EXTRA Dementia and Geriatric Cognitive Disorders

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Original Research Article

Individual and Area Level Socioeconomic Status and Its Association with Cognitive Function and Cognitive Impairment (Low MMSE) among Community-Dwelling Elderly in Singapore

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Key Words
Cognitive impairment · Socioeconomic status · Neighborhood · Asia

Abstract
Background/Aims: Neighborhood socioeconomic status (SES) can affect cognitive function. We assessed cognitive function and cognitive impairment among community-dwelling elderly in a multi-ethnic urban low-SES Asian neighborhood and compared them with a higher-SES neighborhood. ***Methods:*** The study population involved all residents aged ≥60 years in two housing estates comprising owner-occupied housing (higher SES) and rental flats (low SES) in Singapore in 2012. Cognitive impairment was defined as <24 on the Mini Mental State Examination. Demographic/clinical details were collected via questionnaire. Multilevel linear regression was used to evaluate factors associated with cognitive function, while multilevel logistic regression determined predictors of cognitive impairment. ***Results:*** Participation was 61.4% (558/909). Cognitive impairment was found in 26.2% (104/397) of residents in the low-SES community and in 16.1% (26/161) of residents in the higher-SES community. After adjusting for other sociodemographic variables, living in a low-SES community was independently associated with poorer cognitive function ($\beta = -1.41$, SD = 0.58, $p < 0.01$) and cognitive impairment (adjusted odds ratio 5.13, 95% CI 1.98–13.34). Among cognitively impaired elderly in the low-SES community, 96.2% (100/104) were newly detected. ***Conclusion:*** Living in a low-SES community is independently associated with cognitive impairment in an urban Asian society.

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Introduction

The link between individual socioeconomic status (SES) and cognitive impairment is well established in the literature [1–3]. However, research on area level SES and health has increased in recent decades. A significant body of work focuses on mental health and deprived neighborhoods, with several recent Western studies linking neighborhood SES and cognitive impairment. Wight et al. [5] first documented an association between neighborhood educational attainment and cognitive function; subsequent studies have further validated the link between cognitive impairment and living in a deprived neighborhood, independent of individual SES [6–12]. The elderly are particularly vulnerable to neighborhood SES as their social space shrinks due to decreased mobility, limiting their interactions to their immediate community [13]. Several theories have been posited to link neighborhood SES and mental health, such as the 'collective resources' and 'local social inequality' models posited by Stafford and Marmot [14]. In the 'collective resources' model, people living in areas with better social and material collective resources enjoy better health, whereas in the 'local social inequality' model, disparities between individuals' socioeconomic position and the socioeconomic conditions of their local area may interact to influence health [14, 15]. In cognitive impairment, deprived neighborhoods may have less resources and opportunities for social engagement [10] and interactions protective against cognitive decline [16, 17] as residents keep mostly to themselves, given weaker community identity.

However, less is known about SES and cognitive impairment in Asian societies. In Asian societies, individual socioeconomic characteristics are linked with cognitive impairment [18–21]. Multiple individual socioeconomic risk factors interact synergistically to affect cognitive impairment [21] and cognitive impairment is higher in lower-educated suburban neighborhoods [22]. However, no previous Asian studies on cognitive impairment have looked at the interplay between area level and individual SES. Given widening income inequality in Asian societies [23], investigating this interplay may help achieve more equitable access to health services for those with cognitive impairment in Asian societies. Singapore is one such multi-ethnic urbanized Asian society, with Chinese, Malay, and Indian populations. The prevalence of cognitive impairment among community-dwelling elderly was estimated at 30% in a 2007 study [24, 25]. Singapore is the fastest ageing country in the Asia-Pacific after Japan [26], with dementia as a major cause of disability [27]. Locally, cognitive impairment has been linked to ethnicity and educational level [25, 28]; however, the impact of area level SES has not been studied. Singapore has one of the highest rates of income inequality in Asia, with a Gini coefficient of 0.452 in 2011 [29] (the Gini coefficient being a measure of income inequality, with 0 reflecting complete income equality and 1 reflecting maximum income inequality). Locally, equitable access to healthcare is a major issue. Home ownership is a key local indicator of SES. The majority of Singaporeans (≥85%) live in owner-occupied public housing; home ownership is high (90.1%) due to government subsidies [30]. Public rental flats provide heavily subsidized rentals (26–275 SGD/month) [31] for the needy (<3% of the population), especially the needy elderly [32], with 88% of those living in rental housing earning <670 SGD/month [33]. In line with the government's policy of promoting social integration, these blocks of public rental flats are not concentrated in certain areas but are built within the same locations as owner-occupied public housing. Thus, given close geographical proximity of communities of differing area level SES in land-scarce Singapore, we could study cognitive impairment and SES in selected contrasting neighborhoods [4]. As such, we investigated the relationship between individual and area measures of SES and cognitive impairment within a community-dwelling population of elderly aged ≥60 years, living in two integrated Singaporean housing precincts containing both lower area SES (public rental housing) and higher area SES (owner-occupied public housing) communities.

