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Clinical paper

Socioeconomic disadvantage and long-term survival duration in out-of-hospital cardiac arrest patients: A population-based cohort study

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Abstract

Background: Socioeconomic status (SES) is a well-established determinant of cardiovascular health. However, the relationship between SES and clinical outcomes in long-term out-of-hospital cardiac arrest (OHCA) is less well-understood. The Singapore Housing Index (SHI) is a validated building-level SES indicator. We investigated whether SES as measured by SHI is associated with long-term OHCA survival in Singapore.

Methods: We conducted an open cohort study with linked data from the Singapore Pan-Asian Resuscitation Outcomes Study (PAROS), and the Singapore Registry of Births and Deaths (SRBD) from 2010 to 2020. We fitted generalized structural equation models, calculating hazard ratios (HRs) using a Weibull model. We constructed Kaplan–Meier survival curves and calculated the predicted marginal probability for each SHI category.

Results: We included 659 cases. In both univariable and multivariable analyses, SHI did not have a significant association with survival. Indirect pathways of SHI mediated through covariates such as Emergency Medical Services (EMS) response time (HR of low-medium, high-medium and high SHI when compared to low SHI: 0.98 (0.88–1.10), 1.01 (0.93–1.11), 1.02 (0.93–1.12) respectively), and age of arrest (HR of low-medium, high-medium and high SHI when compared to low SHI: 1.02 (0.75–1.38), 1.08 (0.84–1.38), 1.18 (0.91–1.54) respectively) had no significant association with OHCA survival. There was no clear trend in the predicted marginal probability of survival among the different SHI categories.

Conclusions: We did not find a significant association between SES and OHCA survival outcomes in residential areas in Singapore. Among other reasons, this could be due to affordable healthcare across different socioeconomic classes.

Keywords: Cardiac arrest, Out-of-hospital cardiac arrest, Socioeconomic disadvantage, Socioeconomic status, Long-term survival, Mortality

Introduction

Socioeconomic status (SES), typically a composite indicator of income, education level, social status and occupation,[1–3] can be measured at the individual level or areal level.[4–6] SES has been shown to significantly correlate with outcomes in many health conditions.[2,7] SES is well-established as an important determinant of cardiovascular health,[8–10] for example in acute coronary syndrome.[11] However, the relationship between SES and clinical outcomes in out-of-hospital cardiac arrest (OHCA) is less well-understood. OHCA, defined as the absence of cardiac mechanical activity leading to a loss of systemic circulation outside the hospital setting, is a major cause of global mortality.[12,13] OHCA also has a significant disease burden in Singapore, with an age-adjusted incidence of about 50.0 per 100,000 person-years and survival of only up to 3.0%.[14] Early data from the United States and Sweden have shown a positive correlation between neighborhood income levels and survival rates.[15,16] Notwithstanding, these studies relied on areal measures of SES which are susceptible to the ecological fallacy, and a systematic review by van Nieuwenhuizen et al in 2019 highlighted a paucity of studies using individual-level SES data.[17] Furthermore, a critical knowledge gap exists in the relationship between SES and the long-term prognosis of cardiac arrests, as most studies have investigated 30-day survival and survival to discharge.[6,18] Such long-term

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outcomes include mortality and return to work,[19] offering insight into the natural history of OHCA and its disease burden over time.

SES has been shown to be linked with health outcomes in Singapore, for example in pregnancy and child health outcomes.[20] Recent data from Singapore have suggested that lower SES (measured by the Singapore Housing Index (SHI)) was associated with lower rates of bystander cardiopulmonary resuscitation (CPR),[21] defined as CPR delivered by a non-emergency medical system personnel. Such early CPR constitutes a crucial link in the series of post-OHCA rescue actions known as the "chain of survival",[22] contributing most significantly to survival rates.[23,24] However, it is not known whether the association between SES and bystander CPR translated to a change in clinical outcomes such as 1-year survival or survival duration.[21]

A graded relationship has been observed between SES and health,[25] highlighting the relevance of the varying granularity of different SES measures. SES can be measured at the individual level or areal level.[4–6] SHI is a building-level SES indicator, providing a middle ground between individual and area level measures, circumventing the inefficient and biased nature of individual-level SES data collection as well as the lack of detail in area-level SES data collection.[26] SHI is a valid measure of SES in Singapore, and has been shown to be correlated with a number of health outcomes including breast cancer mortality[27] and outcomes after low-falls in elderly.[28] In this study, we investigated whether SES is associated with long-term OHCA survival in Singapore. We hypothesized that a lower SES would be associated with poorer long-term OHCA outcomes.

