

Association between social activity and cognitive enhancement among older adults: results from five longitudinal cohort studies

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ABSTRACT

Background Cognitive impairment is a leading cause of disability and mortality in older adults. The association between social activity engagement and cognitive enhancement remains inconclusive. This study aimed to investigate the association between social activity participation and cognitive function in older adults.

Methods We used a population-based cohort study from five nationally representative surveys: the Health and Retirement Study (HRS), the English Longitudinal Study of Ageing (ELSA), the China Health and Retirement Longitudinal Study (CHARLS), the Mexican Health and Ageing Study (MHAS), and the Survey of Health, Ageing and Retirement in Europe (SHARE). Social activity was self-reported. Cognitive function was assessed using standardised z-scores. Linear mixed models were used to evaluate the association between social activity and cognitive function, with pooled estimates obtained using random-effects models.

Results Our analysis included 57 793 participants over a median (IQR) follow-up period of 6 (4, 8) years. Individuals engaged in social activities exhibited significantly higher cognitive z-scores (pooled $\beta=0.15$, 95% CI 0.11 to 0.18) versus inactive peers. A dose-response relationship was observed: greater participation in social activities was associated with progressively higher cognitive z-scores. Individuals participating in three or more activities demonstrated a higher rate of increase in cognitive z-scores per year (pooled $\beta=0.016$, 95% CI 0.005 to 0.027). Additionally, specific social activities, such as volunteer work and sports clubs, were consistently associated with better cognitive function.

Conclusions Social activity engagement may contribute to improved cognitive health, highlighting the importance of social engagement as a potentially modifiable factor for promoting brain health in older adults.

INTRODUCTION

Dementia is one of the leading causes of disability and mortality among older adults.¹ According to the World Population Prospects: 2015 Revision, the global population aged 60 years and older is projected to more than double by 2050 and more than triple by 2100,² which will undoubtedly result in an increase in cognitive impairment.³ It is estimated that the global prevalence of dementia will rise from 57.4 million cases in 2019 to 152.8 million cases by 2050.¹ Dementia imposes a substantial burden on individuals, families, healthcare systems and society at large. The total costs of healthcare

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Although multiple cohort studies have examined the associations between social activities and cognitive function or dementia, results have been inconsistent. A pooled analysis of harmonised longitudinal cohorts is needed to clarify these relationships.

WHAT THIS STUDY ADDS

⇒ Using data from five nationally representative surveys, we found that participation in social activities was associated with better cognitive function; most specific activity types conferred protective associations.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ These findings support the development and implementation of targeted interventions that promote diverse and sustained social engagement among older adults to mitigate the risk of age-related cognitive decline.

and long-term care are estimated at approximately \$305 billion, with out-of-pocket expenditures projected to reach \$66 billion, accounting for 22% of total payments.⁴ Given the current absence of effective treatments for dementia, identifying modifiable risk factors and implementing evidence-based prevention strategies to delay onset or reduce incidence remain a public health priority.⁵

Several cohort studies have examined the association between social activities and both cognitive function and dementia, yielding inconsistent findings.^{6–13} Some studies have shown that social activities were associated with a reduced risk of cognitive decline or incident dementia,^{6–11 14} whereas others have found no significant association.^{12–14} For example, the Rush Memory and Ageing Project (MAP), with a mean follow-up of 6.7 years, demonstrated that higher levels of social engagement were associated with a 5 year delay in the onset of cognitive impairment.¹¹ In contrast, a Dutch longitudinal study ($n=2\,076$) with a mean follow-up of 6 years reported no significant association between social activity and cognitive function.¹² The discrepancies among studies might be attributable to the small sample sizes ($<3\,000$ participants), limited geographic diversity and heterogeneity in the definitions and measurement approaches for social activity and cognitive outcomes. In addition,



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differences in study design, follow-up duration and adjustment for confounding factors may further contribute to the observed inconsistencies. Therefore, large-scale multinational studies involving diverse populations and employing standardised, validated measures are needed to more definitively clarify this association.

In this study, we aimed to evaluate the association between social activity and cognitive enhancement by a pooled analysis of harmonised longitudinal cohort data from five nationally representative surveys spanning 24 countries, including the Health and Retirement Study (HRS),¹⁵ the English Longitudinal Study of Ageing (ELSA),¹⁶ the China Health and Retirement Longitudinal Study (CHARLS),¹⁷ the Mexican Health and Ageing Study (MHAS)¹⁸ and the Survey of Health, Ageing, and Retirement in Europe (SHARE).¹⁹

METHODS

Study population

Data were obtained from the HRS, ELSA, CHARLS, MHAS and SHARE, conducted in the USA, England, China, Mexico and European countries, respectively. These nationally representative surveys were designed using comparable investigative protocols to facilitate cross-country comparisons. Furthermore, the data we analysed were collected over similar periods to ensure temporal comparability. The survey waves included were Waves 10–15 of HRS (2010–2021), Waves 4–9 of ELSA (2008–2019), Waves 1–4 of CHARLS (2011–2018), Waves 3–5 of MHAS (2012–2018) and Waves 4–8 of SHARE (2011–2020).

Online supplemental figures S1–S5 illustrate the participant selection process for each cohort included in this study. Participants were excluded based on the following criteria: (1) missing data on baseline cognitive assessment or social activity; (2) incomplete covariate information or (3) loss to follow-up or participation in only one survey wave. Baseline characteristics of included and excluded participants are presented in online supplemental tables S1–S5. Original data from HRS, ELSA, CHARLS, MHAS, and SHARE are publicly available through their respective websites.