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Methods

Study Population

The study population involved all Singaporean residents aged ≥60 years living in two integrated public housing sites in Singapore. Rental flats are distributed across four geographical zones; we chose one site in the western zone and another site in the eastern zone as these two zones had the highest concentrations of public rental flats [34]. Site A contains 6 blocks, 3 of which predominantly consist of heavily subsidized public rental flats and the remaining 3 blocks, immediately adjacent, predominantly consist of owner-occupied public flats. Site B contains 9 blocks, 7 of which are predominantly public rental flats and 2, immediately adjacent, are predominantly owner-occupied public flats. These two sites comprised all the public rental flats in their respective estates, as well as all the owner-occupied blocks that were immediately adjacent to them. Prior to study commencement, we surveyed these 15 blocks to determine how many residents were aged ≥60 years. A total of 385 residents in Site A (191 from rental flats, 194 from owner-occupied housing) and 524 residents in Site B (434 from rental flats, 90 from owner-occupied housing) were eligible.

Study Methodology

Over a 1-month period from January to February 2012, residents ≥60 years of age were visited door-to-door to (1) collect baseline information, such as sociodemographic data/medical history, via interviewer-administered standardized questionnaires and (2) assess for cognitive impairment using the Mini Mental State Examination (MMSE), which has been translated into Chinese and Malay and validated in the local population [25, 28]. At baseline, we collected sociodemographic data, assessed functional status using the Lawton-Brody Instrumental Activities of Daily Living (iADL) scale [35] and the Shah-modified Barthel Index [36]; measured medical comorbidity burden using the Charlson Comorbidity Index [37]; social support using the Lubben Social Network Scale-6 (LSNS-6) [38, 39], and depressive symptoms using the Geriatric Depression Scale (GDS-15) where a score of ≥5 is suggestive of depression [40]. Body mass index (BMI) and blood pressure were also measured. The questionnaire was administered by teams of trained 4th year medical students who had completed psychiatry rotations, under the supervision of a physician. To ensure standardization, all teams underwent compulsory training sessions prior to study commencement, with refresher courses at regular intervals. To minimize linguistic barriers, the questionnaire was translated into Chinese, Malay, and Tamil and administered by interviewers conversant in those languages. Based on MMSE scores, residents were offered various services. Residents with MMSE scores below the locally validated cutoffs for cognitive impairment were referred to public primary care clinics called polyclinics for follow-up, while cognitively normal residents were offered a free community-based mental wellness program (Nurture Your Mind) by the national Health Promotion Board [41]. Ethics approval was obtained from the National University of Singapore Institutional Review Board. Informed consent was sought from participants or their caregivers (if the participant was incapable of giving informed consent) and participation was voluntary.

Definitions

Cognitive Impairment

Cognitive impairment was defined as an MMSE score <24, a cutoff that has been previously validated locally in both Chinese and Malay populations with good sensitivity and specificity [25]. We did not stratify cutoffs by educational level, despite lower educational levels in our study population, but instead introduced education as a covariate into the multivariate analysis [28, 42, 43].

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Individual and Area Level SES

Individual level measures of SES included individual employment status, vehicle ownership status, monthly household income, and being a recipient of financial aid. Area level measures of SES included whether the resident was living in a block predominantly composed of public rental units. Rental blocks as an area level indicator of SES has also been shown to influence chronic disease management independently of individual level SES in previous local studies [44, 45]. In our study, we analyzed differences in area level SES at the block level; each block had about 165 households. Additionally, for each block, we also calculated indices of neighborhood deprivation, using factor analysis and the following six measures of neighborhood SES: (1) percentage of families that are composed of husband and wife; (2) percentage of households dependent on public assistance; (3) percentage of households which have an annual income above the median; (4) percentage of adults without secondary education; (5) percentage of housing units that are rentals, and (6) adult unemployment rate. These measures are commonly used in the existing literature on area level SES [10, 46, 47] and could be computed in our local setting. As block level census data was unavailable from the national Department of Statistics, the relevant block level percentages were calculated using information collected as part of a previous study [48] that surveyed all adult residents aged ≥40 years living in the same two integrated public housing sites, for which the participation rate was 78.2%. This dataset was assembled over 2009–2011 and the data was collected independent of, and prior to, the current study, thus ensuring proper temporal sequencing. We then used these six measures to calculate an index of neighborhood deprivation via factor analysis [49]. A principal components factor analysis revealed that the six measures segregated into two empirical factors based on an eigenvalue of 1 and the scree plot (eigenvalues 3.34 and 1.06, explained variance 55.59 and 17.72%, respectively). The first factor contained high loadings on the percentage of those married (–0.76), on financial aid (0.74), rentals (0.93), household income more than the median (–0.75), and adults with lower education (0.77). We termed this factor 'neighborhood disadvantage'. The second factor contained high loadings on the percentage of those unemployed (0.79). We termed this factor 'neighborhood unemployment'. The loadings for each factor were used to compute a neighborhood disadvantage and a neighborhood unemployment factor score for each subject (after reverse scoring the variables with negative weights). Because the number of areas (n = 15) was small, we did not analyze the scores/indices of neighborhood deprivation as a continuous variable but instead stratified into 'disadvantaged' versus 'not disadvantaged' (neighborhood disadvantage score), and 'unemployed' versus 'not unemployed' (neighborhood unemployment score).