Methods

Study design

We linked two population-based datasets: Singapore data from the Pan-Asian Resuscitation Outcomes Study (PAROS),[29] and the Singapore Registry of Births and Deaths (SRBD)[30] from 2010 to 2020 using the National Registration Identity Card numbers of each case. We conducted an open cohort study with the resultant dataset. PAROS is an international, multicenter, prospective registry of OHCA in nine countries across the Asia–Pacific region established in 2009.[29] PAROS is based on Utstein-style reporting[31] and uses a data dictionary and taxonomy aligned with the Cardiac Arrest Registry to Improve Survival (CARES).[32] The SRBD includes data on the cause and date of death of all Singaporeans and Permanent Residents residing in Singapore up to February 28, 2023.[30] From the linked data, we evaluated the survival status and survival duration of the OHCA survivors.

Setting

The study population resides in Singapore, a densely populated Southeast Asian city-state. Emergency ambulances use mechanical CPR devices, and all ambulance personnel are trained in basic life support skills and can use automated external defibrillators.[33] OHCA patients typically receive treatment at the scene of arrest. The EMS then transports the OHCA patient to the hospital after a short period of resuscitation, usually with ongoing CPR.[34] Detailed description regarding EMS management of OHCA in Singapore has been described previously.[35]

Study population and data collection

We included all cases with OHCA in the PAROS dataset (Singapore participants) in this study, defined as any OHCA conveyed by EMS or presenting at emergency departments, as confirmed by the absence of pulse, unresponsiveness, and apnea.[29] Since we are investigating the long-term survival outcomes after OHCA, we excluded all cases that died within 30 days of the date of OHCA, consistent with previous OHCA studies relating to long-term outcomes. We also excluded foreigners who had no follow-up data and hence no death information. We also excluded OHCA cases that did not occur in their own homes, as these cases were deemed as non-residential OHCAs, and the lack of postal codes made calculating the SHI untenable. The study was approved by the SingHealth Centralised Institutional Review Board (CIRB ref: 2018/2937) and qualified for exemption from full review as it analyzed de-identified data.

The linked data included case demographics (age, sex, race), details of OHCA, initiation of targeted hypothermia management, and date and cause of death. Details of OHCA included the presenting rhythm (categorized as shockable, non-shockable, and unknown rhythm), the presence of a witness during the OHCA, the provision of bystander CPR, EMS response time (defined as time between notification of an incident and the parking of the ambulance at the destination, which does not include the time taking for the crew to arrive at the patient side) and Cerebral Performance Category (CPC) categorized to CPC 1 and 2 versus CPC 3 and 4.

The primary outcome of interest was duration of survival after OHCA and was computed as the time from 30 days after the date of OHCA to the date of death as documented by the SRBD. For the time-to-event analysis, the date of censoring was taken as 28 February 2023.

Singapore Housing Index

The main exposure of interest, SES, was measured by SHI. The SHI value is derived by calculating the weighted mean number of rooms per apartment in the building.[26] It takes a value of 1 to 7. In Singapore, a sizeable majority of residents reside in public housing, which encompasses residential apartments built by a government statutory board, the Housing & Development Board (HDB). These apartments are eligible for subsidies and grants from the government.[27] More information on the price and size by housing types can be found in Supplementary Table 1. To obtain an updated SHI dataset, we followed the methodology described by Lim et al., which utilized government open data sources[26] to assign a SHI value to each residential postal code in Singapore. First, we matched each patient by the National Registration Identity Card numbers to their latest known residential address on record. The six-digit postal code was then compared against the land use master plan provided by the Singapore Land Authority to identify its associated HDB block, private apartment, or landed property. Patients staying in public housing (a HDB block) were assigned a SHI value ranging from 1 to 6, with higher values indicating higher SES. In the original SHI, non-subsidized private apartments (condominium apartment buildings) and landed housing blocks were assigned SHI values of 6 and 7 respectively. However, following this open data formulation of the SHI, there is no dataset that can exhaustively distinguish between private property of SHI 6 and 7. Hence, these individuals were all coded as SHI 6. Similar to existing literature,[27] we categorized patients into four ordinal SHI categories: <=2 (low SHI), 2–3 (low-medium SHI), 3–4.99 (high-medium SHI) and >=5 (high SHI).

