Review

Socio-economic differences in incidence, bystander cardiopulmonary resuscitation and survival from out-of-hospital cardiac arrest: A systematic review

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Abstract

Background: Individuals with a low socioeconomic status (SES) may have a greater mortality rate from out of hospital cardiac arrest (OHCA) than those with a high SES. We explored whether SES disparities in OHCA mortality manifest in the incidence of OHCA, the chance of receiving bystander cardiopulmonary resuscitation (CPR) or in the chance of surviving an OHCA. We also studied whether sex and age differences exist in such SES disparities.

Methods: The Medline, Embase and Scopus databases were searched from 01-01-1993 until 31-01-2019. Studies utilising any study design or population were included. Studies were included if the exposure was SES of the OHCA victim or the OHCA location and the outcome was either OHCA incidence, CPR provision and/or survival rate after OHCA. Study selection and quality assessment were conducted by two reviewers independently. Descriptive data and measures of association were extracted, both in the total study population and in subgroups stratified by age and/or sex. This review was carried out following the PRISMA guidelines.

Results: Overall 32 studies were included. Twelve studies reported on OHCA incidence, thirteen on bystander CPR provision and fourteen on survival. Some evidence for SES differences was found in each identified stage. In all the studies on incidence, SES was measured over the area of the OHCA victims’ residence and was consistently associated with OHCA. In studies on bystander CPR, SES of the area in which the OHCA occurred was associated with bystander CPR, while evidence on individual SES was lacking. In studies on OHCA survival, SES of the victim measured at the individual level and SES of the area in which the OHCA occurred were associated, while SES of the victim, measured at the area of residence was not. Studies reporting age and sex differences in the SES trends were scarce.

Conclusion: SES disparities in OHCA mortality likely manifest in OHCA incidence, bystander CPR provision and survival rate after OHCA. However, there is a distinct lack of data on SES measured at the individual level and on differences within subgroups, e.g. by sex and age.

Keywords: Out-of-hospital, Cardiac arrest, Arrhythmia, Socioeconomic, Incidence, Cardiopulmonary resuscitation, Survival, ESCAPE-NET

Introduction

Out of hospital cardiac arrest (OHCA) is the sudden cessation of effective circulation due to the absence of cardiac pump function, in an out of hospital setting.1 OHCA has been reported to be responsible for approximately half of all cardiac related deaths and to account for up to 20% of all natural deaths in industrialised countries.2,3 Marked differences have been shown to exist in OHCA incidence and survival globally.4 Although great strides have been made in resuscitation in...
some settings, survival rates remain relatively low. Thus, improvements in both prevention and resuscitation strategies are required to decrease this vast public health burden. Such efforts to reduce OHCA incidence are likely to benefit from identifying high-risk populations.

Socioeconomic status (SES) disparities occur in OHCA mortality (e.g. higher level of income is associated with lower mortality), but it is unclear from single studies whether SES differences in OHCA mortality manifest mainly in the risk of having an OHCA, in the chance of receiving bystander CPR or in the chance of surviving an OHCA. SES differences in OHCA incidence are conceivable, as established SES gradients in coronary heart disease (CHD) risk factors are likely to translate to OHCA incidence. CHD may lie on the causal path between OHCA and its risk factors or share common risk factors with OHCA. Likewise, the SES of the area in which an OHCA occurs may be associated with (un)favourable resuscitation characteristics such as provision of bystander cardiopulmonary resuscitation (CPR), e.g. due to a lack of knowledge regarding CPR in lower SES areas.

Finally, SES of the individual is likely to be associated with OHCA survival outcome, for instance due to the generally higher comorbidity burden among low SES groups.

It is unclear which subpopulations may be especially vulnerable. Different individual SES indicators (e.g. income, education level, occupational status or composite measures of deprivation) may differ in their ability to identify vulnerable subgroups with regard to OHCA incidence, bystander CPR provision and survival. Important ly, these indicators of SES, when measured at the individual level, may have differing associations with health outcomes than indicators measured at the area level. Additionally, age and sex differences exist in the socioeconomic gradients for cardiovascular risk factors and health outcomes. It is likely that such differences are also found in OHCA. Exploring potential age and sex differences in the socioeconomic gradient of OHCA may serve to further identify groups with high risk of OHCA incidence and/or low chances of surviving an OHCA. Due to the multiplicity in exposure and outcome definitions as well as study populations, patterns of SES differences in OHCA cannot be interpreted from single studies. Thus a systematic review was carried out in order to assess the patterns of SES differences in OHCA.

We carried out a systematic review to explore at which stage, in which populations and which locations disparities in OHCA mortality emerge. We assessed the associations between SES at the level of the individual or that of the area in which OHCA occurred and (1) the incidence of OHCA, (2) bystander CPR and (3) survival rate of OHCA. Moreover, we compared the consistency across individual SES indicators. Lastly, we investigated whether these SES gradients differ by sex or age group.

Methods

The review was written in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) reporting guidelines.

Definitions

SES was defined as a variable describing the relative position in society of an individual or a population, which could include resources and/or skills within the financial, occupational and/or educational domains. SES was defined at the individual level by indicators such as income, highest educational level attained and occupational status. When SES was measured at the individual level, it was referred to in this review by “SESind”. In addition, the SES level of the area of residence of the OHCA victims was considered as a proxy for the SES of the individual, henceforth referred to as “SESres”. Also, in order to capture the environmental factors that may influence the provision of bystander CPR, SES of the area in which the OHCA occurred was considered, which was referred to in this review as “SESloc”. Thus, while SESres and SESloc both measure SES over an area, one characterised the individual based on where the person lives (SESres) and the other the environment where the OHCA took place (SESloc).

OHCA was defined as a sudden cessation of effective circulation due to the absence of cardiac pump function, in an out of hospital setting. Bystander CPR was defined as out-of-hospital CPR provided by bystanders with or without usage of an automated external defibrillator (AED). Survival after OHCA was defined as being alive at the emergency room with return of spontaneous circulation (ROSC), hospitalized with ROSC at any hospital ward (i.e., hospital admission) or being alive at hospital discharge.

Search strategy

We performed a search for studies, worldwide, reporting associations between individual SES or SES of the area in which an OHCA occurs and OHCA incidence, bystander CPR provision and survival after OHCA. A search was performed in the Embase, Medline and Scopus databases from 01-01-1993 databases until 31-01-2019. The lower bound of the year of publication was based on the oldest citation identified in a preliminary search. The search string was developed in collaboration with a medical research librarian (JD), as detailed in Table 1 and Appendix 1. Any study design was permitted as long as it contained original (un)published scientific findings. The search strategy included commonly used indices for SES such as income, education, occupation and unemployment as well as measures of SES such as the Townsend deprivation index and common synonyms for all the identified SES indicators.

Study selection

The results of the search were screened by two reviewers (BN & IO) independently, first by title and abstract, followed by full text review, if not already excluded in the abstract screening. Disagreements between the two reviewers about the inclusion of articles, were resolved by consensus or with arbitration by a third reviewer (IV), if consensus was not reached. Inclusion criteria of the citations are described in Table 1.

Quality assessment

Quality assessment was carried out for each study by two reviewers (BN & IO) independently using the National Institutes of Health (NIH) quality assessment tool for cross-sectional studies, or the appropriate NIH tool for quality assessment for other study designs, as found in Appendix 2. Disagreements between the two reviewers about the quality assessment of the included citations were resolved by consensus or with arbitration by a third reviewer (IV). No studies were excluded on the basis of quality assessment results. However, the quality of the included studies was presented to facilitate interpretation of the results.
Table 1 – Inclusion criteria.