Statistical Analysis

Descriptive statistics were computed for the study population. We used χ^2 analysis to examine sociodemographic and clinical differences between the low area SES community and the high area SES community (i.e. rental versus owner-occupied). Hierarchical linear models were then used to estimate the variance in cognition (measured by the MMSE score). The variance in cognition associated with the neighborhood context at the block level was first estimated with a null model containing only a random intercept. Subsequently, the impact of individual level demographic, clinical, and socioeconomic factors was tested. Finally, the main effect of area level SES on cognition was assessed. We then examined the independent associations of individual and area level SES with cognitive impairment (MMSE score <24) using multi-level logistic regression, controlling for within-group correlation by residential blocks. The criterion for initial entry of variables into multivariate models was $p < 0.2$ on univariate analysis; collinear variables ($|r| > 0.6$) were omitted from the final models in order of decreasing p values. Statistical analysis was performed using SPSS (version 17.0, USA), STATA (version 11.0, USA) and HLM (version 6.01, USA), and statistical significance was set at $p < 0.05$.

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Results

The overall response rate was 61.4% (558/909). The response rate in Site A was 61.0% (235/385) and in Site B it was 61.6% (323/524). There was no difference in response between sites. However, overall the response rate was higher from the rental (lower area SES) blocks compared to the owner-occupied (higher area SES) blocks (63.7%, 397/625, vs. 56.7%, 161/284, $p = 0.0473$). A more detailed profile of participants can be found in table 1. Generally, as expected, the elderly residing in rental flats were less well-off compared to their counterparts dwelling in owner-occupied blocks, having lower household income and lower educational attainment with increased need for financial aid; and this trend held true across both study sites. Elderly in owner-occupied flats also had better social support compared with their counterparts dwelling in rental blocks. For the dependent variable (MMSE), the mean MMSE was 25.64 (SD = 4.23). The range of scores was from 12 to 30; although the sample was in general cognitively well-functioning, some individuals had marked deficits. Only 2.7% (15/558) received a perfect score, alleviating concerns about a ceiling effect.

Overall Neighborhood Variation in Cognitive Function

Our initial analysis using a null model revealed statistically significant between-neighborhood variation in cognitive functioning between blocks ($\tau = 2.10$, $p < 0.001$). The intraclass correlation (ρ), however, was 0.119, indicating that 11.9% of the variation in cognition in this sample could be attributed to living in different blocks (table 2).

Model of Cognitive Function

Prior to examining area level variables, cognitive functioning was regressed on the individual's demographic characteristics and socioeconomic factors (table 2). Model 2 added individual level demographic and clinical factors, which accounted for 19.2% of the individual level within-group variance. Largely consistent with previous research, increased age [20, 28], Chinese (majority) ethnicity, female gender [18–20], lower education [28], having a smaller social network, hearing impairment, and dependence in iADL [50] were all associated with poorer cognitive function. Model 3 added individual level socioeconomic factors, which accounted for another additional 4.5% of the individual level variance in cognition. As shown, being currently employed was positively and significantly associated with cognition. The coefficients for the other individual level demographic and clinical factors were largely unchanged by controlling for individual level SES. Model 4 added the main effects on cognitive functioning of the three area level variables (rental vs. non-rental, neighborhood deprivation, neighborhood unemployment). Model 3 is nested within model 4, hence the difference in their deviation scores tests the null hypothesis that the coefficients for the additional variables all equal 0, a hypothesis we rejected ($\chi^2 = 10.74$, d.f. = 3, $p < 0.05$). Living in a low-SES area (whether by rental versus non-rental, or by a higher neighborhood deprivation score) was associated with low cognitive function, independent of individual level SES and other covariates. The coefficients for the individual level variables were largely unchanged, with the exception of that of ethnicity, for which there was a noticeable decrease; this suggests that area level SES accounted for some of ethnicity's effect on cognition.

