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# BMJ Open

**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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4 1 **The mediating role of depressive symptoms in the association between social**  
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6 2 **engagement and cognitive functioning among older adults: Evidence from Longitudinal**  
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8 3 **Aging Study in India (LASI)**  
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10 4 **Manish Kumar**

11 5 Ph.D. Research scholar, International Institute for Population Sciences, Mumbai,  
12 6 Maharashtra, India, 400088

13 7 E-mail: [kumarmanishiips@gmail.com](mailto:kumarmanishiips@gmail.com)

14 8 ORCID: 0000-0001-5297-6150

15 9 [Telephone number: +91 9702511509](tel:+919702511509)  
16  
17 10

18 11 **T. Muhammad**

19 12 Ph.D. Research scholar, International Institute for Population Sciences, Mumbai,  
20 13 Maharashtra, India, 400088

21 14 E-mail: [muhhammad.iips@gmail.com](mailto:muhhammad.iips@gmail.com)

22 15 ORCID: 0000-0003-1486-7038  
23  
24 16

25 17 **Laxmi Kant Dwivedi, PhD**

26 18 Professor, International Institute for Population Sciences, Mumbai, Maharashtra, India,  
27 19 400088

28 20 Email: [laxmikdwivedi@gmail.com](mailto:laxmikdwivedi@gmail.com)

29 21 ORCID: 0000-0001-9737-2844  
30  
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32  
33 22  
34  
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36 23

37 **Corresponding author:**

38 24 **Manish Kumar**

39 25 Ph.D. Research scholar, International Institute for Population Sciences, Mumbai,  
40 26 Maharashtra, India, 400088

41 27 E-mail: [kumarmanishiips@gmail.com](mailto:kumarmanishiips@gmail.com)

42 28 ORCID: 0000-0001-5297-6150

43 29 [Telephone number: +91 9702511509](tel:+919702511509)  
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4 31 **The mediating role of depressive symptoms in the association between social**  
5 32 **engagement and cognitive functioning among older adults: Evidence from Longitudinal**  
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7 33 **Aging Study in India (LASI)**  
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9  
10 34 **Abstract**

11  
12 35 **Objective** The present study attempts to determine the mediating role of depressive symptoms  
13  
14 36 in the association between social engagement and cognitive functioning among older  
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16 37 individuals, with special attention to sex differences.

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18 38 **Design** A cross-sectional large scale survey data was analyzed in this study.

19  
20  
21 39 **Setting and Participants** The present study utilizes the individual-level data from the first  
22  
23 40 wave of the Longitudinal Aging Study in India (LASI) conducted during 2017-19. The sample  
24  
25 41 for the study included 20,084 individuals aged 60 years and above (10,526 men and 9,558  
26  
27 42 women).

28  
29 43 **Primary and Secondary outcome measures** The primary outcome variable was cognitive  
30  
31 44 functioning which was based on different cognitive measures, including immediate and  
32  
33 45 delayed word recall; orientation related to time, and place; executive functioning based on  
34  
35 46 paper folding and pentagon drawing; arithmetic ability based on serial 7s, computation and  
36  
37 47 backward counting from 20; and object naming.

38  
39 48 **Results** Linear regression results showed that higher levels of social engagements were  
40  
41 49 significantly associated with better cognitive functioning for both men ( $\beta= 0.64$ ,  $p<.001$ ) and  
42  
43 50 women ( $\beta= 0.34$ ,  $p<.001$ ) older adults, after adjusting for sociodemographic factors, lifestyle  
44  
45 51 factors, and chronic conditions. Moreover, greater depressive symptoms significantly reduced  
46  
47 52 the cognitive functioning for both older men and women. KHB method identified a significant  
48  
49 53 mediating effect of depressive symptoms on the relationship between social engagement and  
50  
51 54 cognitive functioning, and the proportional mediation through depressive symptoms was  
52  
53 55 14.4% and 18.1% for men and women older adults, respectively.

54  
55 56 **Conclusion** The results suggest that a positive association of social engagement with cognitive  
56  
57 57 functioning was partly mediated by depressive symptoms. The findings support the possible  
58  
59 58 benefits of maintaining quality social relations that help coping with depressive symptoms on  
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3 59 cognitive functioning among older adults, which need to be confirmed with future  
4  
5 60 interventional studies.  
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8 61 **Keywords:** *social engagement, cognitive functioning, depressive symptoms, KHB-method,*  
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10 62 *older adults.*  
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4 63 **Strengths and limitations of this study**  
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- 6 64 • The utilization of the national representative sample of older adults is a potential strength of the  
7 study  
8 65  
9 66 • Mediation analysis explains the mechanism by which social engagement affects cognitive  
10 function through a mediator, depressive symptoms  
11 67  
12 68 • The social engagements were significantly associated with better cognitive functioning for both  
13 men and women older adults  
14 69  
15 70 • The association of social engagement with cognitive functioning was partly mediated by  
16 depressive symptoms  
17 71  
18 72 • The inability to establish the causal relationship between social engagement and cognitive  
19 functioning is the limitation of the study  
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5 89 **engagement and cognitive functioning among older adults: Evidence from Longitudinal**  
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7 90 **Aging Study in India (LASI)**  
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9  
10 91 **Background**  
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12 92 With the growth of aging population, global challenges in mental health are on the rise. It  
13  
14 93 includes the decline in late-life cognitive abilities which are generally associated with poor  
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16 94 quality of life [1], functional disabilities [2], multimorbidity [3], and higher mortality risk [4].  
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18 95 India is currently facing rapid population aging, with an expected increase in the number of  
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20 96 individuals aged 60 years and above from 104 million in 2011 to 319 million by 2050 [5];  
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22 97 consequently, the disease burden of cognitive impairment in the country is also expected to  
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24 98 increase.

25 99 Social engagement is an umbrella concept usually referring to various factors such as social  
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27 100 relationships, social and emotional connectedness with other people, and participation in social  
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29 101 activities, which provide a sense of belonging, social identity, and fulfilment [6,7]. In the  
30  
31 102 absence of effective pharmacological treatment for persons with cognitive impairment,  
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33 103 especially for the long-term benefits, various methods such as improving social engagement  
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35 104 and active participation in social activities are considered [8]. Multiple cross-sectional studies  
36  
37 105 investigating the association between social environment and cognition in older adults showed  
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39 106 that greater social functioning improves cognitive performances [9,10]. Moreover, several  
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41 107 longitudinal studies among older adults have also indicated that greater engagements with  
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43 108 relatives [11,12], rich social networks [12,13], and frequent participation in social activities  
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45 109 [14] exert protective effects against cognitive decline. Therefore, in the long run, individuals  
46  
47 110 who present trajectories of high and increasing social engagements experience lower levels of  
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49 111 cognitive limitation [15].

50 112 Several interventional studies reported the protective effects of the improved social behaviours  
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52 113 in preventing or delaying dementia among older adults with diagnosed cognitive impairment  
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54 114 [16,17]. Most of the available research on social capital and engagement as to enhance  
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56 115 cognitive reserve and protect cognitive health has been conducted in developed countries [18–  
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58 116 21]. Little is known about the relationship between social engagement and cognitive  
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60 117 functioning in developing countries like India, where the cultural and structural context of  
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social engagement differ from developed countries. In India, traditionally, older adults are more



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3 119 likely to live with their children in multigenerational households where cultural norms  
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5 120 emphasize family ties and the virtue of filial piety [22,23], and a higher proportion of older  
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7 121 people experience psychological distress and mental illnesses [24–26].  
8

9 122 Similarly, depressive disorders are highly prevalent among older adults in low and middle  
10 123 income countries [27–29] and in India in particular [30]. Previously, various studies have found  
11 124 the beneficial effects of greater social engagements (with varying measurements and  
12 125 definitions) against depressive symptoms [31,32]. A cross-sectional study by Jang & Chiriboga  
13 126 (2011) [31] found that a higher level of participation in social activities was associated with a  
14 127 decline in depressive symptoms after controlling for the effects of demographic and health-  
15 128 related factors. Multiple longitudinal studies have also reported similar findings [33–37]. Also,  
16 129 increased participation in social activities and meaningful engagement by older adults may  
17 130 improve their mood, which benefits their emotional functioning and reduces depressive  
18 131 symptoms [38], which is linked to cognitive functioning [39]. According to the ‘depression  
19 132 reduction hypothesis’, depressive symptoms interferes with cognitive health; therefore, as  
20 133 evident from multiple longitudinal studies, practical strategies to reduce depressive symptoms  
21 134 will possibly improve cognitive functioning [40]. Two facts justify such a hypothesis; first,  
22 135 greater depressive symptoms are related to poor cognitive functioning among older adults  
23 136 [41,42]. Second, depressed older adults who engage in social activities may experience a  
24 137 decline in depressive symptoms and improve cognitive functioning [43]. Furthermore, in  
25 138 multiple cohort studies, cognitively impaired older adults with depressive symptoms were  
26 139 associated with more rapid cognitive decline than those without depression [44,45].  
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41 140 However, it is not clear to what extent social engagement may improve cognitive functioning  
42 141 by minimizing depressive symptoms. There is a dearth of studies in low- and middle-income  
43 142 countries on the association of social engagements and cognitive functioning and the mediating  
44 143 role of depressive symptoms in such association. On the other hand, an effective strategy to  
45 144 prevent or delay cognitive impairment for the aging population could be through increased  
46 145 engagements of older individuals in social activities which may enhance their mental health.  
47 146 Filling this gap, the present study using national-level data of older adults in India, attempts to  
48 147 determine the mediating role of depressive symptoms in the association between social  
49 148 engagement and cognitive functioning among older individuals. Previous research theorized  
50 149 gender as the crucial factor to be considered in understanding the role of social engagement  
51 150 and its positive mental health benefits [46]. Thus, the study also explores the sex difference in  
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3 151 the relationship between social engagement and cognitive functioning and the mediating effects  
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5 152 of depressive symptoms. The present study hypothesized that the association between social  
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7 153 engagement and cognitive functioning is partially mediated by depressive symptoms (Figure  
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9 154 1).

## 10 155 **Methods**

### 11 156 *Data*

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15 157 The present study utilizes the individual-level data from the first wave of the Longitudinal  
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17 158 Aging Study in India (LASI) conducted during 2017-19. LASI is a nationally representative  
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19 159 longitudinal survey of more than 72000 older adults aged 45 years and over across all states  
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21 160 and union territories of India that provides vital information on the social, physical,  
22  
23 161 psychological, and cognitive health of the Indian aging population. The LASI survey was  
24  
25 162 conducted through a partnership of the International Institute for Population Sciences (IIPS),  
26  
27 163 Harvard T. H. Chan School of Public Health (HSPH), and the University of Southern California  
28  
29 164 (USC). LASI is envisioned to be conducted every two years for the next 25 years. In LASI  
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31 165 wave 1, the sample selection is based on a multistage stratified cluster sample design, including  
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33 166 a three-stage sampling design in rural areas and a four-stage sampling design in urban areas.  
34  
35 167 LASI survey provided internationally harmonized data that comparable to the United States  
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37 168 Health and Retirement Study (HRS) and other HRS-type surveys in other countries, including  
38  
39 169 England (English Longitudinal Study of Ageing) and China (China Health and Retirement  
40  
41 170 Longitudinal Survey). Further, the details of sampling design, survey instruments, and data  
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43 171 collection procedures are provided elsewhere [47].

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45 172 The sample in the main LASI included 31,464 individuals aged 60 years and above. For the  
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47 173 present analysis, we have excluded those cases with missing data for any variables of interest  
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49 174 (n=7,842). To avoid potential reverse causality, we have excluded 3,390 individuals with poor  
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51 175 cognitive functioning (lowest 10th percentile) [48] and 148 individuals with neurological  
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53 176 problems such as Alzheimer's disease and dementia. Therefore, the sample for the present  
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55 177 study included 20,084 individuals from the LASI survey, and among them 10,526 were men  
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57 178 and 9,558 were women.

### 58 179 *Measures*

#### 59 180 *Cognitive function*

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3 181 By adopting the Health and Retirement Study (HRS) cognition module, the LASI collected  
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5 182 information on measured cognition in various domains – including memory, orientation,  
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7 183 executive functioning, arithmetic, and object naming (Table 1). Previously, various studies  
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9 184 have established high validity and reliability of these cognitive domains for measuring  
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11 185 cognitive impairment among older adults in community settings in the United States [49],  
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13 186 China [50], and India [51]. The cognitive functioning in the present study is based on different  
14  
15 187 cognitive measures, including immediate (0–10 points) and delayed word recall (0–10 points);  
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17 188 orientation related to time (0-4 points), and place (0-4 points); executive functioning based on  
18  
19 189 paper folding (0-3) and pentagon drawing (0-1); arithmetic ability based on serial 7s (0–5  
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21 190 points), computation (0-2) and backward counting from 20 (0–2 points); and object naming (0-  
22  
23 191 2).

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

Domain	Measure	Measurement	Range
<b>Memory</b>	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
<b>Orientation</b>	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
<b>Arithmetic function</b>	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
<b>Executive function: 0-4</b>	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.	
<b>Object naming: 0-2</b>		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
<b>Cognition</b>	Composite cognitive index	Combined score of memory (total word recall), orientation, arithmetic function, executive function, and object naming.	0-43

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

### 199 *Social Engagements*

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

### 213 *Depressive symptoms*

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

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3 218 everything is an effort) and three positive symptoms (feeling happy, satisfied, and hopeful).  
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5 219 The possible responses for these items were: rarely or never (< 1 day), sometimes (1 or 2 days),  
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7 220 often (3 or 4 days), and most or all of the time (5-7 days) in a week prior to the interview. For  
8  
9 221 the negative symptoms, rarely or never (< 1 day) and sometimes (1 or 2 days) were scored zero,  
10  
11 222 and often (3 or 4 days) and most or all of the time (5-7 days) categories were scored one.  
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13 223 Scoring was reversed for positive symptoms. The overall depressive symptoms score,  
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15 224 calculated by adding the scores from ten items, ranges from 0 to 10. A score of four or higher  
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17 225 is considered to represent clinically significant symptoms in the 10-item scale [56].

### 18 226 ***Covariates***

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20 227 After an extensive literature review, potentially related covariates were selected which include  
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22 228 socio-demographic characteristics, lifestyle factors, health conditions, and cognitive and social  
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24 229 activities. Socio-demographic characteristics were: age (in chronological years); gender (men,  
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26 230 women); education (no education, primary, secondary, higher); currently working status (no,  
27  
28 231 yes); residence (rural, urban); religion (Hindu, Muslim, Christian, others); Caste (Scheduled  
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30 232 Caste, Scheduled Tribe, Other Backward Class (OBC), others), Region (North, Central, East,  
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32 233 Northeast, West, and South), monthly per capita expenditure (MPCE) (poorest, poorer, middle,  
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34 234 richer, and richest). The lifestyle factors were: currently smoking (no, yes); currently chewing  
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36 235 tobacco (no, yes), alcohol drinking status (never, infrequent non-heavy, frequent non-heavy,  
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38 236 heavy episodic drinker), and body mass index (underweight (<18.5 kg/m<sup>2</sup>), normal (18.5-24.9  
39  
40 237 kg/m<sup>2</sup>), overweight/obese (>25.0 kg/m<sup>2</sup>)). Health conditions include biometric measurement-  
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42 238 based hypertension status (normal, pre-hypertensive, high blood pressure), and self-reported  
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44 239 conditions such as diabetes, cancer, heart disease, and stroke were coded as no and yes. The  
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46 240 older adults were categorized as having normal blood pressure (BP) (Systolic BP <120 mmHg  
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48 241 and Diastolic BP <80 mmHg), pre-hypertensive (SBP: 120-139 mmHg and DBP: 80-89  
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50 242 mmHg), and high blood pressure (SBP ≥ 140 mmHg and DBP ≥ 90 mmHg).

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52 243 According to the procedure suggested by Dong and Simon [57], we have included the four  
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54 244 social participation activities: (1) eat out of the house, (2) go to the park/beach, visit  
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56 245 relatives/friends, (3) go out to a movie, and (4) attend political/community group meetings.  
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58 246 Based on the frequency of participation, responses were coded as '0' for less than weekly, '1'  
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60 247 for weekly or more frequently for these activities.

### 58 248 ***Statistical analysis***

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3 249 Descriptive statistics (means and percentages) were used to assess the characteristics of the  
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5 250 older adults included in the final sample. The analysis procedure in this study follows three  
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7 251 procedures. First, linear regression models were employed to determine the association of  
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9 252 social engagements and depressive symptoms with cognitive function. Second, correlation  
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11 253 analysis and a linear regression model of depressive symptoms on social engagement were  
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13 254 conducted. Third, the total effect was divided into direct effects (the association of social  
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15 255 engagement with cognitive function controlling for depressive symptoms) and indirect or  
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17 256 mediating effects (the association of social engagement with cognitive function through  
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19 257 depressive symptoms) using linear regression based on Karlson–Holm–Breen (KHB) method  
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21 258 [58,59] for the whole sample, and for men and women subsamples, separately. The KHB  
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23 259 method is a recently developed method for assessing mediating effects that allow total effects  
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25 260 to be divided into direct and indirect (i.e., mediational) effects for both discrete and continuous  
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27 261 variables. Contrary to other decomposition methods, the KHB-method provides unbiased  
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29 262 decomposition results [60]. The mediation percentage (the indirect effect divided by the total  
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31 263 effect) is interpreted as the percentage of the association explained by the mediator variable.  
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33 264 All statistical models were adjusted for various predictors, including age, gender, education,  
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35 265 working status, residence, religion, caste, region, body mass index (BMI), monthly per capita  
36  
37 266 expenditure (MPCE), smoking status, chewing tobacco status, alcohol drinking, hypertension,  
38  
39 267 diabetes, cancer, heart disease, and stroke. The statistical analysis was performed using Stata  
40  
41 268 15.1. A p-value of less than 0.05 was considered statistically significant.

### 269 **Patient and public involvement**

270 No patient was involved.

### 271 **Results**

272 Table 2 presents the descriptive information for cognitive function, socio-demographic factors,  
273  
274 lifestyle factors, and chronic conditions of older men and women included in the analysis. The  
275  
276 mean cognition score of men was higher than that of women (11.0 vs. 7.8). Nearly 86% of  
277  
278 older men had at least a medium level of social engagements, while this proportion was 57%  
279  
280 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

281 obese. A higher proportion of older women in the study compared to men were overweight or  
 282 obese (32.3% vs. 21.2%). Around 25% of men and only 4% of women were current tobacco  
 283 smokers, while 24% of men and 15% of women were consuming tobacco by chewing at the  
 284 time of the survey. Alcohol consumption is way higher among older men than women (31.8%  
 285 vs. 3.5%). According to measured hypertension status, the prevalence of high blood pressure  
 286 is slightly higher among older women than men (39.2% vs. 38.1%). According to religion,  
 287 around three-fourths of both older men and women participants were Hindus. Most of the  
 288 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	%
<b>Social Engagement</b>						
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
<b>Cognition<sup>a</sup></b>	11.0	5.7	7.8	5.6	9.5	5.9
<b>Depressive symptoms score<sup>a</sup></b>	2.8	1.6	2.9	1.7	2.8	1.6
<b>Age (years)<sup>a</sup></b>	68.4	6.8	67.3	6.4	67.9	6.6
<b>Social Activities (0-5)<sup>a</sup></b>	0.3	0.6	0.2	0.5	0.2	0.5
<b>Education level</b>						
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
<b>Currently working</b>						
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
<b>Place of Residence</b>						
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
<b>Religion</b>						
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 <sup>s</sup>	529	5.0	482	5.0	1,011	5.0
<b>Caste</b>						
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 <sup>#</sup>	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
<b>Regions</b>						
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
<b>BMI categories</b>						

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
<b>MPCE quintile</b>						
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
<b>Currently smoking tobacco</b>						
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
<b>Currently chewing tobacco</b>						
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
<b>Drinking Status</b>						
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
<b>Hypertension Status</b>						
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
<b>Diabetes</b>						
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
<b>Cancer</b>						
No	10,456	99.3	9,482	99.2	19,938	99.3
Yes	70	0.7	76	0.8	146	0.7
<b>Heart Disease</b>						
No	9,879	93.9	9,136	95.6	19,015	94.7
Yes	647	6.1	422	4.4	1,069	5.3
<b>Stroke</b>						
No	10,257	97.4	9,410	98.5	19,667	97.9
Yes	269	2.6	148	1.5	417	2.1
<b>Total</b>	<b>10,526</b>	<b>100.0</b>	<b>9,558</b>	<b>100.0</b>	<b>20,084</b>	<b>100.0</b>

Note: <sup>#</sup>Other Backward Classes, <sup>a</sup>Mean and standard deviation; <sup>s</sup>includes Sikh, Buddhist/neo-Buddhist, Jain, Parsi/Zoroastrian and others; BP- Blood Pressure.

289

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



298 0.90,  $p < .001$ ), in men ( $\beta = 0.90$ ,  $p < .001$ ) and women ( $\beta = 1.13$ ,  $p < .001$ ). Additionally, greater  
 299 depressive symptoms significantly reduced the cognitive functioning among both older men  
 300 ( $\beta = -0.31$ ,  $p < .001$ ) and women ( $\beta = -0.28$ ,  $p < .001$ ). The correlation between social engagement  
 301 and depressive symptoms was  $-0.11$  ( $p < .001$ ) (Supplementary; Table S3). The linear  
 302 regression model demonstrated that higher levels of social engagement was negative associated  
 303 with depressive symptoms ( $\beta = -0.17$ ,  $p < .001$ ) (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	
	$\beta$	(95% CI)	$\beta$	(95% CI)	$\beta$	(95% CI)
<b>Social Engagement</b>						
Low <sup>®</sup>						
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)
<b>Depressive symptoms score</b>	-0.31***	(-0.36,-0.25)	-0.28***	(-0.33,-0.23)	-0.29***	(-0.33,-0.25)
<b>N</b>	<b>10,526</b>		<b>9,558</b>		<b>20,084</b>	
<b>R<sup>2</sup></b>	<b>0.32</b>		<b>0.36</b>		<b>0.38</b>	

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.

\*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

304  
 305 Table 4 shows the mediation analysis results for the whole sample, the older men and women  
 306 subsamples. After controlling for all the covariates in the entire sample, the results indicate that  
 307 depressive symptoms significantly mediated 16.9% of the association between social  
 308 engagement and cognitive function. In addition, we found significant mediation percentages  
 309 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	
	$\beta$	(95% CI)	$\beta$	(95% CI)	$\beta$	(95% CI)
<b>Social Engagements</b>						
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)
<b>N</b>	<b>10,526</b>		<b>9,558</b>		<b>20,084</b>	
<b>Conf.-Perc<sup>a</sup></b>	<b>14.4%</b>		<b>18.1%</b>		<b>16.9%</b>	

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. <sup>a</sup>Confounding percentage.

