0.64***	(-0.85,-0.44)	-0.57***	(-0.78,-0.37)	-0.58***	(-0.79,-0.38)
Cancer								
No®								
Yes	0.19	(-0.74,1.12)	0.27	(-0.65,1.20)	0.17	(-0.75,1.10)	0.15	(-0.77,1.07)
Heart Disease								
No®								
Yes	0.75***	(0.43,1.06)	0.52**	(0.21,0.84)	0.70***	(0.39,1.01)	0.66***	(0.35,0.97)
Stroke								
No®								
Yes	-1.33***	(-1.79,-0.87)	-1.71***	(-2.16,-1.25)	-1.54***	(-2.00,-1.08)	-1.51***	(-1.96,-1.05)

Note: CI = confidence interval. [#]Other Backward Classes; [$]includes Sikh, Buddhist/neo-Buddhist, Jain, Parsi/Zoroastrian and others; BP- Blood Pressure; and ® - reference category.
* p<0.05, ** p<0.01, *** p<0.001

Table S3. Linear regression results of stratifications of gender and education on cognitive functioning in older adults, LASI, 2017-18 (N = 23,584).

	β	(95% CI)
Gender # Education		
Men # No education®		
Men # Primary	3.95***	(3.71,4.19)
Men # Secondary	6.73***	(6.46,7.01)
Men # Higher	7.24***	(6.90,7.57)
Women # No education	-2.60***	(-2.82,-2.39)
Women # Primary	1.80***	(1.49,2.10)
Women # Secondary	5.86***	(5.45,6.27)
Women # Higher	7.67***	(7.06,8.28)
Depressive symptoms	-0.38***	(-0.42,-0.34)
Social engagements		
Low®		
Medium	0.84***	(0.68,1.00)
High	1.28***	(0.98,1.58)
Social Activities	0.43***	(0.28,0.57)
Age (years)	-0.13***	(-0.14,-0.12)
Currently working		
No®		
Yes	0.41***	(0.25,0.57)
Place of Residence		
Rural®		
Urban	1.27***	(1.10,1.45)
Religion		
Hindu®		
Muslim	0.13	(-0.10,0.36)
Christian	-0.27	(-0.70,0.16)
Others$	-0.08	(-0.45,0.28)
Caste		
Scheduled caste®		
Scheduled tribe	-1.28***	(-1.57,-1.00)
OBC#	0.59***	(0.40,0.77)
None of them	0.51***	(0.30,0.73)
Region		
North®		
Central	1.54***	(1.29,1.78)
East	0.71***	(0.47,0.95)
Northeast	1.07***	(0.61,1.52)
West	-0.84***	(-1.10,-0.59)
South	1.11***	(0.86,1.36)
BMI categories		
Normal®		
Underweight	-1.08***	(-1.25,-0.92)
Overweight/obese	0.90***	(0.72,1.08)
MPCE quintile		
Poorest®		
Poorer	0.11	(-0.09,0.31)
Middle	0.46***	(0.26,0.67)
Richer	0.72***	(0.50,0.93)
Richest	0.75***	(0.52,0.98)
Currently smoking tobacco		
No®		
Yes	0.13	(-0.08,0.35)

Currently chewing tobacco		
No®		
Yes	-0.02	(-0.19,0.15)
Drinking Status		
Never®		
Infrequent non-heavy	-0.34**	(-0.58,-0.09)
Frequent non-heavy	-1.46***	(-1.86,-1.05)
Heavy episodic drinker	-1.93***	(-2.36,-1.50)
Hypertension Status		
Normal®		
Pre-hypertensive	0.20*	(0.03,0.37)
High BP	0.16	(-0.01,0.34)
Diabetes		
No®		
Yes	-0.57***	(-0.78,-0.37)
Cancer		
No®		
Yes	0.23	(-0.69,1.14)
Heart Disease		
No®		
Yes	0.58***	(0.27,0.89)
Stroke		
No®		
Yes	-1.49***	(-1.94,-1.04)