Social activity

Each ageing cohort asked participants whether they engaged in any social activities during the past month or year, with detailed activity types and corresponding items presented in online supplemental table S6. Participants were categorised into two groups: socially active (participated in at least one social group in the past month (HRS and CHARLS) or year (ELSA, MHAS and SHARE), coded as 1) and socially inactive (did not participate in any social group, coded as 0). For further analyses, participants were stratified into four groups (0, 1, 2 or ≥ 3 groups) according to the number of social activities in which they participated. Baseline social activity status was assumed to remain stable over the follow-up period.

Cognitive assessment

Cognitive assessment was conducted at each survey wave and included measures of memory and executive function. The memory function tests were similar across all five cohorts, whereas the executive function assessment varied. Memory function was assessed using immediate and delayed word recall for 10 random words (8 words in MHAS). Each correctly recalled word was awarded one point. Scores for immediate and delayed recall ranged from 0 to 10 for each test (0 to 8 in MHAS). The memory function score was calculated as the average of the

immediate and delayed word recall scores. In HRS, the executive function included the serial sevens test, in which the participant performed serial subtraction by 7 from 100 (5 successive times, with 1 point given for each correct answer), and the date naming task, which comprised 4 questions (the year, the month, the date and the day of the week), each worth one point. In ELSA, MHAS and SHARE, participants were asked to name as many animals as they could in 1 min, and the number of animal names was recorded as the executive function score. In CHARLS, the executive function was assessed using the serial sevens test, the date naming task and the ability to copy the two overlapping pentagons (1 point was awarded for successfully drawing the figure; otherwise, 0 points were given).

To ensure comparability of cognitive test results across different time points, standardised z-scores for cognitive function were calculated by subtracting the baseline mean and dividing by the baseline SD. The z-score for global cognitive function was first derived by averaging the z-scores of the two tests. This average was subsequently re-standardised based on the baseline mean and SD of the global cognitive z-scores. Higher z-scores indicate better cognitive performance. This method is widely used for computing z-scores of global cognitive function.²⁰

Covariates

Based on existing studies, we included the following covariates: age (continuous variable), sex (male or female), residence (urban or rural), education level (low, middle or high), weight status (underweight or normal weight, overweight or obesity), cohabitation status (live alone or live non-alone), current smoking (yes or no), alcohol consumption (yes or no), non-communicable diseases (none or one or more), depressive symptoms (yes or no) and loneliness (lonely or non-lonely). More detailed definitions and classifications of covariate definitions are provided in online supplemental table S7.

Statistical analysis

Mean $\pm$ SD or median (IQR) were used for continuous variables and the number (percentage) was used for categorical variables to describe baseline characteristics stratified by social activity groups. First, linear regression models were used to examine the association of social activity participation or the number of social activities with baseline cognitive function after adjusting for the aforementioned covariates. Second, considering the heterogeneity of individual-specific trajectories over time and the presence of unbalanced repeated measures, linear mixed models were employed to assess the association between baseline social activity and cognitive enhancement over the follow-up period, with the slope and intercept for follow-up time fitted as random effects at the participant level to address between-participant differences at baseline and rates of cognitive change.²⁰ Trend tests were conducted by treating the number of social activities as a continuous variable within the linear mixed models. To evaluate the robustness of the findings, three models were constructed: Model 1 was adjusted for baseline age and sex; Model 2 was further adjusted for education level, residence, cohabitation status, weight status, current smoking, alcohol consumption and non-communicable diseases based on Model 1; Model 3 was additionally adjusted for depressive symptoms and loneliness based on Model 2. Two regression coefficients were presented: the main-effect coefficient for social activity, representing the absolute change in cognitive z-score, and the interaction term coefficient between social activity and follow-up time, representing the annual rate of change in cognitive z-score.

Third, subgroup analyses were performed stratified by sex (male or female), age (≥ 60 or < 60 years), education level (below high school or high school or above), depressive symptoms (no or yes), cohabitation status (live alone or live non-alone), weight status (normal or overweight), non-communicable diseases (none or one or more), residence (urban or rural), current smoking (no or yes) and alcohol consumption (no or yes). To further assess the robustness of the results, three sensitivity analyses were performed: (1) age was treated as a categorical variable; (2) missing baseline covariates (age, education level, residence, cohabitation status, weight status, current smoking, alcohol consumption, non-communicable diseases, depressive symptoms and loneliness) were addressed using multiple imputation by chained equations (MICE) in R, generating five imputed datasets. Logistic regression models were used for binary variables, proportional odds models for ordered categorical variables and predictive mean matching for continuous covariates and (3) latent class mixed models (LCMM) were used to identify distinct trajectories of cognitive z-scores across the five cohorts, accounting for within-class variability through random intercepts and slopes and accommodating unbalanced repeated measures, rather than using group-based trajectory models (GBTM).²¹ The optimal LCMM model was selected based on the following criteria: (1) lowest Bayesian Information Criterion (BIC) value; (2) proportion of individuals with posterior probability greater than 0.7 in each trajectory exceeding 70% and (3) minimum group sample size exceeding 5% of the total sample, ensuring that the identified subgroups were meaningful and robust. Statistical details for all models are summarised in online supplemental table S8. According to these criteria, two distinct trajectories of cognitive z-scores were identified in the HRS (class 1: low cognitive trajectory, class 2: high cognitive trajectory), MHAS (class 1: low cognitive trajectory, class 2: high cognitive trajectory), CHARLS (class 1: low cognitive trajectory, class 2: high cognitive trajectory), and SHARE (class 1: low-moderate cognitive trajectory, class 2: high-moderate cognitive trajectory) cohorts, but not in ELSA (online supplemental figure S6). Subsequently, logistic regression models were used to examine the association between social activity participation and cognitive trajectory. Finally, pooled estimates and 95% CIs across the five cohorts were generated using random-effects meta-analysis. Between-study heterogeneity, accounting for sampling error, was calculated using I^2 and Q tests. The lme4 package²² was used to perform linear mixed model analyses. All statistical analyses were performed in R V. 4.4.2, with a two-tailed $\alpha=0.05$ as the threshold for statistical significance.