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

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310

## 311 **Discussion**

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

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

331 Although social engagements including the structural support from the spouse and family  
332 members are found to enhance cognitive functioning [68–70], the mechanism that mental  
333 illnesses adversely mediating the association is less investigated. A recent study found the  
334 mediating role of hippocampal volume of brain which is known to be affected by a variety of  
335 psychiatric disorders in the association of emotional support with specific cognitive domains  
336 [71]. Consistently, the current results showed that depressive symptoms were partial mediators  
337 of the social engagement-cognitive functioning relationship. The finding is also in parallel with  
338 a recent study conducted in China showing the mediating role of depressive symptoms in the  
339 protective effect of frequent exercise on cognitive functioning [72]. Therefore, our results  
340 support the previous finding that the protective effect of social relationships is more related to

1  
2  
3 341 the aspects of quality and functionality of such relationships than the quantity and structural  
4 342 characteristics [73].

7 343 Furthermore, the indirect effect of social engagements on cognitive functioning suggest that  
8 344 social resources can be related to better cognitive functioning through minimizing mental  
9 345 disorders in older adults, indicating that depressive symptoms may serve as an important  
10 346 intervening target and that reversing such illnesses might be related to a greater cognitive  
11 347 functioning. This is similar to an earlier finding that lack of social engagements may be  
12 348 particularly detrimental to late-life cognitive abilities when it is associated with mental illnesses  
13 349 [74]. Earlier meta-analyses and reviews have investigated loneliness, being one of the  
14 350 depressive symptoms, and social isolation together as part of health promotion interventions  
15 351 and suggested that loneliness is often experienced as a part of lack of social engagement and  
16 352 partly attribute to the factors of cognitive declines [75,76], indicating the need for social  
17 353 interventions that promote active participation of older people and help them in maintaining  
18 354 social and structural relationships and coping with age-related stress factors.

21 355 The available evidence suggests that there are gender differences in the relationship between  
22 356 social engagement and cognitive functioning. For instance, in developed countries, numerous  
23 357 studies have found that the cognitive performance of older women is as good as or better than  
24 358 that of men [77–79]. By contrast, studies of cognitive abilities in developing countries find  
25 359 older women often perform worse than older men [80,81]. Moreover, earlier studies in India  
26 360 reported a relatively lower cognitive functioning level among older women than men [82,83].  
27 361 Also, another study suggests that a greater social engagement protects against rapid cognitive  
28 362 decline, particularly among low-educated older women [84]. In addition, social networks were  
29 363 reported as highly influential for women than men in determining better health behaviors  
30 364 related to cognitive maintenance [80]. Consistent with these previous studies, the current  
31 365 analyses have shown that social engagement of older women is strongly associated with better  
32 366 cognitive functioning with greater mediating effects of depressive symptoms compared to older  
33 367 men. Nevertheless, it still needs to be further investigated whether sex differences exist in the  
34 368 association of social engagements mediated by depressive symptoms with cognitive  
35 369 functioning and causally inferred with studies of longitudinal design.

36 370 There are several limitations of the present study to be noted. In the analysis, cognitively  
37 371 impaired older adults have been removed to address the reverse causality. However, the  
38 372 possibility of withdrawal of people from social contacts and social activities in the early stages

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3 373 of pathological changes in cognition cannot be ignored. Therefore, the potential impact of  
4  
5 374 reverse causality cannot be completely ruled out. The composite index of social engagement  
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7 375 was generated from the questions which were self-reported. The responses may have been  
8  
9 376 exaggerated or under-reported. However, self-reporting is endorsed as an optimal method to  
10  
11 377 measure how the participants subjectively find themselves having social networks and involved  
12  
13 378 in social activities. On the other hand, exploring the aspect of social engagements that include  
14  
15 379 participating in indoor games for example, as distinct from domains of cognitive activities is  
16  
17 380 questionable, since it is not feasible to completely differentiate social engagement from  
18  
19 381 cognitive engagements. Also many activities have a psychiatric element which may have  
20  
21 382 positive impacts on cognitive processes and a complex confounding effect in the associations  
22  
23 383 of three key variables in our study. Hence, considering the differences in relationships between  
24  
25 384 cognitive domains and the distinct forms of social engagements that also include structural  
26  
27 385 support from marital status and living arrangements, it is important to define social  
28  
29 386 relationships more clearly in future studies to achieve more reliable findings. Besides, in a  
30  
31 387 population with huge proportion of illiterates, the assessment of cognitive functioning with  
32  
33 388 multiple domains might be subject to measurement error which can bias the current findings.  
34  
35 389 Similarly, older women in India who are largely deprived of education and other opportunities  
36  
37 390 including work participation might have resulted in greater gender gap in cognitive functioning  
38  
39 391 observed in our study. Another limitation is the inclusion of only males and females in the  
40  
41 392 study. Since LASI collects the information from males and females only, the inclusion of the  
42  
43 393 other gender was not possible. Finally, the present study was cross-sectional, and thus, a causal  
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45 394 relationship between the variables cannot be inferred. Further investigation with longitudinal  
46  
47 395 design is needed to explore the neural mechanisms that underlie the effects of social  
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49 396 engagements on cognitive decline. Future research might also consider the impact of  
50  
51 397 technology, internet and social media on social relationships, particularly feelings of social  
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53 398 support.

## 54 399 **Conclusion**

55 400 The results suggest that a positive association of social engagement with cognitive functioning  
56  
57 401 was partly mediated by depressive symptoms. The findings support the possible benefits of  
58  
59 402 maintaining quality social relations that help coping with depressive symptoms on cognitive  
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403 functioning among older adults, which need to be confirmed with future interventional studies.  
404 The study also highlights the potential of social engagements independently or with others as  
405 an intervention to prevent cognitive impairment among older individuals.

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3 406 **Abbreviations:**

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5 407 **MPCE:** Monthly Per capita Consumption Expenditure

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7 408 **CES-D:** Center for Epidemiological Studies-Depression

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9 409 **KHB:** Karlson–Holm–Breen

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11 410 **Declarations**

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13  
14 411 **Contributors** MK and LKD conceived and designed the research paper. MK analyzed the data.

15 412 MK and TM contributed agents/materials/analysis tools. MK and TM wrote the manuscript.

16 413 LKD provides supervision and validation. MK, TM and LKD refined the manuscript. All

17 414 authors have read and approved the manuscript.

18  
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20  
21 416 **Competing interest** The authors declare that there is no competing interest.

22  
23 417 **Patient consent for publication** Not required.

24 418 **Ethics approval** Not applicable/No human participants included. Therefore, no Ethics

25 419 Committee or Institutional Board approval is required.

26  
27 420 **Provenance and peer review** Not commissioned; externally peer reviewed

28 421 **Data availability statement** The study uses secondary data which is available in the private

29 422 database and accessible on reasonable request through

30 423 <https://www.iipsindia.ac.in/content/lasiwave-i>

31  
32 424 **Consent for publication** The administrative permission to access and use the data for the

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35  
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429 **References**

- 430 1 Hsiao H-T, Li S-Y, Yang Y-P, *et al.* Cognitive function and quality of life in  
431 community-dwelling seniors with mild cognitive impairment in Taiwan. *Community*  
432 *Ment Health J* 2016;**52**:493–8.
- 433 2 McGuire LC, Ford ES, Ajani UA. The impact of cognitive functioning on mortality  
434 and the development of functional disability in older adults with diabetes: the second  
435 longitudinal study on aging. *BMC Geriatr* 2006;**6**:1–7.
- 436 3 Aarts S, Van den Akker M, Tan FES, *et al.* Influence of multimorbidity on cognition  
437 in a normal aging population: a 12-year follow-up in the Maastricht aging study. *Int J*  
438 *Geriatr Psychiatry* 2011;**26**:1046–53.
- 439 4 Lv X, Li W, Ma Y, *et al.* Cognitive decline and mortality among community-dwelling  
440 Chinese older people. *BMC Med* 2019;**17**:1–10.
- 441 5 United Nation. World Population Ageing 2017 report. 2017.
- 442 6 Bassuk SS, Glass TA, Berkman LF. Social disengagement and incident cognitive  
443 decline in community-dwelling elderly persons. *Ann Intern Med* 1999;**131**:165–73.
- 444 7 Baltes MM. *The many faces of dependency in old age*. Cambridge University Press  
445 1996.
- 446 8 Li Y, Xu L, Chi I, *et al.* Participation in productive activities and health outcomes  
447 among older adults in urban China. *Gerontologist* 2014;**54**:784–96.
- 448 9 Holtzman RE, Rebok GW, Saczynski JS, *et al.* Social network characteristics and  
449 cognition in middle-aged and older adults. *Journals Gerontol - Ser B Psychol Sci Soc*  
450 *Sci* 2004;**59**:278–84. doi:10.1093/geronb/59.6.P278
- 451 10 Krueger KR, Wilson RS, Kamenetsky JM, *et al.* Social engagement and cognitive  
452 function in old age. *Exp Aging Res* 2009;**35**:45–60.  
453 doi:10.1080/03610730802545028.SOCIAL
- 454 11 Béland F, Zunzunegui MV, Alvarado B, *et al.* Trajectories of cognitive decline and  
455 social relations. *Journals Gerontol - Ser B Psychol Sci Soc Sci* 2005;**60**:320–30.  
456 doi:10.1093/geronb/60.6.P320
- 457 12 Zunzunegui MV, Alvarado BE, Del Ser T, *et al.* Social networks, social integration,

- 1  
2  
3 458 and social engagement determine cognitive decline in community-dwelling Spanish  
4 older adults. *Journals Gerontol - Ser B Psychol Sci Soc Sci* 2003;**58**:93–100.  
5 459 doi:10.1093/geronb/58.2.S93  
6 460  
7  
8  
9 461 13 Kim YB, Lee SH. Social network types and cognitive decline among older Korean  
10 adults: A longitudinal population-based study. *Int J Geriatr Psychiatry* 2019;**34**:1845–  
11 462 54. doi:10.1002/gps.5200  
12 463  
13  
14  
15 464 14 Lee SH, Kim YB. Which type of social activities may reduce cognitive decline in the  
16 elderly?: A longitudinal population-based study. *BMC Geriatr* 2016;**16**:1–9.  
17 465 doi:10.1186/s12877-016-0343-x  
18 466  
19  
20  
21 467 15 Thomas PA. Trajectories of social engagement and limitations in late life. *J Health Soc*  
22 468 *Behav* 2011;**52**:430–43.  
23  
24  
25 469 16 Maffei L, Picano E, Andreassi MG, *et al.* Randomized trial on the effects of a  
26 combined physical/cognitive training in aged MCI subjects: the Train the Brain study.  
27 470 *Sci Rep* 2017;**7**:39471.  
28 471  
29  
30  
31 472 17 Straubmeier M, Behrnt E-M, Seidl H, *et al.* Non-pharmacological treatment in people  
32 with cognitive impairment: results from the randomized controlled german day care  
33 473 study. *Dtsch Arztebl Int* 2017;**114**:815.  
34 474  
35  
36  
37 475 18 Ihle A, Oris M, Baeriswyl M, *et al.* The longitudinal relation between social reserve  
38 and smaller subsequent decline in executive functioning in old age is mediated via  
39 476 cognitive reserve. *Int Psychogeriatrics* 2021;**33**:461–7.  
40 477 doi:10.1017/S1041610219001789  
41 478  
42  
43  
44 479 19 González-Ortega I, González-Pinto A, Alberich S, *et al.* Influence of social cognition  
45 as a mediator between cognitive reserve and psychosocial functioning in patients with  
46 480 first episode psychosis. *Psychol Med* Published Online First: 2019.  
47 481 doi:10.1017/S0033291719002794  
48 482  
49  
50  
51 483 20 Haslam C, Cruwys T, Haslam SA. ‘The we’s have it’: Evidence for the distinctive  
52 484 benefits of group engagement in enhancing cognitive health in aging. *Soc Sci Med*  
53 485 2014;**120**:57–66. doi:10.1016/j.socscimed.2014.08.037  
54  
55  
56  
57 486 21 Conroy RM, Golden J, Jeffares I, *et al.* Boredom-proneness, loneliness, social  
58 487 engagement and depression and their association with cognitive function in older  
59  
60

- 1  
2  
3 488 people: A population study. *Psychol Heal Med* 2010;**15**:463–73.  
4  
5 489 doi:10.1080/13548506.2010.487103  
6  
7 490 22 Samanta T, Chen F, Vanneman R. Living arrangements and health of older adults in  
8  
9 491 India. *Journals Gerontol Ser B Psychol Sci Soc Sci* 2015;**70**:937–47.  
10  
11 492 23 Srivastava S, Shaw S, Chaurasia H, *et al*. Feeling about living arrangements and  
12  
13 493 associated health outcomes among older adults in India : a cross-sectional study. *BMC*  
14  
15 494 *Public Health* 2021;**21**:1–14.  
16  
17 495 24 Muhammad T, Srivastava S, Sekher T V. Association of self-perceived income status  
18  
19 496 with psychological distress and subjective well-being: a cross-sectional study among  
20  
21 497 older adults in India. *BMC Psychol* 2021;**9**:1–13. doi:10.1186/s40359-021-00588-5  
22  
23 498 25 Srivastava S, Chauhan S, Muhammad T, *et al*. Older adults' psychological and  
24  
25 499 subjective well-being as a function of household decision making role: Evidence from  
26  
27 500 cross-sectional survey in India. *Clin Epidemiol Glob Heal* 2021;**10**:100676.  
28  
29 501 doi:10.1016/j.cegh.2020.100676  
30  
31 502 26 Srivastava S, Purkayastha N, Chaurasia H, *et al*. Socioeconomic inequality in  
32  
33 503 psychological distress among older adults in India : a decomposition analysis. *BMC*  
34  
35 504 *Psychiatry* 2021;**21**:1–15. doi:10.1186/s12888-021-03192-4  
36  
37 505 27 Fernández-Niño JA, Bonilla-Tinoco LJ, Manrique-Espinoza BS, *et al*. Work status,  
38  
39 506 retirement, and depression in older adults: An analysis of six countries based on the  
40  
41 507 Study on Global Ageing and Adult Health (SAGE). *SSM - Popul Heal* 2018;**6**:1–8.  
42  
43 508 doi:10.1016/j.ssmph.2018.07.008  
44  
45 509 28 Anand A. Understanding Depression among Older Adults in Six Low-Middle Income  
46  
47 510 Countries using WHO-SAGE Survey. *Behav Heal* 2015;**1**.  
48  
49 511 29 Smith L, Il Shin J, McDermott D, *et al*. Association between food insecurity and  
50  
51 512 depression among older adults from low- and middle-income countries. *Depress*  
52  
53 513 *Anxiety* 2021;**38**:439–46. doi:10.1002/da.23147  
54  
55 514 30 Srivastava S, Debnath P, Shri N, *et al*. The association of widowhood and living alone  
56  
57 515 with depression among older adults in India. *Sci Rep* 2021;:1–13. doi:10.1038/s41598-  
58  
59 516 021-01238-x  
60  
61 517 31 Jang Y, Chiriboga DA. Social activity and depressive symptoms in Korean American



- 1  
2  
3 518 older adults: The conditioning role of acculturation. *J Aging Health* 2011;**23**:767–81.  
4  
5  
6 519 32 Strauss J, Park A, Smith JP. Health Outcomes and Socio-Economic Status Among the  
7 Elderly in Gansu and Zhejiang Provinces, China: Evidence from the CHARLS Pilot.  
8 520 2013;**3**:111–42. doi:10.1007/s12062-011-9033-9.Health  
9 521  
10  
11 522 33 Chiao C, Weng L-J, Botticello AL. Social participation reduces depressive symptoms  
12 among older adults: an 18-year longitudinal analysis in Taiwan. *BMC Public Health*  
13 523 2011;**11**:1–9.  
14 524  
15  
16  
17 525 34 Isaac V, Stewart R, Artero S, *et al*. Social activity and improvement in depressive  
18 symptoms in older people: a prospective community cohort study. *Am J Geriatr*  
19 526 *Psychiatry* 2009;**17**:688–96.  
20 527  
21  
22  
23 528 35 Lou VWQ, Chi I, Kwan CW, *et al*. Trajectories of social engagement and depressive  
24 symptoms among long-term care facility residents in Hong Kong. *Age Ageing*  
25 529 2013;**42**:215–22.  
26 530  
27  
28  
29 531 36 Takagi D, Kondo K, Kawachi I. Social participation and mental health: moderating  
30 effects of gender, social role and rurality. *BMC Public Health* 2013;**13**:1–8.  
31 532  
32  
33 533 37 Glass TA, De Leon CFM, Bassuk SS, *et al*. Social engagement and depressive  
34 symptoms in late life: longitudinal findings. *J Aging Health* 2006;**18**:604–28.  
35 534  
36  
37 535 38 Fiske A, Wetherell JL, Gatz M. Depression in older adults. *Annu Rev Clin Psychol*  
38 2009;**5**:363–89.  
39 536  
40  
41 537 39 Pressman SD, Matthews KA, Cohen S, *et al*. Association of enjoyable leisure activities  
42 with psychological and physical well-being. *Psychosom Med* 2009;**71**:725.  
43 538  
44  
45 539 40 Vance DE, Marson DC, Triebel KL, *et al*. Physical activity and cognitive function in  
46 older adults: The mediating effect of depressive symptoms. *J Neurosci Nurs J Am*  
47 540 *Assoc Neurosci Nurses* 2016;**48**:E2.  
48 541  
49  
50  
51 542 41 Muhammad T, Meher T. Association of late-life depression with cognitive  
52 impairment: evidence from a cross-sectional study among older adults in India. *BMC*  
53 543 *Geriatr* 2021;**21**:1–13. doi:10.1186/s12877-021-02314-7  
54 544  
55  
56  
57 545 42 van den Kommer TN, Comijs HC, Aartsen MJ, *et al*. Depression and cognition: how  
58 do they interrelate in old age? *Am J Geriatr Psychiatry* 2013;**21**:398–410.  
59 546  
60

- 1  
2  
3 547 43 Dickinson WJ, Potter GG, Hybels CF, *et al.* Change in stress and social support as  
4 548 predictors of cognitive decline in older adults with and without depression. *Int J*  
5 549 *Geriatr Psychiatry* 2011;**26**:1267–74.
- 6  
7  
8  
9 550 44 Van Der Musselle S, Fransen E, Struyfs H, *et al.* Depression in mild cognitive  
10 551 impairment is associated with progression to alzheimer’s disease: A longitudinal study.  
11 552 *J Alzheimer’s Dis* 2014;**42**:1239–50. doi:10.3233/JAD-140405
- 12  
13  
14  
15 553 45 Verdelho A, Madureira S, Moleiro C, *et al.* Depressive symptoms predict cognitive  
16 554 decline and dementia in older people independently of cerebral white matter changes:  
17 555 The LADIS study. *J Neurol Neurosurg Psychiatry* 2013;**84**:1250–4. doi:10.1136/jnnp-  
18 556 2012-304191
- 19  
20  
21  
22 557 46 Agahi N, Parker MG. Leisure activities and mortality: does gender matter? *J Aging*  
23 558 *Health* 2008;**20**:855–71.
- 24  
25  
26  
27 559 47 International Institute for Population Sciences (IIPS), NPHCE, MoHFW HTHCS of  
28 560 PH (HSPH) and the U of SC (USC). Longitudinal Ageing Study in India ( LASI )  
29 561 Wave 1, 2017-18, India Report. Mumbai.: 2020.
- 30  
31  
32 562 48 Pandav R, Fillenbaum G, Ratcliff G, *et al.* Sensitivity and specificity of cognitive and  
33 563 functional screening instruments for dementia: The Indo-US Dementia Epidemiology  
34 564 Study. *J Am Geriatr Soc* 2002;**50**:554–61.
- 35  
36  
37  
38 565 49 Herzog AR, Wallace RB. Measures of cognitive functioning in the AHEAD study.  
39 566 *Journals Gerontol - Ser B Psychol Sci Soc Sci* 1997;**52**:37–48.  
40 567 doi:10.1093/geronb/52b.special\_issue.37
- 41  
42  
43  
44 568 50 Meng Q, Wang H, Strauss J, *et al.* Validation of neuropsychological tests for the China  
45 569 Health and Retirement Longitudinal Study Harmonized Cognitive Assessment  
46 570 Protocol. *Int Psychogeriatrics* 2019;**31**:1709–19. doi:10.1017/S1041610219000693
- 47  
48  
49  
50 571 51 Gupta M, Gupta V, Nagar Buckshee R, *et al.* Validity and reliability of hindi translated  
51 572 version of Montreal cognitive assessment in older adults. *Asian J Psychiatr*  
52 573 2019;**45**:125–8. doi:10.1016/j.ajp.2019.09.022
- 53  
54  
55  
56 574 52 Zhou Z, Mao F, Han Y, *et al.* Social engagement and cognitive impairment in older  
57 575 Chinese adults: The mediating role of psychological well-being. *J Aging Health*  
58 576 2020;**32**:573–81.