Model of Cognitive Impairment

In our study population of community-dwelling elderly, the prevalence of cognitive impairment (MMSE score <24) was 23.3% (130/558). Of these, 8 had a prior history of doctor-diagnosed dementia, with equal numbers in rental and owner-occupied blocks. Six of them

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Table 1. Sociodemographic characteristics of community-dwelling elderly (n = 558) living in rental blocks and owner-occupied blocks in two integrated public housing precincts in Singapore

Characteristic	Precinct A (n = 235)		p value[a]	Precinct B (n = 323)		p value[a]	Total (n = 558)		p value[a]
	owner-occupied (n = 107)	rental (n = 128)		owner-occupied (n = 54)	rental (n = 269)		owner-occupied (n = 161)	rental (n = 397)	
Demographics									
Age									
60–70 years	59 (55.1)	56 (43.8)	0.090	25 (46.3)	123 (45.7)	1.000	84 (52.2)	179 (45.1)	0.135
≥71 years	48 (44.9)	72 (56.2)		29 (53.7)	146 (54.3)		77 (47.8)	218 (54.9)	
Gender									
Male	40 (37.4)	51 (39.8)	0.788	21 (38.9)	138 (51.3)	0.103	61 (37.9)	189 (47.6)	0.039
Female	67 (62.6)	77 (60.2)		33 (61.1)	131 (48.7)		100 (62.1)	208 (52.4)	
Marital status									
Not currently married	44 (41.1)	71 (55.5)	0.036	19 (35.2)	139 (51.7)		63 (39.1)	210 (52.9)	0.004
Currently married	63 (58.9)	57 (44.5)		35 (64.8)	130 (48.3)	0.036	98 (60.9)	187 (47.1)	
Ethnicity									
Malay	26 (24.3)	45 (35.2)	Referent	7 (13.0)	64 (23.8)	Referent	33 (20.5)	109 (27.5)	Referent
Chinese	67 (62.6)	64 (50.0)	0.270	37 (68.5)	183 (68.0)	0.155	104 (64.6)	247 (62.2)	0.175
Indian	8 (7.5)	15 (11.7)	0.560	9 (16.7)	20 (7.4)	0.059	17 (10.6)	35 (8.8)	0.397
Other	6 (5.6)	4 (3.1)	0.842	1 (1.9)	2 (0.7)	0.337	7 (4.3)	6 (1.5)	0.209
Highest educational attainment									
No formal education	34 (31.8)	66 (51.6)	Referent	9 (16.7)	97 (36.1)	Referent	43 (26.7)	163 (41.1)	Referent
Primary education	50 (46.7)	41 (32.0)	0.006	18 (33.3)	113 (42.0)	0.324	68 (42.2)	154 (38.8)	0.054
Secondary or higher education	23 (21.5)	21 (16.4)	0.052	27 (50.0)	59 (21.9)	0.007	50 (31.1)	80 (20.2)	0.019
Socioeconomic indicators									
Currently employed	33 (30.8)	29 (22.7)	0.182	9 (16.7)	80 (29.7)	0.065	42 (26.1)	109 (27.5)	0.833
Car ownership (yes)	4 (3.7)	0 (0.0)	0.042	6 (11.1)	14 (5.2)	0.119	10 (6.2)	14 (3.5)	0.170
Monthly household income									
<500 SGD	19 (19.0)	58 (46.0)	Referent	11 (20.4)	107 (40.4)	Referent	30 (19.5)	165 (42.2)	Referent
≥500, <1,000 SGD	30 (30.0)	37 (29.4)	0.023	15 (27.8)	83 (31.3)	0.265	45 (29.2)	120 (30.7)	0.012
≥1,000 SGD	51 (51.0)	31 (24.6)	<0.001	28 (51.9)	75 (28.3)	0.009	79 (51.3)	106 (27.1)	<0.001
On financial aid	18 (16.8)	30 (23.4)	0.256	1 (1.9)	49 (18.2)	0.001	19 (11.8)	79 (19.9)	0.027
Geriatric history									
History of falls									