| I. Criteria related to the search | Publications after 1993, English published articles, original research, full text available. Studies including a majority adult human general population (not selected on a condition or disease) |
| II. Population, or participant and conditions of interest | Socioeconomic status (both individual and area level). One or multiple indicators including: education level, occupation status/level, income, wealth, poverty, social epidemiology, social security, deprivation and inequality as well as synonyms thereof. Composite measures of SES: Townsend deprivation score, Carstairs index, Evaluation of Deprivation and Inequalities in Health Examination Centres, New Zealand Index of Deprivation, Index of Local Conditions, Index of Local Deprivation, Indices of multiple deprivation, Social vulnerability index, Duncan socioeconomic index, Nam-Powers Occupational Status Score, Household prestige scale, Cambridge Social Interaction and Stratification Scale and Statistics Socioeconomic classification |
| III. Interventions or exposures | IV. Comparisons or control groups |
| V. Outcomes of interest | Comparisons are made between individuals with diverging levels of SES. Control groups are not applicable for this study |
| VI. Setting | Incidence\(^1\) of out-of-hospital cardiac arrest (data from emergency medical services attended cases), survival after out-of-hospital cardiac arrest (at hospital admission, hospital discharge, 30 day survival) and bystander CPR provision for OHCA and circumstances (e.g. rates of bystander cardiopulmonary resuscitation, Emergency Medical services (EMS) arrival times, EMS transport times, rates of external automatic defibrillator (AEDs) use, witnessed/unwitnessed arrest rate) |
| VII. Study designs | Any setting |
| * Any study reporting on mortality from sudden cardiac arrest i.e. the incidence of sudden cardiac death or sudden unexpected death were excluded on the basis of being composed of both the incidence and survival rates of a given population; two aspects we aimed to highlight separately and compare (eTable 2, eTable 3) |

Data extraction

The extraction form included identifiers of the citation (including the name of the first author, year of publication and journal), information about the population under study (e.g. city/region, country, ethnic groups, population size and age range), the definitions of exposure and outcome variables used and the results (i.e. risk ratios or odds ratios and confidence intervals). The Supplementary materials, if available, were also checked for relevant results. The extraction table was first piloted in 2 articles\(^{16,21}\) and checked for inconsistencies between the two reviewers (BN & IO) before proceeding with data extraction from the remaining citations. Information was extracted from published manuscripts. If associations were reported separately across the sexes or in different age groups, this information was also extracted.

Synthesis of results

We gave an overview of the SES gradients by assessing direction, strength and consistency of associations between individual SES indicators and SES of the area in which an OHCA occurred within each outcome measure (OHCA incidence, bystander CPR provision or survival rate after OHCA). We specifically compared consistency across SESind indicators. To be able to understand differences in survival, we also included resuscitation characteristics that may influence the association between SES and survival rate: location of OHCA (residential versus public setting), initial rhythm of the OHCA victim (shockable rhythm versus non-shockable rhythm), whether bystander CPR was performed (yes versus no), witnessed status of the OHCA (yes versus no) and time to defibrillator connection. Moreover, we compared the relative SES differences in incidence and survival across age groups and sex.

Results

Our search strategy yielded 32 results that satisfied the inclusion criteria.\(^{16,21,28,31,35,38-42,47,48}\) A flowchart of the study selection is presented in Fig. 1. The majority of exclusions at the phase of abstract screening were due to citations reporting results on bystander CPR education efforts, for instance education efforts in primary schools. At the full text screening phase, citations were excluded due to not reporting associations between SES and OHCA incidence, bystander CPR provision or survival after OHCA. Out of the included studies, twelve measured SES differences in OHCA incidence,\(^{25,29-31,35,38-42,47,48}\) thirteen measured SES differences in bystander CPR provision for OHCA\(^{22,23,26,28,32,34,36,37,40,44,45,48,50}\) and fourteen measured SES differences in survival rate after an OHCA.\(^{16,21,24,26-28,33,39,43,45,46,49-51}\) Descriptive characteristics are provided in Table 2.

Stage: OHCA incidence

For analyses of OHCA incidence all the included studies reported associations based on the number of events occurring within one year, apart from one study which reported lifetime cumulative incidences. All twelve of the studies that reported on OHCA incidence reported that low SESres was associated with a higher OHCA incidence than high SESres (Fig. 2, Table 3). As all the studies measured SES with an area proxy, it was not possible to compare associations found with OHCA incidence across different indicators of SES (e.g. education level vs. income).

One citation, with sex-specific information, reported evidence for a modifying effect of sex on the association between SESres and OHCA.\(^{38}\) Puigades-Rodriguez found women with low SESres to have a higher risk of OHCA incidence than high SESres women, while for men this was not the case. Both the papers that stratified results by age found a stronger trend in those aged 0–64 than in the older group.\(^{31,42}\) For instance, Reinier (2006) reported a weaker association, although in the same direction, between SESres and OHCA incidence in the group aged over 65 compared to the younger age group.
Stage: bystander CPR provision

All thirteen studies that reported on bystander CPR provision, measured SESloc, e.g. by household income, mean property value, education, employment or deprivation (Table 4). Studies on individual SES were lacking. Ten of the twelve studies, reporting on CPR provision, found a low SESloc to be associated with a low rate of bystander CPR (Fig. 2). The single paper to investigate AED connection rates by bystanders, found a significant association between a low SESloc and lower AED connection rates, when adjusted for resuscitation characteristics. \( ^{32} \) None of the studies reported associations separately by age or sex groups.

Stage: survival rate after OHCA

Of the fourteen studies that reported on survival rate, five measured SESind, \( ^{16,27,49-51} \) seven measured SESres, \( ^{24,27,28,33,39,46,49} \) four studies studied SESloc, \( ^{21,26,43,45} \) while two papers reported results on both SESind and SESres (Fig. 2, Table 5). Thirteen studies defined the outcome as survival to hospital discharge and one defined the outcome as 30-day survival. \( ^{32} \) The associations between individual SES and survival were mixed, with a clear difference between individual indicators compared to area level indicators (Fig. 2). All five studies that reported results on SESind found a significantly lower survival in the unemployed, \( ^{16,27,50} \) those with low property value, \( ^{16,27,50} \) and those with low education \( ^{51} \), but not low occupation level. \( ^{51} \) In contrast, only one of the studies that assessed SESres found a significant difference in OHCA survival rate. \( ^{32} \) For SESloc, all four studies, \( ^{21,26,43,45} \) found a significant trend between higher SES and higher survival. Two of the four studies adjusted for individual level demographic variables, resuscitation characteristics and bystander CPR, factors that may function as mediators in the relationship between SESres and survival rate. \( ^{21,49} \) Four studies \( ^{21,24,52,53} \) reported ROSC on top of survival to hospital discharge (eTable 1). Studies showed consistent results across ROSC and survival to hospital discharge.