Statistical analyses

Baseline characteristics were presented as frequencies and proportions for categorical variables, and median (interquartile range) or

mean (standard deviation) for continuous variables. To compare baseline characteristics of cases who were alive and dead at one year follow-up, we used the Pearson Chi-squared test for categorical data and the independent Student's t-test (or the Mann-Whitney test when data was not distributed normally) for continuous variables.

To investigate the long-term survival of patients with OHCA, we fitted univariable and multivariable generalized structural equation models (GSEMs) to estimate the direct and indirect effects of SHI on OHCA survival as the Cox regression model does not allow us to study mediating effects. The GSEM framework has been previously described in the existing literature.[36–38] Through GSEM, we can assess the possible causal pathway by which SHI influences OHCA survivorship indirectly. The direct and indirect effects of SHI, hypothermia therapy, EMS ambulance response time on OHCA survival were estimated using fitted GSEMs. Within our GSEM framework, we fitted survival time using a Weibull distribution. Covariates included in the models were demographics (age, sex, and race), details of OHCA (presenting rhythm, witnessed arrest, bystander CPR, EMS response time, and CPC category) and initiation of targeted hypothermia management. Missing data within variables was kept as a separate category in the models to preserve the overall sample size. The indirect relationship between SHI and mortality through hypothermia therapy initiated, EMS response time and age at arrest was specified a-priori based on clinical reasoning and prior evidence.[21] Kaplan–Meier survival curves were constructed for the overall population. We calculated the proportion surviving annually for up to ten years post-OHCA. Associations were estimated as hazard ratios (HR) along with the 95%-confidence intervals (95% CI). The 95% confidence intervals were estimated with bootstrapping with 200 iterations. Predicted marginal probability of death was calculated for each SHI category using the margins command. Level of significance was set at 5% and analysis performed in Stata 17 (Stata Corp, College Station, Tx, USA).

Results

We included 659 cases in the analysis. The detailed population flowchart can be found in Supplementary Fig. 1. 98 cases had died within one year. The mean age was 56.7 (SD 21.0) and the majority of the cohort was male (439 cases, 66.6%) and of Chinese race (431 cases, 65.4%). OHCA survivors who died within one year of follow-up had significantly older age, higher CPC category at baseline and significantly different racial distributions (Table 1).

We calculated the proportion alive at each year of follow up (Table 2). The proportion surviving at one year of follow up was 0.85 (95% CI 0.82–0.88), at five years of follow up was 0.73 (95% CI 0.69–0.76), and at ten years of follow up was 0.67 (95% CI 0.62–0.72).

In the univariable generalized structural equation model (Supplementary Table 2), older age at arrest (HR: 1.03, 95% CI 1.02–1.04) and higher CPC category (HR: 4.19, 95% CI 3.09–5.70) were significantly associated with poorer survival ($p < 0.05$). There was no association found between long-term OHCA survival and female

Table 1 – Demographic and clinical characteristics of cohort.