≥1 fall in past year	26 (24.3)	30 (23.4)	0.879	9 (16.7)	59 (21.9)	0.467	35 (21.7)	89 (22.4)	0.911
General health									
Visual impairment	8 (7.5)	21 (16.4)	0.046	6 (11.1)	42 (15.6)	0.530	14 (8.7)	63 (15.9)	0.030
Hearing impairment	6 (5.6)	11 (8.6)	0.454	4 (7.4)	26 (9.7)	0.798	10 (6.2)	37 (9.3)	0.312
Systolic blood pressure[b]	138.2 ± 18.5	137.9 ± 16.7	0.897	131.4 ± 13.4	139.6 ± 20.4	<0.001	136.0 ± 17.3)	139.1 ± 19.3	0.066
Diastolic blood pressure[b]	81.8 ± 10.9	81.6 ± 12.4	0.884	81.5 ± 8.62	80.6 ± 12.8	0.535	81.7 ± 10.1)	81.0 ± 12.6	0.454
Underweight (BMI <18.5)	10 (9.6)	6 (4.9)	0.199	1 (2.0)	29 (11.2)	0.039	11 (7.1)	35 (9.2)	0.499
Overweight (BMI ≥23)	65 (62.5)	71 (58.2)	0.586	20 (39.2)	135 (52.3)	0.094	85 (54.8)	206 (54.2)	0.924
Depression[c]	16 (15.0)	33 (25.8)	0.053	8 (14.8)	71 (26.4)	0.083	24 (14.9)	104 (26.2)	0.004
Functional history									
iADL (Lawton-Brody iADL scale <8)	19 (17.8)	27 (21.1)	0.621	3 (5.6)	37 (13.8)	0.114	22 (13.7)	64 (16.1)	0.519
Basic ADL (Barthel Index <100)	13 (12.1)	21 (16.4)	0.457	3 (5.6)	51 (94.4)	0.591	16 (9.9)	44 (11.1)	0.764
Medical history									
Charlson Comorbidity Index >0	36 (33.6)	54 (42.2)	0.225	23 (42.6)	101 (37.5)	0.540	59 (36.6)	155 (39.0)	0.632
Ischemic heart disease	7 (6.5)	17 (13.3)	0.129	2 (3.7)	18 (6.7)	0.546	9 (5.6)	35 (8.8)	0.228
Diabetes	23 (21.5)	28 (21.9)	1.000	15 (27.8)	58 (21.6)	0.372	38 (23.6)	86 (21.7)	0.653
Hypertension	56 (52.3)	44 (34.4)	0.008	23 (42.6)	121 (45.0)	0.767	79 (49.1)	165 (41.6)	0.110
Hyperlipidemia	38 (35.5)	20 (15.6)	<0.001	17 (31.5)	69 (25.7)	0.400	55 (34.2)	89 (22.4)	0.005
Cerebrovascular disease	3 (2.8)	8 (6.2)	0.234	3 (5.6)	17 (6.3)	1.000	6 (3.7)	25 (6.3)	0.308
Social history									
Living arrangements									
Living with family	83 (77.6)	83 (64.8)	Referent	42 (77.8)	163 (60.6)	Referent	125 (77.6)	246 (62.0)	Referent
Living with others	10 (9.3)	14 (10.9)	0.431	1 (1.9)	47 (17.5)	0.015	11 (6.8)	61 (15.4)	0.003
Living alone	14 (13.1)	31 (24.2)	0.024	11 (20.4)	59 (21.9)	0.383	25 (15.5)	90 (22.7)	0.015
No. of people in household									
<3	52 (48.6)	90 (70.3)	0.001	29 (53.7)	198 (73.6)	0.005	81 (50.3)	288 (72.5)	<0.001
≥3	55 (51.4)	38 (29.7)		25 (46.3)	71 (26.4)		80 (49.7)	109 (27.5)	
Social support									
Poorer social support (LSNS-6 ≤12)	65 (60.7)	98 (76.6)		18 (33.3)	179 (66.5)		83 (51.6)	277 (69.8)	
Better social support (LSNS-6 >12)	42 (39.3)	30 (23.4)	0.011	36 (66.7)	90 (33.5)	<0.001	78 (48.4)	120 (30.2)	<0.001
Has family as caregiver									
No	24 (22.4)	47 (36.7)		13 (24.1)	107 (39.8)		37 (23.0)	154 (38.8)	
Yes	83 (77.6)	81 (63.3)	0.022	41 (75.9)	162 (60.2)	0.031	124 (77.0)	243 (61.2)	<0.001
MMSE score	25.73 ± 4.75	25.05 ± 4.16	0.242	26.56 ± 3.30	25.71 ± 4.23	0.107	26.01 ± 4.32	25.50 ± 4.22	0.202
MMSE score <24	18 (16.8)	41 (32.0)	0.010	8 (14.8)	63 (23.4)	0.208	26 (16.1)	104 (26.2)	0.011