There was a lack of evidence on differences in the SES gradient by sex and age. Wells et al. \( ^{51} \) found no significant difference between men and women in the association between individual level education or occupation and OHCA survival. None of the other studies made comparisons by sex or age in the association between individual level SES and OHCA survival, nor between SES of the area in which the OHCA occurred and survival rate.
| Name author | Year of publication | City, country | Study design      | Study time             | Population size (% female) | Age range | Ethnic composition | SES level | Outcome measure                                                                 | Adjusted for                                                                 |
|-------------|---------------------|--------------|-------------------|------------------------|-----------------------------|-----------|-------------------|-----------|---------------------------------------------------------------------------------|--------------------------------------------------------------------------------|
| Ahn, K.O.   | 2011                | South Korea  | Cross-sectional   | January 2006–December 2007 | 34227 (39.5)                | NA        | Korean             | SESloc    | Survival at hospital discharge, ROSC                                           | Model 1: Age, sex; Model 2 added: witnessed status, bystander CPR, initial ECG rhythm; Model 3 added: EMS response time, call to ED arrival |
| Andersen, L.W. | 2018              | USA          | Cross-sectional   | January 2013–December 2016 | 25182 (22.3)                | NA        | White, Black, Hispanic, other         | SESloc    | Bystander AED use                                                              | Median age, %white, %living alone, Location, witnessed, initial ECG rhythm, presumed aetiology |
| Brown, T.P. | 2019                | England, UK  | Cross-sectional   | January 2013–December 2015 | 67219 (39.5)                | NA        | White: 88.4%, Mixed: 2.8%, Non-white: 8.8% | SESloc    | Bystander CPR                                                                  | Not adjusted                                                                  |
| Buick, J.E. | 2016                | Toronto, Canada | Cross-sectional      | January 2006–December 2014 | 9485 (37)                    | ≥20 years | NR                | SESres    | Survival at hospital discharge, ROSC at emergency department arrival           | Age, sex, location, neighbourhood instability, neighbourhood dependency, material deprivation, ethnic concentration, crime rate, density family physicians, witnessed, bystander CPR, bystander AED, initial ECG rhythm, EMS response time, ALS skill |
| Castra, L.  | 2018                | Crown area   | Spatial analysis   | August 2013–August 2015   | 3414 (39)                   | NA        | NR                | SESres    | OHCA incidence                                                                 | Age (standardisation)                                                         |
| Chiang, W.C.| 2014                | Taipei, Taiwan | Cross-sectional      | January 2008–December 2009 | 3573 (37.7)                  | >17 years | NR                | SESloc    | Bystander CPR, ROSC, survival at hospital discharge                           | Age, sex, witnessed status, location, recognized by online dispatcher,        |
| Clarke, S.O.| 2005                | King County, USA | Cross-sectional      | January 1999–December 2003 | 1789 (30.1)                  | >17 years | NR                | SESInd & SESres | Survival at hospital discharge                                                   | Model 1: age, sex; Model 4 added: witnessed status, bystander CPR, initial ECG rhythm, location, EMS response time, EMS witnessed arrest |
| Fake, A.L.  | 2013                | Wellington, New Zealand | Cross-sectional      | July 2007–June 2010       | 413 (30.8)                   | >15 years | NR                | SESloc    | Bystander CPR, ROSC and survival at hospital discharge                        | Witnessed arrest, bystander CPR, initial ECG rhythm, EMS response time       |
| Feero, S.   | 1995                | Portland, USA | Cross-sectional   | January–December 1991    | 322 (NR)                     | NA        | 84% White in total of Portland | SESres    | OHCA incidence                                                                 | Age, sex                                                                      |
| Folke, F.   | 2010                | Central Copenhagen, Denmark | Cross-sectional      | January 1994–December 2005 | 4828 (61.8)                  | NA        | NR                | SESres    | OHCA incidence                                                                 | Age, household income, population density                                   |
| Fosbol, E.L. | 2014               | North Carolina, USA | Cross-sectional      | January 2010–December 2011 | 1466 (36.6)                  | NA        | 48% White, 39% Black, 13% Other | SESres    | OHCA incidence                                                                 | Age, sex, ethnicity, population density, location, EMS response time        |
| Hallstrom, A.| 1993               | King County, USA | Cross-sectional      | May 1986–August 1988     | 356 (21)                     | NA        | 90% White          | SESInd    | Survival at hospital discharge                                                  | Age, witnessed status, location, EMS response time, time to defibrillation, chronic comorbidity index |
| Name author          | Year of publication | City, country                  | Study design | Study time                        | Population size | Age range | Ethnic composition | SES level | Outcome measure | Adjusted for                                                                 |
|---------------------|---------------------|-------------------------------|--------------|-----------------------------------|-----------------|-----------|--------------------|-----------|-----------------|-----------------------------------------------------------------------------|
| Iwashyna, T.J.      | 1999                | Chicago, USA                  | Cross-sectional | January 1987–December 1988       | 4379 (42.9)     | NA        | 44.7% Black        | SESloc    | Bystander CPR    | Sex, ethnicity, 10 years older than mean, witnessed status; if neighbourhood had: twice as many arrests per capita, was not all not white, 1000 more people per km², 10% more linguistically isolated, 10% more working, 10% more in health related jobs, 10% more with college education, 10% more with age >65, compared to mean of neighbourhoods |
| Jonsson, M.         | 2018                | Stockholm County, Sweden      | Cross-sectional | January 2006–December 2015       | 7431 (34.6)     | NR        | NR                 | SESres    | 30-day survival   | Sex, age, population density, witnessed status, bystander CPR, initial ECG rhythm, location, EMS response time, year of cardiac arrest, aetiology |
| Lee, S.Y.           | 2016                | South Korea                   | Cross-sectional | January 2012–December 2013       | 10694 (32.5)    | >17 years | NR                 | SESloc    | Bystander CPR    | Age, sex, metropolitan area, location, dispatcher-provided CPR instruction, past medical history |
| Masterson, S.       | 2018                | Republic of Ireland           | Cross-sectional | January 2012–December 2014       | 4755 (32.6)     | >17 years | NR                 | SESres    | OHCA incidence    | Age, sex                                                                 |
| Mitchell, M.J.      | 2009                | King County, USA              | Cross-sectional | January 1999–December 2005       | 2618 (36.6)     | NA        | White, black, latino, asian | SESloc    | Bystander CPR    | Age, sex, population density, percentage of healthcare practitioners, households linguistically isolated, household size, proportion of population of several ethnic groups, witnessed, initial ECG rhythm, EMS response time |
| Moncur, L.          | 2015                | North East England, United Kingdom | Cross-sectional | January 2011–December 2011       | 3179 (40.5)     | NA        | NR                 | SESloc    | Bystander CPR    | Not adjusted                                                                |
| Pujades-Rodríguez, M.| 2014                | United Kingdom                | Time to event analysis | January 1997–March 2010         | 1301 (37)       | >30 years | White 90.5%, south-Asian 2.9% black 3.1% (in total population) | SESres    | OHCA incidence    | Sex, age, ethnicity, diabetes mellitus, smoking status, body mass index, systolic blood pressure, total and HDL cholesterol, medication use |
| Raun, L.H.          | 2013                | Houston, USA                  | Spatial analysis | January 2004–December 2011       | 11389 (NR)      | >17 years | White, African American, other | SESloc    | Bystander CPR    | Population size                                                            |
| Reinier, K.         | 2006                | Multnomah County, USA          | Cross-sectional | February 2002–January 2004       | 714 (39)        | NA        | American           | SESres    | OHCA incidence    | Not adjusted                                                                |
| Reinier, K.         | 2011                | Dallas, Pittsburgh, Portland and | Cross-sectional | April 2006–March 2007            | 9235 (39.9)     | NA        | American and Canadian | SESres    | OHCA incidence    | Country and study site                                                     |
| Name author | Year of publication | City, country | Study design | Study time | Population size (% female) | Age range | Ethnic composition | SES level | Outcome measure | Adjusted for |
|-------------|---------------------|---------------|--------------|------------|---------------------------|-----------|-------------------|-----------|-----------------|-------------|
| Rakun, A.   | 2018                | Washington, USA; Ottawa, Toronto, and Vancouver, Canada | Cross-sectional | April 2010–December 2015 | 8900 (36.2) | NA | 72.5% Chinese, 16.5% Malay, 11.0% Indian | SESloc | OHCA incidence, 30-day survival | Age, ethnicity, bystander CPR, location, EMS response time, comorbidities |
| Rivera, N.T. | 2016              | South Florida, USA | Cross-sectional | 25 month period | 125 (41.6) | NA | Classification: White - Black | SESloc | Bystander CPR and survival at hospital discharge | NR |
| Sasson, C.C. | 2011              | Fulton County, USA | Cross-sectional | October 2005–November 2008 | 1108 (42.1) | NA | White, black, Hispanic, other, or unknown | SESloc | Bystander CPR and survival at hospital discharge | Age (decades), sex, ethnicity, witnessed arrest, location |
| Sasson, C.C. | 2012              | 29 sites, USA | Cross-sectional | October 2005–December 2009 | 14225 (37.3) | NA | White, black, Hispanic, other, unknown | SESloc | Bystander CPR | Age, sex, witnessed status, location |
| Sayegh, A.J. | 1998              | Michigan, USA | Cross-sectional | January 1991–December 1996 | 1317 (40.8) | >17 years | Black and White | SESres | Survival at hospital discharge | Age greater than 80, sex, ethnicity, witnessed status, initial ECG rhythm, ALS response interval less than 9 min |
| Soo, L.       | 2001              | County of Nottinghamshire, United Kingdom | Cross-sectional | January 1991–December 1993 | 1634 (24.6) | NA | | SESres | OHCA incidence | |
| Straney, L.D. | 2016              | Victoria, Australia | Spatial analysis | January 2011–December 2013 | 10487 (NR) | NA | | SESres | OHCA incidence and bystander CPR | Population aged over 65, born overseas, population density, current smokers, high-risk alcohol consumption, obese |
| Uray, T.      | 2015              | Pittsburgh, USA | Cross-sectional | January 2010–July 2012 | 415 (NR) | >17 years<65 years | NR | SESInd & SESres | Unadjusted |
| Vaillancourt, C. | 2008              | Ontario, Canada | Cross-sectional | January 1995–December 1999 | 3600 (29.2) | NA | | SESInd | Survival at hospital discharge | Age, witnessed status, bystander CPR, EMS response time |
| Wells, D.V.   | 2016              | King County, USA | Cross-sectional | January 1999–December 2005 | 1390 (26.5) | >17 years | African-American, Asian-American, White, Other | SESInd | Survival at hospital discharge | Age, sex, ethnicity, marital status, witnessed status, bystander CPR, location, EMS response time |

Abbreviations: ALS, advance life support; CPR, cardiopulmonary resuscitation; EMS, emergency medical services; NA, not applicable; NR, not reported; OHCA, out of hospital cardiac arrest; ROSC, return of spontaneous circulation; SES, socioeconomic status; SESInd, socioeconomic status of the individual; SESloc, socioeconomic status of the area in which the OHCA occurred; SESres, socioeconomic status of the area of OHCA victims residence; USA, United States of America.