Variables	Alive in Year 1	Dead in Year 1	All	p-value
N	**561**	**98**	**659**	
Gender				0.18
Male	368 (65.6%)	71 (72.4%)	439 (66.6%)	
Age, mean (SD)	55.2 (21.0)	65.3 (18.4)	56.7 (21.0)	<0.001
Race				0.037
Chinese	358 (63.8%)	73 (74.5%)	431 (65.4%)	
Indian	67 (11.9%)	10 (10.2%)	77 (11.7%)	
Malay	75 (13.4%)	13 (13.3%)	88 (13.4%)	
Other	61 (10.9%)	2 (2.0%)	63 (9.6%)	
Bystander CPR				0.29
No	267 (47.6%)	41 (41.8%)	308 (46.7%)	
Arrest witnessed				0.32
No	153 (27.3%)	22 (22.4%)	175 (26.6%)	
Hypothermia therapy initiated				0.59
No	400 (71.8%)	73 (74.5%)	473 (72.2%)	
EMS Ambulance response time, median (IQR)	8.1 (6.6, 10.2)	8.3 (7.2, 10.3)	8.1 (6.6, 10.3)	0.54
Shockable first arrest rhythm				0.23
Non-shockable	229 (40.8%)	49 (50.0%)	278 (42.2%)	
Shockable	276 (49.2%)	40 (40.8%)	316 (48.0%)	
Unknown	56 (10.0%)	9 (9.2%)	65 (9.9%)	
Cerebral Performance Category Grouped				<0.001
1–2	290 (57.9%)	25 (27.8%)	315 (53.3%)	
3–4	114 (22.8%)	64 (71.1%)	178 (30.1%)	
Missing	97 (19.4%)	1 (1.1%)	98 (16.6%)	
SHI Group				0.12
<=2 (Low SHI)	26 (4.6%)	2 (2.0%)	28 (4.2%)	
2–3 (Low-medium SHI)	27 (4.8%)	3 (3.1%)	30 (4.6%)	
3–4.99 (High-medium SHI)	314 (56.0%)	68 (69.4%)	382 (58.0%)	
5+ (High SHI)	45 (8.0%)	8 (8.2%)	53 (8.0%)	
Missing	149 (26.6%)	17 (17.3%)	166 (25.2%)	

Table 2 – Survival by follow-up period.

Follow-up/years	Proportion surviving	95% confidence intervals	
1	0.8513	0.8218	0.8763
2	0.8058	0.7734	0.834
3	0.7725	0.7384	0.8027
4	0.7483	0.7126	0.7802
5	0.7266	0.6895	0.7601
6	0.7074	0.6684	0.7427
7	0.696	0.6554	0.7329
8	0.6904	0.6485	0.7284
9	0.6904	0.6485	0.7284
10	0.6729	0.6248	0.7163

gender, arrest witnessed, initiation of hypothermia therapy, EMS ambulance response time or shockable first arrest rhythm (Supplementary Table 2). In the multivariable generalized structural equation model (Supplementary Table 2), older age at arrest (HR: 1.03, 95% CI 1.02–1.04) and higher CPC category (HR: 3.49, 95% CI 2.49–4.91) were significantly associated with poorer survival, and female gender was significantly associated with improved survival (HR: 0.67, 95% CI 0.48–0.95). There was still no association found between long-term OHCA survival and race, initiation of bystander CPR, arrest witnessed, initiation of hypothermia therapy, EMS ambulance response time and shockable first arrest rhythm were still insignificantly associated with their survival.

In both the univariable (Fig. 1) and multivariable analysis, SHI did not have a significant total association with survival (Table 3). As detailed in Table 4, the indirect pathways of SHI mediated through different covariates such as hypothermic therapy initiation (HR of low-medium, high-medium and high SHI when compared to low SHI: 0.96 (0.86–1.07), 0.99 (0.92–1.06), 0.94 (0.83–1.06) respectively), EMS response time (HR of low-medium, high-medium and high SHI when compared to low SHI: 0.98 (0.88–1.10), 1.01 (0.93–1.11), 1.02 (0.93–1.12) respectively), and age of arrest (HR of low-medium, high-medium and high SHI when compared to low SHI: 1.02 (0.75–1.38), 1.08 (0.84–1.38), 1.18 (0.91–1.54) respectively) had no significant association with OHCA survival. The differences in probability of survival between categories were not clinically significant (Fig. 2).