Note: #Other Backward Classes; $includes Sikh, Buddhist/neo-Buddhist, Jain, Parsi/Zoroastrian and others; BP- Blood Pressure; CI = confidence interval; ® - reference category.
* p<0.05, ** p<0.01, *** p<0.001

Table S4. Mean, standard deviation, and correlation between social engagement and depression (n=23,584). LASI, 2017-19

Variables	1	2
Depression	-	
Social engagement	-0.12***	-
Mean	2.97	1.69
Standard deviation	1.68	0.67

Note: *p<0.05, **p<0.01, ***p<0.001

Table S5. Linear regression results of social engagement on depressive symptoms, by gender, (N = 23,584), LASI, 2017-19

	Men		Women		Total	
	β	**(95% CI)**	**β**	**(95% CI)**	**β**	**(95% CI)**
Social Engagement	-0.16***	(-0.22,-0.11)	-0.21***	(-0.25,-0.16)	-0.18***	(-0.22,-0.15)
Cognitive function	-0.03***	(-0.04,-0.03)	-0.04***	(-0.05,-0.04)	-0.04***	(-0.04,-0.03)
Social Activities	0.01	(-0.04,0.07)	0.06	(-0.01,0.13)	0.04	(-0.00,0.08)
Age (years)	-0.01**	(-0.01,-0.00)	0.00	(-0.00,0.00)	0.00	(-0.01,0.00)
Gender						
Men®	-	-	-	-		
Women	-	-	-	-	-0.06*	(-0.12,-0.00)
Education level						
No education®						
Primary	0.00	(-0.08,0.08)	-0.01	(-0.10,0.08)	-0.01	(-0.06,0.05)
Secondary	-0.03	(-0.13,0.06)	0.15*	(0.02,0.29)	0.03	(-0.05,0.10)
Higher	-0.08	(-0.20,0.04)	0.33**	(0.13,0.53)	0.03	(-0.07,0.13)
Currently working						
No®						
Yes	-0.10**	(-0.16,-0.03)	-0.04	(-0.11,0.04)	-0.06*	(-0.11,-0.01)
Place of Residence						
Rural®						
Urban	0.03	(-0.04,0.11)	-0.02	(-0.09,0.06)	0.01	(-0.04,0.06)
Religion						
Hindu®						
Muslim	0.10	(-0.00,0.20)	0.13*	(0.03,0.24)	0.12**	(0.05,0.19)
Christian	-0.41***	(-0.60,-0.21)	0.07	(-0.12,0.25)	-0.14*	(-0.28,-0.01)
Others$	-0.41***	(-0.57,-0.25)	-0.18*	(-0.34,-0.01)	-0.29***	(-0.40,-0.18)
Caste						
Scheduled caste®						
Scheduled tribe	-0.27***	(-0.40,-0.14)	-0.03	(-0.15,0.10)	-0.14**	(-0.23,-0.05)
OBC#	-0.25***	(-0.33,-0.16)	-0.05	(-0.13,0.03)	-0.15***	(-0.21,-0.09)
None of them	-0.23***	(-0.33,-0.14)	-0.07	(-0.16,0.03)	-0.15***	(-0.21,-0.08)
Region						
North®						
Central	0.46***	(0.35,0.57)	0.60***	(0.49,0.71)	0.53***	(0.45,0.61)
East	0.07	(-0.03,0.18)	0.08	(-0.03,0.18)	0.08*	(0.00,0.15)
Northeast	-0.15	(-0.35,0.05)	-0.37***	(-0.57,-0.17)	-0.27***	(-0.41,-0.13)
West	-0.55***	(-0.67,-0.44)	-0.60***	(-0.71,-0.48)	-0.57***	(-0.65,-0.49)
South	0.35***	(0.23,0.46)	0.25***	(0.13,0.36)	0.30***	(0.22,0.38)
BMI categories						
Normal®						
Underweight	0.29***	(0.22,0.36)	0.07	(-0.01,0.14)	0.18***	(0.13,0.23)
Overweight/obese	0.05	(-0.03,0.14)	-0.08*	(-0.16,-0.00)	-0.02	(-0.08,0.03)
MPCE quintile						
Poorest®						
Poorer	-0.09	(-0.18,0.01)	-0.10*	(-0.19,-0.02)	-0.09**	(-0.16,-0.03)
Middle	-0.06	(-0.16,0.03)	-0.10*	(-0.19,-0.01)	-0.08*	(-0.14,-0.02)
Richer	-0.07	(-0.16,0.03)	-0.10*	(-0.19,-0.00)	-0.08*	(-0.15,-0.02)
Richest	-0.05	(-0.15,0.06)	-0.02	(-0.12,0.08)	-0.03	(-0.11,0.04)
Currently smoking tobacco						
No®						
Yes	0.14***	(0.07,0.22)	0.03	(-0.13,0.20)	0.15***	(0.08,0.21)
Currently chewing tobacco						
No®						
Yes	-0.01	(-0.08,0.07)	0.07	(-0.02,0.15)	0.02	(-0.04,0.07)