RESULTS

Baseline characteristics of participants in all cohorts

Baseline characteristics of participants in the five cohorts are shown in table 1. A total of 57 793 participants were included in this study, 4 131 from HRS, 5 626 from ELSA, 9 187 from CHARLS, 11 168 from MHAS, and 27 681 from SHARE, respectively. The proportion of males was 41.9% in HRS, 47.1% in ELSA, 51.1% in CHARLS, 42.5% in MHAS, and 45.6% in SHARE, respectively. The median age of participants varied across the cohorts, ranging from 57 years in CHARLS to 73 years in HRS. Baseline cognitive z-scores in HRS, ELSA, CHARLS, MHAS, and SHARE were 0.11 (-0.47, 0.56), 0.17 (-0.33, 0.66), 0.14 (-0.42, 0.64), 0.10 (-0.45, 0.66), and 0.28 (-0.51, 0.81), respectively. Baseline characteristics stratified by social activity status in each cohort are shown in online supplemental tables S9–S13.

Baseline social activity and cognitive enhancement cross-sectional analyses

In baseline cross-sectional analyses from five cohorts, individuals who reported engagement in social activity had higher global cognitive z-scores compared with socially inactive participants across all cohorts, including HRS ($\beta=0.09$, 95% CI 0.04 to 0.14), ELSA ($\beta=0.10$, 95% CI 0.06 to 0.14), CHARLS ($\beta=0.16$, 95% CI 0.13 to 0.19), MHAS ($\beta=0.16$, 95% CI 0.13 to 0.19), and SHARE ($\beta=0.19$, 95% CI 0.17 to 0.21) (table 2). Individuals with an increasing number of social activities, specifically 1 (pooled $\beta=0.12$, 95% CI 0.09 to 0.14), 2 (pooled $\beta=0.21$, 95% CI: 0.17, 0.24) and 3 or more (pooled $\beta=0.27$, 95% CI: 0.20, 0.35), exhibited progressively higher cognitive z-scores compared with socially inactive participants (online supplemental table S14).

Baseline social activity and cognitive enhancement longitudinal analyses

Baseline social activity was significantly associated with an improvement in global cognitive function during follow-up (pooled $\beta=0.15$, 95% CI 0.11 to 0.18, $I^2=85.00\%$), as well as memory function (pooled $\beta=0.13$, 95% CI 0.09 to 0.18, $I^2=90.91\%$) and executive function (pooled $\beta=0.15$, 95% CI 0.10 to 0.20, $I^2=88.17\%$) (figure 1). Compared with socially inactive participants, individuals with an increasing number of social activities, specifically 1 (pooled $\beta=0.12$, 95% CI 0.09 to 0.14), 2 (pooled $\beta=0.20$, 95% CI 0.16 to 0.24), and 3 or more (pooled $\beta=0.28$, 95% CI 0.22 to 0.35) demonstrated higher cognitive z-scores over the follow-up period (P for trend < 0.001) (online supplemental figure S7). Meanwhile, a significant association was observed between the number of social activities and both cognitive domains, with greater levels of social engagement associated with a stronger protective effect against impairments in both memory and executive function (P for trend < 0.001) (online supplemental figure S7).

As shown in figure 1, compared with socially inactive participants, those who participated in social activity exhibited a significantly higher rate of increase in cognitive z-scores per year in HRS ($\beta=0.015$, 95% CI 0.007 to 0.024) and MHAS ($\beta=0.019$, 95% CI 0.013 to 0.025). Specifically, when social activity was categorised by the number of activities, individuals participating in three or more activities demonstrated a significantly greater rate of increase in cognitive z-scores per year compared with socially inactive individuals (pooled $\beta=0.016$, 95% CI 0.005 to 0.027). Similarly, the rate of increase in memory z-scores per year was also significant in the 3 or more group (pooled $\beta=0.008$, 95% CI 0.001 to 0.016). However, no significant association was observed for the rate of increase per year in executive function z-scores (pooled $\beta=0.002$, 95% CI -0.002 to 0.006) (online supplemental figure S8).

Subgroup analyses

In subgroup analysis, the positive effects of social activity on cognitive function were more pronounced among females (vs males), adults aged ≥ 60 years (vs adults aged < 60 years), individuals with educational levels of high school or above (vs those with below high school), individuals without depressive symptoms (vs those with depression), individuals living alone (vs those living non-alone), individuals with normal weight (vs those with overweight), individuals residing in rural areas (vs those residing in urban areas), individuals with current smoking status (vs those without current smoking) and individuals with alcohol consumption (vs those without alcohol consumption) (figure 2).