Discussion

In this population-based cohort study, we investigated the relationship between SES and long-term clinical outcomes in OHCA in

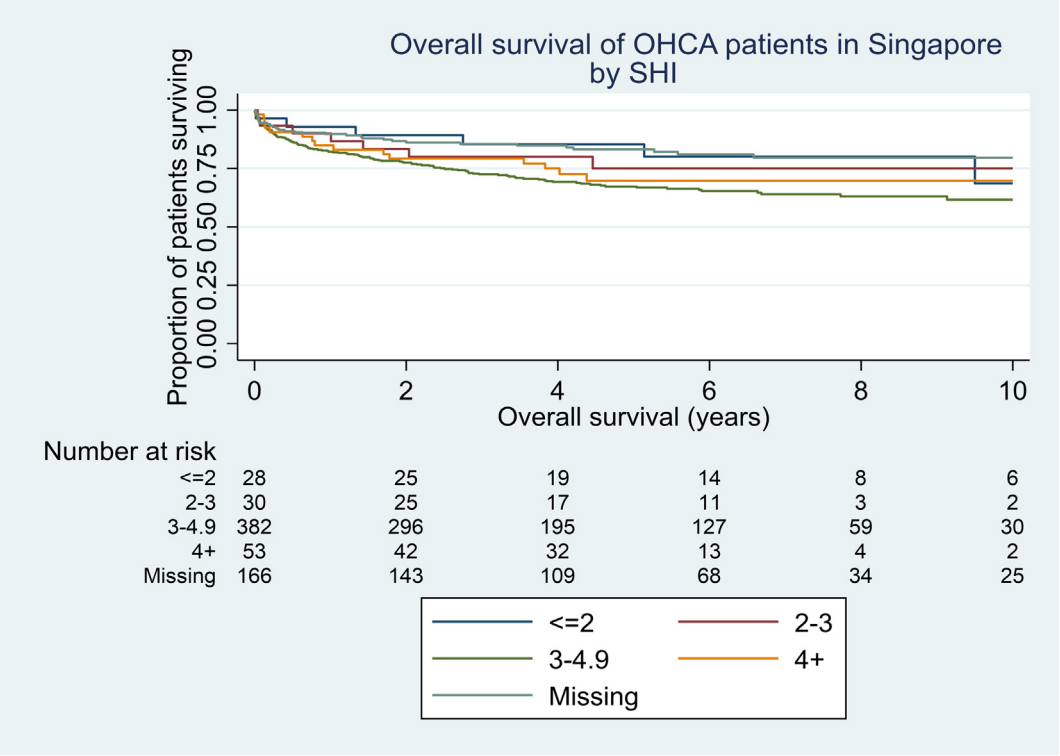

Fig. 1 – Overall survival of OHCA patients in Singapore by SHI.

Table 3 – Demographic and clinical factors associated with survival.

Covariate	HR	95% confidence intervals		p-value	HR	95% confidence intervals		p-value
	Crude analysis				Adjusted analysis			
SHI Group								
<=2 (Low SHI)	Reference				Reference			
2–3 (Low-medium SHI)	1.20	0.40	3.58	0.739	1.59	0.51	4.96	0.425
3–4.99 (High-medium SHI)	1.84	0.81	4.18	0.143	1.25	0.53	2.97	0.611
5+ (High SHI)	1.55	0.60	3.99	0.365	1.37	0.52	3.64	0.522
Missing	0.91	0.38	2.19	0.841	0.75	0.29	1.90	0.542

Based on Generalised Structural Equation Models with causal pathways.

Table 4 – Indirect pathways of SHI through moderating variables.

Covariate	HR	95% confidence intervals *		p-value
through hypothermia therapy initiated				
SHI Group				
<=2 (Low SHI)	Reference			
2–3 (Low-medium SHI)	0.96	0.86	1.07	0.430
3–4.99 (High-medium SHI)	0.99	0.92	1.06	0.750
5+ (High SHI)	0.94	0.83	1.06	0.290
Missing	1.02	0.95	1.09	0.640
through EMS Ambulance response time				
SHI Group				
<=2 (Low SHI)	Reference			
2–3 (Low-medium SHI)	0.98	0.88	1.10	0.760
3–4.99 (High-medium SHI)	1.01	0.93	1.11	0.740
5+ (High SHI)	1.02	0.93	1.12	0.710
Missing	1.03	0.94	1.13	0.490
through age at arrest				
SHI Group				
<=2 (Low SHI)	Reference			
2–3 (Low-medium SHI)	1.02	0.75	1.38	0.920
3–4.99 (High-medium SHI)	1.08	0.84	1.38	0.560
5+ (High SHI)	1.18	0.91	1.54	0.220
Missing	0.97	0.74	1.27	0.850

Based on Generalised Structural Equation Models with causal pathways.