Drinking Status						
Never®						
Infrequent non-heavy	-0.15***	(-0.23,-0.07)	0.05	(-0.20,0.31)	-0.12**	(-0.20,-0.05)
Frequent non-heavy	-0.22**	(-0.35,-0.08)	-0.41*	(-0.77,-0.06)	-0.24***	(-0.37,-0.12)
Heavy episodic drinker	-0.05	(-0.20,0.09)	-0.15	(-0.54,0.24)	-0.07	(-0.20,0.07)
Hypertension Status						
Normal®						
Pre-hypertensive	-0.04	(-0.12,0.03)	-0.09*	(-0.17,-0.01)	-0.07*	(-0.12,-0.01)
High BP	-0.04	(-0.12,0.04)	0.02	(-0.06,0.09)	-0.01	(-0.07,0.05)
Diabetes						
No®						
Yes	0.10*	(0.02,0.19)	0.02	(-0.08,0.11)	0.06	(-0.00,0.13)
Cancer						
No®						
Yes	0.59**	(0.17,1.01)	-0.36	(-0.75,0.03)	0.06	(-0.23,0.35)
Heart Disease						
No®						
Yes	0.11	(-0.01,0.24)	0.17*	(0.01,0.32)	0.14**	(0.04,0.24)
Stroke						
No®						
Yes	0.56***	(0.38,0.74)	0.31**	(0.09,0.54)	0.46***	(0.32,0.61)
N	11,403		12,181		23,584	
R^2	0.10		0.09		0.09	

Note: # Other Backward Classes, $ includes Sikh, Buddhist/neo-Buddhist, Jain, Parsi/Zoroastrian and others; BP- Blood Pressure; ® - reference category.

Note: *p<0.05, **p<0.01, ***p<0.001

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Recommendation	Page No
Title and abstract	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
	(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2-3
Introduction		
Background/rationale	Explain the scientific background and rationale for the investigation being reported	5-6
Objectives	State specific objectives, including any prespecified hypotheses	6
Methods		
Study design	Present key elements of study design early in the paper	7
Setting	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7
Participants	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	7
Variables	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-10
Data sources/ measurement	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7
Study size	Explain how the study size was arrived at	7
Quantitative variables	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	
Statistical methods	(*a*) Describe all statistical methods, including those used to control for confounding	11
	(*b*) Describe any methods used to examine subgroups and interactions	
	(*c*) Explain how missing data were addressed	7
	(*d*) If applicable, describe analytical methods taking account of sampling strategy	
	(*e*) Describe any sensitivity analyses	
Results		
Participants	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	11
	(b) Give reasons for non-participation at each stage	
	(c) Consider use of a flow diagram	
Descriptive data	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	12
	(b) Indicate number of participants with missing data for each variable of interest	
Outcome data	Report numbers of outcome events or summary measures	12-16
Main results	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	12-16
	(*b*) Report category boundaries when continuous variables were categorized	

	(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion		
Key results	Summarise key results with reference to study objectives	18
Limitations	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	20
Interpretation	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	17-20
Generalisability	Discuss the generalisability (external validity) of the study results	17-20
Other information		
Funding	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	21

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.