- 1  
2  
3 577 53 Sampson EL, Bulpitt CJ, Fletcher AE. Survival of community-dwelling older people:  
4 the effect of cognitive impairment and social engagement. *J Am Geriatr Soc*  
5 578 2009;**57**:985–91.  
6  
7 579  
8  
9 580 54 Radloff LS. The CES-D scale: A self-report depression scale for research in the  
10 general population. *Appl Psychol Meas* 1977;**1**:385–401.  
11 581  
12  
13 582 55 Irwin M, Artin KH, Oxman MN. Screening for Depression in the Older Adult. *Arch*  
14 *Intern Med* 1999;**159**:1701. doi:10.1001/archinte.159.15.1701  
15 583  
16  
17 584 56 Kumar S, Nakulan A, Thoppil SP, *et al.* Screening for depression among community-  
18 dwelling elders: usefulness of the center for epidemiologic studies depression scale.  
19 585 *Indian J Psychol Med* 2016;**38**:483–5.  
20 586  
21  
22  
23 587 57 Dong X, Li Y, Simon MA. Social engagement among U.S. Chinese older adults-  
24 findings from the PINE study. *Journals Gerontol - Ser A Biol Sci Med Sci*  
25 588 2014;**69**:S82–9. doi:10.1093/gerona/glu152  
26 589  
27  
28  
29 590 58 Karlson KB, Holm A. Decomposing primary and secondary effects: A new  
30 decomposition method. *Res Soc Stratif Mobil* 2011;**29**:221–37.  
31 591  
32  
33 592 59 Karlson KB, Holm A, Breen R. Comparing regression coefficients between same-  
34 sample nested models using logit and probit: A new method. *Sociol Methodol*  
35 593 2012;**42**:286–313.  
36 594  
37  
38  
39 595 60 Kohler U, Karlson KB, Kohler U, *et al.* KHB: Stata module to decompose total effects  
40 into direct and indirect via KHB-method. 2019.  
41 596  
42  
43 597 61 Li M, Dong X. Is Social Network a Protective Factor for Cognitive Impairment in US  
44 Chinese Older Adults? Findings from the PINE Study. *Gerontology* 2018;**64**:246–56.  
45 598 doi:10.1159/000485616  
46 599  
47  
48  
49 600 62 Ozbay F, Johnson DC, Dimoulas E, *et al.* Social support and resilience to stress: from  
50 neurobiology to clinical practice. *Psychiatry (Edgmont)* 2007;**4**:35–40.  
51 601  
52  
53 602 63 Hughes TF, Andel R, Small BJ, *et al.* The association between social resources and  
54 cognitive change in older adults: Evidence from the Charlotte County Healthy Aging  
55 603 Study. *Journals Gerontol - Ser B Psychol Sci Soc Sci* 2008;**63**:241–4.  
56 604 doi:10.1093/geronb/63.4.P241  
57 605  
58  
59  
60

- 1  
2  
3 606 64 Thoits PA. Mechanisms linking social ties and support to physical and mental health. *J*  
4 *Health Soc Behav* 2011;**52**:145–61. doi:10.1177/0022146510395592  
5 607  
6  
7 608 65 Kuiper JS, Zuidersma M, Zuidema SU, *et al.* Social relationships and cognitive  
8 decline: a systematic review and meta-analysis of longitudinal cohort studies. *Int J*  
9 *Epidemiol* 2016;**45**:1169–206. doi:10.1093/ije/dyw089  
10 610  
11  
12  
13 611 66 Muhammad T, Srivastava S, Sekher T V. Association of self-perceived income  
14 sufficiency with cognitive impairment among older adults: a population-based study in  
15 India. *BMC Psychiatry* 2021;**21**:1–14. doi:10.1186/s12888-021-03257-4  
16 613  
17  
18  
19 614 67 Kelly ME, Duff H, Kelly S, *et al.* The impact of social activities, social networks,  
20 social support and social relationships on the cognitive functioning of healthy older  
21 adults: A systematic review. *Syst Rev* 2017;**6**. doi:10.1186/s13643-017-0632-2  
22 616  
23  
24  
25 617 68 Barnes LL, De Leon CFM, Wilson RS, *et al.* Social resources and cognitive decline in  
26 a population of older African Americans and whites. *Neurology* 2004;**63**:2322–6.  
27 618  
28  
29 619 69 Ayotte BJ, Allaire JC, Whitfield KE. Social support, physical functioning, and  
30 cognitive functioning among older African American adults. *Aging, Neuropsychol*  
31 *Cogn* 2013;**20**:494–510. doi:10.1080/13825585.2012.761669  
32 621  
33  
34  
35 622 70 Muhammad T, Govindu M, Srivastava S. Relationship between chewing tobacco,  
36 smoking, consuming alcohol and cognitive impairment among older adults in India: a  
37 cross-sectional study. *BMC Geriatr* 2021;**21**:85. doi:10.1186/s12888-021-03257-4  
38 624  
39  
40  
41 625 71 Kim GE, Han JW, Kim TH, *et al.* Hippocampus mediates the effect of emotional  
42 support on cognitive function in older adults Authors. *Journals Gerontol Ser A*  
43 2020;**75**:1502–7.  
44 627  
45  
46  
47 628 72 Yuan M, Fu H, Liu R, *et al.* Effect of frequency of exercise on cognitive function in  
48 older adults: Serial mediation of depression and quality of sleep. *Int J Environ Res*  
49 *Public Health* 2020;**17**. doi:10.3390/ijerph17030709  
50 630  
51  
52  
53 631 73 Amieva H, Stoykova R, Matharan F, *et al.* What aspects of social network are  
54 protective for dementia? Not the quantity but the quality of social interactions is  
55 protective up to 15 years later. *Psychosom Med* 2010;**72**:905–11.  
56 633  
57 doi:10.1097/PSY.0b013e3181f5e121  
58 634  
59  
60 635 74 Yang R, Wang H, Edelman LS, *et al.* Loneliness as a mediator of the impact of social

- 1  
2  
3 636 isolation on cognitive functioning of Chinese older adults. *Age Ageing* 2020;**49**:599–  
4 604. doi:10.1093/ageing/afaa020  
5 637  
6  
7 638 75 Valtorta N, Hanratty B. Loneliness, isolation and the health of older adults: Do we  
8 need a new research agenda? *J R Soc Med Suppl* 2012;**105**:518–22.  
9 639 doi:10.1258/jrsm.2012.120128  
10 640  
11  
12  
13 641 76 Cattan M, White M, Bond J, *et al*. Preventing social isolation and loneliness among  
14 older people: A systematic review of health promotion interventions. *Ageing Soc*  
15 642 2005;**25**:41–67. doi:10.1017/S0144686X04002594  
16 643  
17  
18  
19 644 77 Langa KM, Llewellyn DJ, Lang IA, *et al*. Cognitive health among older adults in the  
20 United States and in England. *BMC Geriatr* 2009;**9**:1–11.  
21 645  
22  
23 646 78 De Frias CM, Nilsson L-G, Herlitz A. Sex differences in cognition are stable over a  
24 10-year period in adulthood and old age. *Aging, Neuropsychol Cogn* 2006;**13**:574–87.  
25 647  
26  
27 648 79 Van Hooren S, Valentijn A, Bosma H, *et al*.  
28 Cognitive\_Functioning\_in\_Healthy\_Older\_A.pdf. 2007;:40–54.  
29 649  
30  
31 650 80 Lei X, Hu Y, McArdle JJ, *et al*. Gender differences in cognition among older adults in  
32 China. *J Hum Resour* 2012;**47**:951–71.  
33 651  
34  
35 652 81 Maurer J. Education and male-female differences in later-life cognition: International  
36 evidence from Latin America and the Caribbean. *Demography* 2011;**48**:915–30.  
37 653  
38  
39 654 82 Lee J, Shih R, Feeney K, *et al*. Gender disparity in late-life cognitive functioning in  
40 India: findings from the longitudinal aging study in India. *Journals Gerontol Ser B*  
41 655 *Psychol Sci Soc Sci* 2014;**69**:603–11.  
42 656  
43  
44 657 83 Angrisani M, Jain U, Lee J. Sex differences in cognitive health among older adults in  
45 India. *J Am Geriatr Soc* 2020;**68**:S20–8.  
46 658  
47  
48 659 84 Lee Y, Jean Yeung WJ. Gender matters: Productive social engagement and the  
49 subsequent cognitive changes among older adults. *Soc Sci Med* 2019;**229**:87–95.  
50 660 doi:10.1016/j.socscimed.2018.08.024  
51 661  
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5 664 Figure 1. Framework for mediation analysis  
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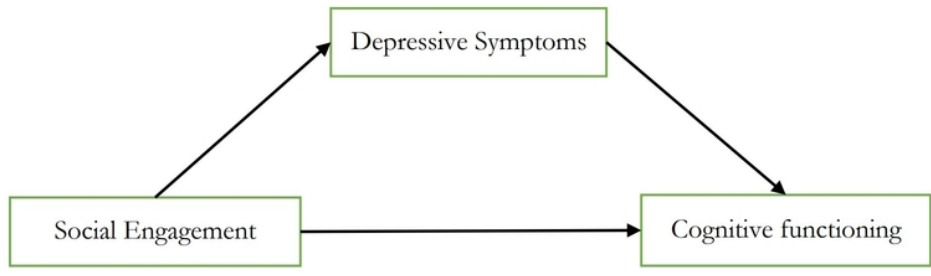


Figure 1. Framework for mediation analysis

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## Supplementary file

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

	Cognitive function (0-27)		Social engagements						
			Low (n=5,542)		Medium (n=12,522)		High (n=2,020)		
	N	Mean (sd.)							
<b>Social Engagements</b>									
Low	5,542	7.7 (5.5)	-	-	-	-	-	-	-
Medium	12,522	9.9 (5.8)	-	-	-	-	-	-	-
High	2,020	11.5 (5.8)	-	-	-	-	-	-	-
<b>Depression<sup>a</sup></b>									
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	
<b>Age (years)</b>									
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	
<b>Social Activities</b>									
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	
<b>Education level</b>									
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	
<b>Currently working</b>									
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	
<b>Place of Residence</b>									
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	
<b>Religion</b>									
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 <sup>s</sup>	1,011	9.4 (5.9)	235	4.2	633	5.1	143	7.1	
<b>Caste</b>									
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 <sup>#</sup>	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	
<b>Regions</b>									
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	
<b>BMI categories</b>									
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	



1									
2									
3	Overweight/Obese	5,319	11.2 (5.9)	1,419	25.6	3,275	26.2	625	30.9
4	<b>MPCE quintile</b>								
5	Poorest	3,852	8.2 (5.6)	1,183	21.3	2,359	18.8	310	15.3
6	Poorer	4,036	8.8 (5.7)	1,179	21.3	2,510	20.0	347	17.2
7	Middle	4,166	9.4 (5.8)	1,115	20.1	2,604	20.8	447	22.1
8	Richer	4,104	9.8 (5.8)	1,086	19.6	2,604	20.8	414	20.5
9	Richest	3,926	11.1 (6)	979	17.7	2,445	19.5	502	24.9
10									
11	<b>Currently smoking</b>								
12	<b>tobacco</b>								
13	No	17,119	9.5 (5.9)	5,020	90.6	10,453	83.5	1,646	81.5
14	Yes	2,965	9.3 (5.5)	522	9.4	2,069	16.5	374	18.5
15	<b>Currently chewing</b>								
16	<b>tobacco</b>								
17	No	16,109	9.6 (5.9)	4,467	80.6	9,987	79.8	1,655	81.9
18	Yes	3,975	8.9 (5.6)	1,075	19.4	2,535	20.2	365	18.1
19	<b>Drinking Status</b>								
20	Never	16,432	9.4 (5.9)	4,938	89.1	9,892	79.0	1,602	79.3
21	Infrequent non-heavy	2,278	10.3 (5.6)	360	6.5	1,622	13.0	296	14.7
22	Frequent non-heavy	732	9.4 (5.6)	143	2.6	534	4.3	55	2.7
23	Heavy episodic drinker	642	9.1 (5.5)	101	1.8	474	3.8	67	3.3
24	<b>Hypertension Status</b>								
25	Normal	4,547	8.9 (5.6)	1,112	20.1	2,978	23.8	457	22.6
26	Pre-hypertensive	7,779	9.7 (5.9)	2,022	36.5	4,930	39.4	827	40.9
27	High BP	7,758	9.6 (5.9)	2,408	43.5	4,614	36.8	736	36.4
28	<b>Diabetes</b>								
29	No	16,789	9.1 (5.8)	4,737	85.5	10,383	82.9	1,669	82.6
30	Yes	3,295	11.1 (5.9)	805	14.5	2,139	17.1	351	17.4
31	<b>Cancer</b>								
32	No	19,938	9.5 (5.9)	5,509	99.4	12,430	99.3	1,999	99.0
33	Yes	146	10.1 (5.8)	33	0.6	92	0.7	21	1.0
34	<b>Heart Disease</b>								
35	No	19,015	9.4 (5.9)	5,293	95.5	11,824	94.4	1,898	94.0
36	Yes	1,069	11.2 (5.8)	249	4.5	698	5.6	122	6.0
37	<b>Stroke</b>								
38	No	19,667	9.5 (5.9)	5,450	98.3	12,239	97.7	1,978	97.9
39	Yes	417	9.3 (5.6)	92	1.7	283	2.3	42	2.1
40									
41									
42	<b>Total</b>	<b>20,084</b>	<b>9.5 (5.9)</b>	<b>5,542</b>	<b>100.0</b>	<b>12,522</b>	<b>100.0</b>	<b>2,020</b>	<b>100.0</b>

Note: <sup>a</sup> overall score ranges from zero to 10 and individuals with score of four or more are considered as depressed; <sup>#</sup> Other Backward Classes, <sup>§</sup> 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	
	$\beta$	(95% CI)	$\beta$	(95% CI)	$\beta$	(95% CI)
<b>Social Engagement</b>						
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)
<b>Depression score</b>	-0.31***	(-0.36,-0.25)	-0.28***	(-0.33,-0.23)	-0.29***	(-0.33,-0.25)
<b>Social Activities</b>	0.15	(-0.03,0.32)	0.41***	(0.22,0.60)	0.26***	(0.13,0.39)
<b>Age (years)</b>	-0.08***	(-0.09,-0.06)	-0.07***	(-0.08,-0.05)	-0.07***	(-0.08,-0.06)
<b>Gender</b>						
Men®	-	-	-	-		
Women					-1.55***	(-1.71,-1.38)
<b>Education level</b>						
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)
<b>Currently working</b>						
No®						
Yes	0.01	(-0.19,0.21)	0.31**	(0.08,0.54)	0.14	(-0.00,0.29)
<b>Place of Residence</b>						
Rural®						
Urban	1.05***	(0.82,1.28)	0.85***	(0.63,1.06)	0.99***	(0.84,1.15)
<b>Religion</b>						
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)
<b>Caste</b>						
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)
<b>Region</b>						
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)
<b>BMI categories</b>						
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)
<b>MPCE quintile</b>						
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)
<b>Currently smoking tobacco</b>						
No®						

1								
2								
3	Yes	0.01	(-0.22,0.23)	-0.56*	(-1.06,-0.05)	0.02	(-0.18,0.22)	
4	<b>Currently chewing tobacco</b>							
5	No®							
6	Yes	0.07	(-0.15,0.29)	-0.19	(-0.43,0.06)	0.00	(-0.16,0.16)	
7	<b>Drinking Status</b>							
8	Never®							
9	Infrequent non-heavy	-0.34**	(-0.58,-0.10)	-0.49	(-1.29,0.31)	-0.29*	(-0.51,-0.06)	
10	Frequent non-heavy	-0.67**	(-1.09,-0.26)	-0.93	(-2.17,0.30)	-0.72***	(-1.10,-0.34)	
11	Heavy episodic drinker	-1.33***	(-1.78,-0.89)	-0.69	(-2.21,0.83)	-1.27***	(-1.68,-0.86)	
12	<b>Hypertension Status</b>							
13	Normal®							
14	Pre-hypertensive	0.15	(-0.08,0.38)	0.09	(-0.14,0.32)	0.11	(-0.05,0.27)	
15	High BP	0.36**	(0.12,0.60)	0.01	(-0.22,0.25)	0.18*	(0.01,0.34)	
16	<b>Diabetes</b>							
17	No®							
18	Yes	-0.68***	(-0.94,-0.42)	-0.66***	(-0.92,-0.41)	-0.74***	(-0.92,-0.56)	
19	<b>Cancer</b>							
20	No®							
21	Yes	0.34	(-0.91,1.58)	-0.16	(-1.27,0.95)	0.19	(-0.64,1.03)	
22	<b>Heart Disease</b>							
23	No®							
24	Yes	0.68***	(0.30,1.05)	-0.26	(-0.69,0.17)	0.32*	(0.04,0.60)	
25	<b>Stroke</b>							
26	No®							
27	Yes	-0.85**	(-1.43,-0.27)	-0.59	(-1.29,0.10)	-0.77***	(-1.21,-0.32)	
28								
29								
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31								
32	<b>Observations</b>	<b>10,526</b>		<b>9,558</b>		<b>20,084</b>		
33	<b>R<sup>2</sup></b>	<b>0.34</b>		<b>0.39</b>		<b>0.41</b>		
34	<i>Note: #Other Backward Classes; \$includes Sikh, Buddhist/neo-Buddhist, Jain, Parsi/Zoroastrian and others; BP- Blood Pressure.</i>							
35	<i>* p&lt;0.05, ** p&lt;0.01, *** p&lt;0.001</i>							
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**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*

For peer review only

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

	Men		Women		Total	
	$\beta$	(95% CI)	$\beta$	(95% CI)	$\beta$	(95% CI)
<b>Social Engagement</b>	-0.17***	(-0.23,-0.12)	-0.18***	(-0.23,-0.13)	-0.17***	(-0.21,-0.14)
<b>Cognitive function</b>	-0.04***	(-0.04,-0.03)	-0.04***	(-0.05,-0.03)	-0.04***	(-0.04,-0.03)
<b>Social Activities</b>	0.02	(-0.04,0.08)	0.06	(-0.02,0.13)	0.04	(-0.01,0.09)
<b>Age (years)</b>	-0.01**	(-0.01,-0.00)	0.00	(-0.01,0.01)	0.00	(-0.01,0.00)
<b>Gender</b>						
Men®	-	-	-	-		
Women	-	-	-	-	-0.06	(-0.12,0.00)
<b>Education level</b>						
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)
<b>Currently working</b>						
No®						
Yes	-0.10**	(-0.17,-0.03)	-0.02	(-0.11,0.06)	-0.06*	(-0.11,-0.01)
<b>Place of Residence</b>						
Rural®						
Urban	0.04	(-0.04,0.12)	-0.02	(-0.11,0.06)	0.01	(-0.05,0.07)
<b>Religion</b>						
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 <sup>s</sup>	-0.37***	(-0.54,-0.20)	-0.21*	(-0.39,-0.03)	-0.30***	(-0.42,-0.17)
<b>Caste</b>						
Scheduled caste®						
Scheduled tribe	-0.22**	(-0.36,-0.08)	-0.08	(-0.23,0.08)	-0.14**	(-0.24,-0.04)
OBC <sup>#</sup>	-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)
<b>Region</b>						
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)
<b>BMI categories</b>						
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)
<b>MPCE quintile</b>						
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)
<b>Currently smoking tobacco</b>						
No®						
Yes	0.15***	(0.07,0.22)	0.10	(-0.10,0.29)	0.15***	(0.08,0.23)
<b>Currently chewing tobacco</b>						
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<sup>2</sup>****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*

		Page No
<b>Recommendation</b>		
<b>Title and abstract</b>	(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
<b>Introduction</b>		
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
<b>Methods</b>		
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	
<b>Results</b>		
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	
<b>Discussion</b>		
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
<b>Other information</b>		
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](http://www.strobe-statement.org).



# BMJ Open

## 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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6 **Longitudinal Aging Study in India (LASI)**  
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10  
11 4 **Manish Kumar**

12 5 Ph.D. Research scholar, International Institute for Population Sciences, Mumbai,  
13 Maharashtra, India, 400088

14 7 E-mail: [kumarmanishiips@gmail.com](mailto:kumarmanishiips@gmail.com)

15 8 ORCID: 0000-0001-5297-6150

16 9 [Telephone number: +91 9702511509](tel:+919702511509)

17 10  
18 11 **T. Muhammad**

19 12 Ph.D. Research scholar, International Institute for Population Sciences, Mumbai,  
20 Maharashtra, India, 400088

21 14 E-mail: [muhhammad.iips@gmail.com](mailto:muhhammad.iips@gmail.com)

22 15 ORCID: 0000-0003-1486-7038

23 16  
24 17 **Laxmi Kant Dwivedi, PhD**

25 18 Professor, International Institute for Population Sciences, Mumbai, Maharashtra, India,  
26 400088

27 20 Email: [laxmikdwivedi@gmail.com](mailto:laxmikdwivedi@gmail.com)

28 21 ORCID: 0000-0001-9737-2844

29 22  
30 23 **Corresponding author:**

31 24  
32 25 **Manish Kumar**

33 26 Ph.D. Research scholar, International Institute for Population Sciences, Mumbai,  
34 Maharashtra, India, 400088

35 27 E-mail: [kumarmanishiips@gmail.com](mailto:kumarmanishiips@gmail.com)

36 28 ORCID: 0000-0001-5297-6150

37 29 [Telephone number: +91 9702511509](tel:+919702511509)

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4 31 **Assessing the role of depressive symptoms in the association between social engagement**  
5 32 **and cognitive functioning among older adults: analysis of cross-sectional data from the**  
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7 33 **Longitudinal Aging Study in India (LASI)**  
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10 34 **Abstract**

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12 35 **Objective:** The present study aimed to examine the confounding effects of depressive  
13 36 symptoms and the role of gender in the association between social engagement and cognitive  
14 37 functioning among older Indian adults.

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18 38 **Design:** A cross-sectional large scale survey data was analyzed in this study.

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21 39 **Setting and Participants:** Data from Longitudinal Aging Study in India (LASI; 2017-19) was  
22 40 used in analysis. The sample included 23,584 individuals aged 60 years and above (11,403 men  
23 41 and 12,181 women).

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27 42 **Primary and Secondary outcome measures:** The outcome variable was cognitive  
28 43 functioning which was based on different measures, including immediate and delayed word  
29 44 recall, orientation, executive functioning, arithmetic ability and object naming. Social  
30 45 engagement measure consists of marital status, living arrangement, availability of confidant,  
31 46 and participation in indoor games, and social and cultural functions. Moreover, the Center for  
32 47 Epidemiologic Studies Depression Scale (CES-D) was used to assess depressive symptoms.

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39 48 **Results:** Significant gender differences in the mean cognition scores (men: 25.8, women: 21.1;  
40 49 on a scale of 0-43) were observed. Regression results suggests that two-way interactions  
41 50 between social engagement and depressive symptoms were significant after controlling for  
42 51 explanatory factors. Men with high level of social engagements have significantly better  
43 52 cognitive functioning ( $\beta=1.12$ ; 95%CI: 0.72-1.53) compared with their counterparts. Also, as  
44 53 compared to men with lower social engagements, women with higher social engagements  
45 54 performs poorly on the cognitive tests (-0.42; 95%CI: -0.95-0.11), however, the result was not  
46 55 significant. Three-way interaction between social engagement, gender, and depressive  
47 56 symptoms were significantly associated with the cognitive functioning and showed a female  
48 57 disadvantage. KHB method identified a significant confounding effect of depressive symptoms  
49 58 on the relationship between social engagement and cognitive functioning.  
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4 59 **Conclusion:** The positive association of social engagement with cognitive functioning was  
5 60 significantly confounded by depressive symptoms, suggesting the need for maintaining social  
6 61 relations that help improve cognitive functioning among older adults.  
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9 62 **Keywords:** *social engagement, cognitive functioning, depressive symptoms, KHB-method,*  
10 63 *older adults.*  
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4 64 **Strengths and limitations of this study**  
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- 6 65 • The utilization of the national representative sample of older adults is a potential strength of the  
7 study  
8 66  
9 67 • KHB analysis explains the mechanism by which social engagement associated with cognitive  
10 function through a confounder, depressive symptoms  
11 68  
12 69 • The social engagements were significantly associated with better cognitive functioning for both  
13 older men and women  
14 70  
15 71 • The association of social engagement with cognitive functioning was significantly confounded  
16 by depressive symptoms  
17 72  
18 73 • The inability to establish the causal relationship between the variables of interest is the  
19 limitation of the study  
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## 89 Introduction

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

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

110 Several interventional studies reported the protective effects of the improved social behaviours  
111 in preventing or delaying dementia among older adults with diagnosed cognitive impairment  
112 [16, 17]. Most of the available research on social capital and engagement as to enhance  
113 cognitive reserve and protect cognitive health has been conducted in developed countries [18–  
114 21]. Little is known about the relationship between social engagement and cognitive  
115 functioning in developing countries like India, where the cultural and structural context of  
116 social engagement differ from developed countries. In India, traditionally, older adults are more  
117 likely to live with their children in multigenerational households where cultural norms  
118 emphasize family ties and the virtue of filial piety [22, 23], and a higher proportion of older  
119 people experience psychological distress and mental illnesses [24–26].