* Bootstrapped with 200 iterations.

Singapore. We found that SES had no significant association with long-term clinical outcomes in OHCA, both before and after adjustment for covariates such as demographic variables and CPC category. We also found that there was a significant association between OHCA survival and older age, as well as higher CPC category at baseline.

Such a significant association between OHCA survival and older age has been found in previous research, which recognizes the physiological effects of aging like reduced organ reserve and rising comorbidity, and their adverse association with OHCA survival.[39] While less research has been done on baseline CPC, higher CPC at discharge has been previously found to be significantly associated with OHCA survival.[40]

SES has been found to be significant for other non-communicable diseases such as cancer.[5,17] Several papers investigating long-term outcomes in OHCA have found an association with SES. However, while most studies have found a relationship between SES and OHCA outcomes, some have found no evidence of this. In the context of Singapore, the following circumstances could have contributed to a situation where SES does not significantly correlate with OHCA outcomes, as we have found in our paper.

Firstly, health system characteristics (e.g. universal health coverage) can mitigate the adverse effect of SES on health outcomes. In Singapore, free or subsidized healthcare allows access to healthcare regardless of SES, including preventative care, emergency response, and post-resuscitation care. Prior to an OHCA, means-tested subsidies that Singapore provides ensure that healthcare is affordable for all across different socioeconomic classes.[41] This includes services like primary care interventions like lifestyle management that can reduce comorbidities, which has been linked to OHCA outcomes.[42] In the event of an OHCA, the emergency ambulance service the patient utilizes is publicly funded in Singapore and provided free-of-charge to patients.[43] After being admitted into a hospital, subsidies are also available to make post-resuscitation care affordable regardless of SES. Existing literature offers a mixed picture about how SES affects OHCA survival, with some studies showing that individual-level SES predicted OHCA survival,[44,45] while

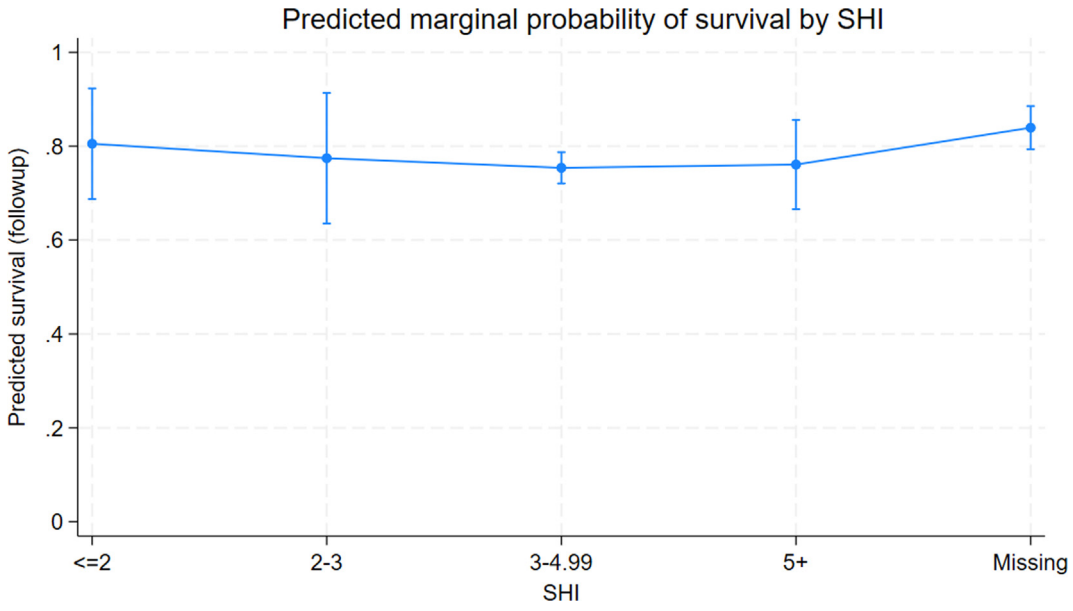

Fig. 2 – Predicted marginal probability of survival by SHI.