Values are numbers with percentages in parentheses or means ± SD. LSNS-6 = Lubbens Social Network Scale-6. [a] Computed using χ^2 test. [b] Computed using t test. [c] Depression defined as Geriatric Depression Scale-15 ≥5 at baseline or history of doctor-diagnosed depression.

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Table 2. Multilevel regressions of cognitive function [β (standard deviation)] amongst elderly communities living in two integrated public housing precincts in Singapore

Factors	Model 1	Model 2	Model 3	Model 4
Cognitive function (n = 558)				
Demographic factors				
Age ≥70 years (vs. age <70 years)***		−1.56 (0.32)***	−1.52 (0.33)***	−1.44 (0.33)***
Chinese ethnicity (vs. non-Chinese ethnicity)*		1.09 (0.31)**	1.06 (0.32)*	0.59 (0.31)*
Female gender (vs. male gender)***		−0.91 (0.32)**	−0.93 (0.33)*	−0.91 (0.33)**
Currently married (vs. not currently married)**		−0.07 (0.31)	−0.10 (0.33)	−0.18 (0.32)
Secondary education or higher (vs. primary education and below)***		1.81 (0.38)***	1.80 (0.39)***	1.78 (0.38)***
Larger social network (vs. smaller social network)**		0.69 (0.34)*	0.70 (0.34)*	0.65 (0.34)*
Clinical factors				
Hearing impairment (vs. no hearing impairment)**		−1.70 (0.58)**	−1.78 (0.57)**	−1.78 (0.57)**
Had a fall in the past year (vs. no fall in the past year)**		−0.16 (0.38)	−0.10 (0.39)***	−0.16 (0.38)
Independent in iADL (vs. impaired in iADL)***		4.06 (0.45)***	3.92 (0.46)***	3.83 (0.45)***
Depression (vs. no depression)*		−0.05 (0.39)	−0.13 (0.39)	−0.08 (0.39)
Intercept	25.62 (0.21)***	22.53 (1.48)***	21.26 (0.89)***	21.55 (0.89)***
Area socioeconomic factors				
Public rental flat neighborhood (vs. owner-occupied flat neighborhood)**				−1.41 (0.58)**
Higher neighborhood deprivation (vs. lower neighborhood deprivation)*				−1.31 (0.55)**
Higher neighborhood unemployment (vs. lower neighborhood unemployment)				−0.14 (0.35)
Individual socioeconomic factors				
Employed (vs. unemployed)**			0.78 (0.39)*	0.82 (0.38)*
Monthly household income ≥1,000 SGD (vs. monthly household income <1,000 SGD)**			0.11 (0.35)	0.09 (0.35)
Owns a car (vs. does not own a car)**			0.20 (0.78)	0.11 (0.77)
Receiving financial aid (vs. not receiving financial aid)			−0.21 (0.33)	−0.20 (0.35)
Random variance component				
Between-group intercept, τ	2.10***	0.44***	0.35***	0.30***
Within-group, σ^2	15.60	12.60	11.90	11.84
Changes in within-group variance, %	–	19.23	4.49	0.38
Intraclass correlation, ρ	0.12	0.03	0.03	0.02

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

were on medical treatment. The prevalence of cognitive impairment was 26.2% (104/397) in rental blocks (low area SES), compared with 16.1% (26/161) in owner-occupied blocks (higher area SES). The association between individual and neighborhood level socioeconomic characteristics with cognitive impairment in our study population is presented in tables 3 and 4. On univariate analysis (table 3), living in rental blocks (low area SES) was associated with cognitive impairment (odds ratio, OR 1.84, 95% CI 1.15–2.97, p = 0.011). After adjustment for individual SES, other clinical factors, and demographic factors (including age, gender, educational level, and ethnicity), elderly living in the low area SES communities were more likely to have cognitive impairment (adjusted OR 5.13, 95% CI 1.98–13.34, p = 0.001) compared to their counterparts in owner-occupied blocks (table 4). This association between area SES and cognitive impairment was also replicated, albeit to a lesser extent, when comparing the blocks with higher neighborhood disadvantage (as measured by the neighborhood disadvantage score) to those blocks with lower neighborhood disadvantage (adjusted OR 3.83, 95% CI 1.65–8.85, p = 0.002). However, neighborhood unemployment (as measured by the neighborhood unemployment score) was not significantly associated with cognitive impairment.

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Table 3. Individual and area-level socioeconomic characteristics associated with prevalence of cognitive impairment (n = 558) in community-dwelling elderly living in two integrated public housing precincts in Singapore

Factors	Prevalence of cognitive impairment (n = 558)			
	No cognitive impairment n (%)	Cognitive impairment n (%)	Unadjusted OR (95% CI)	p value
Area level SES indicators				
Type of block				
Owner-occupied flats	135 (83.9)	26 (16.1)	1.00	
Rental flats	293 (73.8)	104 (26.2)	1.84 (1.15–2.97)	0.011
Neighborhood disadvantage score				
Not disadvantaged	173 (79.7)	44 (20.3)	1.00	
Disadvantaged	255 (74.8)	86 (25.2)	1.33 (0.88–2.00)	0.184
Neighborhood unemployment score				
Relatively lower unemployment	149 (78.0)	42 (22.0)	1.00	
Relatively higher unemployment	279 (76.0)	88 (24.0)	1.11 (0.74–1.70)	0.673
Individual level SES indicators				
Employment status				
Not working	295 (72.5)	112 (27.5)	1.00	
Working	133 (88.1)	18 (11.9)	0.36 (0.21–0.61)	<0.001
Vehicle ownership				
No	405 (75.8)	129 (24.2)	1.00	
Yes	23 (95.8)	1 (4.2)	0.14 (0.02–1.02)	0.024
Household income (monthly)				
<1,000 SGD	262 (72.8)	98 (27.2)	1.00	
≥1,000 SGD	157 (84.9)	28 (15.1)	0.48 (0.30–0.76)	0.002
Financial aid				
No	356 (77.4)	104 (22.6)	1.00	
Yes	72 (73.5)	26 (26.5)	1.23 (0.75–2.04)	0.430