Table 1 Characteristics of participants from five cohort studies at baseline

Characteristics	HRS n=4 131	ELSA n=5 626	CHARLS n=9 187	MHAS n=11 168	SHARE n=27 681
Age, median (IQR), years	73.0 (68.0, 78.0)	63.0 (58.0, 71.0)	57.0 (49.0, 63.0)	62.0 (56.0, 69.0)	63.0 (57.0, 71.0)
Sex, %					
Male	1 729 (41.9)	2 648 (47.1)	4 697 (51.1)	4 750 (42.5)	12 616 (45.6)
Female	2 402 (58.1)	2 978 (52.9)	4 490 (48.9)	6 418 (57.5)	15 065 (54.4)
Residence status, * %					
Urban	2 835 (68.6)		3 603 (39.2)	7 939 (71.1)	17 329 (62.6)
Rural	1 296 (31.4)		5 584 (60.8)	3 229 (28.9)	10 352 (37.4)
Cohabitation status, %					
Live alone	1 574 (38.1)	1 451 (25.8)	887 (9.65)	2 994 (26.8)	6 525 (23.6)
Live non-alone	2 557 (61.9)	4 175 (74.2)	8 300 (90.3)	8 174 (73.2)	21 156 (76.4)
Education level, %					
Less than lower secondary	719 (17.4)	1 586 (28.2)	8 026 (87.4)	9 449 (84.6)	10 674 (38.6)
Upper secondary and vocational training	2 503 (60.6)	2 920 (51.9)	1 016 (11.1)	445 (3.98)	10 845 (39.2)
Tertiary	909 (22.0)	1 120 (19.9)	145 (1.58)	1274 (11.4)	6 162 (22.3)
Current smoking, %					
No	3 736 (90.4)	4 939 (87.8)	6 192 (67.4)	9 790 (87.7)	22 411 (81.0)
Yes	395 (9.56)	687 (12.2)	2 995 (32.6)	1 378 (12.3)	5 270 (19.0)
Alcohol consumption, %					
No	1 941 (47.0)	518 (9.21)	5 396 (58.7)	8 349 (74.8)	2 704 (9.77)
Yes	2 190 (53.0)	5 108 (90.8)	3 791 (41.3)	2 819 (25.2)	24 977 (90.2)
Weight status, %					
Underweight or normal weight	1 214 (29.4)	1 523 (27.1)	5 271 (57.4)	3 439 (30.8)	10 575 (38.2)
Overweight	1 575 (38.1)	2 372 (42.2)	2 809 (30.6)	4 667 (41.8)	11 585 (41.9)
Obesity	1 342 (32.5)	1 731 (30.8)	1 107 (12.0)	3 062 (27.4)	5 521 (19.9)
Depression, %					
No	3 363 (81.4)	4 617 (82.1)	6 948 (75.6)	7 794 (69.8)	20 981 (75.8)
Yes	768 (18.6)	1 009 (17.9)	2 239 (24.4)	3 374 (30.2)	6 700 (24.2)
Loneliness, %					
Not lonely	1 838 (44.5)	5 058 (89.9)	6 802 (74.0)	8 014 (71.8)	24 062 (86.9)
Lonely	2 293 (55.5)	568 (10.1)	2 385 (26.0)	3 154 (28.2)	3 619 (13.1)
Non-communicable diseases, %					
None	420 (10.2)	2 009 (35.7)	3 981 (43.3)	3 787 (33.9)	10 179 (36.8)
One or more	3 711 (89.8)	3 617 (64.3)	5 206 (56.7)	7 381 (66.1)	17 502 (63.2)
Cognitive z-score, median (IQR)	0.11 (−0.47, 0.56)	0.17 (−0.33, 0.66)	0.14 (−0.42, 0.64)	0.10 (−0.45, 0.66)	0.28 (−0.51, 0.81)

Continuous variables were described by mean (SD) or median (IQR), and categorical variables were presented as number (percentage).

*For ELSA, the question on residence status was unavailable.

CHARLS, China Health and Retirement Longitudinal Study; ELSA, English Longitudinal Study of Ageing; HRS, Health and Retirement Study; MHAS, Mexican Health and Ageing Study; SHARE, Survey of Health, Ageing and Retirement in Europe.

The subgroup analysis on the association between the number of social activities and global cognitive function is presented in online supplemental table S15.

Baseline-specific social activity and cognitive enhancement longitudinal analyses

The associations between specific social activities and cognitive outcomes are shown in online supplemental table S16. Participation in volunteer work and sports clubs was associated with a reduced risk of cognitive decline across all five cohorts. Longitudinal analyses showed that attendance at training courses and taking care of children at baseline were significantly associated with the change rate of cognitive z-score per year increase across the five cohorts (all P values < 0.05) (online supplemental table S17). Results for other specific social activities in relation to cognitive function are comprehensively presented in online supplemental tables S16 and S17.

Sensitivity analyses

Sensitivity analyses yielded results consistent with the primary analyses when age was treated as a categorical variable and missing baseline covariates were imputed (online supplemental tables S18 and S19). In addition, latent class mixed model analyses showed that participation in social activities was associated with more favourable cognitive trajectories across multiple cohorts, with similar findings observed for the number of social activities (online supplemental figure S6; online supplemental tables S20 and S21).