* Aside from the incidence results, this author used a combined outcome measure of low CPR and high OHCA areas compared to areas with the opposing characteristics. This meant that it was impossible for us to separate the SES differences in bCPR and the SES differences in OHCA incidence.
### Discussion

**Key findings**

In this systematic review, we investigated where the SES differences in mortality from OHCA are likely to stem from by comparing three major stages at which SES differences may arise (OHCA incidence, bystander CPR provision and survival rate after OHCA). We found a relatively consistent trend of a SES influence across the three stages: an increased risk of OHCA incidence, a decreased chance of receiving bystander CPR and a decreased chance of survival after an OHCA in low SES compared to high SES populations and locations. Although SES gradients were found for different indicators in all three stages, sufficient data to compare the strength of associations across stages or across indicators was lacking (Fig. 2). There was minimal evidence that was suggestive of sex and age differences in the SES gradients although it was similarly too sparse to draw conclusions.

**Limitations**

This systematic review has several limitations. It may have been the case that we missed relevant citations in our search. We included only full papers in the English language, disregarding data published in other languages. However, we noticed that only one article, in German, would have met the inclusion criteria, which suggests that disregarding of this criterion likely would not have changed the conclusions of our review. Additionally, we did not investigate the potential role of publication bias in minimizing the inclusion of negative results in the published literature.

While not related to the methodology applied, our review also suffers from the low number of studies that appeared to be eligible for this systematic review. In particular, a notable lack of studies measuring individual SES, measured at the individual level (SESind; Fig. 2). This constrains the potential inferences that could be made, as SES measured at the individual level usually highlights greater contrasts in health outcomes and comparisons could have been made between effect sizes of different SES indicators, such as education level and income level. This is a key limitation of the literature, as the comparison between SES indicators may have provided insight into which populations are the most vulnerable. It may also have provided an opportunity to compare findings across national contexts. We also found very few studies that reported results by age or sex groups (Fig. 2). Moreover, we found that several studies had a small sample size, which may have reduced the accuracy of the point estimates found in these papers. Finally, the heterogeneity of indicators, outcomes, populations and definitions as well as the

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**Fig. 2 – Overview of available studies by measured level of SES across stages of OHCA.**

Abbreviations: CPR, cardiopulmonary resuscitation; SESind, socioeconomic level of the individual; SESloc, socioeconomic level of the area in which the OHCA occurred; SESres, socioeconomic level of the area of OHCA victims residence.

A paper that reported results for different measures of SES (SES of the individual, SES of the area of OHCA victims residence or SES of the area in which the OHCA took place) or with different SES indicators is shown more than once.
## Table 3 – Incidence.

| Author, year | 1. Income | Result | P value | 2. Education | Result | P value | 3. Occupation | Result | P value |
|--------------|-----------|--------|---------|--------------|--------|---------|--------------|--------|---------|
| Castra L., 2018 | Median income for areas with high CA | 16575 | | Median for areas with high CA | 0.194 | | Median for areas with high CA | 0.081 | |
| | Median income for areas with normal CA | 25286 | | Median for areas with normal CA | 0.096 | | Median for areas with normal CA | 0.053 | |
| | Median income for areas with low CA | 22438 | | Median for areas with low CA | 0.102 | | Median for areas with low CA | 0.056 | |
| | Test for trend | Test for trend | | Test for trend | | | Test for trend | | <0.01 |
| Feero S., 1995 | R | -0.79 | <0.01 | | | | | 0.03 |
| Folke F., 2010 | IRR (95%CI); Qa1 | 1.48 (1.20–1.82) | NR | | | | | NR |
| | IRR (95%CI); Qa2 | 1.03 (0.84–1.27) | | | | | | |
| | IRR (95%CI); Qa3 | 0.98 (0.81–1.19) | | | | | | |
| | IRR (95%CI); Qa4 | Ref. | | | | | | |
| Raun L.H., 2014 | <$10,000 per year RR (95%CI) | 4.4 (2.2–6.7) | NR | | | | | 3.2 (1.7–4.8) | NR |
| Reiner K., 2006 | IRR (95%CI) | 1.3 (1.1–1.7) | | | | | | 1.8 (1.5–2.4) | NR |
| Reiner K., 2011 | IRR (95%CI) | 1.9 (1.8–2.0) | NR | | | | | |
| Straney L.D., 2016 | IRR (95%CI) | 0.91 (0.88–0.94) | <0.01 | | | | | |
| Author, year | 4. Combined measure | Result | P value | 5. Other measure | Result | P value |
|--------------|-----------|--------|---------|--------------|--------|---------|
| Castra L., 2018 | Poverty | | | | | |
| | Median for areas with low CA | 9.75 | | | | |
| | Median for areas with normal CA | 12.1 | | | | |
| | Median for areas with high CA | 25.1 | <0.01 | | | |
| Fosbol E.L., 2014 | Percent under poverty threshold | | | | | |
| Masterson S., 2018 | SAHRU Deprivation index | IRR (95%CI) | 0.09 (0.06–0.12) | NR | | |
| Pujades-Rodriquez M., 2014 | Index of multiple deprivation | HR (95%CI); Q1 | 1.34 (1.09, 1.66) | | | |
| | HR (95%CI); Q2 | 1.24 (1.02, 1.51) | | | | |
| | HR (95%CI); Q3 | 1.06 (0.87, 1.28) | | | | |
| | HR (95%CI); Q4 | 1.11 (0.92, 1.33) | | | | |
| | HR (95%CI); Q5 | Ref. | | | | |
| | Male | HR (95%CI); Q1 | 0.89 (0.75, 1.06) | | | |
| | HR (95%CI); Q2 | 0.90 (0.77, 1.05) | | | | |
| | HR (95%CI); Q3 | 0.87 (0.75, 1.01) | | | | |
### Table 3 (continued)

| Result | P.value |
|--------|---------|
| HR (95%CI; Q4) | 0.98 (0.77-1.25) |
| HR (95%CI; Q5) | 0.96 (0.72-1.28) |
| OR (95%CI; T1) | 1.09 (0.86-1.35) |
| OR (95%CI; T2) | 1.13 (0.96-1.31) |
| OR (95%CI; T3) | 1.10 (0.93-1.29) |
| Townsend index of material deprivation | 0.03 (0.40-0.90) |
| SEIFA | 0.95 (0.86-1.09) |

**References:**
- HR: hazard ratio; 95%CI: 95% confidence interval; T: tertile; OR: odds ratio; Qa: quartile; Qi: quintile; SAHRU, small area health research unit; SE: standard error; SEDI: Singapore socioeconomic disadvantage index; SEIFA: socio-economic indexes for areas; SES: socioeconomic status; SESind: socioeconomic status of the individual; SESloc: socioeconomic status of the area in which the OHCA occurred; SESres: socioeconomic status of the area of OHCA victims residence.

**Appendix:**
- **Abbreviations:** CA, cardiac arrest; CI, confidence interval; T, tertile; IRR, incidence rate ratio; SEIFA, socio-economic indexes for areas; SES, socioeconomic status; SESind, socioeconomic status of the individual; SESloc, socioeconomic status of the area in which the OHCA occurred; SESres, socioeconomic status of the area of OHCA victims residence; Ref, reference category; RR, risk ratio.

**Notes:**
- aRanking of quantiles or categories: low to high SES.
- bHousehold income unless otherwise defined.
- dProportion employed unless otherwise defined.

**Discussion of key findings**

Taken together, the evidence from our review suggests that SES influences may occur within each step in the process leading up to SES differences in OHCA mortality. Below we discuss how our findings fit in with previous knowledge on OHCA and SES differences in health and signal some important gaps for further research.