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3 120 Similarly, depressive disorders are highly prevalent among older adults in low and middle  
4 121 income countries [27–29] and in India in particular [30]. Previously, various studies have found  
5 122 the beneficial effects of greater social engagements (with varying measurements and  
6 123 definitions) against depressive symptoms [31, 32]. A cross-sectional study by Jang &  
7 124 Chiriboga (2011) [31] found that a higher level of participation in social activities was  
8 125 associated with a decline in depressive symptoms after controlling for the effects of  
9 126 demographic and health-related factors. Multiple longitudinal studies have also reported  
10 127 similar findings [33–37]. Also, increased participation in social activities and meaningful  
11 128 engagement by older adults may improve their mood, which benefits their emotional  
12 129 functioning and reduces depressive symptoms [38], which is linked to cognitive functioning  
13 130 [39]. According to the ‘depression reduction hypothesis’, depressive symptoms interferes with  
14 131 cognitive health; therefore, as evident from multiple longitudinal studies, practical strategies to  
15 132 reduce depressive symptoms will possibly improve cognitive functioning [40]. Two facts  
16 133 justify such a hypothesis; first, greater depressive symptoms are related to poor cognitive  
17 134 functioning among older adults [41, 42]. Second, depressed older adults who engage in social  
18 135 activities may experience a decline in depressive symptoms and improve cognitive functioning  
19 136 [43]. Furthermore, in multiple cohort studies, cognitively impaired older adults with depressive  
20 137 symptoms were associated with more rapid cognitive decline than those without depression  
21 138 [44, 45].

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37 139 However, it is not clear to what extent social engagement may improve cognitive functioning  
38 140 by minimizing depressive symptoms. There is a dearth of studies in low- and middle-income  
39 141 countries on the association of social engagements and cognitive functioning and the role of  
40 142 depressive symptoms in such association. Filling this gap, the present study using national-  
41 143 level data of older adults in India, aimed to examine the role of the depressive symptoms on  
42 144 the association between social engagement and cognitive functioning (Figure 1). Previous  
43 145 research showed a greater female disadvantage and theorized gender as the crucial factor to be  
44 146 considered in understanding the differences in cognitive functioning in Indian context [46–48].  
45 147 Also, studies have shown the significant gender differences in the association between social  
46 148 engagement and cognitive functioning [49, 50]. Thus, the study also explored the moderation  
47 149 effects of gender in the relationship between social engagement and cognitive functioning. The  
48 150 present study hypothesized that the association between social engagement and cognitive  
49 151 functioning is significantly confounded by depressive symptoms (Figure 2).

## 152 **Methods**



## 153 **Data**

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

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

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

## 180 **Measures**

### 181 **Cognitive function**

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

184 executive functioning, arithmetic, and object naming (Table 1). Previously, various studies  
 185 have established high validity and reliability of these cognitive domains for measuring  
 186 cognitive impairment among older adults in community settings in the United States [52],  
 187 China [53], and India [54]. The cognitive functioning in the present study is based on different  
 188 cognitive measures, including immediate (0–10 points) and delayed word recall (0–10 points);  
 189 orientation related to time (0-4 points), and place (0-4 points); executive functioning based on  
 190 paper folding (0-3) and pentagon drawing (0-1); arithmetic ability based on serial 7s (0–5  
 191 points), computation (0-2) and backward counting from 20 (0–2 points); and object naming (0-  
 192 2).

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

Domain	Measure	Measurement	Range
<b>Memory</b>	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
<b>Orientation</b>	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
<b>Arithmetic function</b>	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
<b>Executive function: 0-4</b>	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

<b>Object naming: 0-2</b>		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
<b>Cognition</b>	Composite cognitive index	Combined score of memory (total word recall), orientation, arithmetic function, executive function, and object naming.	0-43

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

### 196 *Social Engagements*

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

### 211 *Depressive symptoms*

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

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

### 224 *Covariates*

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

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

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

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3 252 frequency of participation, responses were coded as '0' for less than weekly, '1' for weekly or  
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5 253 more frequently for these activities.

### 254 ***Statistical analysis***

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

### 280 **Patient and public involvement**

281 No patient or public involvement.

### 282 **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	%
<b>Social Engagement</b>						
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
<b>Cognition<sup>a</sup></b>	25.9	6.7	21.3	7.0	23.5	7.3
<b>Depressive symptoms score<sup>a</sup></b>	2.8	1.6	3.0	1.7	2.9	1.7
<b>Age (years)<sup>a</sup></b>	68.7	7.1	68.2	7.2	68.5	7.1
<b>Social Activities (0-5)<sup>a</sup></b>	0.3	0.6	0.2	0.5	0.2	0.5
<b>Education level</b>						
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
<b>Currently working</b>						
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
<b>Place of Residence</b>						
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
<b>Religion</b>						

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

No	11,091	97.3	11,978	98.3	23,069	97.8
Yes	312	2.7	203	1.7	515	2.2

<b>Total</b>	<b>11,403</b>	<b>100.0</b>	<b>12,181</b>	<b>100.0</b>	<b>23,584</b>	<b>100.0</b>
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Note: #Other Backward Classes, <sup>a</sup>Mean and standard deviation; <sup>s</sup>includes Sikh, Buddhist/neo-Buddhist, Jain, Parsi/Zoroastrian and others; BP- Blood Pressure.

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301 The average cognitive score increased with an increase in the level of social engagement, and  
 302 it was higher among the non-depressed older adults (24.0 vs. 22.1) (Supplementary; Table S1).  
 303 Moreover, the prevalence of depressive symptoms decreased with an increase in the level of  
 304 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 <sup>1</sup>
<b>Social Engagement</b>				
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
<b>Age groups</b>				
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
<b>Social activities</b>				
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
<b>Education level</b>				
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
<b>Currently working</b>				
No	25.7	21.2	4.5	<0.001
Yes	26.0	20.8	5.2	<0.001
<b>Place of Residence</b>				
Rural	24.7	19.8	4.9	<0.001
Urban	28.7	24.4	4.3	<0.001
<b>Religion</b>				
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 <sup>s</sup>	24.3	21.2	3.1	<0.001
<b>Caste</b>				
Scheduled caste	24.1	19.4	4.7	<0.001
Scheduled tribe	22.2	17.8	4.4	<0.001
OBC <sup>#</sup>	26.2	21.7	4.5	<0.001
Others	27.4	22.4	5.0	<0.001
<b>Regions</b>				



1					
2					
3	North	25.4	20.0	5.4	<0.001
4	Central	25.9	20.8	5.1	<0.001
5	East	25.4	20.2	5.2	<0.001
6	Northeast	26.5	21.3	5.2	<0.001
7	West	25.7	21.0	4.7	<0.001
8	South	26.3	23.2	3.1	<0.001
9					
10	<b>BMI categories</b>				
11	Normal	26.0	20.8	5.2	<0.001
12	Underweight	23.3	18.2	5.1	<0.001
13	Overweight/Obese	28.7	24.5	4.2	<0.001
14					
15	<b>MPCE quintile</b>				
16	Poorest	24.2	19.6	4.6	<0.001
17	Poorer	24.9	20.3	4.6	<0.001
18	Middle	26.4	21.7	4.7	<0.001
19	Richer	26.3	21.9	4.4	<0.001
20	Richest	27.4	22.7	4.7	<0.001
21					
22	<b>Currently smoking tobacco</b>				
23	No	26.1	21.2	4.9	<0.001
24	Yes	24.7	18.1	6.6	<0.001
25					
26	<b>Currently consuming smokeless tobacco</b>				
27	No	26.1	21.4	4.7	<0.001
28	Yes	25.0	19.5	5.5	<0.001
29					
30	<b>Drinking Status</b>				
31	Never	26.2	21.2	5.0	<0.001
32	Infrequent non-heavy	25.4	18.9	6.5	<0.001
33	Frequent non-heavy	23.5	16.7	6.8	<0.001
34	Heavy episodic drinker	22.9	15.7	7.2	<0.001
35					
36	<b>Hypertension Status</b>				
37	Normal	24.7	20.6	4.1	<0.001
38	Pre-hypertensive	26.1	21.6	4.5	<0.001
39	High BP	26.2	20.9	5.3	<0.001
40					
41	<b>Diabetes</b>				
42	No	25.5	20.8	4.7	<0.001
43	Yes	27.7	23.3	4.4	<0.001
44					
45	<b>Cancer</b>				
46	No	25.8	21.1	4.7	<0.001
47	Yes	27.8	22.4	5.4	<0.001
48					
49	<b>Heart Disease</b>				
50	No	25.7	21.1	4.6	<0.001
51	Yes	27.7	22.5	5.2	<0.001
52					
53	<b>Stroke</b>				
54	No	25.8	21.1	4.7	<0.001
55	Yes	24.3	19.4	4.9	<0.001
56					
57	<b>Total</b>	<b>25.8</b>	<b>21.1</b>	<b>4.7</b>	<b>&lt;0.001</b>

Note: <sup>1</sup>Based on two sample t-test.

<sup>#</sup>Other Backward Classes; <sup>\$</sup>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 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 ( $\beta=1.12$ ; 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 ( $\beta = -0.18$ ,  $p<.001$ ) (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	
	$\beta$	(95% CI)
<b>Social engagements # Depressive symptoms</b>		
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)
<b>Social engagements # Gender</b>		
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)
<b>Social engagements # Gender # Depressive symptoms</b>		
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

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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

	$\beta$	(95% CI)
<b>Social Engagements</b>		
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)
<b>N</b>	<b>23,584</b>	
<b>Conf.-Perc<sup>a</sup></b>	<b>14.40%</b>	

*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. <sup>a</sup>Confounding percentage.

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

331

## 332 Discussion

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

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3 345 Structural aspects of social network are recommended to be essential to maintain an optimal  
4 346 level of cognitive functioning [67]. As documented, social networks and activity are related  
5 347 concepts and individuals who have a larger social networks tend to take part in more social  
6 348 activities [68]. Similarly, the satisfaction achieved from the social and support networks was  
7 349 observed to lead to better episodic memory performance, and processing speed and global  
8 350 cognition [69]. The main effect hypothesis in the present study is confirmed by the results  
9 351 showing that social engagements are independently associated with a greater level of cognitive  
10 352 functioning. The finding is consistent with previous studies linking the social involvement  
11 353 enhancing the wellbeing and boosting the self-esteem and creating a sense of belonging that  
12 354 result in better cognitive functioning [70–72]. A systematic review reported that although the  
13 355 exact nature of the associations are unclear, different aspects of social relationships such as  
14 356 social activity, social networks and social support and a composite measures of social  
15 357 relationships are associated with cognitive functioning [73]. Thus, social engagement  
16 358 interventions should be prioritized in public policy to help older adults optimize their cognitive  
17 359 health, regardless of underlying mechanisms.

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30 360 Although social engagements including the structural support from the spouse and family  
31 361 members are found to enhance cognitive functioning [74–76], the role of mental illnesses  
32 362 adversely affecting the association is less investigated. A recent study found the mediating role  
33 363 of hippocampal volume of brain which is known to be affected by a variety of psychiatric  
34 364 disorders in the association of emotional support with specific cognitive domains [77].  
35 365 Consistently, the current results showed that depressive symptom was significant confounder  
36 366 in the social engagement-cognitive functioning relationship. The finding is also in parallel with  
37 367 a recent study conducted in China showing the mediating role of depressive symptoms in the  
38 368 protective effect of frequent exercise on cognitive functioning [78]. Therefore, our results  
39 369 support the previous finding that the protective effect of social relationships is more related to  
40 370 the aspects of quality and functionality of such relationships than the quantity and structural  
41 371 characteristics [79]. Furthermore, the indirect effect of social engagements on cognitive  
42 372 functioning suggest that social resources can be related to better cognitive functioning through  
43 373 minimizing mental disorders in older adults, indicating that depressive symptoms may serve as  
44 374 an important intervening target and that reversing such illnesses might be related to a greater  
45 375 cognitive functioning. This is similar to an earlier finding that lack of social engagements may  
46 376 be particularly detrimental to late-life cognitive abilities when it is associated with mental  
47 377 illnesses [80]. Earlier meta-analyses and reviews have investigated loneliness, being one of the

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3 378 depressive symptoms, and social isolation together as part of health promotion interventions  
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5 379 and suggested that loneliness is often experienced as a part of lack of social engagement and  
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7 380 partly attribute to the factors of cognitive declines [81, 82], indicating the need for social  
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9 381 interventions that promote active participation of older people and help them in maintaining  
10  
11 382 social and structural relationships and coping with age-related stress factors.

12  
13 383 The available evidence suggests that there are gender differences in the relationship between  
14  
15 384 social engagement and cognitive functioning. For instance, in developed countries, numerous  
16  
17 385 studies have found that the cognitive performance of older women is as good as or better than  
18  
19 386 that of men [83–85]. By contrast, studies of cognitive abilities in developing countries find  
20  
21 387 older women often perform worse than older men [86, 87]. Moreover, earlier studies in India  
22  
23 388 reported a relatively lower cognitive functioning level among older women than men [46, 47].  
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25 389 In line with the previous literature, the current findings suggest a significant female  
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27 390 disadvantage in cognitive function among older Indian adults and call for special attention with  
28  
29 391 regard to public policy frameworks, clinical practice and future research.

30  
31 392 On the other hand, studies suggest that a greater social engagement protects against rapid  
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33 393 cognitive decline, particularly among low-educated older women [88]. In addition, social  
34  
35 394 networks were reported as highly influential for women than men in determining better health  
36  
37 395 behaviors related to cognitive maintenance [86]. Consistent with these previous studies, the  
38  
39 396 current analyses have shown that social engagement of older women is strongly associated with  
40  
41 397 better cognitive functioning with greater moderation effects of depressive symptoms compared  
42  
43 398 to older men. Nevertheless, it still needs to be further investigated whether gender differences  
44  
45 399 exist in the association of social engagements confounded by depressive symptoms with  
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47 400 cognitive functioning and causally inferred with studies of longitudinal design.

48  
49 401 There are several limitations of the present study to be noted. The composite index of social  
50  
51 402 engagement was generated from the questions which were self-reported. The responses may  
52  
53 403 have been exaggerated or under-reported. However, self-reporting is endorsed as an optimal  
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55 404 method to measure how the participants subjectively find themselves having social networks  
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57 405 and involved in social activities. On the other hand, exploring the aspect of social engagements  
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59 406 that include participating in indoor games for example, as distinct from domains of cognitive  
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407 activities is questionable, since it is not feasible to completely differentiate social engagement  
408 from cognitive engagements. Also many activities have a psychiatric element which may have  
409 positive impacts on cognitive processes and a complex confounding effect in the associations

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3 410 of three key variables in our study. Hence, considering the differences in relationships between  
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5 411 cognitive domains and the distinct forms of social engagements that also include structural  
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7 412 support from marital status and living arrangements, it is important to define social  
8  
9 413 relationships more clearly in future studies to achieve more reliable findings.

10  
11 414 Besides, in a population with huge proportion of illiterates, the assessment of cognitive  
12  
13 415 functioning with multiple domains might be subject to measurement error which can bias the  
14  
15 416 current findings. Similarly, older women in India who are largely deprived of education and  
16  
17 417 other opportunities including work participation might have resulted in greater gender gap in  
18  
19 418 cognitive functioning observed in our study. Another limitation is the inclusion of only men  
20  
21 419 and women in the study. Since LASI collects the information from men and women only, the  
22  
23 420 inclusion of the other gender was not possible. Finally, the present study was cross-sectional,  
24  
25 421 and thus, a causal relationship between the variables cannot be inferred. Further investigation  
26  
27 422 with longitudinal design is needed to explore the neural mechanisms that underlie the effects  
28  
29 423 of social engagements on cognitive decline. Future research might also consider the impact of  
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31 424 technology, internet and social media on social relationships, particularly feelings of social  
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33 425 support.

## 32 426 **Conclusion**

34  
35 427 The positive association of social engagement with cognitive functioning was significantly  
36  
37 428 confounded by depressive symptoms, suggesting the need for maintaining social relations that  
38  
39 429 help improve cognitive functioning among older adults. This needs to be confirmed with future  
40  
41 430 longitudinal and interventional studies. The study also highlights the potential of social  
42  
43 431 engagements independently or with others as an intervention to prevent cognitive impairment  
44  
45 432 among older individuals, especially among women.

## 46 433 **Abbreviations:**

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48 434 **MPCE:** Monthly Per capita Consumption Expenditure

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50 435 **CES-D:** Center for Epidemiological Studies-Depression

51  
52 436 **KHB:** Karlson–Holm–Breen

## 53 54 437 **Declarations**

55  
56 438 **Contributors:** MK and LKD conceived and designed the research paper. MK analyzed the  
57  
58 439 data. MK and TM contributed agents/materials/analysis tools. MK and TM wrote the  
59  
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3 440 manuscript. LKD provides supervision and validation. MK, TM and LKD refined the  
4 441 manuscript. All authors have read and approved the manuscript.

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6  
7 442 **Funding:** No funding was received for the study.

8  
9 443 **Competing interest:** The authors declare that there is no competing interest.

10  
11 444 **Patient consent for publication:** Not required.

12  
13 445 **Ethics approval:** The present study used the existing data, therefore, no ethics approval was  
14 446 required.

15  
16  
17 447 **Provenance and peer review:** Not commissioned; externally peer reviewed

18  
19 448 **Data availability statement:** The study uses secondary data which is available in the private  
20 449 database and accessible on reasonable request through

21  
22  
23 450 <https://www.iipsindia.ac.in/content/lasiwave-i>

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25  
26 451 **Consent for publication:** The administrative permission to access and use the data for the  
27 452 present study was taken from the International Institute for Population Sciences, Mumbai,  
28 453 which conducted the LASI survey.

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30  
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456 **References**

- 457 [1] Hsiao H-T, Li S-Y, Yang Y-P, et al. Cognitive function and quality of life in community-  
458 dwelling seniors with mild cognitive impairment in Taiwan. *Community mental health journal*  
459 2016; 52: 493–498.
- 460 [2] McGuire LC, Ford ES, Ajani UA. The impact of cognitive functioning on mortality and the  
461 development of functional disability in older adults with diabetes: the second longitudinal  
462 study on aging. *BMC geriatrics* 2006; 6: 1–7.
- 463 [3] Aarts S, Van den Akker M, Tan FES, et al. Influence of multimorbidity on cognition in a  
464 normal aging population: a 12-year follow-up in the Maastricht aging study. *International*  
465 *journal of geriatric psychiatry* 2011; 26: 1046–1053.
- 466 [4] Lv X, Li W, Ma Y, et al. Cognitive decline and mortality among community-dwelling Chinese  
467 older people. *BMC medicine* 2019; 17: 1–10.
- 468 [5] United Nation. *World Population Ageing 2017 report*. 2017.
- 469 [6] Bassuk SS, Glass TA, Berkman LF. Social disengagement and incident cognitive decline in  
470 community-dwelling elderly persons. *Annals of internal medicine* 1999; 131: 165–173.
- 471 [7] Baltes MM. *The many faces of dependency in old age*. Cambridge University Press, 1996.
- 472 [8] Li Y, Xu L, Chi I, et al. Participation in productive activities and health outcomes among older  
473 adults in urban China. *The Gerontologist* 2014; 54: 784–796.
- 474 [9] Holtzman RE, Rebok GW, Saczynski JS, et al. Social network characteristics and cognition in  
475 middle-aged and older adults. *Journals of Gerontology - Series B Psychological Sciences and*  
476 *Social Sciences* 2004; 59: 278–284.
- 477 [10] Krueger KR, Wilson RS, Kamenetsky JM, et al. Social engagement and cognitive function in  
478 old age. *Experimental aging research* 2009; 35: 45–60.
- 479 [11] Béland F, Zunzunegui MV, Alvarado B, et al. Trajectories of cognitive decline and social  
480 relations. *Journals of Gerontology - Series B Psychological Sciences and Social Sciences*  
481 2005; 60: 320–330.
- 482 [12] Zunzunegui MV, Alvarado BE, Del Ser T, et al. Social networks, social integration, and social  
483 engagement determine cognitive decline in community-dwelling Spanish older adults.  
484 *Journals of Gerontology - Series B Psychological Sciences and Social Sciences* 2003; 58: 93–  
485 100.
- 486 [13] Kim YB, Lee SH. Social network types and cognitive decline among older Korean adults: A  
487 longitudinal population-based study. *International Journal of Geriatric Psychiatry* 2019; 34:  
488 1845–1854.
- 489 [14] Lee SH, Kim YB. Which type of social activities may reduce cognitive decline in the elderly?:  
490 A longitudinal population-based study. *BMC Geriatrics* 2016; 16: 1–9.
- 491 [15] Thomas PA. Trajectories of social engagement and limitations in late life. *Journal of Health*  
492 *and Social Behavior* 2011; 52: 430–443.