DISCUSSION

To the best of our knowledge, this study is the first cohort analysis to investigate the association between social activity and subsequent cognitive enhancement using data from five nationally representative ageing cohorts. Our findings demonstrated that engagement in social activity was positively associated with

Table 2 Cross-sectional association between social activity and global cognitive function at baseline from five cohorts

	Model 1		Model 2		Model 3	
	β (95% CI)	P value	β (95% CI)	P value	β (95% CI)	P value
HRS						
Social activity vs non	0.23 (0.17 to 0.28)	<0.001	0.11 (0.06 to 0.16)	<0.001	0.09 (0.04 to 0.14)	<0.001
ELSA						
Social activity vs non	0.22 (0.18 to 0.26)	<0.001	0.11 (0.07 to 0.15)	<0.001	0.10 (0.06 to 0.14)	<0.001
CHARLS						
Social activity vs non	0.21 (0.18 to 0.24)	<0.001	0.17 (0.14 to 0.20)	<0.001	0.16 (0.13 to 0.19)	<0.001
MHAS						
Social activity vs non	0.21 (0.18 to 0.24)	<0.001	0.16 (0.13 to 0.18)	<0.001	0.16 (0.13 to 0.19)	<0.001
SHARE						
Social activity vs non	0.36 (0.34 to 0.38)	<0.001	0.20 (0.18 to 0.22)	<0.001	0.19 (0.17 to 0.21)	<0.001
Pooled analysis						
Social activity vs non	0.25 (0.17 to 0.32)	<0.001	0.15 (0.12 to 0.19)	<0.001	0.14 (0.11 to 0.18)	<0.001
Heterogeneity	I^2 statistic, %	Q test	I^2 statistic, %	Q test	I^2 statistic, %	Q test
Social activity vs non	96.54	<0.001	83.13	<0.001	83.84	<0.001

Model 1: Adjusted for age and sex; Model 2: Model 1+education level, residence, cohabitation status, weight status, current smoking, alcohol consumption, and non-communicable diseases; Model 3: Model 2+depressive symptoms and loneliness.
CHARLS, China Health and Retirement Longitudinal Study; ELSA, English Longitudinal Study of Ageing; HRS, Health and Retirement Study; MHAS, Mexican Health and Ageing Study; SHARE, Survey of Health, Ageing and Retirement in Europe.

cognitive function, with most specific social activities exhibiting protective associations. Notably, we identified a dose-response relationship, whereby greater participation in social activities was associated with progressively stronger protective effects on cognitive function. Furthermore, these associations appeared to be more pronounced among females, adults aged ≥ 60 years, individuals with a high education level, those without depression, those living alone, those with normal weight, those living in rural areas, those currently smoking, and those consuming alcohol.

Consistent with previous research, our findings further support the notion that greater engagement in social activities confers stronger protective effects on cognitive function. However, the

effect estimates varied across cohorts, with substantial heterogeneity observed in the associations, which may be partially explained by differences in recall periods and the types of social activities assessed across cohorts. Specifically, the measurement of social activity was not fully standardised. In ELSA, MHAS, and SHARE, the use of a 12 month assessment period may have introduced recall bias.²³ Furthermore, although our exposures were social activity (binary status) and the number of social activities, both the activity types and the number of assessed items differed among cohorts. Importantly, not all forms of social activities may confer protection against cognitive decline.²⁴ Our analyses of specific social activities indicated that volunteer work, participation in sports clubs, attendance at training courses, and caring

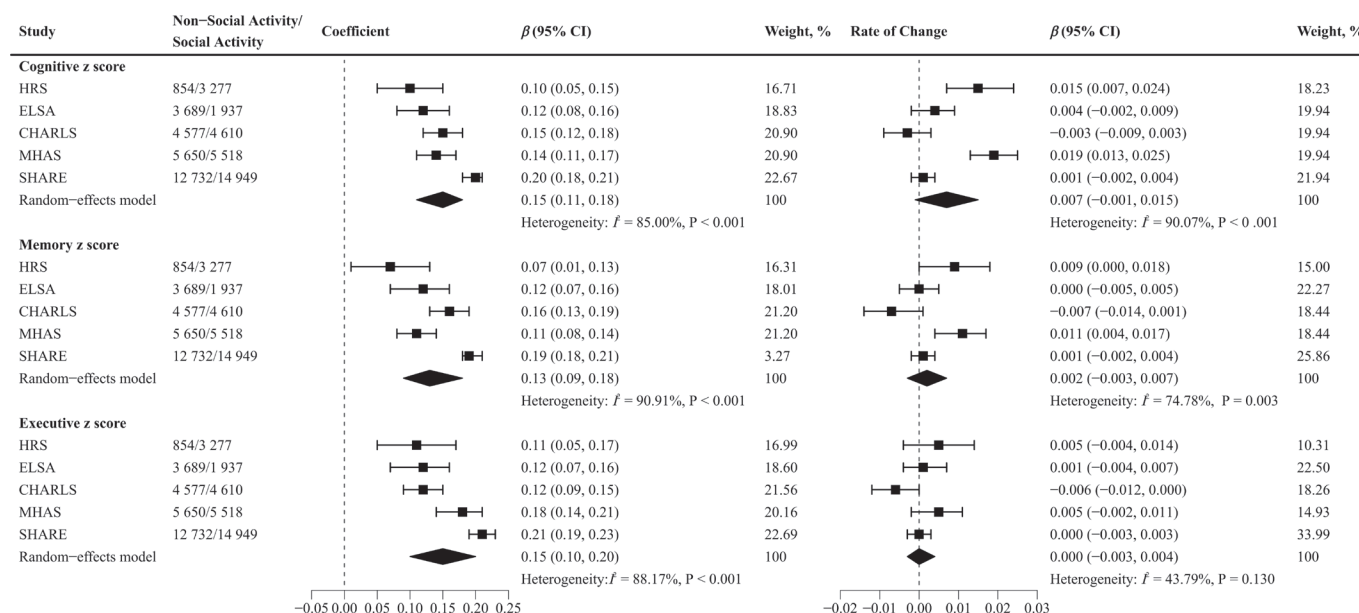


Figure 1 Specific and pooled effect of social activity on global cognitive function and two cognitive domains in five cohorts. CHARLS, China Health and Retirement Longitudinal Study; ELSA, English Longitudinal Study of Ageing; HRS, Health and Retirement Study; MHAS, Mexican Health and Ageing Study; SHARE, Survey of Health, Ageing and Retirement in Europe. The models were fully adjusted for age, sex, education level, residence, cohabitation status, weight status, current smoking, alcohol consumption, non-communicable diseases, depressive symptoms, and loneliness.