Discussion

Low area SES was significantly associated with poorer cognitive function and cognitive impairment in our study population of community-dwelling elderly in Singapore, a multiethnic Asian city state. Importantly, the main effect of area SES occurred independently of individual level SES, age, and education, highlighting that the area level effect was not merely the manifestation of compositional differences across neighborhoods. This contributes an Asian perspective to the growing body of research on neighborhood SES and mental health, and demonstrates that area level SES affects cognition in Asian societies as well. Several theories have been postulated as to how area level SES can affect cognition, largely drawn from experiences in Western societies. Such theories include: differences in distribution of cognitively stimulating resources in low-SES neighborhoods (such as health facilities and libraries); differences in cultural perceptions of illness and mental health in low-SES areas (e.g. perception of cognitive deficits as a normal part of ageing, delaying treatment and intervention); an ethnic enclave effect, and restricted opportunities for cognitive stimulation via social interaction in deprived neighborhoods [5, 10].

In our local context, the ethnic enclave effect is unlikely to play as large a role, because of government policy in ensuring a balanced ethnic mix in public housing that precludes the formation of ethnic enclaves. However, it is still possible that ethnicity can be a modifier of

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Table 4. Individual and area level socioeconomic characteristics independently associated with cognitive impairment (n = 558), after adjustment for other demographic and clinical variables, amongst elderly communities living in two integrated public housing precincts in Singapore

Factors	Adjusted[a] OR (95% CI)[b]	p value
Prevalence of cognitive impairment (n = 558)		
Demographic factors		
Age ≥70 years (vs. age <70 years)[d]	2.42 (1.36–4.30)	0.003
Female gender (vs. male gender)[d]	1.69 (0.97–2.96)	0.066
Currently married (vs. not currently married)[c]	0.86 (0.51–1.49)	0.607
Secondary education or higher (vs. primary education and below)[d]	0.26 (0.10–0.66)	0.005
Larger social network (vs. smaller social network)[c]	0.60 (0.33–1.09)	0.091
Clinical factors		
Visual impairment (vs. no visual impairment)[c]	1.13 (0.54–2.34)	0.756
Hearing impairment (vs. no hearing impairment)[c]	2.28 (1.29–5.20)	0.049
Had a fall in the past year (vs. no fall in the past year)[c]	1.17 (0.64–2.15)	0.613
Overweight (vs. not overweight)	0.64 (0.38–1.09)	0.099
Independent in iADL (vs. impaired in iADL)[d]	0.18 (0.09–0.35)	<0.001
Charlson Comorbidity Index >0 (vs. Charlson Comorbidity Index = 0)	1.08 (0.60–1.97)	0.790
History of ischemic heart disease (vs. no history of ischemic heart disease)	0.40 (0.13–1.21)	0.104
History of cerebrovascular disease (vs. no history of cerebrovascular disease)[c]	2.17 (0.77–6.06)	0.141
Depression (vs. no depression)[c]	1.10 (0.61–2.02)	0.742
Average systolic blood pressure, mm Hg[d]	1.02 (1.01–1.03)	0.013
Area socioeconomic factors		
Public rental flat neighborhood (vs. owner-occupied flat neighborhood)[c]	5.13 (1.98–13.34)	0.001
Higher neighborhood deprivation (vs. lower neighborhood deprivation)	3.83 (1.65–8.85)	0.002
Higher neighborhood unemployment (vs. lower neighborhood unemployment)	1.45 (0.81–2.59)	0.208
Individual socioeconomic factors		
Employed (vs. unemployed)[d]	0.76 (0.37–1.58)	0.464
Monthly household income ≥1,000 SGD (vs. monthly household income <1,000 SGD)[c]	0.67 (0.34–1.25)	0.208
Owns a car (vs. does not own a car)[c]	0.33 (0.04–2.73)	0.302
Receiving financial aid (vs. not receiving financial aid)	1.10 (0.57–2.11)	0.780

[a] Criterion for entry of demographic and clinical factors into the final model on multivariate analysis was $p < 0.2$ on univariate analysis. Demographic factors entered into the model included age, gender, marital status, education level, and social network. Clinical factors entered into the model included: visual impairment; hearing impairment; had a fall in the past 1 year; overweight; impairment in iADL; having medical comorbidities as quantified using the Charlson Comorbidity Index; history of ischemic heart disease; history of cerebrovascular disease; history of depression, and average systolic blood pressure. All area and individual level indicators of socioeconomic status were also entered into the model. We did not enter impairment in basic ADL (measured via Barthel Index) into the final model because of significant collinearity between measurements of basic ADL and measurements of iADL ($|r| > 0.6$). Collinear variables were omitted from the final models in order of decreasing p values.