- 1  
2  
3 493 [16] Maffei L, Picano E, Andreassi MG, et al. Randomized trial on the effects of a combined  
4 494 physical/cognitive training in aged MCI subjects: the Train the Brain study. *Scientific Reports*  
5 495 2017; 7: 39471.
- 6  
7 496 [17] Straubmeier M, Behrndt E-M, Seidl H, et al. Non-pharmacological treatment in people with  
8 497 cognitive impairment: results from the randomized controlled german day care study.  
9 498 *Deutsches Ärzteblatt International* 2017; 114: 815.
- 10  
11 499 [18] Ihle A, Oris M, Baeriswyl M, et al. The longitudinal relation between social reserve and  
12 500 smaller subsequent decline in executive functioning in old age is mediated via cognitive  
13 501 reserve. *International Psychogeriatrics* 2021; 33: 461–467.
- 14  
15 502 [19] González-Ortega I, González-Pinto A, Alberich S, et al. Influence of social cognition as a  
16 503 mediator between cognitive reserve and psychosocial functioning in patients with first episode  
17 504 psychosis. *Psychological Medicine*. Epub ahead of print 2019. DOI:  
18 505 10.1017/S0033291719002794.
- 19  
20 506 [20] Haslam C, Cruwys T, Haslam SA. ‘The we’s have it’: Evidence for the distinctive benefits of  
21 507 group engagement in enhancing cognitive health in aging. *Social Science and Medicine* 2014;  
22 508 120: 57–66.
- 23  
24 509 [21] Conroy RM, Golden J, Jeffares I, et al. Boredom-proneness, loneliness, social engagement and  
25 510 depression and their association with cognitive function in older people: A population study.  
26 511 *Psychology, Health and Medicine* 2010; 15: 463–473.
- 27  
28 512 [22] Samanta T, Chen F, Vanneman R. Living arrangements and health of older adults in India.  
29 513 *Journals of Gerontology Series B: Psychological Sciences and Social Sciences* 2015; 70: 937–  
30 514 947.
- 31  
32 515 [23] Srivastava S, Shaw S, Chaurasia H, et al. Feeling about living arrangements and associated  
33 516 health outcomes among older adults in India : a cross-sectional study. *BMC Public Health*  
34 517 2021; 21: 1–14.
- 35  
36 518 [24] Muhammad T, Srivastava S, Sekher T V. Association of self-perceived income status with  
37 519 psychological distress and subjective well-being: a cross-sectional study among older adults in  
38 520 India. *BMC Psychology* 2021; 9: 1–13.
- 39  
40 521 [25] Srivastava S, Chauhan S, Muhammad T, et al. Older adults’ psychological and subjective well-  
41 522 being as a function of household decision making role: Evidence from cross-sectional survey  
42 523 in India. *Clinical Epidemiology and Global Health* 2021; 10: 100676.
- 43  
44 524 [26] Srivastava S, Purkayastha N, Chaurasia H, et al. Socioeconomic inequality in psychological  
45 525 distress among older adults in India : a decomposition analysis. *BMC Psychiatry* 2021; 21: 1–  
46 526 15.
- 47  
48 527 [27] Fernández-Niño JA, Bonilla-Tinoco LJ, Manrique-Espinoza BS, et al. Work status, retirement,  
49 528 and depression in older adults: An analysis of six countries based on the Study on Global  
50 529 Ageing and Adult Health (SAGE). *SSM - Population Health* 2018; 6: 1–8.
- 51  
52 530 [28] Anand A. Understanding Depression among Older Adults in Six Low-Middle Income  
53 531 Countries using WHO-SAGE Survey. *Behavioral Health*; 1.
- 54  
55 532 [29] Smith L, Il Shin J, McDermott D, et al. Association between food insecurity and depression  
56 533 among older adults from low- and middle-income countries. *Depression and Anxiety* 2021; 38:  
57 534 439–446.
- 58  
59  
60

- 1  
2  
3 535 [30] Srivastava S, Debnath P, Shri N, et al. The association of widowhood and living alone with  
4 536 depression among older adults in India. *Scientific Reports* 2021; 1–13.
- 5  
6 537 [31] Jang Y, Chiriboga DA. Social activity and depressive symptoms in Korean American older  
7 538 adults: The conditioning role of acculturation. *Journal of Aging and Health* 2011; 23: 767–781.
- 8  
9 539 [32] Strauss J, Park A, Smith JP. Health Outcomes and Socio-Economic Status Among the Elderly  
10 540 in Gansu and Zhejiang Provinces, China: Evidence from the CHARLS Pilot. 2013; 3: 111–  
11 541 142.
- 12  
13 542 [33] Chiao C, Weng L-J, Botticello AL. Social participation reduces depressive symptoms among  
14 543 older adults: an 18-year longitudinal analysis in Taiwan. *BMC public health* 2011; 11: 1–9.
- 15  
16 544 [34] Isaac V, Stewart R, Artero S, et al. Social activity and improvement in depressive symptoms in  
17 545 older people: a prospective community cohort study. *The American Journal of Geriatric  
18 546 Psychiatry* 2009; 17: 688–696.
- 19  
20 547 [35] Lou VWQ, Chi I, Kwan CW, et al. Trajectories of social engagement and depressive  
21 548 symptoms among long-term care facility residents in Hong Kong. *Age and Ageing* 2013; 42:  
22 549 215–222.
- 23  
24 550 [36] Takagi D, Kondo K, Kawachi I. Social participation and mental health: moderating effects of  
25 551 gender, social role and rurality. *BMC public health* 2013; 13: 1–8.
- 26  
27 552 [37] Glass TA, De Leon CFM, Bassuk SS, et al. Social engagement and depressive symptoms in  
28 553 late life: longitudinal findings. *Journal of aging and health* 2006; 18: 604–628.
- 29  
30 554 [38] Fiske A, Wetherell JL, Gatz M. Depression in older adults. *Annual review of clinical  
31 555 psychology* 2009; 5: 363–389.
- 32  
33 556 [39] Pressman SD, Matthews KA, Cohen S, et al. Association of enjoyable leisure activities with  
34 557 psychological and physical well-being. *Psychosomatic medicine* 2009; 71: 725.
- 35  
36 558 [40] Vance DE, Marson DC, Triebel KL, et al. Physical activity and cognitive function in older  
37 559 adults: The mediating effect of depressive symptoms. *The Journal of neuroscience nursing:  
38 560 journal of the American Association of Neuroscience Nurses* 2016; 48: E2.
- 39  
40 561 [41] Muhammad T, Meher T. Association of late-life depression with cognitive impairment:  
41 562 evidence from a cross-sectional study among older adults in India. *BMC Geriatrics* 2021; 21:  
42 563 1–13.
- 43  
44 564 [42] van den Kommer TN, Comijs HC, Aartsen MJ, et al. Depression and cognition: how do they  
45 565 interrelate in old age? *The American Journal of Geriatric Psychiatry* 2013; 21: 398–410.
- 46  
47 566 [43] Dickinson WJ, Potter GG, Hybels CF, et al. Change in stress and social support as predictors  
48 567 of cognitive decline in older adults with and without depression. *International journal of  
49 568 geriatric psychiatry* 2011; 26: 1267–1274.
- 50  
51 569 [44] Van Der Mussele S, Fransen E, Struyfs H, et al. Depression in mild cognitive impairment is  
52 570 associated with progression to alzheimer's disease: A longitudinal study. *Journal of  
53 571 Alzheimer's Disease* 2014; 42: 1239–1250.
- 54  
55 572 [45] Verdelho A, Madureira S, Moleiro C, et al. Depressive symptoms predict cognitive decline and  
56 573 dementia in older people independently of cerebral white matter changes: The LADIS study.  
57 574 *Journal of Neurology, Neurosurgery and Psychiatry* 2013; 84: 1250–1254.

- 1  
2  
3 575 [46] Lee J, Shih R, Feeney K, et al. Gender disparity in late-life cognitive functioning in India:  
4 576 findings from the longitudinal aging study in India. *Journals of Gerontology Series B:*  
5 577 *Psychological Sciences and Social Sciences* 2014; 69: 603–611.
- 7 578 [47] Angrisani M, Jain U, Lee J. Sex differences in cognitive health among older adults in India.  
8 579 *Journal of the American Geriatrics Society* 2020; 68: S20–S28.
- 10 580 [48] Jain U, Angrisani M, Langa KM, et al. How much of the female disadvantage in late-life  
11 581 cognition in India can be explained by education and gender inequality. *Sci Rep* 2022; 12:  
12 582 5684.
- 15 583 [49] Pillemer S, Ayers E, Holtzer R. Gender-stratified analyses reveal longitudinal associations  
16 584 between social support and cognitive decline in older men. *Aging & mental health* 2019; 23:  
17 585 1326–1332.
- 19 586 [50] Oh SS, Cho E, Kang B. Social engagement and cognitive function among middle-aged and  
20 587 older adults: gender-specific findings from the Korean longitudinal study of aging (2008–  
21 588 2018). *Scientific Reports* 2021; 11: 1–9.
- 23 589 [51] International Institute for Population Sciences (IIPS), NPHCE, MoHFW HTHCS of PH  
24 590 (HSPH) and the U of SC (USC). *Longitudinal Ageing Study in India (LASI) Wave 1, 2017-18,*  
25 591 *India Report*. Mumbai., 2020.
- 27 592 [52] Herzog AR, Wallace RB. Measures of cognitive functioning in the AHEAD study. *Journals of*  
28 593 *Gerontology - Series B Psychological Sciences and Social Sciences* 1997; 52: 37–48.
- 30 594 [53] Meng Q, Wang H, Strauss J, et al. Validation of neuropsychological tests for the China Health  
31 595 and Retirement Longitudinal Study Harmonized Cognitive Assessment Protocol. *International*  
32 596 *Psychogeriatrics* 2019; 31: 1709–1719.
- 34 597 [54] Gupta M, Gupta V, Nagar Buckshee R, et al. Validity and reliability of hindi translated version  
35 598 of Montreal cognitive assessment in older adults. *Asian Journal of Psychiatry* 2019; 45: 125–  
36 599 128.
- 38 600 [55] Zhou Z, Mao F, Han Y, et al. Social engagement and cognitive impairment in older Chinese  
39 601 adults: The mediating role of psychological well-being. *Journal of aging and health* 2020; 32:  
40 602 573–581.
- 42 603 [56] Sampson EL, Bulpitt CJ, Fletcher AE. Survival of community-dwelling older people: the effect  
43 604 of cognitive impairment and social engagement. *Journal of the American Geriatrics Society*  
44 605 2009; 57: 985–991.
- 46 606 [57] Radloff LS. The CES-D scale: A self-report depression scale for research in the general  
47 607 population. *Applied psychological measurement* 1977; 1: 385–401.
- 49 608 [58] Irwin M, Artin KH, Oxman MN. Screening for Depression in the Older Adult. *Archives of*  
50 609 *Internal Medicine* 1999; 159: 1701.
- 52 610 [59] Kumar S, Nakulan A, Thoppil SP, et al. Screening for depression among community-dwelling  
53 611 elders: usefulness of the center for epidemiologic studies depression scale. *Indian Journal of*  
54 612 *Psychological Medicine* 2016; 38: 483–485.
- 56 613 [60] Chitnis S. Definition of the terms scheduled castes and scheduled tribes: a crisis of  
57 614 ambivalence. *The Politics of Backwardness: Reservation Policy in India New Delhi, India:*  
58 615 *Centre for Policy Research*.

- 1  
2  
3 616 [61] Dong X, Li Y, Simon MA. Social engagement among U.S. Chinese older adults-findings from  
4 617 the PINE study. *Journals of Gerontology - Series A Biological Sciences and Medical Sciences*  
5 618 2014; 69: S82–S89.
- 6  
7 619 [62] Karlson KB, Holm A. Decomposing primary and secondary effects: A new decomposition  
8 620 method. *Research in Social Stratification and mobility* 2011; 29: 221–237.
- 9  
10 621 [63] Karlson KB, Holm A, Breen R. Comparing regression coefficients between same-sample  
11 622 nested models using logit and probit: A new method. *Sociological methodology* 2012; 42: 286–  
12 623 313.
- 13  
14 624 [64] Kohler U, Karlson KB, Kohler U, et al. KHB: Stata module to decompose total effects into  
15 625 direct and indirect via KHB-method.
- 16  
17 626 [65] Bethell J, Aelick K, Babineau J, et al. Social Connection in Long-Term Care Homes: A  
18 627 Scoping Review of Published Research on the Mental Health Impacts and Potential Strategies  
19 628 During COVID-19. *Journal of the American Medical Directors Association* 2021; 22: 228-  
20 629 237.e25.
- 21  
22  
23 630 [66] Doll-Wilhelm JL. The Impact of Social Isolation and Cognitive Decline in Older Adults: A  
24 631 Systematic Literature Review.
- 25  
26 632 [67] Li M, Dong X. Is Social Network a Protective Factor for Cognitive Impairment in US Chinese  
27 633 Older Adults? Findings from the PINE Study. *Gerontology* 2018; 64: 246–256.
- 28  
29 634 [68] Ozbay F, Johnson DC, Dimoulas E, et al. Social support and resilience to stress: from  
30 635 neurobiology to clinical practice. *Psychiatry (Edgmont (Pa : Township))* 2007; 4: 35–40.
- 31  
32 636 [69] Hughes TF, Andel R, Small BJ, et al. The association between social resources and cognitive  
33 637 change in older adults: Evidence from the Charlotte County Healthy Aging Study. *Journals of*  
34 638 *Gerontology - Series B Psychological Sciences and Social Sciences* 2008; 63: 241–244.
- 35  
36 639 [70] Thoits PA. Mechanisms linking social ties and support to physical and mental health. *Journal*  
37 640 *of Health and Social Behavior* 2011; 52: 145–161.
- 38  
39 641 [71] Kuiper JS, Zuidersma M, Zuidema SU, et al. Social relationships and cognitive decline: a  
40 642 systematic review and meta-analysis of longitudinal cohort studies. *International Journal of*  
41 643 *Epidemiology* 2016; 45: 1169–1206.
- 42  
43 644 [72] Muhammad T, Srivastava S, Sekher T V. Association of self-perceived income sufficiency  
44 645 with cognitive impairment among older adults: a population-based study in India. *BMC*  
45 646 *Psychiatry* 2021; 21: 1–14.
- 46  
47 647 [73] Kelly ME, Duff H, Kelly S, et al. The impact of social activities, social networks, social support  
48 648 and social relationships on the cognitive functioning of healthy older adults: A systematic  
49 649 review. *Systematic Reviews*; 6. Epub ahead of print 2017. DOI: 10.1186/s13643-017-0632-2.
- 50  
51  
52 650 [74] Barnes LL, De Leon CFM, Wilson RS, et al. Social resources and cognitive decline in a  
53 651 population of older African Americans and whites. *Neurology* 2004; 63: 2322–2326.
- 54  
55 652 [75] Ayotte BJ, Allaire JC, Whitfield KE. Social support, physical functioning, and cognitive  
56 653 functioning among older African American adults. *Aging, Neuropsychology, and Cognition*  
57 654 2013; 20: 494–510.
- 58  
59  
60

- 1  
2  
3 655 [76] Muhammad T, Govindu M, Srivastava S. Relationship between chewing tobacco, smoking,  
4 656 consuming alcohol and cognitive impairment among older adults in India: a cross-sectional  
5 657 study. *BMC Geriatrics* 2021; 21: 85.
- 7 658 [77] Kim GE, Han JW, Kim TH, et al. Hippocampus mediates the effect of emotional support on  
8 659 cognitive function in older adults Authors. *The Journals of Gerontology: Series A* 2020; 75:  
9 660 1502–1507.
- 11 661 [78] Yuan M, Fu H, Liu R, et al. Effect of frequency of exercise on cognitive function in older  
12 662 adults: Serial mediation of depression and quality of sleep. *International Journal of*  
13 663 *Environmental Research and Public Health*; 17. Epub ahead of print 2020. DOI:  
14 664 10.3390/ijerph17030709.
- 16 665 [79] Amieva H, Stoykova R, Matharan F, et al. What aspects of social network are protective for  
17 666 dementia? Not the quantity but the quality of social interactions is protective up to 15 years  
18 667 later. *Psychosomatic Medicine* 2010; 72: 905–911.
- 21 668 [80] Yang R, Wang H, Edelman LS, et al. Loneliness as a mediator of the impact of social isolation  
22 669 on cognitive functioning of Chinese older adults. *Age and Ageing* 2020; 49: 599–604.
- 24 670 [81] Valtorta N, Hanratty B. Loneliness, isolation and the health of older adults: Do we need a new  
25 671 research agenda? *Journal of the Royal Society of Medicine, Supplement* 2012; 105: 518–522.
- 27 672 [82] Cattan M, White M, Bond J, et al. Preventing social isolation and loneliness among older  
28 673 people: A systematic review of health promotion interventions. *Ageing and Society* 2005; 25:  
29 674 41–67.
- 31 675 [83] Langa KM, Llewellyn DJ, Lang IA, et al. Cognitive health among older adults in the United  
32 676 States and in England. *BMC geriatrics* 2009; 9: 1–11.
- 34 677 [84] De Frias CM, Nilsson L-G, Herlitz A. Sex differences in cognition are stable over a 10-year  
35 678 period in adulthood and old age. *Ageing, Neuropsychology, and Cognition* 2006; 13: 574–587.
- 37 679 [85] Van Hooren S, Valentijn A, Bosma H, et al. Cognitive\_Functioning\_in\_Healthy\_Older\_A.pdf.  
38 680 2007; 40–54.
- 40 681 [86] Lei X, Hu Y, McArdle JJ, et al. Gender differences in cognition among older adults in China.  
41 682 *Journal of Human Resources* 2012; 47: 951–971.
- 43 683 [87] Maurer J. Education and male-female differences in later-life cognition: International evidence  
44 684 from Latin America and the Caribbean. *Demography* 2011; 48: 915–930.
- 46 685 [88] Lee Y, Jean Yeung WJ. Gender matters: Productive social engagement and the subsequent  
47 686 cognitive changes among older adults. *Social Science and Medicine* 2019; 229: 87–95.
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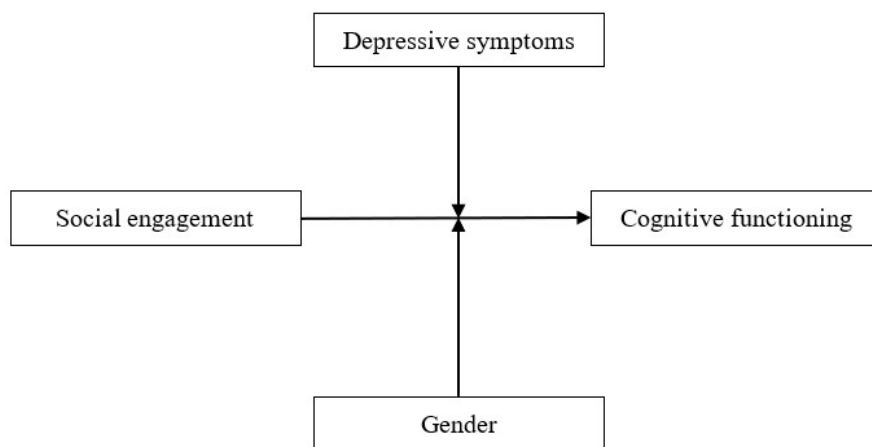
688 Figure Legend:

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

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

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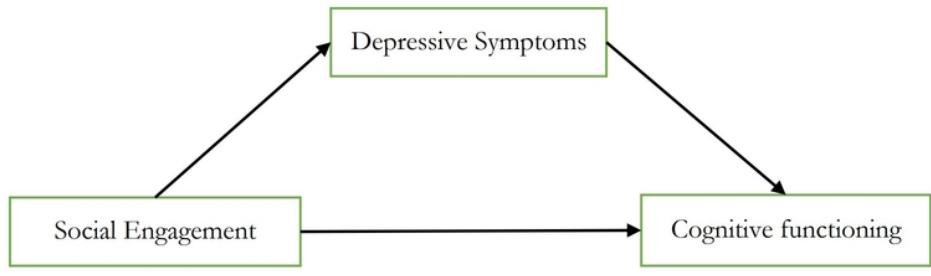
For peer review only



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

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

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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)		<i>Low (n=7,401)</i>		<i>Medium (n=14,052)</i>		<i>High (n=2,131)</i>	
	<i>N</i>	<i>Mean (sd.)</i>						
<b>Social Engagements</b>								
Low	7,401	20.7 (7.1)	-	-	-	-	-	-
Medium	14,052	24.5 (7)	-	-	-	-	-	-
High	2,131	26.8 (6.6)	-	-	-	-	-	-
<b>Depression<sup>a</sup></b>								
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
<b>Age (years)</b>								
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
<b>Social Activities</b>								
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
<b>Education level</b>								
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
<b>Currently working</b>								
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
<b>Place of Residence</b>								
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
<b>Religion</b>								
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 <sup>s</sup>	1,184	23.5 (7.2)	315	4.3	718	5.1	151	7.1
<b>Caste</b>								
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 <sup>#</sup>	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
<b>Regions</b>								
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
<b>BMI categories</b>								
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

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3	Overweight/Obese	5,781	26.1 (7)	1,676	22.6	3,461	24.6	644	30.2	
4	<b>MPCE quintile</b>									
5	Poorest	4,827	21.8 (7.1)	1,695	22.9	2,795	19.9	337	15.8	
6	Poorer	4,861	22.7 (7.1)	1,614	21.8	2,873	20.4	374	17.6	
7	Middle	4,862	23.6 (7.1)	1,478	20.0	2,909	20.7	475	22.3	
8	Richer	4,647	24.3 (7.1)	1,389	18.8	2,832	20.2	426	20.0	
9	Richest	4,387	25.6 (7.3)	1,225	16.6	2,643	18.8	519	24.4	
10										
11	<b>Currently smoking tobacco</b>									
12	No	20,210	23.5 (7.3)	6,719	90.8	11,747	83.6	1,744	81.8	
13	Yes	3,374	23.7 (6.7)	682	9.2	2,305	16.4	387	18.2	
14	<b>Currently chewing tobacco</b>									
15	No	18,871	23.7 (7.3)	5,930	80.1	11,198	79.7	1,743	81.8	
16	Yes	4,713	22.9 (6.9)	1,471	19.9	2,854	20.3	388	18.2	
17	<b>Drinking Status</b>									
18	Never	19,368	23.4 (7.3)	6,573	88.8	11,099	79.0	1,696	79.6	
19	Infrequent non-heavy	2,568	24.8 (6.9)	484	6.5	1,781	12.7	303	14.2	
20	Frequent non-heavy	870	23.3 (7.2)	191	2.6	617	4.4	62	2.9	
21	Heavy episodic drinker	778	22.9 (7.1)	153	2.1	555	3.9	70	3.3	
22										
23	<b>Hypertension Status</b>									
24	Normal	5,386	22.9 (7)	1,512	20.4	3,386	24.1	488	22.9	
25	Pre-hypertensive	9,015	23.9 (7.2)	2,644	35.7	5,505	39.2	866	40.6	
26	High BP	9,183	23.5 (7.4)	3,245	43.8	5,161	36.7	777	36.5	
27	<b>Diabetes</b>									
28	No	19,987	23.1 (7.2)	6,436	87.0	11,782	83.8	1,769	83.0	
29	Yes	3,597	25.9 (7)	965	13.0	2,270	16.2	362	17.0	
30	<b>Cancer</b>									
31	No	23,420	23.5 (7.3)	7,355	99.4	13,955	99.3	2,110	99.0	
32	Yes	164	24.5 (7.2)	46	0.6	97	0.7	21	1.0	
33	<b>Heart Disease</b>									
34	No	22,399	23.4 (7.3)	7,096	95.9	13,300	94.6	2,003	94.0	
35	Yes	1,185	25.8 (7)	305	4.1	752	5.4	128	6.0	
36	<b>Stroke</b>									
37	No	23,069	23.5 (7.3)	7,258	98.1	13,726	97.7	2,085	97.8	
38	Yes	515	23 (7.2)	143	1.9	326	2.3	46	2.2	
39										
40										
41	<b>Total</b>	<b>23,584</b>	<b>23.5 (7.3)</b>	<b>7,401</b>	<b>100.0</b>	<b>14,052</b>	<b>100.0</b>	<b>2,131</b>	<b>100.0</b>	
42	<i>Note:</i> <sup>a</sup> overall score ranges from zero to 10 and individuals with score of four or more are considered as depressed; <sup>#</sup>									
43	Other Backward Classes, <sup>\$</sup> includes Sikh, Buddhist/neo-Buddhist, Jain, Parsi/Zoroastrian and others; BP- Blood									
44	Pressure.									
45	<i>Note:</i> *p<0.05, **p<0.01, ***p<0.001									
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50 **Table S2.** Linear regression results of interaction of social engagement and depressive symptoms on cognitive functioning,  
51 by gender, (N = 23,584).