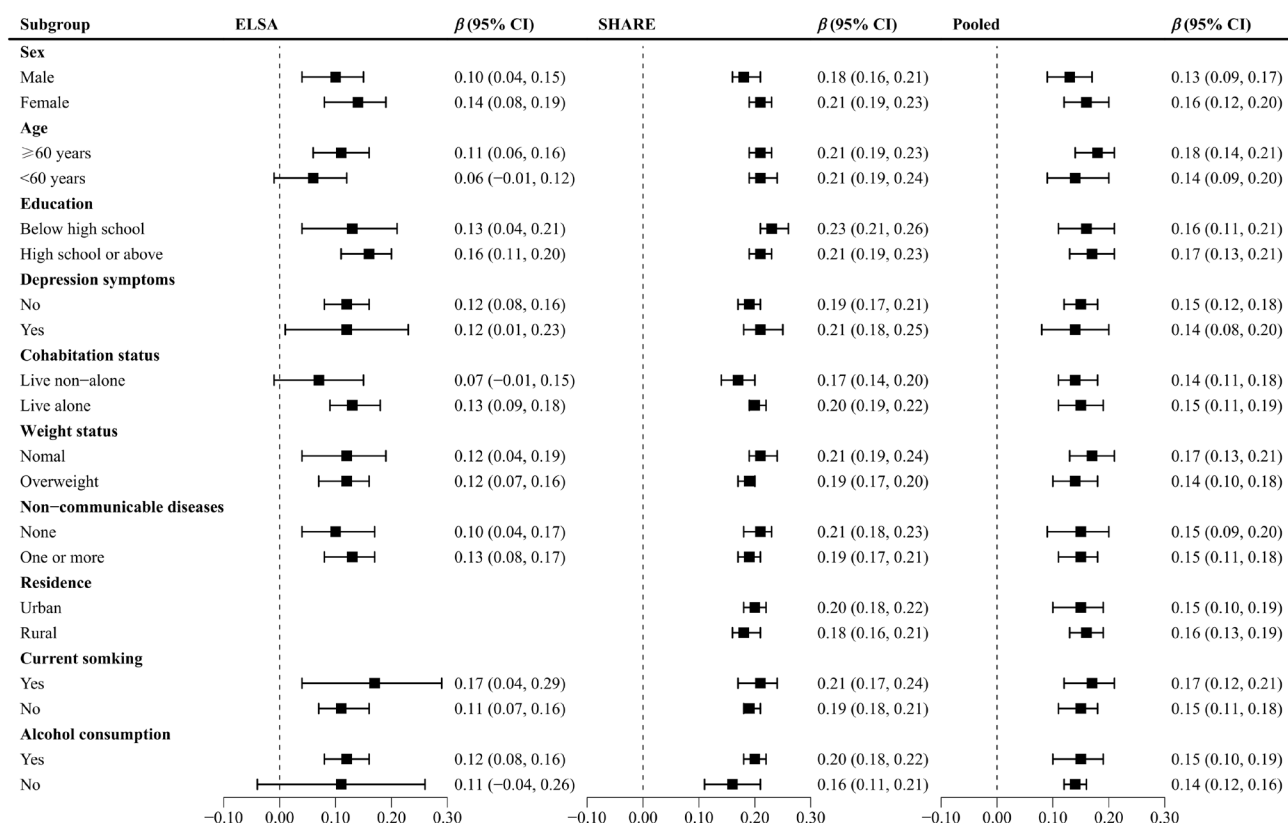
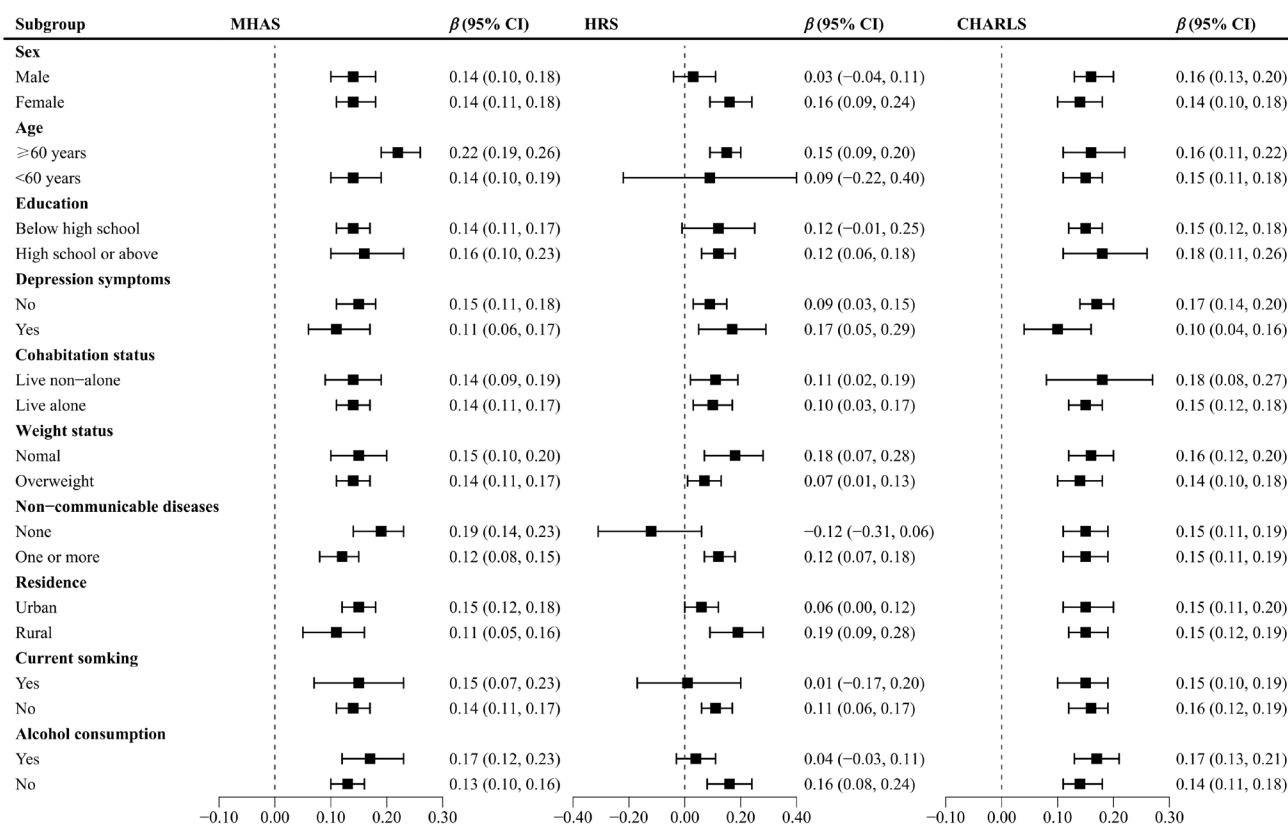