The observation across studies in this review that the incidence of OHCA varies by individual SES is in line with a multitude of previous studies that have shown SES differences in overall cardiovascular disease morbidity, mortality and risk factors. These results also are in line with prior studies that have shown a similar SES gradient in sudden cardiac death (eTable 3). It may be the case that the absolute incidence by SES differs across national contexts. However, we observed consistent patterns within the different contexts we observe consistent patterns of relative differences in OHCA incidence across different SES indicators that reflect the relative position of individuals within societal hierarchies. Individual SES differences in OHCA incidence may be mediated indirectly by SES differences in CHD. As 80% of the OHCAs occur in individuals that have CHD, it is likely that CHD lies on the causal pathway between SES and SCA. CHD and OHCA share several common risk factors. SES differences may occur due to behavioural factors (e.g. smoking, physical inactivity), biomedical factors (e.g. dyslipidaemia, high blood pressure), or psychosocial factors (e.g. depression), and are associated with SES and CVD/CHD. Additionally, a more direct pathway linking SES with OHCA incidence may also exist. Both acute and chronic stressors have been linked to SCA, via dysregulation of the autonomic nervous system. Natural disasters, such as earthquakes, a clear source of acute stress, are often followed by a spike in cardiac arrest incidence. Low SES may also be associated with chronic stress and both low SES and chronic stress have been associated with sympathetic nervous system overactivity, as assessed by heart rate variability. In turn, such chronic overactivity in the sympathetic nervous system has been associated with increased risk of cardiovascular disease and cardiovascular mortality and thus possibly also with OHCA.

Related to bystander CPR, the majority of studies (10 out of 12) found a consistent association with SESloc. The two papers that did not find a significant difference across SES areas, had a notably small study population or reported older data (1999 as compared to 2005 and 2018). The latter paper may have suffered from a lower general knowledge on CPR at the time of data collection; one to two decades ago, there was generally little CPR training offered to the public. Furthermore, the observation that lower bystander CPR provision was associated with low SESloc is consistent with findings of reduced bystander support in medical emergencies in general in deprived areas. This may be due to decreased community cohesion in low SES neighbourhoods, decreased security, or simply less knowledge about how to perform CPR and alert the EMS.

It may further be the case that a substantial part of the reported associations between SESloc and bystander CPR provision are actually due to individual SES differences. While the chances of bystanders in an area providing CPR may be the product of factors related to a low SES area, factors associated with the individual OHCA victim may also influence the chances of receiving CPR. Individual demographic variables, such as sex and age, have been suggested to...
### Table 4 – Bystander CPR.

| Author, year | 1. Income<sup>a</sup> | Result | P value | 2. Education<sup>b</sup> | Result | P value | 3. Occupation<sup>c</sup> | Result | P value |
|--------------|------------------------|--------|---------|--------------------------|--------|---------|--------------------------|--------|---------|
| **SESloc**   |                        |        |         |                          |        |         |                          |        |         |
| Andersen L.W., 2018 | OR (95%CI); Qa1 | 0.99 (0.78-1.26) | 0.92 | OR (95%CI); Qa1 | 0.74 (0.59-0.92) | <0.01 | OR (95%CI); Qa1 | 1.00 (0.83-1.21) | 0.99 |
|              | OR (95%CI); Qa2      | 0.99 (0.82-1.19) | 0.92 | OR (95%CI); Qa2      | 0.74 (0.62-0.88) | 0.01 | OR (95%CI); Qa2      | 0.90 (0.75-1.08) | 0.26 |
|              | OR (95%CI); Qa3      | 0.98 (0.85-1.14) | 0.79 | OR (95%CI); Qa3      | 0.85 (0.74-0.99) | 0.03 | OR (95%CI); Qa3      | 0.78 (0.68-0.88) | <0.01 |
|              | OR (95%CI); Qa4      | Ref.   |        | OR (95%CI); Qa4      | Ref.   |        | OR (95%CI); Qa4      | Ref.   |        |
| Brown T.P., 2019 | Proportion education qualifications (Yes) |        |         |                          |        |         |                          |        |         |
|              | In postcode districts with low CPR: Mean (SD) | 58.6 (9.3) | <0.01 | In postcode districts with low CPR: Mean (SD) | 32.2 (9.4) | <0.01 |
|              | In postcode districts with high CPR: Mean (SD) | 60.6 (8.9) |        | In postcode districts with high CPR: Mean (SD) | 29.8 (9.4) |        |
| Iwashyna, T.J., 1999 | Units = US$ 1000 | 1.03 (1.01-1.05) | NR |                          |        |         |                          |        |         |
| Lee S.Y., 2016 | OR (95%CI)          |        |         |                          |        |         |                          |        |         |
|              | OR (95%CI); Qa1      | 0.71 (0.60-0.85) | NR |                          |        |         |                          |        |         |
|              | OR (95%CI); Qa2      | 0.78 (0.66-0.92) | NR |                          |        |         |                          |        |         |
|              | OR (95%CI); Qa3      | 0.84 (0.74-0.95) | NR |                          |        |         |                          |        |         |
|              | OR (95%CI); Qa4      | Ref.   |        |                          |        |         |                          |        |         |
| Mitchell M.J., 2009 | OR (95%CI); Qa1      | Ref.   |        |                          |        |         |                          |        |         |
|              | OR (95%CI); Qa2      | 0.82 (0.60-1.11) | 0.19 | OR (95%CI); Qa2      | 0.96 (0.71-1.29) | 0.78 | OR (95%CI); Qa2      | 1.05 (0.78-1.42) | 0.74 |
|              | OR (95%CI); Qa3      | 1.32 (0.99-1.76) | 0.06 | OR (95%CI); Qa3      | 1.00 (0.74-1.34) | 1.00 | OR (95%CI); Qa3      | 1.24 (0.92-1.66) | 0.16 |
|              | OR (95%CI); Qa4      | 1.12 (0.83-1.50) | 0.46 | OR (95%CI); Qa4      | 1.10 (0.82-1.48) | 0.52 | OR (95%CI); Qa4      | 1.22 (0.91-1.65) | 0.19 |
| Sasson C.C., 2011 | C1: < $21600 | Ref. |        |                          |        |         |                          |        |         |
|              | OR (95%CI); C2: $21,601–$30,500 |        |         |                          |        |         |                          |        |         |
|              | OR (95%CI); Qa4      | 0.94 (0.49-1.81) | ≥0.05 |                          |        |         |                          |        |         |
| Author, year | 1. Income$^a$ | Result | P value | 2. Education$^b$ | Result | P value | 3. Occupation$^c$ | Result | P value |
|-------------|---------------|--------|---------|----------------|--------|---------|----------------|--------|---------|
| Raun L.H., 2014 | OR (95%CI); C3: $\leq 35,501$ | $30,501 - 42,000$ | 1.57 (0.72-3.40) | $\geq 0.05$ | | | | | |
| | OR (95%CI); C4: $\leq 42,001$ | $42,001 - 62,000$ | 2.02 (0.83-4.93) | $\geq 0.05$ | | | | | |
| Brown T.P., 2019 | Deprivation | In postcode districts with low CPR: Mean (SD) | 55.7 (8.6) | $<0.01$ | | | | | |
| | In postcode districts with high CPR Mean (SD) | 57.1 (8.8) | | | | | | | |
| Chiang W.C., 2014 | N (%) low mean house value | 241 (14.5%) | $<0.01$ | | | | | | |
| | N (%) high mean house value | 376 (19.6%) | | | | | | | |
| Fake A.L., 2013 | N (%); D1 | 24 (48.0) | | | | | | | |
| | N (%); D2 | 13 (38.2) | | | | | | | |
| | N (%); D3 | 18 (56.3) | | | | | | | |
| | N (%); D4 | 8 (40.0) | | | | | | | |
| | N (%); D5 | 7 (30.4) | | | | | | | |
| | N (%); D6 | 46 (43.2) | | | | | | | |
| | N (%); D7 | 17 (37.8) | | | | | | | |
| | N (%); D8 | 4 (22.2) | | | | | | | |
| | N (%); D9 | 14 (48.3) | | | | | | | |
| | N (%); D10 | 24 (64.9) | | | | | | | |
| | Test for trend | | | | | | | | 0.12 |
| Moncur L., 2015 | Indices of Multiple Deprivation | OR (95%CI); Q1 | Ref. | | | | | NR |
| | OR (95%CI); Q2 | 1.3 (0.9-1.7) | | | | | | |
| | OR (95%CI); Q3 | 1.5 (1.1-2.0) | | | | | | |
| | OR (95%CI); Q4 | 1.8 (1.3-2.4) | | | | | | |
| | OR (95%CI); Q5 | 1.8 (1.3-2.4) | | | | | | |
| Sasson C.C., 2012 | Median household income x ethnic composition | OR (95%CI); C1: $<40,000$ and $>80\%$ black | 0.49 (0.41-0.58) | 0.90 | | | | | |
| | OR (95%CI); C2: $<40,000$ and integrate | 0.62 (0.56-0.70) | $<0.01$ | | | | | | |
| | OR (95%CI); C3: $<40,000$ and $>80\%$ white | 0.65 (0.51-0.82) | $<0.01$ | | | | | | |
| | OR (95%CI); C4: $\geq 40,000$ and $>80\%$ black | 0.77 (0.68-0.86) | $<0.01$ | | | | | | |
| | OR (95%CI); CS: $<40,000$ and integrated | | | | | | | | |