area-level measures of SES did not,[45] while some other studies demonstrated that higher community-level SES translated to improvement in OHCA survival.[46,47] However, the results from these studies could have been confounded by differences in access to care. Countries with disparities in health outcomes on account of SES might look to health system reforms to reduce such health inequities in access to care. Hence, access to care, while challenging to measure, could be an area of future research to elucidate how it interacts with SES in altering OHCA survival.

Secondly, health literacy and resuscitation education strategies could be possible factors that account for the absence of SES effect on OHCA survival. High-quality CPR and good provider knowledge have been recognized as key prehospital determinants in OHCA survival.[48] Public understanding regarding cardiac arrests has improved over the years in Singapore,[49] due to many interventions across the community. These initiatives span across people of different SES, namely the school-based CPR training and teaching of national servicemen conscripted into mandatory military training. Other efforts include Dispatcher-Assisted CPR, the DARE (Dispatcher-Assisted First Responder) Programme,[50] and the MyResponder smartphone application which activates first responder volunteers. Thus, good health literacy and education extending across all SES levels in Singapore's context could explain the lack of association between SES and OHCA outcomes.

Thirdly, air pollution is a potential geographic confounder. While SHI indicates the size of the flat, the location of flats may be more significant. For example, flats located next to busy roads, expressways, petrol stations or industrial areas may have increased benzene exposure. Although there have been mixed findings on the association of air pollutants with OHCA incidence, an association has been demonstrated in Singapore.[51–53] Higher levels of air pollutants may also worsen OHCA outcomes, making air pollution a potential confounding factor that is left unaddressed by SHI.

Fourthly, the building level on which the patient lived could have impacted OHCA outcomes. Being a small country with scarce land, many flats in Singapore are high-rise buildings. As such, living on a higher floor could pose an obstacle to the EMS, who could then take a longer time to access the patient's house if the OHCA occurred at home. Previous data from Singapore have demonstrated that vertical distance was inversely related to chance of surviving OHCA.[54] The building floor is not taken into account in the SHI, hence this could have contributed to the lack of a link between SES and OHCA survival.

Fifthly, the demographic of each housing estate could have affected OHCA outcomes. The maturity of the estate could change the average patient profile, regardless of the size of the flat. For instance, a person living in a 3-room flat in an older, mature housing estate is more likely to be an elderly person as compared to a 3-room flat in a younger, non-mature estate, and correspondingly the patient residing in the mature housing estate is more likely to have poorer OHCA outcomes. Additionally, public rental flats, with a higher proportion of lower-income residents,[55] have a different resident profile. Since such neighborhood demographics are not incorporated into the SHI, they could be confounders that explain the absence of an association between SES and OHCA survival.

Lastly, SES has been postulated to affect OHCA outcomes due to illicit drug use, but Singapore has low levels of drug abuse. This relationship has been suggested in previous research,[56,57] which recognizes the unwillingness of individuals engaging in illicit substance use to contact emergency services immediately upon witnessing a drug-induced OHCA, for fear of legal action against themselves. This delay extends the time with reduced blood supply to the heart and the brain, worsening OHCA survival rates. However, drug abuse in Singapore is extremely low relative to the rest of the world,[58] with only 2,826 drug-related arrests in 2022[59] (0.05% of the Singapore population[60] compared to a global best estimate of drug use levels between 0.39–4.27% across different drugs, according to the UNODC World Drug Report 2023.[61] Therefore, illicit drug use is unlikely to have made an appreciable impact on the rates of OHCA outcomes. Given the previously described link between SES and drug use,[57] this insignificance of illicit drug use in Singapore further explains the lack of an association between SES and OHCA survival.