52		Men		Women		Total	
53		$\beta$	(95% CI)	$\beta$	(95% CI)	$\beta$	(95% CI)
54	<b>Social engagements # Depressive</b>						
55	<b>symptoms</b>						
56	Low + depressive symptoms	-0.53***	(-0.62,-0.45)	-0.49***	(-0.55,-0.43)	-0.61***	(-0.66,-0.56)
57	Medium + depressive						
58	symptoms	-0.33***	(-0.40,-0.27)	-0.32***	(-0.39,-0.26)	-0.28***	(-0.33,-0.23)
59	High + depressive symptoms	-0.19**	(-0.31,-0.07)	-0.16*	(-0.32,-0.01)	-0.10*	(-0.20,-0.01)
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3	<b>Social Activities</b>	0.26**	(0.07,0.44)	0.76***	(-0.55,0.97)	0.48*** (0.33,0.62)
4	<b>Age (years)</b>	-0.11***	(-0.13,-0.10)	-0.15***	(-0.17,-0.14)	-0.11*** (-0.12,-0.10)
5	<b>Education level</b>					
6	No education®					
7	Primary	4.06***	(3.82,4.30)	4.23***	(3.96,4.50)	4.82*** (4.64,4.99)
8	Secondary	6.92***	(6.63,7.21)	8.12***	(7.73,8.52)	8.27*** (8.05,8.49)
9	Higher	7.61***	(7.24,7.97)	9.99***	(9.39,10.59)	9.28*** (8.99,9.56)
10	<b>Currently working</b>					
11	No®					
12	Yes	0.31**	(0.10,0.52)	0.59***	(0.35,0.84)	0.87*** (0.71,1.03)
14	<b>Place of Residence</b>					
15	Rural®					
16	Urban	1.28***	(1.03,1.53)	1.26***	(1.02,1.50)	1.16*** (0.99,1.34)
17	<b>Religion</b>					
18	Hindu®					
19	Muslim	0.72***	(0.38,1.06)	-0.38*	(-0.70,-0.05)	0.37** (0.13,0.60)
20	Christian	-0.63	(-1.27,0.00)	0.06	(-0.51,0.63)	-0.26 (-0.70,0.17)
21	Others\$	-0.65*	(-1.18,-0.13)	0.41	(-0.10,0.91)	0.13 (-0.24,0.49)
22	<b>Caste</b>					
23	Scheduled caste®					
24	Scheduled tribe	-1.36***	(-1.78,-0.94)	-1.15***	(-1.55,-0.76)	-1.40*** (-1.69,-1.11)
25	OBC#	0.46**	(0.18,0.73)	0.74***	(0.48,1.00)	0.58*** (0.39,0.77)
26	None of them	0.40*	(0.10,0.71)	0.66***	(0.36,0.95)	0.44*** (0.23,0.66)
27	<b>Region</b>					
28	North®					
29	Central	1.17***	(0.81,1.53)	1.81***	(1.47,2.15)	1.58*** (1.33,1.83)
30	East	0.43*	(0.08,0.78)	0.96***	(0.63,1.29)	0.69*** (0.45,0.93)
31	Northeast	1.10***	(0.45,1.76)	1.10***	(0.47,1.72)	0.87*** (0.41,1.33)
32	West	-1.13***	(-1.51,-0.76)	-0.57**	(-0.92,-0.23)	-0.93*** (-1.19,-0.67)
33	South	0.27	(-0.10,0.64)	1.82***	(1.47,2.16)	1.11*** (0.85,1.36)
35	<b>BMI categories</b>					
36	Normal®					
37	Underweight	-0.93***	(-1.17,-0.70)	-1.19***	(-1.42,-0.96)	-1.07*** (-1.24,-0.91)
38	Overweight/obese	0.76***	(0.50,1.02)	1.00***	(0.76,1.24)	0.77*** (0.59,0.95)
39	<b>MPCE quintile</b>					
40	Poorest®					
41	Poorer	0.03	(-0.27,0.32)	0.15	(-0.12,0.43)	0.10 (-0.11,0.30)
42	Middle	0.39*	(0.09,0.69)	0.60***	(0.32,0.88)	0.38*** (0.17,0.59)
43	Richer	0.73***	(0.42,1.04)	0.70***	(0.40,0.99)	0.65*** (0.43,0.87)
44	Richest	0.79***	(0.45,1.12)	0.72***	(0.41,1.04)	0.63*** (0.40,0.87)
45	<b>Currently smoking tobacco</b>					
46	No®					
47	Yes	0.25*	(0.00,0.49)	-0.53*	(-1.03,-0.03)	0.84*** (0.63,1.05)
49	<b>Currently chewing tobacco</b>					
50	No®					
51	Yes	0.10	(-0.14,0.33)	-0.23	(-0.49,0.02)	0.25** (0.07,0.42)
52	<b>Drinking Status</b>					
53	Never®					
54	Infrequent non-heavy	-0.32*	(-0.58,-0.06)	-0.41	(-1.21,0.38)	0.39** (0.15,0.64)
55	Frequent non-heavy	-1.14***	(-1.58,-0.70)	-2.44***	(-3.55,-1.33)	-0.69*** (-1.09,-0.29)
56	Heavy episodic drinker	-1.74***	(-2.21,-1.28)	-2.56***	(-3.77,-1.36)	-1.22*** (-1.65,-0.78)
57	<b>Hypertension Status</b>					
58	Normal®					
59	Pre-hypertensive	0.25*	(0.00,0.50)	0.21	(-0.03,0.46)	0.20* (0.03,0.38)
60	High BP	0.37**	(0.11,0.63)	0.00	(-0.24,0.25)	0.10 (-0.08,0.28)

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3	<b>Diabetes</b>						
4	No®						
5	Yes	-0.59***	(-0.87,-0.30)	-0.47**	(-0.76,-0.18)	-0.52*** (-0.73,-0.32)	
6	<b>Cancer</b>						
7	No®						
8	Yes	0.81	(-0.57,2.20)	-0.34	(-1.55,0.87)	0.19 (-0.74,1.12)	
9	<b>Heart Disease</b>						
10	No®						
11	Yes	0.81***	(0.40,1.22)	0.24	(-0.24,0.71)	0.75*** (0.43,1.06)	
12	<b>Stroke</b>						
13	No®						
14	Yes	-1.55***	(-2.14,-0.96)	-1.41***	(-2.11,-0.71)	-1.33*** (-1.79,-0.87)	
15							
16	N	11,403		12,181		23,584	
17	R <sup>2</sup>	0.39		0.42		0.45	
18	Note: # Other Backward Classes, \$ includes Sikh, Buddhist/neo-Buddhist, Jain, Parsi/Zoroastrian and others; BP- Blood Pressure.						
19	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	
	$\beta$	(95% CI)	$\beta$	(95% CI)	$\beta$	(95% CI)
<b>Social Engagement</b>	-0.16***	(-0.22,-0.11)	-0.21***	(-0.25,-0.16)	-0.18***	(-0.22,-0.15)
<b>Cognitive function</b>	-0.03***	(-0.04,-0.03)	-0.04***	(-0.05,-0.04)	-0.04***	(-0.04,-0.03)
<b>Social Activities</b>	0.01	(-0.04,0.07)	0.06	(-0.01,0.13)	0.04	(-0.00,0.08)
<b>Age (years)</b>	-0.01**	(-0.01,-0.00)	0.00	(-0.00,0.00)	0.00	(-0.01,0.00)
<b>Gender</b>						
Men®	-	-	-	-	-	-
Women	-	-	-	-	-0.06*	(-0.12,-0.00)
<b>Education level</b>						
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)
<b>Currently working</b>						
No®						
Yes	-0.10**	(-0.16,-0.03)	-0.04	(-0.11,0.04)	-0.06*	(-0.11,-0.01)
<b>Place of Residence</b>						
Rural®						
Urban	0.03	(-0.04,0.11)	-0.02	(-0.09,0.06)	0.01	(-0.04,0.06)
<b>Religion</b>						

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3	Hindu®						
4	Muslim	0.10	(-0.00,0.20)	0.13*	(0.03,0.24)	0.12**	(0.05,0.19)
5	Christian	-0.41***	(-0.60,-0.21)	0.07	(-0.12,0.25)	-0.14*	(-0.28,-0.01)
6	Others\$	-0.41***	(-0.57,-0.25)	-0.18*	(-0.34,-0.01)	-0.29***	(-0.40,-0.18)
7	<b>Caste</b>						
8	Scheduled caste®						
9	Scheduled tribe	-0.27***	(-0.40,-0.14)	-0.03	(-0.15,0.10)	-0.14**	(-0.23,-0.05)
10	OBC#	-0.25***	(-0.33,-0.16)	-0.05	(-0.13,0.03)	-0.15***	(-0.21,-0.09)
11	None of them	-0.23***	(-0.33,-0.14)	-0.07	(-0.16,0.03)	-0.15***	(-0.21,-0.08)
12	<b>Region</b>						
13	North®						
14	Central	0.46***	(0.35,0.57)	0.60***	(0.49,0.71)	0.53***	(0.45,0.61)
15	East	0.07	(-0.03,0.18)	0.08	(-0.03,0.18)	0.08*	(0.00,0.15)
16	Northeast	-0.15	(-0.35,0.05)	-0.37***	(-0.57,-0.17)	-0.27***	(-0.41,-0.13)
17	West	-0.55***	(-0.67,-0.44)	-0.60***	(-0.71,-0.48)	-0.57***	(-0.65,-0.49)
18	South	0.35***	(0.23,0.46)	0.25***	(0.13,0.36)	0.30***	(0.22,0.38)
19	<b>BMI categories</b>						
20	Normal®						
21	Underweight	0.29***	(0.22,0.36)	0.07	(-0.01,0.14)	0.18***	(0.13,0.23)
22	Overweight/obese	0.05	(-0.03,0.14)	-0.08*	(-0.16,-0.00)	-0.02	(-0.08,0.03)
23	<b>MPCE quintile</b>						
24	Poorest®						
25	Poorer	-0.09	(-0.18,0.01)	-0.10*	(-0.19,-0.02)	-0.09**	(-0.16,-0.03)
26	Middle	-0.06	(-0.16,0.03)	-0.10*	(-0.19,-0.01)	-0.08*	(-0.14,-0.02)
27	Richer	-0.07	(-0.16,0.03)	-0.10*	(-0.19,-0.00)	-0.08*	(-0.15,-0.02)
28	Richest	-0.05	(-0.15,0.06)	-0.02	(-0.12,0.08)	-0.03	(-0.11,0.04)
29	<b>Currently smoking tobacco</b>						
30	No®						
31	Yes	0.14***	(0.07,0.22)	0.03	(-0.13,0.20)	0.15***	(0.08,0.21)
32	<b>Currently chewing tobacco</b>						
33	No®						
34	Yes	-0.01	(-0.08,0.07)	0.07	(-0.02,0.15)	0.02	(-0.04,0.07)
35	<b>Drinking Status</b>						
36	Never®						
37	Infrequent non-heavy	-0.15***	(-0.23,-0.07)	0.05	(-0.20,0.31)	-0.12**	(-0.20,-0.05)
38	Frequent non-heavy	-0.22**	(-0.35,-0.08)	-0.41*	(-0.77,-0.06)	-0.24***	(-0.37,-0.12)
39	Heavy episodic drinker	-0.05	(-0.20,0.09)	-0.15	(-0.54,0.24)	-0.07	(-0.20,0.07)
40	<b>Hypertension Status</b>						
41	Normal®						
42	Pre-hypertensive	-0.04	(-0.12,0.03)	-0.09*	(-0.17,-0.01)	-0.07*	(-0.12,-0.01)
43	High BP	-0.04	(-0.12,0.04)	0.02	(-0.06,0.09)	-0.01	(-0.07,0.05)
44	<b>Diabetes</b>						
45	No®						
46	Yes	0.10*	(0.02,0.19)	0.02	(-0.08,0.11)	0.06	(-0.00,0.13)
47	<b>Cancer</b>						
48	No®						
49	Yes	0.59**	(0.17,1.01)	-0.36	(-0.75,0.03)	0.06	(-0.23,0.35)
50	<b>Heart Disease</b>						
51	No®						
52	Yes	0.11	(-0.01,0.24)	0.17*	(0.01,0.32)	0.14**	(0.04,0.24)
53	<b>Stroke</b>						
54	No®						
55	Yes	0.56***	(0.38,0.74)	0.31**	(0.09,0.54)	0.46***	(0.32,0.61)
56	<b>N</b>						
57		11,403		12,181		23,584	
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<b>R<sup>2</sup></b>	<b>0.10</b>	<b>0.09</b>	<b>0.09</b>
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*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*

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

		Page No
<b>Recommendation</b>		
<b>Title and abstract</b>	(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
<b>Introduction</b>		
Background/rationale	Explain the scientific background and rationale for the investigation being reported	5-6
Objectives	State specific objectives, including any prespecified hypotheses	6
<b>Methods</b>		
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	
<b>Results</b>		
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	

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	(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	
<b>Discussion</b>		
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
<b>Other information</b>		
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](http://www.strobe-statement.org).



# BMJ Open

## 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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<b>Primary Subject Heading</b>:	Public health
Secondary Subject Heading:	Mental health
Keywords:	PUBLIC HEALTH, Neurology < INTERNAL MEDICINE, MENTAL HEALTH

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4 1 **Assessing the role of depressive symptoms in the association between social engagement**  
5 **and cognitive functioning among older adults: analysis of cross-sectional data from the**  
6 **Longitudinal Aging Study in India (LASI)**  
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10 4 **Manish Kumar**

11 5 Ph.D. Research scholar, International Institute for Population Sciences, Mumbai,  
12 Maharashtra, India, 400088

13 6 E-mail: [kumarmanishiips@gmail.com](mailto:kumarmanishiips@gmail.com)

14 7 ORCID: 0000-0001-5297-6150

15 8 [Telephone number: +91 9702511509](tel:+919702511509)  
16 9

17 10  
18 11 **T. Muhammad**

19 12 Ph.D. Research scholar, International Institute for Population Sciences, Mumbai,  
20 Maharashtra, India, 400088

21 13 E-mail: [muhhammad.iips@gmail.com](mailto:muhhammad.iips@gmail.com)

22 14 ORCID: 0000-0003-1486-7038  
23 15  
24 16

25 17 **Laxmi Kant Dwivedi, PhD**

26 18 Professor, International Institute for Population Sciences, Mumbai, Maharashtra, India,  
27 19 400088

28 20 Email: [laxmikdwivedi@gmail.com](mailto:laxmikdwivedi@gmail.com)

29 21 ORCID: 0000-0001-9737-2844  
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23 **Correspondence to:**

24 **Manish Kumar**

25 25 Ph.D. Research scholar, International Institute for Population Sciences, Mumbai,  
26 Maharashtra, India, 400088

27 26 E-mail: [kumarmanishiips@gmail.com](mailto:kumarmanishiips@gmail.com)

28 27 ORCID: 0000-0001-5297-6150

29 28 [Telephone number: +91 9702511509](tel:+919702511509)  
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## 31 Abstract

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

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

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

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

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

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

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4 60 **Keywords:** *social engagement, cognitive functioning, depressive symptoms, KHB-method,*  
5 61 *older adults.*  
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## 62 **Strengths and limitations of this study**

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

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## 85 Introduction

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

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

106 Several interventional studies reported the protective effects of the improved social behaviours  
107 in preventing or delaying dementia among older adults with diagnosed cognitive impairment  
108 [16, 17]. Most of the available research on social capital and engagement as to enhance  
109 cognitive reserve and protect cognitive health has been conducted in developed countries [18–  
110 21]. Little is known about the relationship between social engagement and cognitive  
111 functioning in developing countries like India, where the cultural and structural context of  
112 social engagement differ from developed countries. In India, traditionally, older adults are more  
113 likely to live with their children in multigenerational households where cultural norms  
114 emphasize family ties and the virtue of filial piety [22, 23], and a higher proportion of older  
115 people experience psychological distress and mental illnesses [24–26].

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3 116 Similarly, depressive disorders are highly prevalent among older adults in low- and middle  
4 117 income countries (LMICs) [27–29] and in India in particular [30]. Previously, various studies  
5 118 have found the beneficial effects of greater social engagements (with varying measurements  
6 119 and definitions) against depressive symptoms [31, 32]. A cross-sectional study by Jang &  
7 120 Chiriboga (2011) [31] found that a higher level of participation in social activities was  
8 121 associated with a decline in depressive symptoms after controlling for the effects of  
9 122 demographic and health-related factors. Multiple longitudinal studies have also reported  
10 123 similar findings [33–37]. Also, increased participation in social activities and meaningful  
11 124 engagement by older adults may improve their mood, which benefits their emotional  
12 125 functioning and reduces depressive symptoms [38], which is linked to cognitive functioning  
13 126 [39]. According to the ‘depression reduction hypothesis’, depressive symptoms interferes with  
14 127 cognitive health; therefore, as evident from multiple longitudinal studies, practical strategies to  
15 128 reduce depressive symptoms will possibly improve cognitive functioning [40]. Two facts  
16 129 justify such a hypothesis; first, greater depressive symptoms are related to poor cognitive  
17 130 functioning among older adults [41, 42]. Second, depressed older adults who engage in social  
18 131 activities may experience a decline in depressive symptoms and improve cognitive functioning  
19 132 [43]. Furthermore, in multiple cohort studies, cognitively impaired older adults with depressive  
20 133 symptoms were associated with more rapid cognitive decline than those without depression  
21 134 [44, 45].

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37 135 However, it is not clear to what extent social engagement may improve cognitive functioning  
38 136 by minimizing depressive symptoms. There is a dearth of studies in LMICs on the association  
39 137 of social engagements and cognitive functioning and the role of depressive symptoms in such  
40 138 association. Filling this gap, the present study using national-level data of older adults in India,  
41 139 aimed to examine the role of the depressive symptoms on the association between social  
42 140 engagement and cognitive functioning (Figure 1). Previous research showed a greater female  
43 141 disadvantage and theorized gender as the crucial factor to be considered in understanding the  
44 142 differences in cognitive functioning in Indian context [46–48]. Also, studies have shown the  
45 143 significant gender differences in the association between social engagement and cognitive  
46 144 functioning [49, 50]. Thus, the study also explored the moderation effects of gender in the  
47 145 relationship between social engagement and cognitive functioning. The present study  
48 146 hypothesized that the association between social engagement and cognitive functioning is  
49 147 significantly confounded by depressive symptoms (Figure 2).

## 148 **Methods**



## 149 **Data**

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

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

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

## 176 **Measures**

### 177 ***Cognitive function***

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

180 executive functioning, arithmetic, and object naming (Table 1). Previously, various studies  
 181 have established high validity and reliability of these cognitive domains for measuring  
 182 cognitive impairment among older adults in community settings in the United States [52],  
 183 China [53], and India [54]. The cognitive functioning in the present study is based on different  
 184 cognitive measures, including immediate (0–10 points) and delayed word recall (0–10 points);  
 185 orientation related to time (0-4 points), and place (0-4 points); executive functioning based on  
 186 paper folding (0-3) and pentagon drawing (0-1); arithmetic ability based on serial 7s (0–5  
 187 points), computation (0-2) and backward counting from 20 (0–2 points); and object naming (0-  
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**Table 1. Description of domain-wise cognitive measures in LASI, 2017-18**

Domain	Measure	Measurement	Range
<b>Memory</b>	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
<b>Orientation</b>	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
<b>Arithmetic function</b>	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
<b>Executive function: 0-4</b>	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

<b>Object naming: 0-2</b>		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
<b>Cognition</b>	Composite cognitive index	Combined score of memory (total word recall), orientation, arithmetic function, executive function, and object naming.	0-43

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

### 192 *Social engagements*

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

### 208 *Depressive symptoms*

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

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3 217 and often (3 or 4 days) and most or all of the time (5-7 days) categories were scored one.  
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5 218 Scoring was reversed for positive symptoms. The overall depressive symptoms score,  
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7 219 calculated by adding the scores from ten items, ranges from 0 to 10. A score of four or higher  
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9 220 is considered to represent clinically significant symptoms in the 10-item scale [59].

### 10 11 221 *Covariates*

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13 222 After an extensive literature review, potentially related covariates were selected which include  
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15 223 socio-demographic characteristics, lifestyle factors, health conditions, and cognitive and social  
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17 224 activities. Socio-demographic characteristics were: age (in chronological years); gender (men,  
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19 225 women); education (no education, primary, secondary, higher); currently working status (no,  
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21 226 yes); residence (rural, urban); religion (Hindu, Muslim, Christian, others); and Region (North,  
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23 227 Central, East, Northeast, West, and South), monthly per capita expenditure (MPCE) (poorest,  
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25 228 poorer, middle, richer, and richest). The lifestyle factors were currently smoking (no, yes);  
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27 229 currently consuming smokeless tobacco (no, yes), alcohol drinking (never, infrequent non-  
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29 230 heavy, frequent non-heavy, heavy episodic drinker), and body mass index (BMI) (underweight  
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31 231 (<18.5 kg/m<sup>2</sup>), normal (18.5-24.9 kg/m<sup>2</sup>), overweight/obese (>25.0 kg/m<sup>2</sup>)). Health conditions  
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33 232 include biometric measurement-based hypertension status (normal, pre-hypertensive, high  
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35 233 blood pressure), and self-reported conditions such as diabetes, cancer, heart disease, and stroke  
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37 234 were coded as no and yes. The older adults were categorized as having normal blood pressure  
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39 235 (BP) (Systolic BP <120 mmHg and Diastolic BP <80 mmHg), pre-hypertensive (SBP: 120-139  
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41 236 mmHg and DBP: 80-89 mmHg), and high blood pressure (SBP ≥ 140 mmHg and DBP ≥ 90  
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43 237 mmHg).

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45 238 The 'caste' of the household is reported by the head of the household, and it is generally  
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47 239 grouped as four categories: Scheduled Caste (SC), Schedules Tribes (ST), Other Backward  
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49 240 Class (OBC), and other than SC/ST/OBC. SC and ST are considered as among the most  
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51 241 deprived and socioeconomically disadvantaged groups in India. The individuals in the general  
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53 242 class represent the hierarchically higher social status in India. On the other hand, although,  
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55 243 OBC is an educationally, economically, and socially backward group, but, hierarchically, this  
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57 244 group is considered as in better social position than SC and ST category [60].

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59 245 According to the procedure suggested by Dong and Simon [61], we included four social  
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246 participation activities: (1) eat out of the house, (2) go to the park/beach, visit relatives/friends,  
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248 (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

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3 249 weekly, and '0' for several times a month/at least once a month/rarely/once in a year/never/not  
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5 250 relevant for these activities.

### 6 7 251 ***Statistical analysis***

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9 252 Descriptive statistics (means and percentages) were used to present the characteristics of the  
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11 253 older adults included in the final sample. Two sample test for difference of mean/ proportion  
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13 254 was used to assess the gender differences in the reporting of cognition score. Moreover, linear  
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15 255 regression models were employed to determine the association of two-way stratification of  
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17 256 social engagements and depressive symptoms, and social engagement and gender, and gender  
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19 257 and depressive symptoms with cognitive function. Also, linear regression models were used to  
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21 258 assess the association of three-way stratification of social engagement, gender, and depressive  
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23 259 symptoms with cognitive functioning. We conducted a correlation analysis and a linear  
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25 260 regression analysis of depressive symptoms on social engagement. The total effect was divided  
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27 261 into direct effects (the association of social engagement with cognitive function controlling for  
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29 262 depressive symptoms) and indirect effects (the association of social engagement with cognitive  
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31 263 function through depressive symptoms) using linear regression based on Karlson–Holm–Breen  
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33 264 (KHB) method [62–64] for the whole sample. The KHB method is a recently developed method  
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35 265 for assessing the confounding effects that allow total effects to be divided into direct and  
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37 266 indirect effects for both discrete and continuous variables. Contrary to other decomposition  
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39 267 methods, the KHB-method provides unbiased decomposition results [65]. The confounding  
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41 268 percentage (the indirect effect divided by the total effect) is interpreted as the percentage of the  
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43 269 association explained by the confounder variable. All statistical models were adjusted for  
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45 270 various predictors, including age, gender, education, working status, residence, religion, caste,  
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47 271 region, BMI, MPCE, smoking status, consuming smokeless tobacco, alcohol drinking,  
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49 272 hypertension, diabetes, cancer, heart disease, and stroke. The statistical analysis was performed  
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51 273 using Stata 15.1. We incorporated the complex design of the survey data used in the study.  
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53 274 Stata's survey command (*svyset*) was used to incorporate the complex design of LASI, and  
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55 275 adjusted for sampling weight, clustering, and stratification in the sampling design. The data set  
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57 276 do not contain the information of stratum and so, place of residence (rural/urban) is considered  
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59 277 as two different strata. A p-value of less than 0.05 was considered statistically significant.