Figure 2 Subgroup analysis on association of social activity with the global cognitive function. CHARLS, China Health and Retirement Longitudinal Study; ELSA, English Longitudinal Study of Ageing; HRS, Health and Retirement Study; MHAS, Mexican Health and Ageing Study; SHARE, Survey of Health, Ageing and Retirement in Europe. The models were fully adjusted for age, sex, education level, residence, cohabitation status, weight status, current smoking, alcohol consumption, non-communicable diseases, depressive symptoms and loneliness.

for children or disabled adults were associated with better cognitive function. In contrast, participation in political, community, church, and religious groups was not consistently associated with cognitive enhancement across cohorts.

Our findings also indicate that engagement in social activities is associated with more favourable cognitive trajectories, consistent with evidence from multiple longitudinal studies.^{8 25 26} For instance, a 5 year cohort study reported that individuals who frequently engaged in social activities experienced more favourable cognitive trajectories than non-participants.²⁵ Similarly, Mose *et al* found that older adults with sustained social activity engagement were more likely to maintain a high-stable cognitive trajectory.²⁶ However, Floud *et al*,¹³ using data from the Million Women Study, observed no significant association between social activity participation and dementia risk during long-term follow-up, potentially attributable to demographic constraints in the sample composition and regional variations in social activity patterns. Previous studies have predominantly focused on Chinese populations and have commonly employed the GBTM, which neglects individual heterogeneity within trajectory groups. By contrast, we applied LCMM to perform trajectory analyses across four ageing cohorts from 23 countries (excluding ELSA cohort), thereby improving the precision of trajectory curve fitting and enhancing the generalisability and representativeness of the findings. Notably, only a borderline significant association was observed between social activity participation and membership in a high-moderate cognitive trajectory within the SHARE cohort. One possible explanation is selection bias, whereby individuals with better baseline cognitive function may be more likely to engage in social activities. Accordingly, the observed modest association may partly reflect baseline cognitive status rather than indicating a causal relationship between social activity participation and cognitive trajectory. In addition, the unequal distribution of participants across trajectory groups and minimal differences in social participation rates may have contributed to the CI approaching 1.00. Finally, regional and cultural contextual factors may also have influenced these findings, as comparable associations were not consistently observed across other cohorts.

We additionally observed that the association between social activity and cognitive function was more pronounced among females, adults aged ≥ 60 years, individuals with higher education levels, those without depressive symptoms, individuals with normal weight, rural residents, current smokers, and alcohol consumers. Sex differences may be explained by biological (eg, sex hormones), genetic (eg, APOE), and social and cultural factors.²⁷ Older adults (≥ 60 years) may have increased availability of discretionary time following retirement, thereby facilitating greater engagement in social activities compared with younger adults. Older adults with higher education levels tend to possess greater health literacy and access to resources, which may support participation in intellectually demanding or health-promoting activities in later life.²⁸ Depression can reduce motivation, self-efficacy and social interest, thereby limiting social participation.²⁹ Weight gain is frequently associated with chronic illnesses and reduced mobility, both of which may restrict social participation and exacerbate the risk of cognitive decline.³⁰ Additionally, individuals residing in rural areas may maintain closer interpersonal and familial networks, which may facilitate more frequent social interactions.³¹ Notably, an unexpected finding was that the positive association between social activity and cognitive function appeared more pronounced among current smokers and alcohol consumers. One possible explanation is that these individuals may engage in social

activities within structured group or community contexts that provide cognitive stimulation. A cross-sectional study in the USA similarly reported that smoking behaviours were positively correlated with cultural activity.³² Another study suggested that socially embedded alcohol consumption may be associated with cognitive benefits comparable to other forms of social engagement, including activities such as laughter, singing and dancing, which serve to initiate and reinforce social bonds.³³ However, this interpretation remains speculative and may be influenced by residual confounding and unmeasured behavioural or socio-economic factors. Accordingly, these subgroup findings should be considered exploratory, and further research is warranted to validate and elucidate these associations. Collectively, these findings may have important implications for the design and implementation of targeted interventions to enhance cognitive function in specific populations.