[b] ORs reported are adjusted for all variables presented in model.

[c] p value of <0.05 on univariate analysis.

[d] p value of <0.001 on univariate analysis.

the effects of SES on cognitive function. Singapore's high urban density means that low- and high-SES communities often share the same amenities, and disparities in distribution of cognitively stimulating resources are therefore less marked. However, the opportunities for social interaction in high-rise, high-density public housing, a common feature in Singapore's urban landscape, are worth closer examination. Singapore, with a small land area of just 690 km^2, has often been described as an urban laboratory for high-rise public housing, given that the vast majority of the resident population stays in such housing estates [51]. Research sug-

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gests that in high-rise developments, the overall sense of residential community is low; most residents interact only with neighbors on their own floor and are strangers to the vast majority of people sharing the same dwelling [52, 53]. In Singapore, while satisfaction with the quality of amenities and standard of high-rise public housing is high [32, 54] and there is less concern about safety and security in such estates [55], there is concern about the effect of such housing on social interaction. In the words of one author, 'In tall residential buildings, there is no need to borrow garden tools and when the 24-hour provision shop is just an elevator ride away, there is little reason to borrow a cup of sugar from a neighbor' [56]. Thus, Singapore's urban landscape, with reduced opportunities for social interaction, could further reinforce the possible link between low area SES, limited social participation, and cognitive functioning. Residents of poor neighborhoods, regardless of their own class, are likely to have interaction with neighbors who, because of disadvantage, may be unable to offer extensive cognitive stimulation, constrained by limited education and financial stress, whereas residents in more affluent neighborhoods are exposed to neighbors who can provide more extensive cognitive stimulation [10]. Locally, although there is no data directly linking social interaction to cognitive impairment, other local studies have linked social networks to depressive symptoms among the elderly [38], and in turn, depressive symptoms to cognitive impairment [57]. Additionally, in densely urbanized Singapore, close juxtaposition of richer communities in proximity to poorer neighborhoods could exacerbate the health consequences of poverty, as suggested by the 'local social inequality' model [14, 58]. Higher income inequality is also associated with lower societal trust in several studies [59], including Asian societies [60], and diminished trust can lead to social withdrawal, further social isolation and negative effects on cognition. Urban planning of living space can be better designed to foster social interaction and, hopefully, improve cognitive function of the elderly staying in such estates. Given Singapore's unique constraints on living space, though, high-rise public housing is likely to persist as a significant component of the built environment. Similarly, in other rapidly urbanizing Asian cities with space constraints, high-rise housing is likely to increase [56]. Hence, apart from rethinking urban planning, interventions are also important in targeting at-risk groups within these low-SES communities, in order to slow cognitive decline and ease access to mental health services. Many cultural misperceptions and poor awareness about cognitive impairment and dementia exist even in developed countries [61, 62]. More needs to be done to encourage participation in preventive and early detection programs.

The limitations of our study are as follows. Our study design was cross-sectional in nature; hence we can only draw associations between neighborhood SES and cognitive impairment, and cannot infer causality. In addition, we did not account for the length of residence, as such data was not available. Furthermore, this study was only carried out in two geographical sites and a limited number of blocks (n = 15) as our aim was to compare a small number of purposely selected contrasting neighborhoods. While such methods have their strengths [4, 63, 64], their weakness is in the generalizability of results [4]. Our results might not be fully generalizable to other integrated housing precincts in Singapore, and the owner-occupied blocks in our study may not be fully representative of national demographic patterns as a whole. We note, however, that the demographic makeup of our owner-occupied blocks (higher area SES) is similar to national averages for similar types of blocks (e.g. 64.6% Chinese ethnicity vs. 68.4% Chinese ethnicity nationally; employment rates of 26.1 vs. 29% nationally; 51.3% with monthly household income ≥1,000 SGD, compared with median household income of 1,267 SGD nationally; 50.3% with household size <3, compared with median household size of 2 nationally). Also, these findings may be relevant in the local sociocultural milieu, but might not be easily generalizable to other Asian societies and other populations. In addition, we used the MMSE to diagnose cognitive impairment. While its use and

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the cutoffs were locally validated [25, 28], the MMSE is only a screening tool for cognitive impairment and cannot diagnose dementia.

In conclusion, living in a low-SES community was independently associated with poorer cognitive function and cognitive impairment among community-dwelling elderly living in integrated public housing precincts in Singapore, an urbanized Asian city state. This association was independent of individual SES as well as demographic and clinical factors. Causal pathways by which neighborhood deprivation can potentially affect cognitive function among elderly in urbanized Asian societies need to be better understood.

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Disclosure Statement

The authors declare no conflicts of interest.

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