### 60 278 ***Patient and public involvement***

61 279 None.

### 62 280 **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	%		
<b>Social engagement</b>						
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
<b>Cognition<sup>a</sup></b>	25.9	6.7	21.3	7.0	4.6	<0.001 <sup>†</sup>
<b>Depressive symptoms score<sup>a</sup></b>	2.8	1.6	3.0	1.7	-0.2	<0.001 <sup>†</sup>
<b>Age (years)<sup>a</sup></b>	68.7	7.1	68.2	7.2	0.5	<0.001 <sup>†</sup>
<b>Social Activities (0-5)<sup>a</sup></b>	0.3	0.6	0.2	0.5	0.1	<0.001 <sup>†</sup>
<b>Education level</b>						
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
<b>Currently working</b>						
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
<b>Place of residence</b>						
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

<b>Religion</b>							
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 <sup>S</sup>	579	5.1	605	5.0	0.1	0.697	
<b>Caste</b>							
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 <sup>#</sup>	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	
<b>Regions</b>							
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	
<b>BMI categories</b>							
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	
<b>MPCE quintile</b>							
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	
<b>Currently smoking tobacco</b>							
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	
<b>Currently consuming smokeless tobacco</b>							
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	
<b>Drinking status</b>							
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	
<b>Hypertension Status</b>							
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	
<b>Diabetes</b>							
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	
<b>Cancer</b>							
No	11,332	99.4	12,088	99.2	0.2	0.193	
Yes	71	0.6	93	0.8	-0.2	0.193	
<b>Heart disease</b>							
No	10,721	94.0	11,678	95.9	-1.9	<0.001	
Yes	682	6.0	503	4.1	1.9	<0.001	
<b>Stroke</b>							
No	11,091	97.3	11,978	98.3	-1.0	<0.001	
Yes	312	2.7	203	1.7	1.0	<0.001	
<b>Total</b>	<b>11,403</b>	<b>100</b>	<b>12,181</b>	<b>100</b>			

Note. <sup>#</sup>Other Backward Classes, <sup>a</sup>Mean and standard deviation; <sup>S</sup>includes Sikh, Buddhist/neo-Buddhist, Jain, Parsi/Zoroastrian and others; BP- Blood Pressure.

301 The average cognitive score increased with an increase in the level of social engagement, and  
 302 it was higher among the non-depressed older adults (24.0 vs. 22.1) (Supplementary; Table S1).  
 303 Moreover, the prevalence of depressive symptoms decreased with an increase in the level of  
 304 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 <sup>1</sup>
<b>Social engagement</b>				
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
<b>Age groups</b>				
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
<b>Social activities</b>				
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
<b>Education level</b>				
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
<b>Currently working</b>				
No	25.7	21.2	4.5	<0.001
Yes	26.0	20.8	5.2	<0.001
<b>Place of residence</b>				
Rural	24.7	19.8	4.9	<0.001
Urban	28.7	24.4	4.3	<0.001
<b>Religion</b>				
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 <sup>§</sup>	24.3	21.2	3.1	<0.001
<b>Caste</b>				
Scheduled caste	24.1	19.4	4.7	<0.001
Scheduled tribe	22.2	17.8	4.4	<0.001
OBC <sup>#</sup>	26.2	21.7	4.5	<0.001
Others	27.4	22.4	5.0	<0.001
<b>Regions</b>				
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



<b>BMI categories</b>					
	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
<b>MPCE quintile</b>					
	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
<b>Currently smoking tobacco</b>					
	No	26.1	21.2	4.9	<0.001
	Yes	24.7	18.1	6.6	<0.001
<b>Currently consuming smokeless tobacco</b>					
	No	26.1	21.4	4.7	<0.001
	Yes	25.0	19.5	5.5	<0.001
<b>Drinking status</b>					
	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
<b>Hypertension status</b>					
	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
<b>Diabetes</b>					
	No	25.5	20.8	4.7	<0.001
	Yes	27.7	23.3	4.4	<0.001
<b>Cancer</b>					
	No	25.8	21.1	4.7	<0.001
	Yes	27.8	22.4	5.4	<0.001
<b>Heart disease</b>					
	No	25.7	21.1	4.6	<0.001
	Yes	27.7	22.5	5.2	<0.001
<b>Stroke</b>					
	No	25.8	21.1	4.7	<0.001
	Yes	24.3	19.4	4.9	<0.001
<b>Total</b>		25.8	21.1	4.7	<0.001

Note: <sup>1</sup>Based on two sample t-test.

#Other Backward Classes; \$includes Sikh, Buddhist/neo-Buddhist, Jain, Parsi/Zoroastrian and others; BP- Blood Pressure.

305

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

310 quintiles, tobacco and alcohol use, and morbidity status. With regard to education, women with  
 311 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)**

	$\beta$	(95% CI)
<b>Social engagements # Depressive symptoms</b>		
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)
<b>Social engagements # Gender</b>		
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)
<b>Gender # Depressive symptoms</b>		
Men + depressive symptoms	-0.10***	(-0.15, -0.05)
Women + depressive symptoms	-0.66***	(-0.70, -0.61)
<b>Social engagements # Gender # Depressive symptoms</b>		
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

312

313 Table 4 shows the linear regression results for the two-way stratifications of social engagement  
 314 and depressive symptoms, and social engagement and gender, and, gender and depressive  
 315 symptoms, and three-way stratification of the social engagement, gender, and depressive  
 316 symptoms on the cognitive functioning after adjusting the selected explanatory variables  
 317 including socio-demographic, lifestyle, and chronic conditions. Two-way stratification of  
 318 social engagements and depressive symptoms depicts the estimated effects of the depressive  
 319 symptoms on cognitive functioning for all levels of social engagement. The negative  
 320 relationship between depressive symptoms and cognitive score significantly reduces with  
 321 higher level of social engagement. Furthermore, the two-way stratification of social  
 322 engagement and gender suggests that men with low level of social engagements had  
 323 significantly poor cognitive functioning ( $\beta=-1.12$ ; 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 ( $\beta=-1.54$ ; 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)**

	$\beta$	(95% CI)
<b>Gender # Education</b>		
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 ( $\beta=7.24$ ; 95% CI: 6.90, 7.57). Women with no education had poor cognitive performance than men with no education ( $\beta=-2.60$ ; 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 ( $\beta=-0.18$ ,  $p<.001$ ) (Supplementary; Table S4). Table 6 shows the results obtained from KHB analysis for the

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

347

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

	$\beta$	(95% CI)
<b>Social Engagements</b>		
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)
<b>N</b>	<b>23,584</b>	
<b>Conf.-Perc<sup>a</sup></b>	<b>14.40%</b>	
<i>Note:</i> 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. <sup>a</sup> Confounding percentage.		
* p<0.05, ** p<0.01, *** p<0.001		

348

## 349 Discussion

350 The COVID-19 pandemic has called for international attention on the importance of social  
 351 relationships/ social engagement/ social inclusion in terms of supporting the physical,  
 352 emotional and cognitive health of older adults [66, 67]. Evidence suggests significant  
 353 correlations exist between engaging in social activities with enhanced cognitive outcomes [10,  
 354 50]. However, depression and other mental illnesses that may lead to reduced social networks  
 355 and activities resulting in cognitive decline among older adults are little explored, especially in  
 356 LMICs. The present study examined the direct, indirect, and total effects of social engagement  
 357 on cognitive functioning confounded by depressive symptoms among older adults in India. We  
 358 found that a higher level of social engagement was associated with greater cognitive  
 359 functioning, whereas depressive symptoms confounded 14.4% of the observed association. In  
 360 addition, gender-based moderation effects were also examined which were found significant  
 361 with female disadvantages.

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

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3 367 cognition [70]. The main effect hypothesis in the present study is confirmed by the results  
4  
5 368 showing that social engagements are independently associated with a greater level of cognitive  
6  
7 369 functioning. The finding is consistent with previous studies linking the social involvement  
8  
9 370 enhancing the wellbeing and boosting the self-esteem and creating a sense of belonging that  
10  
11 371 result in better cognitive functioning [71–73]. A systematic review reported that although the  
12  
13 372 exact nature of the associations are unclear, different aspects of social relationships such as  
14  
15 373 social activity, social networks and social support and composite measures of social  
16  
17 374 relationships are associated with cognitive functioning [74]. Thus, social engagement  
18  
19 375 interventions should be prioritized in public policy to help older adults optimize their cognitive  
20  
21 376 health, regardless of underlying mechanisms.

22  
23 377 Although social engagements including the structural support from the spouse and family  
24  
25 378 members are found to enhance cognitive functioning [75–77], the role of mental illnesses  
26  
27 379 adversely affecting the association is less investigated. A recent study found the mediating role  
28  
29 380 of hippocampal volume of brain which is known to be affected by a variety of psychiatric  
30  
31 381 disorders in the association of emotional support with specific cognitive domains [78].  
32  
33 382 Consistently, the current results showed that depressive symptom was significant confounder  
34  
35 383 in the social engagement-cognitive functioning relationship. The finding is also in parallel with  
36  
37 384 a recent study conducted in China showing the mediating role of depressive symptoms in the  
38  
39 385 protective effect of frequent exercise on cognitive functioning [79]. Therefore, our results  
40  
41 386 support the previous finding that the protective effect of social relationships is more related to  
42  
43 387 the aspects of quality and functionality of such relationships than the quantity and structural  
44  
45 388 characteristics [80]. Furthermore, the indirect effect of social engagements on cognitive  
46  
47 389 functioning suggest that social resources can be related to better cognitive functioning through  
48  
49 390 minimizing mental disorders in older adults, indicating that depressive symptoms may serve as  
50  
51 391 an important intervening target and that reversing such illnesses might be related to a greater  
52  
53 392 cognitive functioning. This is similar to an earlier finding that lack of social engagements may  
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55 393 be particularly detrimental to late-life cognitive abilities when it is associated with mental  
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57 394 illnesses [81]. Earlier meta-analyses and reviews have investigated loneliness, being one of the  
58  
59 395 depressive symptoms, and social isolation together as part of health promotion interventions  
60  
396 and suggested that loneliness is often experienced as a part of lack of social engagement and  
397 partly attribute to the factors of cognitive declines [82, 83]. This indicates the need for social  
398 interventions that promote active participation of older people and help them in maintaining  
399 social and structural relationships and coping with age-related stress factors.

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3 400 The available evidence suggests that there are gender differences in the relationship between  
4 401 social engagement and cognitive functioning. For instance, in developed countries, numerous  
5 402 studies have found that the cognitive performance of older women is as good as or better than  
6 403 that of men [84–86]. In contrast, studies of cognitive abilities in developing countries find older  
7 404 women often perform worse than older men [87, 88]. Moreover, earlier studies in India reported  
8 405 a relatively lower cognitive functioning level among older women than men [46–48, 89]. In  
9 406 line with the previous literature, the current findings suggest a significant female disadvantage  
10 407 in cognitive function among older Indian adults and call for special attention with regard to  
11 408 public policy frameworks, clinical practice and future research.

12 409 On the other hand, studies suggest that a greater social engagement protects against rapid  
13 410 cognitive decline, particularly among low-educated older women [90]. In addition, social  
14 411 networks were reported as highly influential for women than men in determining better health  
15 412 behaviours related to cognitive maintenance [87]. In contrast to these studies, our findings  
16 413 suggest a greater buffering effects of the social engagements on cognitive functioning in men  
17 414 than in women. Nevertheless, it still needs to be further investigated whether gender differences  
18 415 exist in the association of social engagements confounded by depressive symptoms with  
19 416 cognitive functioning using longitudinal design.

20 417 There are several limitations of the present study to be noted. The composite index of social  
21 418 engagement was generated from the questions which were self-reported. The responses may  
22 419 have been exaggerated or under-reported. However, self-reporting is endorsed as an optimal  
23 420 method to measure how the participants subjectively find themselves having social networks  
24 421 and involved in social activities. On the other hand, exploring the aspect of social engagements  
25 422 that include participating in indoor games for example, as distinct from domains of cognitive  
26 423 activities is questionable, since it is not feasible to completely differentiate social engagement  
27 424 from cognitive engagements. Also, many activities have a psychiatric element which may have  
28 425 positive impacts on cognitive processes and a complex confounding effect in the associations  
29 426 of three key variables in our study. Hence, considering the differences in relationships between  
30 427 cognitive domains and the distinct forms of social engagements that also include structural  
31 428 support from marital status and living arrangements, it is important to define social  
32 429 relationships more clearly in future studies to achieve more reliable findings.

33 430 Besides, in a population with huge proportion of illiterate people, the assessment of cognitive  
34 431 functioning with multiple domains might be subject to measurement error which can create

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3 432 bias in the current findings. Similarly, older women in India who are largely deprived of  
4 433 education and other opportunities including work participation might have resulted in greater  
5 434 gender gap in cognitive functioning observed in our study. Finally, the present study was cross-  
6 435 sectional, and thus, a causal relationship between the variables cannot be inferred. Further  
7 436 investigation with longitudinal design is needed to explore the neural mechanisms that underlie  
8 437 the effects of social engagements on cognitive decline. Future research might also consider the  
9 438 impact of technology, internet and social media on social relationships, particularly feelings of  
10 439 social support.

## 17 440 **Conclusion**

20 441 The positive association of social engagement with cognitive functioning was significantly  
21 442 confounded by depressive symptoms, suggesting the need for maintaining social relations that  
22 443 help improve cognitive functioning among older adults. This needs to be confirmed with future  
23 444 longitudinal and interventional studies. The study also highlights the potential of social  
24 445 engagements independently or with others as an intervention to prevent cognitive impairment  
25 446 among older individuals, especially among women.

## 31 447 **Abbreviations:**

33 448 **MPCE:** Monthly Per capita Consumption Expenditure

35 449 **CES-D:** Center for Epidemiological Studies-Depression

37 450 **KHB:** Karlson–Holm–Breen

## 39 451 **Declarations**

42 452 **Contributors:** MK and LKD conceived and designed the research paper. MK analyzed the  
43 453 data. MK and TM contributed agents/materials/analysis tools. MK and TM wrote the  
44 454 manuscript. LKD provides supervision and validation. MK, TM and LKD refined the  
45 455 manuscript. All authors have read and approved the manuscript.

49 456 **Funding:** No funding was received for the study.

52 457 **Competing interests:** The authors declare that there is no competing interest.

54 458 **Patient consent for publication:** Not required.

56 459 **Ethics approval:** The present study used the existing data; therefore, no ethics approval was  
57 460 required. The administrative permission to access and use the data for the present study was

1  
2  
3 461 taken from the International Institute for Population Sciences, Mumbai, which conducted the  
4  
5 462 LASI survey.

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7 463 **Provenance and peer review:** Not commissioned; externally peer reviewed.

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9  
10 464 **Data availability statement:** The study uses secondary data which is available in the private  
11  
12 465 database and accessible on reasonable request via  
13 466 <https://www.iipsindia.ac.in/content/lasiwave-i>.

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For peer review only



468 **References**

- 469 [1] Hsiao H-T, Li S-Y, Yang Y-P, et al. Cognitive function and quality of life in community-  
470 dwelling seniors with mild cognitive impairment in Taiwan. *Community mental health journal*  
471 2016; 52: 493–498.
- 472 [2] McGuire LC, Ford ES, Ajani UA. The impact of cognitive functioning on mortality and the  
473 development of functional disability in older adults with diabetes: the second longitudinal  
474 study on aging. *BMC geriatrics* 2006; 6: 1–7.
- 475 [3] Aarts S, Van den Akker M, Tan FES, et al. Influence of multimorbidity on cognition in a  
476 normal aging population: a 12-year follow-up in the Maastricht aging study. *International*  
477 *journal of geriatric psychiatry* 2011; 26: 1046–1053.
- 478 [4] Lv X, Li W, Ma Y, et al. Cognitive decline and mortality among community-dwelling Chinese  
479 older people. *BMC medicine* 2019; 17: 1–10.
- 480 [5] United Nation. *World Population Ageing 2017 report*. 2017.
- 481 [6] Bassuk SS, Glass TA, Berkman LF. Social disengagement and incident cognitive decline in  
482 community-dwelling elderly persons. *Annals of internal medicine* 1999; 131: 165–173.
- 483 [7] Baltes MM. *The many faces of dependency in old age*. Cambridge University Press, 1996.
- 484 [8] Li Y, Xu L, Chi I, et al. Participation in productive activities and health outcomes among older  
485 adults in urban China. *The Gerontologist* 2014; 54: 784–796.
- 486 [9] Holtzman RE, Rebok GW, Saczynski JS, et al. Social network characteristics and cognition in  
487 middle-aged and older adults. *Journals of Gerontology - Series B Psychological Sciences and*  
488 *Social Sciences* 2004; 59: 278–284.
- 489 [10] Krueger KR, Wilson RS, Kamenetsky JM, et al. Social engagement and cognitive function in  
490 old age. *Experimental aging research* 2009; 35: 45–60.
- 491 [11] Béland F, Zunzunegui MV, Alvarado B, et al. Trajectories of cognitive decline and social  
492 relations. *Journals of Gerontology - Series B Psychological Sciences and Social Sciences*  
493 2005; 60: 320–330.
- 494 [12] Zunzunegui MV, Alvarado BE, Del Ser T, et al. Social networks, social integration, and social  
495 engagement determine cognitive decline in community-dwelling Spanish older adults.  
496 *Journals of Gerontology - Series B Psychological Sciences and Social Sciences* 2003; 58: 93–  
497 100.
- 498 [13] Kim YB, Lee SH. Social network types and cognitive decline among older Korean adults: A  
499 longitudinal population-based study. *International Journal of Geriatric Psychiatry* 2019; 34:  
500 1845–1854.
- 501 [14] Lee SH, Kim YB. Which type of social activities may reduce cognitive decline in the elderly?:  
502 A longitudinal population-based study. *BMC Geriatrics* 2016; 16: 1–9.
- 503 [15] Thomas PA. Trajectories of social engagement and limitations in late life. *Journal of Health*  
504 *and Social Behavior* 2011; 52: 430–443.

- 1  
2  
3 505 [16] Maffei L, Picano E, Andreassi MG, et al. Randomized trial on the effects of a combined  
4 506 physical/cognitive training in aged MCI subjects: the Train the Brain study. *Scientific Reports*  
5 507 2017; 7: 39471.
- 7 508 [17] Straubmeier M, Behrndt E-M, Seidl H, et al. Non-pharmacological treatment in people with  
8 509 cognitive impairment: results from the randomized controlled german day care study.  
9 510 *Deutsches Ärzteblatt International* 2017; 114: 815.
- 11 511 [18] Ihle A, Oris M, Baeriswyl M, et al. The longitudinal relation between social reserve and  
12 512 smaller subsequent decline in executive functioning in old age is mediated via cognitive  
13 513 reserve. *International Psychogeriatrics* 2021; 33: 461–467.
- 15 514 [19] González-Ortega I, González-Pinto A, Alberich S, et al. Influence of social cognition as a  
16 515 mediator between cognitive reserve and psychosocial functioning in patients with first episode  
17 516 psychosis. *Psychological Medicine*. Epub ahead of print 2019. DOI:  
18 517 10.1017/S0033291719002794.
- 21 518 [20] Haslam C, Cruwys T, Haslam SA. ‘The we’s have it’: Evidence for the distinctive benefits of  
22 519 group engagement in enhancing cognitive health in aging. *Social Science and Medicine* 2014;  
23 520 120: 57–66.
- 25 521 [21] Conroy RM, Golden J, Jeffares I, et al. Boredom-proneness, loneliness, social engagement and  
26 522 depression and their association with cognitive function in older people: A population study.  
27 523 *Psychology, Health and Medicine* 2010; 15: 463–473.
- 29 524 [22] Samanta T, Chen F, Vanneman R. Living arrangements and health of older adults in India.  
30 525 *Journals of Gerontology Series B: Psychological Sciences and Social Sciences* 2015; 70: 937–  
31 526 947.
- 33 527 [23] Srivastava S, Shaw S, Chaurasia H, et al. Feeling about living arrangements and associated  
34 528 health outcomes among older adults in India : a cross-sectional study. *BMC Public Health*  
35 529 2021; 21: 1–14.
- 37 530 [24] Muhammad T, Srivastava S, Sekher T V. Association of self-perceived income status with  
38 531 psychological distress and subjective well-being: a cross-sectional study among older adults in  
39 532 India. *BMC Psychology* 2021; 9: 1–13.
- 41 533 [25] Srivastava S, Chauhan S, Muhammad T, et al. Older adults’ psychological and subjective well-  
42 534 being as a function of household decision making role: Evidence from cross-sectional survey  
43 535 in India. *Clinical Epidemiology and Global Health* 2021; 10: 100676.
- 45 536 [26] Srivastava S, Purkayastha N, Chaurasia H, et al. Socioeconomic inequality in psychological  
46 537 distress among older adults in India : a decomposition analysis. *BMC Psychiatry* 2021; 21: 1–  
47 538 15.
- 49 539 [27] Fernández-Niño JA, Bonilla-Tinoco LJ, Manrique-Espinoza BS, et al. Work status, retirement,  
50 540 and depression in older adults: An analysis of six countries based on the Study on Global  
51 541 Ageing and Adult Health (SAGE). *SSM - Population Health* 2018; 6: 1–8.
- 53 542 [28] Anand A. Understanding Depression among Older Adults in Six Low-Middle Income  
54 543 Countries using WHO-SAGE Survey. *Behavioral Health*; 1.
- 56 544 [29] Smith L, Il Shin J, McDermott D, et al. Association between food insecurity and depression  
57 545 among older adults from low- and middle-income countries. *Depression and Anxiety* 2021; 38:  
58 546 439–446.