The mechanisms underlying the association between social activity and cognitive function in older adults remain incompletely understood. The present findings suggest several plausible explanatory pathways. First, the observed dose-response relationship between the number of social activities and cognitive performance is consistent with the 'use it or lose it' hypothesis,³⁴ which proposes that sustained engagement in cognitively stimulating activities may enhance neural plasticity and strengthen synaptic connections, thereby preserving cognitive function in older adults.³⁵ The graded association observed in our study suggests that participation in a broader range of social activities may provide cumulative neurocognitive stimulation, potentially reinforcing neural networks over time. This neuro-protective effect may also be modified by individual biological and genetic susceptibility.³⁶ Second, the stronger association observed among individuals with higher educational attainment aligns with the cognitive reserve hypothesis.³⁷ Higher educational exposure is thought to enhance neural efficiency and compensatory capacity,³⁸ thereby increasing resilience to age-related and dementia-related neuropathological changes. Social activities could contribute to the accumulation and maintenance of this reserve, potentially delaying the onset or progression of cognitive impairment. Accordingly, social activity may interact with preexisting reserve to postpone the clinical manifestation of cognitive decline. Third, participation in meaningful social activities, such as volunteering or participation in sports clubs, may promote positive affect and psychological well-being. The positive affect hypothesis posits that these emotional benefits may modulate neuroendocrine function via the hypothalamic-pituitary-adrenal (HPA) axis,³⁹ thereby attenuating the adverse effects of chronic stress on hippocampal structure and function⁴⁰ and reducing cardiovascular risk factors³⁹ that are also implicated in cognitive decline. Collectively, these findings suggest that social activities may operate as a multidimensional protective factor against cognitive deterioration in older adults.

The primary strength of the study is that we evaluated the association between social activity and cognitive function based on five nationally representative longitudinal surveys, encompassing large sample sizes and ethnically diverse populations. Several limitations warrant consideration. First, although the assessment instruments demonstrated acceptable reliability and validity in epidemiological research, the measurement of executive function varied across the five cohorts. Only MHAS, ELSA and SHARE applied consistent measurement frameworks, which may limit cross-national comparability. Second, residual confounding remains a concern, as our analysis only partially adjusted for potential confounders. Third, selection bias may have influenced the findings, given characteristic differences

between included and excluded participants, potentially compromising the representativeness of the findings. Fourth, the lack of standardised social activity assessment across cohorts highlights the need for harmonised measures in future multinational studies. Fifth, although some pooled results showed substantial heterogeneity, the consistency of findings across all five cohorts supports the validity of the observed associations. Nonetheless, the observed heterogeneity remains a noteworthy limitation and may be partly attributable to variations across cohorts in cohabitation status, residential setting, smoking status, alcohol consumption and geographic region (online supplemental table S22). Future studies should implement more stringent inclusion criteria and strengthen study design harmonisation to further validate these findings. Sixth, despite the longitudinal design, residual confounding related to baseline cognitive function cannot be excluded. Individuals with higher baseline cognitive performance may have been more likely to engage in social activities, potentially resulting in reverse causation. Seventh, our study primarily focused on the quantity of social activities. However, the quality, initiative and emotional experience associated with social activities may be equally or more influential. Future research incorporating detailed assessments of these qualitative and experiential dimensions may provide a more comprehensive understanding of the associations.

In conclusion, engagement in social activity was associated with improved cognitive function, particularly among females, older adults aged ≥ 60 years, individuals with higher education levels and those without depressive symptoms. Notably, participation in a specific single activity, such as volunteer work, sports clubs, training courses, and taking care of children, was also linked to better cognitive performance. These results underscore the importance of developing and implementing targeted interventions aimed at promoting diverse and sustained social engagement among older adults as a viable strategy to mitigate the risk of age-related cognitive decline.

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Contributors BX and JS conceived and supervised the whole study. YW conducted data curation, performed statistical analysis, interpreted results, and drafted the manuscript. YW, MZ, FL, JS, and BX reviewed and revised the manuscript. JS and YW have accessed and verified the underlying data. All authors had full access to the data in the study and approved the final draft of the manuscript for publication. BX is the guarantor of this work.

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Ethics approval This study involves human participants. The HRS was approved by the University of Michigan Institutional Review Board; the ELSA was approved by the National Research Ethics Service Committee South Central-Berkshire; the CHARLS was approved by the Biomedical Ethics Review Committee of Peking University (IRB00001052-11015); the MHAS was approved by the Institutional Review Boards and Ethics Committees of the University of Texas Medical Branch in the USA, the National Institute of Statistics and Geography (INEGI), and the National Institute of Public Health (INSP) in Mexico; and the SHARE was approved by the Ethics Council of the Max Planck Society. No additional approvals were required. All participants across the five cohorts provided informed consent. Participants gave informed consent to participate in the study before taking part.

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Data availability statement Data are available in a public, open access repository. The datasets generated and analysed during the current study are available in the HRS, the ELSA, the CHARLS, the MHAS, and the SHARE. These harmonised datasets are available to qualified researchers through the Gateway to Global Aging Data platform (<https://g2aging.org/home>), which operates under certified data-sharing protocols.

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