(continued on next page)
| Author | Year | Table 4 (continued) | P value | Result | OR (95%CI) |
|--------|------|---------------------|---------|--------|------------|
| Straney L.D., 2016 | | SEIFA score | 0.90 | | 0.90 - 1.04 |
| Vaillaincourt C., 2008 | | Property value; unit $100,000 OR (95%CI) | 0.24 | | 1.07 (1.01 - 1.14) |

Abbreviations: C, category; CI, confidence interval; D, decile; IRR, incidence rate ratio; N, number; NA, not applicable; NR, not reported; OR, odds ratio; Q, quartile; Qi, quintile; SEIFA, socio-economic indexes for areas; US, United States; USD, United States dollar; SES, socioeconomic status; SESloc, socioeconomic status of the area in which the OHCA occurred; Ref, reference category.

aHousehold income unless otherwise defined.

cProportion employed unless otherwise defined.

dRanking of quantiles or categories: low to high SES.

Influence a bystander to provide CPR or not. However, no studies, as of yet, appear to have investigated the association between individual SES and bystander CPR provision (Fig. 2).

Survival after OHCA was found to be consistently associated with a higher SES when measured at the individual level (SESind). The independence from demographic and resuscitation characteristics indicate that differences are likely, at least in part, to be associated with physical resilience, which may be affected by the level of comorbidities. In line with this hypothesis, several studies have shown an increasing Charlson comorbidity index to be associated with a decreased chance of survival, though some studies reported no association.

All but one of the studies reporting SESres, observed no association with survival after OHCA. Two of these studies are likely to have suffered from low sample sizes of n = 413 and n = 415, while over adjusted statistical models may have hampered the detection of an association in two other studies. It may, on the other hand, be the case that individual SES measured at the area level (SESres) generates weaker associations with health outcomes due to the heterogeneity of individuals’ SES (SESind) within any given area.

Other than serving as a proxy for individual SES, SESres may also capture aspects of the environment in which the OHCA victim resides, which may have an influence on the risk of suffering an OHCA. Individuals living in low SES areas may be more frequently exposed to factors linked to the physical and social environment not captured by SES measured at the individual level. Such factors may include the availability of healthy or fast food outlets, parks and recreational spaces, air pollution levels and neighbourhood safety to name a few. These factors have been reported to be associated with CVD.

In contrast to the studies reporting SESres, we observed an association between OHCA survival and SESloc. Although the reasons are unknown, the differences found in survival rate by SES of the area in which the OHCA has occurred are likely to be, at least in part, due to differences in bystander resuscitation rates. However, the SES differences remained in two studies that adjusted for bystander CPR, suggesting that the disparity in survival rate appears not to be solely dependent on bystander CPR. We speculate that the remaining difference may partly be explained by differences in health-care related factors. Potential reasons for SES differences in these health-care related factors may be a number of system factors, including the distribution of ambulances in the city, neighbourhood structures that influence Emergency Medical Services response time (including road design and traffic patterns), and proximity of high socioeconomic status neighbourhoods to hospital. These factors were not assessed in the studies included in this review. Other factors, not included in this review include potential SES differences in in-hospital care. This choice was made given the focus on an out-of-hospital population. While, SES differences in survival to discharge may be mediated by both pre- as well as in-hospital factors, other reported (pre-hospital) indicators of survival showed consistent results. Thus, it is likely that SES differences reported in survival to discharge was not solely influenced by in-hospital factors.

Sex and age differences

The association between individual SES and OHCA incidence was stronger in women than in men. This finding is in line with previous findings on sex differences in social inequalities in cardiovascular disease. While in men, SES gradients in total mortality are steeper, women exhibit a greater SES disparity in cardiovascular disease mortality, morbidity and risk factors (e.g. smoking) than men. Two
| Author, year | 1. Income | Result | P value | 2. Education | Result | P value | 3. Occupation | Result | P value |
|--------------|-----------|--------|---------|--------------|--------|---------|--------------|--------|---------|
| **SESind**   |           |        |         |              |        |         |              |        |         |
| Uray T., 2015|           |        |         |              |        |         | Unemployment | 0.39 (0.18-0.84) | 0.02    |
| Wells D.V., 2016 | Female |        |         |              |        |         | C1: Routine and manual | 0.87 (0.43-1.77) |         |
|              |          |        |         |              |        |         | C2: Intermediate | 1.0 (0.48-2.09) |         |
|              |          |        |         |              |        |         | C3: Higher managerial and professional | 0.44 (0.21-0.92) |         |
|              |          |        |         |              |        |         | Test for trend | 1.02 (0.70-1.47) |         |
| Male         |          |        |         |              |        |         | C1: Routine and manual | Ref. |         |
|              |          |        |         |              |        |         | C2: Intermediate | 1.02 (0.68-1.54) |         |
|              |          |        |         |              |        |         | C3: Higher managerial and professional | 1.35 (1.0-1.83) |         |
| **SESres**   |           |        |         |              |        |         |              |        |         |
| Jonsson, M. 2018 | Qi1 | Ref. |        | Qa1 University degree | Ref. |        |              |        |         |
|              | Qi2      |        | 1.34 (0.96-1.87) | Qa2 University degree | 1.27 (0.92-1.75) |         |
|              | Qi3      |        | 1.56 (1.14-2.14) | Qa3 University degree | 1.65 (1.21-2.24) |         |
|              | Qi4      |        | 1.49 (1.08-2.05) | Qa4 University degree | 1.76 (1.30-2.40) |         |
|              | Qi5      |        | 1.88 (1.36-2.59) |              |        |         |              |        |         |
| Sayegh A.J., 1998 | >$33,945-$33,945 | OR (95% CI) | 1.51 (0.8-2.6) | NR |        |              |        |         |
| **SESloc**   |           |        |         |              |        |         |              |        |         |
| Rivera N.T., 2016 | $<30000-$>50,000 | OR (95% CI) | 2.72 (0.72-10.27) | Ref. |        |              |        |         |
| Sasson C.C., 2011 | <$21600 | OR (95% CI) | 2.49 (0.49-12.69) |              |        |              |        |         |

(continued on next page)
| Author, year | 1. Income<sup>a</sup> | Result | P value | 2. Education<sup>b</sup> | Result | P value | 3. Occupation<sup>c</sup> | Result | P value |
|--------------|------------------|--------|---------|------------------|--------|---------|------------------|--------|---------|
| Vaillancourt C., 2008 | OR (95%CI) 2.30 (0.48–10.99) | C5: >$62001 | 9.11 (1.17–71.00) | <0.05 |
| Clarke S.O., 2005 | Property value per unit $100000 | OR (95%CI) 0.77 (0.61–0.97) | 0.03 |
| OR (95%CI) | Ref. |
| C2: $166,000–$212999 | 1.03 (0.60, 1.47) |
| C3: $213,000–$282999 | 1.42 (0.97, 1.87) |
| C4: >$283000 | Test for trend 1.81 (1.21, 2.42) |
| Hallstrom A., 1993 | Property value | OR (95%CI) 1.6 (1.1–2.4) | NR |
| C1: ≤50,000% | %survival | 28.3 |
| %survival | 25.8 |
| C3: 75000–100000 | % survival | 30.6 |
| C4: >100000 | % survival | 38.2 |
| Test for trend |