- 1  
2  
3 547 [30] Srivastava S, Debnath P, Shri N, et al. The association of widowhood and living alone with  
4 548 depression among older adults in India. *Scientific Reports* 2021; 1–13.
- 6 549 [31] Jang Y, Chiriboga DA. Social activity and depressive symptoms in Korean American older  
7 550 adults: The conditioning role of acculturation. *Journal of Aging and Health* 2011; 23: 767–781.
- 9 551 [32] Strauss J, Park A, Smith JP. Health Outcomes and Socio-Economic Status Among the Elderly  
10 552 in Gansu and Zhejiang Provinces, China: Evidence from the CHARLS Pilot. 2013; 3: 111–  
11 553 142.
- 13 554 [33] Chiao C, Weng L-J, Botticello AL. Social participation reduces depressive symptoms among  
14 555 older adults: an 18-year longitudinal analysis in Taiwan. *BMC public health* 2011; 11: 1–9.
- 16 556 [34] Isaac V, Stewart R, Artero S, et al. Social activity and improvement in depressive symptoms in  
17 557 older people: a prospective community cohort study. *The American Journal of Geriatric  
18 558 Psychiatry* 2009; 17: 688–696.
- 20 559 [35] Lou VWQ, Chi I, Kwan CW, et al. Trajectories of social engagement and depressive  
21 560 symptoms among long-term care facility residents in Hong Kong. *Age and Ageing* 2013; 42:  
22 561 215–222.
- 24 562 [36] Takagi D, Kondo K, Kawachi I. Social participation and mental health: moderating effects of  
25 563 gender, social role and rurality. *BMC public health* 2013; 13: 1–8.
- 27 564 [37] Glass TA, De Leon CFM, Bassuk SS, et al. Social engagement and depressive symptoms in  
28 565 late life: longitudinal findings. *Journal of aging and health* 2006; 18: 604–628.
- 30 566 [38] Fiske A, Wetherell JL, Gatz M. Depression in older adults. *Annual review of clinical  
31 567 psychology* 2009; 5: 363–389.
- 33 568 [39] Pressman SD, Matthews KA, Cohen S, et al. Association of enjoyable leisure activities with  
34 569 psychological and physical well-being. *Psychosomatic medicine* 2009; 71: 725.
- 36 570 [40] Vance DE, Marson DC, Triebel KL, et al. Physical activity and cognitive function in older  
37 571 adults: The mediating effect of depressive symptoms. *The Journal of neuroscience nursing:  
38 572 journal of the American Association of Neuroscience Nurses* 2016; 48: E2.
- 40 573 [41] Muhammad T, Meher T. Association of late-life depression with cognitive impairment:  
41 574 evidence from a cross-sectional study among older adults in India. *BMC Geriatrics* 2021; 21:  
42 575 1–13.
- 44 576 [42] van den Kommer TN, Comijs HC, Aartsen MJ, et al. Depression and cognition: how do they  
45 577 interrelate in old age? *The American Journal of Geriatric Psychiatry* 2013; 21: 398–410.
- 47 578 [43] Dickinson WJ, Potter GG, Hybels CF, et al. Change in stress and social support as predictors  
48 579 of cognitive decline in older adults with and without depression. *International journal of  
49 580 geriatric psychiatry* 2011; 26: 1267–1274.
- 51 581 [44] Van Der Musselle S, Fransen E, Struyfs H, et al. Depression in mild cognitive impairment is  
52 582 associated with progression to alzheimer's disease: A longitudinal study. *Journal of  
53 583 Alzheimer's Disease* 2014; 42: 1239–1250.
- 55 584 [45] Verdelho A, Madureira S, Moleiro C, et al. Depressive symptoms predict cognitive decline and  
56 585 dementia in older people independently of cerebral white matter changes: The LADIS study.  
57 586 *Journal of Neurology, Neurosurgery and Psychiatry* 2013; 84: 1250–1254.

- 1  
2  
3 587 [46] Lee J, Shih R, Feeney K, et al. Gender disparity in late-life cognitive functioning in India:  
4 588 findings from the longitudinal aging study in India. *Journals of Gerontology Series B:*  
5 589 *Psychological Sciences and Social Sciences* 2014; 69: 603–611.  
6  
7 590 [47] Angrisani M, Jain U, Lee J. Sex differences in cognitive health among older adults in India.  
8 591 *Journal of the American Geriatrics Society* 2020; 68: S20–S28.  
9  
10 592 [48] Jain U, Angrisani M, Langa KM, et al. How much of the female disadvantage in late-life  
11 593 cognition in India can be explained by education and gender inequality. *Sci Rep* 2022; 12:  
12 594 5684.  
13  
14 595 [49] Pillemer S, Ayers E, Holtzer R. Gender-stratified analyses reveal longitudinal associations  
15 596 between social support and cognitive decline in older men. *Aging & mental health* 2019; 23:  
16 597 1326–1332.  
17  
18 598 [50] Oh SS, Cho E, Kang B. Social engagement and cognitive function among middle-aged and  
19 599 older adults: gender-specific findings from the Korean longitudinal study of aging (2008–  
20 600 2018). *Scientific Reports* 2021; 11: 1–9.  
21  
22 601 [51] International Institute for Population Sciences (IIPS), NPHCE, MoHFW HTHCS of PH  
23 602 (HSPH) and the U of SC (USC). *Longitudinal Ageing Study in India (LASI) Wave 1, 2017-18,*  
24 603 *India Report*. Mumbai., 2020.  
25  
26 604 [52] Herzog AR, Wallace RB. Measures of cognitive functioning in the AHEAD study. *Journals of*  
27 605 *Gerontology - Series B Psychological Sciences and Social Sciences* 1997; 52: 37–48.  
28  
29 606 [53] Meng Q, Wang H, Strauss J, et al. Validation of neuropsychological tests for the China Health  
30 607 and Retirement Longitudinal Study Harmonized Cognitive Assessment Protocol. *International*  
31 608 *Psychogeriatrics* 2019; 31: 1709–1719.  
32  
33 609 [54] Gupta M, Gupta V, Nagar Buckshee R, et al. Validity and reliability of hindi translated version  
34 610 of Montreal cognitive assessment in older adults. *Asian Journal of Psychiatry* 2019; 45: 125–  
35 611 128.  
36  
37 612 [55] Zhou Z, Mao F, Han Y, et al. Social engagement and cognitive impairment in older Chinese  
38 613 adults: The mediating role of psychological well-being. *Journal of aging and health* 2020; 32:  
39 614 573–581.  
40  
41 615 [56] Sampson EL, Bulpitt CJ, Fletcher AE. Survival of community-dwelling older people: the effect  
42 616 of cognitive impairment and social engagement. *Journal of the American Geriatrics Society*  
43 617 2009; 57: 985–991.  
44  
45 618 [57] Radloff LS. The CES-D scale: A self-report depression scale for research in the general  
46 619 population. *Applied psychological measurement* 1977; 1: 385–401.  
47  
48 620 [58] Irwin M, Artin KH, Oxman MN. Screening for Depression in the Older Adult. *Archives of*  
49 621 *Internal Medicine* 1999; 159: 1701.  
50  
51 622 [59] Kumar S, Nakulan A, Thoppil SP, et al. Screening for depression among community-dwelling  
52 623 elders: usefulness of the center for epidemiologic studies depression scale. *Indian Journal of*  
53 624 *Psychological Medicine* 2016; 38: 483–485.  
54  
55 625 [60] Chitnis S. Definition of the terms scheduled castes and scheduled tribes: a crisis of  
56 626 ambivalence. *The Politics of Backwardness: Reservation Policy in India New Delhi, India:*  
57 627 *Centre for Policy Research*.

- 1  
2  
3 628 [61] Dong X, Li Y, Simon MA. Social engagement among U.S. Chinese older adults-findings from  
4 629 the PINE study. *Journals of Gerontology - Series A Biological Sciences and Medical Sciences*  
5 630 2014; 69: S82–S89.
- 6  
7 631 [62] Karlson KB, Holm A. Decomposing primary and secondary effects: A new decomposition  
8 632 method. *Research in Social Stratification and mobility* 2011; 29: 221–237.
- 9  
10 633 [63] Karlson KB, Holm A, Breen R. Comparing regression coefficients between same-sample  
11 634 nested models using logit and probit: A new method. *Sociological methodology* 2012; 42: 286–  
12 635 313.
- 13  
14 636 [64] Kohler U, Karlson KB, Holm A. Comparing coefficients of nested nonlinear probability  
15 637 models. *The Stata Journal* 2011; 11: 420–438.
- 16  
17 638 [65] Kohler U, Karlson K. KHB: Stata module to decompose total effects into direct and indirect  
18 639 via KHB-method.
- 19  
20 640 [66] Bethell J, Aelick K, Babineau J, et al. Social Connection in Long-Term Care Homes: A  
21 641 Scoping Review of Published Research on the Mental Health Impacts and Potential Strategies  
22 642 During COVID-19. *Journal of the American Medical Directors Association* 2021; 22: 228-  
23 643 237.e25.
- 24  
25 644 [67] Doll-Wilhelm JL. The Impact of Social Isolation and Cognitive Decline in Older Adults: A  
26 645 Systematic Literature Review.
- 27  
28 646 [68] Li M, Dong X. Is Social Network a Protective Factor for Cognitive Impairment in US Chinese  
29 647 Older Adults? Findings from the PINE Study. *Gerontology* 2018; 64: 246–256.
- 30  
31 648 [69] Ozbay F, Johnson DC, Dimoulas E, et al. Social support and resilience to stress: from  
32 649 neurobiology to clinical practice. *Psychiatry (Edgmont (Pa : Township))* 2007; 4: 35–40.
- 33  
34 650 [70] Hughes TF, Andel R, Small BJ, et al. The association between social resources and cognitive  
35 651 change in older adults: Evidence from the Charlotte County Healthy Aging Study. *Journals of*  
36 652 *Gerontology - Series B Psychological Sciences and Social Sciences* 2008; 63: 241–244.
- 37  
38 653 [71] Thoits PA. Mechanisms linking social ties and support to physical and mental health. *Journal*  
39 654 *of Health and Social Behavior* 2011; 52: 145–161.
- 40  
41 655 [72] Kuiper JS, Zuidersma M, Zuidema SU, et al. Social relationships and cognitive decline: a  
42 656 systematic review and meta-analysis of longitudinal cohort studies. *International Journal of*  
43 657 *Epidemiology* 2016; 45: 1169–1206.
- 44  
45 658 [73] Muhammad T, Srivastava S, Sekher T V. Association of self-perceived income sufficiency  
46 659 with cognitive impairment among older adults: a population-based study in India. *BMC*  
47 660 *Psychiatry* 2021; 21: 1–14.
- 48  
49 661 [74] Kelly ME, Duff H, Kelly S, et al. The impact of social activities, social networks, social support  
50 662 and social relationships on the cognitive functioning of healthy older adults: A systematic  
51 663 review. *Systematic Reviews*; 6. Epub ahead of print 2017. DOI: 10.1186/s13643-017-0632-2.
- 52  
53 664 [75] Barnes LL, De Leon CFM, Wilson RS, et al. Social resources and cognitive decline in a  
54 665 population of older African Americans and whites. *Neurology* 2004; 63: 2322–2326.
- 55  
56  
57  
58  
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2  
3 666 [76] Ayotte BJ, Allaire JC, Whitfield KE. Social support, physical functioning, and cognitive  
4 667 functioning among older African American adults. *Aging, Neuropsychology, and Cognition*  
5 668 2013; 20: 494–510.
- 6  
7 669 [77] Muhammad T, Govindu M, Srivastava S. Relationship between chewing tobacco, smoking,  
8 670 consuming alcohol and cognitive impairment among older adults in India: a cross-sectional  
9 671 study. *BMC Geriatrics* 2021; 21: 85.
- 10  
11 672 [78] Kim GE, Han JW, Kim TH, et al. Hippocampus mediates the effect of emotional support on  
12 673 cognitive function in older adults Authors. *The Journals of Gerontology: Series A* 2020; 75:  
13 674 1502–1507.
- 14  
15 675 [79] Yuan M, Fu H, Liu R, et al. Effect of frequency of exercise on cognitive function in older  
16 676 adults: Serial mediation of depression and quality of sleep. *International Journal of*  
17 677 *Environmental Research and Public Health*; 17. Epub ahead of print 2020. DOI:  
18 678 10.3390/ijerph17030709.
- 19  
20  
21 679 [80] Amieva H, Stoykova R, Matharan F, et al. What aspects of social network are protective for  
22 680 dementia? Not the quantity but the quality of social interactions is protective up to 15 years  
23 681 later. *Psychosomatic Medicine* 2010; 72: 905–911.
- 24  
25 682 [81] Yang R, Wang H, Edelman LS, et al. Loneliness as a mediator of the impact of social isolation  
26 683 on cognitive functioning of Chinese older adults. *Age and Ageing* 2020; 49: 599–604.
- 27  
28 684 [82] Valtorta N, Hanratty B. Loneliness, isolation and the health of older adults: Do we need a new  
29 685 research agenda? *Journal of the Royal Society of Medicine, Supplement* 2012; 105: 518–522.
- 30  
31 686 [83] Cattan M, White M, Bond J, et al. Preventing social isolation and loneliness among older  
32 687 people: A systematic review of health promotion interventions. *Ageing and Society* 2005; 25:  
33 688 41–67.
- 34  
35 689 [84] Langa KM, Llewellyn DJ, Lang IA, et al. Cognitive health among older adults in the United  
36 690 States and in England. *BMC geriatrics* 2009; 9: 1–11.
- 37  
38 691 [85] De Frias CM, Nilsson L-G, Herlitz A. Sex differences in cognition are stable over a 10-year  
39 692 period in adulthood and old age. *Aging, Neuropsychology, and Cognition* 2006; 13: 574–587.
- 40  
41 693 [86] Van Hooren S, Valentijn A, Bosma H, et al. Cognitive\_Functioning\_in\_Healthy\_Older\_A.pdf.  
42 694 2007; 40–54.
- 43  
44 695 [87] Lei X, Hu Y, McArdle JJ, et al. Gender differences in cognition among older adults in China.  
45 696 *Journal of Human Resources* 2012; 47: 951–971.
- 46  
47  
48 697 [88] Maurer J. Education and male-female differences in later-life cognition: International evidence  
49 698 from Latin America and the Caribbean. *Demography* 2011; 48: 915–930.
- 50  
51 699 [89] Muhammad T. The role of religiosity and religious participation in the relationship between  
52 700 depressive symptoms and cognitive impairment among older Indian adults. *Scientific reports*  
53 701 2022; 12: 1–16.
- 54  
55 702 [90] Lee Y, Jean Yeung WJ. Gender matters: Productive social engagement and the subsequent  
56 703 cognitive changes among older adults. *Social Science and Medicine* 2019; 229: 87–95.
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5 706 **Figure 1. Conceptual framework of the study**  
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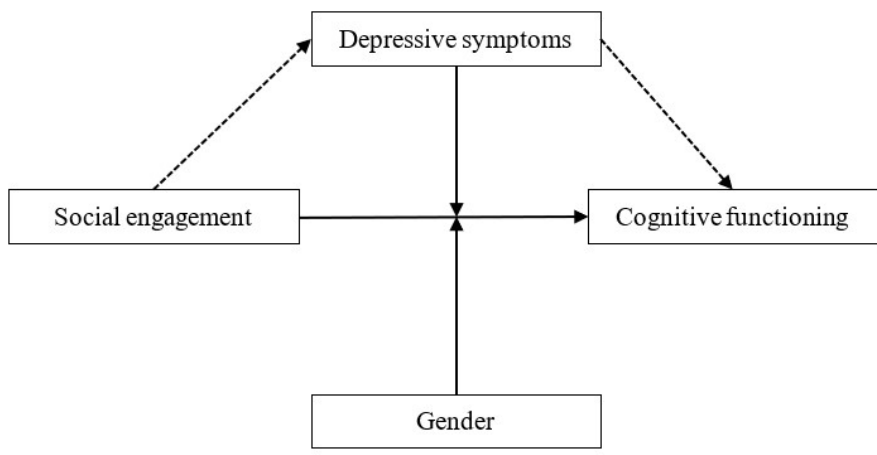


Figure 1. Conceptual framework of the study.

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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)		<i>Low (n=7,401)</i>		<i>Medium (n=14,052)</i>		<i>High (n=2,131)</i>	
	<i>N</i>	<i>Mean (sd.)</i>						
<b>Social Engagements</b>								
Low	7,401	20.7 (7.1)	-	-	-	-	-	-
Medium	14,052	24.5 (7)	-	-	-	-	-	-
High	2,131	26.8 (6.6)	-	-	-	-	-	-
<b>Depression<sup>a</sup></b>								
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
<b>Age (years)</b>								
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
<b>Social Activities</b>								
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
<b>Education level</b>								
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
<b>Currently working</b>								
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
<b>Place of Residence</b>								
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
<b>Religion</b>								
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 <sup>s</sup>	1,184	23.5 (7.2)	315	4.3	718	5.1	151	7.1
<b>Caste</b>								
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 <sup>#</sup>	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
<b>Regions</b>								
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
<b>BMI categories</b>								
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
<b>MPCE quintile</b>								
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
<b>Currently smoking tobacco</b>								
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
<b>Currently chewing tobacco</b>								
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
<b>Drinking Status</b>								
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
<b>Hypertension Status</b>								
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
<b>Diabetes</b>								
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
<b>Cancer</b>								
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
<b>Heart Disease</b>								
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
<b>Stroke</b>								
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
<b>Total</b>	<b>23,584</b>	<b>23.5 (7.3)</b>	<b>7,401</b>	<b>100.0</b>	<b>14,052</b>	<b>100.0</b>	<b>2,131</b>	<b>100.0</b>

Note: <sup>a</sup> overall score ranges from zero to 10 and individuals with score of four or more are considered as depressed; <sup>#</sup> Other Backward Classes, <sup>\$</sup> 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).

	$\beta$	(95% CI)	$\beta$	(95% CI)	$\beta$	(95% CI)	$\beta$	(95% CI)
<b>Social engagements # Depressive symptoms</b>								
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)	-	-	-	-	-	-
<b>Social engagements # Gender</b>								
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)	-	-	-	-
<b>Gender # Depressive symptoms</b>								
Men + depressive symptoms	-	-	-	-	-0.10***	(-0.15,-0.05)	-	-
Women + depressive symptoms	-	-	-	-	-0.66***	(-0.70,-0.61)	-	-
<b>Social engagements # Gender # Depressive symptoms</b>								
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)
<b>Social Activities</b>								
Age (years)	0.48***	(0.33,0.62)	0.43***	(0.28,0.57)	0.57***	(0.43,0.71)	0.48***	(0.34,0.63)
Education level	-0.11***	(-0.12,-0.10)	-0.13***	(-0.14,-0.12)	-0.14***	(-0.15,-0.13)	-0.13***	(-0.14,-0.12)
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)
<b>Currently working</b>								
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)
<b>Place of Residence</b>								

1										
2										
3		Rural®								
4		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)
5		<b>Religion</b>								
6		Hindu®								
7		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)
8		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)
9		Others\$	0.13	(-0.24,0.49)	0.07	(-0.30,0.44)	0.06	(-0.20,0.43)	0.05	(-0.31,0.42)
10		<b>Caste</b>								
11		Scheduled caste®								
12		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)
13		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)
14		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)
15		<b>Region</b>								
16		North®								
17		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)
18		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)
19		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)
20		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)
21		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)
22		<b>BMI categories</b>								
23		Normal®								
24		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)
25		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)
26		<b>MPCE quintile</b>								
27		Poorest®								
28		Poorer	0.10	(-0.11,0.30)	0.15	(-0.06,0.35)	0.08	(-0.22,0.29)	0.09	(-0.11,0.30)
29		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)
30		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)
31		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)
32		<b>Currently smoking tobacco</b>								
33		No®								
34		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)
35		<b>Currently chewing tobacco</b>								
36		No®								
37		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)
38										
39										
40										
41										
42										
43										
44										
45										
46										

**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	(-0.21,0.34)	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	(-0.65,1.10)	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).

	$\beta$	(95% CI)
<b>Gender # Education</b>		
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)
<b>Depressive symptoms</b>	-0.38***	(-0.42,-0.34)
<b>Social engagements</b>		
Low®		
Medium	0.84***	(0.68,1.00)
High	1.28***	(0.98,1.58)
<b>Social Activities</b>	0.43***	(0.28,0.57)
<b>Age (years)</b>	-0.13***	(-0.14,-0.12)
<b>Currently working</b>		
No®		
Yes	0.41***	(0.25,0.57)
<b>Place of Residence</b>		
Rural®		
Urban	1.27***	(1.10,1.45)
<b>Religion</b>		
Hindu®		
Muslim	0.13	(-0.10,0.36)
Christian	-0.27	(-0.70,0.16)
Others\$	-0.08	(-0.45,0.28)
<b>Caste</b>		
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)
<b>Region</b>		
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)
<b>BMI categories</b>		
Normal®		
Underweight	-1.08***	(-1.25,-0.92)
Overweight/obese	0.90***	(0.72,1.08)
<b>MPCE quintile</b>		
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)
<b>Currently smoking tobacco</b>		
No®		
Yes	0.13	(-0.08,0.35)

<b>Currently chewing tobacco</b>		
No <sup>®</sup>		
Yes	-0.02	(-0.19,0.15)
<b>Drinking Status</b>		
Never <sup>®</sup>		
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)
<b>Hypertension Status</b>		
Normal <sup>®</sup>		
Pre-hypertensive	0.20*	(0.03,0.37)
High BP	0.16	(-0.01,0.34)
<b>Diabetes</b>		
No <sup>®</sup>		
Yes	-0.57***	(-0.78,-0.37)
<b>Cancer</b>		
No <sup>®</sup>		
Yes	0.23	(-0.69,1.14)
<b>Heart Disease</b>		
No <sup>®</sup>		
Yes	0.58***	(0.27,0.89)
<b>Stroke</b>		
No <sup>®</sup>		
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; <sup>®</sup> - 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	
	$\beta$	(95% CI)	$\beta$	(95% CI)	$\beta$	(95% CI)
<b>Social Engagement</b>	-0.16***	(-0.22,-0.11)	-0.21***	(-0.25,-0.16)	-0.18***	(-0.22,-0.15)
<b>Cognitive function</b>	-0.03***	(-0.04,-0.03)	-0.04***	(-0.05,-0.04)	-0.04***	(-0.04,-0.03)
<b>Social Activities</b>	0.01	(-0.04,0.07)	0.06	(-0.01,0.13)	0.04	(-0.00,0.08)
<b>Age (years)</b>	-0.01**	(-0.01,-0.00)	0.00	(-0.00,0.00)	0.00	(-0.01,0.00)
<b>Gender</b>						
Men®	-	-	-	-	-	-
Women	-	-	-	-	-0.06*	(-0.12,-0.00)
<b>Education level</b>						
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)
<b>Currently working</b>						
No®						
Yes	-0.10**	(-0.16,-0.03)	-0.04	(-0.11,0.04)	-0.06*	(-0.11,-0.01)
<b>Place of Residence</b>						
Rural®						
Urban	0.03	(-0.04,0.11)	-0.02	(-0.09,0.06)	0.01	(-0.04,0.06)
<b>Religion</b>						
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)
<b>Caste</b>						
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)
<b>Region</b>						
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)
<b>BMI categories</b>						
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)
<b>MPCE quintile</b>						
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)
<b>Currently smoking tobacco</b>						
No®						
Yes	0.14***	(0.07,0.22)	0.03	(-0.13,0.20)	0.15***	(0.08,0.21)
<b>Currently chewing tobacco</b>						
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)

<b>N</b>	11,403	12,181	23,584
<b>R<sup>2</sup></b>	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*

		Page No
<b>Recommendation</b>		
<b>Title and abstract</b>	(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
<b>Introduction</b>		
Background/rationale	Explain the scientific background and rationale for the investigation being reported	5-6
Objectives	State specific objectives, including any prespecified hypotheses	6
<b>Methods</b>		
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	
<b>Results</b>		
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	
<b>Discussion</b>		
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
<b>Other information</b>		
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](http://www.strobe-statement.org).