This study is significant because of its unique SHI measure, which offers more granularity than area-level SES data, and avoids the bias that individual-level SES data can have. An alternative measure of SES in Singapore is the socioeconomic disadvantage index (SEDI),[62] which has been used to investigate visual impairment.[4] Compared to the alternative SES indicator SEDI, SHI has greater granularity, making this a strength of our study. Another strength of this investigation is its comprehensive national coverage due to the use of population-level data, which is likely accurate given the small size of Singapore and the predominantly public emergency healthcare system.

However, this study is not without its limitations. The high social mobility in Singapore means that childhood SES, differing from the measured adult SES, could have affected adult health and thus OHCA outcomes. According to the World Economic Forum's Global Social Mobility Report 2020,[63] Singapore is ranked 20th in terms of social mobility, with a relatively high score of 74.6. Although slowing social mobility is a concern nowadays,[64] the effect of social mobility on changing SES over time was likely most pronounced when Singapore was a younger country, thus affecting today's generation of adults. The significance of this impact is noted in particular with regards to cardiovascular mortality.[65] As such, the adult SES we measured using SHI might not have been an optimal reflection of their childhood SES, which would have significantly affected their cardiovascular health and hence OHCA survival. Further study could investigate a more comprehensive measurement of SES, to explore the relationship between SES over the life course and OHCA outcomes.

Another limitation of this investigation was the reduced sample size due to the exclusion of foreigners treated in Singapore that had no follow-up data. We also excluded OHCA cases that did not occur in a residential location, further shrinking the cohort size. Additionally, the link between SES and OHCA outcomes could perhaps be more pronounced among non-residential OHCA. This is because people who experience non-residential OHCA are more likely to be working, so there could be a greater gradient in SES as compared to that among retirees. This exacerbates the exclusion of non-residential OHCA as a limitation of this study.

We were also limited by the presence of missing data in our analysis. We did not conduct imputation as the missing data in our primary analysis related mainly to the SHI index and we were unable to ascertain if this data was missing at random, which is a necessary assumption. Hence, multiple imputation may not be appropriate for our data. Thus, we included missing SHI as a category in our analysis to preserve the overall sample size.

Additionally, SHI has its own limitations as a measure of SES. Since SHI is dependent on the number of rooms per apartment, this measure is subject to potential variability over the study period. With the decreasing total fertility rate over the last few decades[66,67] and increasing housing prices,[68] people of the same SES may choose an apartment with fewer rooms, resulting in a lower SHI.

Another limitation of the SHI is the possibility of SES misclassification. As the SHI is a building-level indicator, the highest and lowest SES within the same building have the same SHI. This means that people of a higher SES living in a 5-room apartment in a building with many flats with fewer rooms would have a low SHI, reflecting a lower SES.

Conclusion

We did not find a significant association between SES and OHCA survival outcomes in residential areas in Singapore. While the strength of this conclusion is limited by the relatively small study sample size, many factors can possibly explain this result. Among other factors, affordable healthcare and widespread CPR public education across all SES levels stand out as possible drivers for the lack of association. Future studies should investigate how SES measured longitudinally can affect OHCA survival, and how potential confounders such as access to care and environmental factors such as air pollution can influence this association.

Ethical approval and consent to participate

The study was approved by the SingHealth Centralised Institutional Review Board (CIRB ref: 2018/2937) and qualified for exemption from full review as it analyzed de-identified data.

Consent for publication

The study was approved by the SingHealth Centralised Institutional Review Board (CIRB ref: 2018/2937) and qualified for exemption from full review as it analyzed de-identified data.

Availability of data and materials

Data can be made available upon reasonable request.

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CRediT authorship contribution statement

Dawn Yi Xin Lee: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Chun En Yau:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Maeve Pin Pin Pek:** Writing – review & editing, Methodology, Investigation, Formal analysis, Data curation. **Hanzhang Xu:** Writing – review & editing. **Daniel Yan Zheng Lim:** Writing – review & editing. **Arul Earnest:** Writing – review & editing, Methodology, Investigation, Formal analysis, Data curation. **Marcus Eng Hock Ong:** Writing – review & editing. **Andrew Fu Wah Ho:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.resplu.2024.100610.

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