SESind

Buick J.E., 2016 | Deprivation | OR (95%CI); Q1 | Ref. |
| OR (95%CI); Q2 | 1.53 (1.00–2.33) |
| OR (95%CI); Q3 | 1.10 (0.68–1.77) |
| OR (95%CI); Q4 | 0.98 (0.61–1.59) |
| OR (95%CI); Q5 | 1.03 (0.58–1.84) |
| Clarke S.O., 2005 | Value per unit $0–$45699 | OR (95%CI); Qa1 | Ref. |
| OR (95%CI); Qa2 | 1.13 (0.77, 1.50) |
| Author, year | 4. Combined measure | Result | P value | 5. Other measure | Result | P value |
|-------------|---------------------|--------|---------|------------------|--------|---------|
| Fake A.L., 2016 | New Zealand deprivation index 2006 | N (%) | D1 4 (8.0) | 1.16 (0.77, 1.54) | OR (95%CI); Qa3 >$68500 | 1.03 (0.67, 1.39) |
| Uray T., 2015 | Poverty >16% | OR (95%CI) | 1.01 (0.48–2.10) | 0.98 |
| Rakun, 2018 | SEDI | OR (95%CI) | 1.011 (0.978–1.045) |
| Ahn K.O., 2011 | Carstairs index of deprivation | OR (95%CI); Qi1 0.57 (0.45–0.72) | 0.57 (0.45–0.72) | 0.61 (0.49–0.77) | 0.74 (0.61–0.91) | 0.88 (0.72–1.07) | Ref. |
| Chiang W.C., 2014 | N (%) low mean house value | 69 (4.3) | N (%) high mean house value | 128 (6.8) |

Abbreviations: C, category; CI, confidence interval; D, decile; N, number; NA, not applicable; NR, not reported; OR, odds ratio; Qi, quintile; Qi, quintile; SES, socioeconomic status; SESind, socioeconomic status of the individual; SESloc, socioeconomic status of the area in which the OHCA occurred; SESres, socioeconomic status of the area of OHCA victims residence; Ref, reference category.

Household income unless otherwise defined.
Proportion with high school degree unless otherwise defined.
Proportion employed (level of employment) unless otherwise defined.
Ranking of quantiles or categories: low to high SES.
Secondary analyses are provided in eTable 5.
studies that showed SES differences in sudden cardiac death stratified the results by sex and found contradicting results. One found a significant modifying effect by sex with a stronger gradient in men while the other did not find a significant interaction with sex although the SES gradients appeared stronger in women than in men.

Age differences in the association between individual SES and OHCA incidence were found in two studies.\textsuperscript{41,42} Both were limited in only stratifying OHCA cases aged below and above 65 years of age. The higher age group was found to have narrower SES differences in OHCA incidence than the lower age group,\textsuperscript{41,42} implying that while absolute differences in incidence may still be larger in high SES versus low SES groups, the relative SES differences are attenuated at a higher age. This finding is in accordance with findings of several studies that have found converging SES differences in health above the age of around 60. This is attributed to a ceiling effect at higher ages due to the morbidity in high SES groups catching up at later ages to their low SES counterparts at lower ages.\textsuperscript{77}

**Conclusion**

We found a consistent trend of an increased risk of OHCA incidence and a decreased chance of receiving bystander CPR and surviving an OHCA in low SES compared to high SES populations and locations. This suggests that SES disparities in OHCA mortality likely manifest at each of these stages relevant to OHCA. Despite the clear SES differences, this review has highlighted several gaps in the literature. One such gap is caused by the lack of detailed information in which specific populations SES disparities in OHCA occur, e.g. differences between men and women and by age groups, and a distinct lack of data on SES measured at the individual level. Furthermore, research into the factors mediating SES disparities in OHCA incidence, bystander CPR and survival rate after OHCA is warranted. This could inform targets such as risk factor prevention in socioeconomically deprived individuals and targeted AED placement in socioeconomically deprived areas.

**Conflicts of interest**

None.

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**Appendix A. Supplementary data**

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.resuscitation.2019.05.018.

**References**

1. Myat A, Song KJ, Rea T. Out-of-hospital cardiac arrest: current concepts. Lancet 2018;391:970-9.
2. Gillum RF. Geographic variation in sudden coronary death. Am Heart J 1990;119:380-9.
3. Myerburg RJ, Interian Jr. A, Mitran R, Kessler KM, Castellanos A. Frequency of sudden cardiac death and profiles of risk. Am J Cardiol 1997;80:109-19.
4. Berdowski J, Berg RA, Tijsen JG, Koster RW. Global incidences of out-of-hospital cardiac arrest and survival rates: systematic review of 67 prospective studies. Resuscitation 2010;81:1479-87.
5. Zijlstra JA, Stiegels R, Riedijk F, Smeeekes M, van der Worp WE, Koster RW. Local lay rescuers with AEDs, alerted by text messages, contribute to early defibrillation in a Dutch out-of-hospital cardiac arrest dispatch system. Resuscitation 2014;85:1444-9.
6. Foraker RE, Rose KM, Kucharska-Newton AM, Ni H, Suchindran CM, Whitsel EA. Variation in rates of fatal coronary heart disease by neighborhood socioeconomic status: the atherosclerosis risk in communities surveillance (1992-2002). Ann Epidemiol 2011;21:580-8.
7. Kucharska-Newton AM, Harald K, Rosamond WD, Rose KM, Rea TD, Salomaa V. Socioeconomic indicators and the risk of acute coronary heart disease events: comparison of population-based data from the United States and Finland. Ann Epidemiol 2011;21:572-9.
8. Mounsey LA, Lin FC, Pursell I, et al. Relation of household income to incidence of sudden unexpected death in Wake County, North Carolina. Am J Cardiol 2017;119:1039-50.
9. Greenland P, Knoll MD, Stamler J, et al. Major risk factors as antecedents of fatal and nonfatal coronary heart disease events. JAMA 2003;290:891–7.
10. Kanjiil A, Gregg EW, Cheng YJ, et al. Socioeconomic status and trends in disparities in 4 major risk factors for cardiovascular disease among US adults, 1971-2002. Arch Intern Med 2006;166:2348-55.
11. Matthews KA, Gallo LC, Taylor SE. Are psychosocial factors mediators of socioeconomic status and health connections? A progress report and blueprint for the future. Ann N Y Acad Sci 2010;1186:146-73.
12. Ram RV, Trivedi AV. Behavioral risk factors of coronary artery disease: a paired matched case control study. J Cardiovasc Dis Res 2012;3:213-7.
13. Rozanski A, Blumenthal JA, Kaplan J. Impact of psychological factors on the pathogenesis of cardiovascular disease and implications for therapy. Circulation 1999;99:2192-217.
14. Stringhini S, Carmeli C, Jokela M, et al. Socioeconomic status and the 25 × 25 risk factors as determinants of premature mortality: a multicohort study and meta-analysis of 1.7 million men and women. Lancet 2017;389:1229-37.
15. Willett WC. Dietary fats and coronary heart disease. J Intern Med 2012;272:13-24.
16. Hallstrom A, Boutin P, Cobb L, Johnson E. Socioeconomic status and prediction of ventricular fibrillation survival. Am J Public Health 1993;83:245-8.
17. Winkleby MA, Jatulis DE, Frank E, Fortmann SP. Socioeconomic status and health: how education, income, and occupation contribute to risk factors for cardiovascular disease. Am J Public Health 1992;82:816-20.
18. Galobardes B, Shaw M, Lawlor DA, Lynch JW, Davey Smith G. Indicators of socioeconomic position (part 1). J Epidemiol Community Health 2006;60:7-12.
19. Backholler K, Peters SAE, Bots SH, Peeters A, Huxley RR, Woodward M. Sex differences in the relationship between socioeconomic status and cardiovascular disease: a systematic review and meta-analysis. J Epidemiol Community Health 2017;71:550-7.
20. Mackenbach JP, Cavelaars AE, Kunst AE, Groenhof F. Socioeconomic inequalities in cardiovascular disease mortality: an international study. Eur Heart J 2000;21:1141-51.
21. Ahn KO, Shin SD, Hwang SS, et al. Association between deprivation status at community level and outcomes from out-of-hospital cardiac arrest: a nationwide observational study. Resuscitation 2011;82:270-6.
22. Andersen LW, Holmberg MJ, Granfeldt A, et al. Neighborhood characteristics, bystander automated external defibrillator use, and patient outcomes in public out-of-hospital cardiac arrest. Resuscitation 2018;126:72-9.
23. Brown TP, Booth S, Hawkes CA, et al. Characteristics of neighbourhoods with high incidence of out-of-hospital cardiac arrest and low bystander cardiopulmonary resuscitation rates in England. Eur Heart J Qual Care Clin Outcomes 2019;5:51-62.

24. Buick JE, Ray JG, Kiss A, Morrison LJ. The association between neighborhood effects and out-of-hospital cardiac arrest outcomes. Resuscitation 2016;103:14-9.

25. Castra L, Genin M, Escutenaire J, et al. Socioeconomic status and incidence of cardiac arrest: a spatial approach to social and territorial disparities. Eur J Emerg Med 2018;04:04.

26. Chiang TC, Wang CY. Dead-on-arrival patients in Panchiao, Taipei. Chin Med J (Taipei) 1999;62:509-13.

27. Clarke SO, Schellenbaum GD, Rea TD. Socioeconomic status and survival from out-of-hospital cardiac arrest. Acad Emerg Med 2005;12:941-7.

28. Fake AL, Swain AH, Larsen PD. Survival from out-of-hospital cardiac arrest in Wellington in relation to socioeconomic status and arrest location. N Z Med J 2013;137E:126.

29. Feero S, Hedges JR, Stevens P. Demographics of cardiac arrest: association with residence in a low-income area. Acad Emerg Med 1995;2:11-6.

30. Folke F, Gislason GH, Lippert FK, et al. Differences between out-of-hospital cardiac arrest in residential and public locations and implications for public-access defibrillation. Circulation 2010;122:623-30.

31. Fosbol EL, Dupre ME, Strauss B, et al. Association of neighborhood characteristics with incidence of out-of-hospital cardiac arrest and rates of bystander-initiated CPR: implications for community-based education intervention. Resuscitation 2014;85:1512-7.

32. Iwasthya TJ, Christakis NA, Becker LB. Neighborhoods matter: a population-based study of provision of cardiopulmonary resuscitation. Ann Emerg Med 1999;34:459-68.

33. Jonsson M, Harkonen J, Ljungman P, et al. Survival after out-of-hospital cardiac arrest is associated with area-level socioeconomic status. Heart 2018;105(8):633-8.

34. Lee SY, Ro YS, Shin SD, et al. Interaction effects between highly-educated neighborhoods and dispatcher-provided instructions on provision of bystander cardiopulmonary resuscitation. Resuscitation 2016;99:84-91.

35. Masterson S, Wright P, O’Donnell C, et al. Urban and rural differences in out-of-hospital cardiac arrest in Ireland. Resuscitation 2015;91:42-7.

36. Mitchell MJ, Stubbs BA, Eisenberg MS. Socioeconomic status is associated with provision of bystander cardiopulmonary resuscitation. Prehosp Emerg Care 2009;13:478-86.

37. Moncur L, Ainsborough N, Ghose R, Kendal SP, Salvatorti M, Wright J. Does the level of socioeconomic deprivation at the location of cardiac arrest in an English region influence the likelihood of receiving bystander-initiated cardiopulmonary resuscitation? Emerg Med J 2016;33:105-8.

38. Pujades-Rodriguez M, Timmis A, Stogiannis D, et al. Socioeconomic deprivation and the incidence of 12 cardiovascular diseases in 1.9 million women and men: implications for risk prediction and prevention. PLoS One 2014;9:e104671.

39. Rakun A, Allen J, Shahdah N, et al. Ethnic and neighborhood socioeconomic differences in incidence and survival from out of hospital cardiac arrest in Singapore. Prehosp Emerg Care 2018;1-12.

40. Raun LH, Jefferson LS, Persse D, Ensor KB. Geospatial analysis for targeting out-of-hospital cardiac arrest intervention. Am J Prev Med 2013;45:137-42.

41. Reinier K, Stecker EC, Vickers C, Gunson K, Jui J, Chugh SS. Incidence of sudden cardiac arrest is higher in areas of low socioeconomic status: a prospective two year study in a large United States community. Resuscitation 2006;7:186-92.

42. Reinier K, Thomas E, Andrusiek DL, et al. Socioeconomic status and incidence of sudden cardiac arrest. CMAJ 2011;183:1705-12.

43. Rivera NT, Kumar SL, Bhandari RK, Kumar SD. Disparities in survival with bystander CPR following cardiopulmonary arrest based on neighborhood characteristics. Emerg Med Int Print 2016;2016:6983750.

44. Sasson C, Magid DJ, Chan P, et al. Association of neighborhood characteristics with bystander-initiated CPR. N Engl J Med 2012;367:1607-15.

45. Root ED, Gonzales L, Perse D, Hinchee PR, McNally B, Sasson C. A tale of two cities: the role of neighborhood socioeconomic status in spatial clustering of bystander CPR in Austin and Houston. Resuscitation 2013;84(6):759-9.

46. Sayegh AJ, Swor R, Chu KH, et al. Does race or socioeconomic status predict adverse outcome after out of hospital cardiac arrest: a multi-center study. Resuscitation 1999;40:141-6.

47. Soo L, Huff N, Gray D, Hampton JR. Geographical distribution of cardiac arrest in Nottinghamshire. Resuscitation 2001;48:137-47.

48. Straney LD, Bray JE, Beck B, Bernard S, Lijovic M, Smith K. Are sociodemographic characteristics associated with spatial variation in the incidence of OHCA and bystander CPR rates? A population-based observational study in Victoria, Australia. BMJ Open 2016;6: e012434.

49. Uray T, Mayr FB, Fitzgibbon J, et al. Socioeconomic factors associated with outcome after cardiac arrest in patients under the age of 65. Resuscitation 2015;93:14-9.

50. Vallancourt C, Chartrette ML, Stiell IG, Wells GA. An evaluation of 9-1-1 calls to assess the effectiveness of dispatch-assisted cardiopulmonary resuscitation (CPR) instructions: design and methodology. BMC Emerg Med 2008;8:12.

51. Wells DM, White LL, Fahrenbruch CE, Rea TD. Socioeconomic status and survival from ventricular fibrillation out-of-hospital cardiac arrest. Ann Epidemiol 2016;26: 418-423.e1.

52. Fake AL, Swain AH, Larsen PD. Survival from out-of-hospital cardiac arrest in Wellington in relation to socioeconomic status and arrest location. N Z Med J 2013;126:28-37.

53. Chiang WC, Ko PC, Chang AM, Chen WT, Liu SS, Huang YS, et al. Bystander-initiated CPR in an Asian metropolitan: does the socioeconomic status matter? Resuscitation 2014;85(1):53-8.

54. Janssen I, Boyle WF, Simpson K, Pickett W. Influence of individual- and area-level measures of socioeconomic status on obesity, unhealthy eating, and physical inactivity in Canadian adolescents. Am J Clin Nutr 2006;83:139-45.

55. Pardo-Crespo MR, Narla NP, Williams AR, et al. Comparison of individual-level versus area-level socioeconomic measures in assessing health outcomes of children in Olmsted County, Minnesota. J Epidemiol Community Health 2013;67:305-10.

56. Steenland K, Henley J, Calle E, Thun M. Individual- and area-level socioeconomic status variables as predictors of mortality in a cohort of 179,383 persons. Am J Epidemiol 2004;159:1047-56.

57. de Mestral C, Stringhini S. Socioeconomic status and cardiovascular disease: an update. Curr Cardiol Rep 2017;19:115.

58. Steptoe A, Marmot M. The role of psychological pathways in socioeconomic inequalities in cardiovascular disease risk. Eur Heart J 2002;23:13-25.

59. Hayman KG, Sharma D, Wardlow RD, Singh S. Burden of cardiovascular morbidity and mortality following humanitarian emergencies: a systematic literature review. Prehosp Disaster Med 2015;30:80-8.

60. Brotman DJ, Golden SH, Wittstein IS. The cardiovascular toll of stress. Lancet 2007;370:1089-100.

61. Cohen MC, Rohtla KM, Lavery CE, Muller JE, Mittleman MA. Meta-analysis of the morning excess of acute myocardial infarction and sudden cardiac death. Am J Cardiol 1997;79:1512-6.

62. Hemingway H, Shipley M, Brunner E, Britton A, Malik M, Marmot M. Does autonomic function link social position to coronary risk? The Whitehall II study. Circulation 2005;111:307-17.

63. Lamport R, Iokovic J, Horwitz R, Lee F. Depressed autonomic nervous system function in African Americans and individuals of lower social class: a potential mechanism of race- and class-related disparities in health outcomes. Am Heart J 2005;150:153-60.

64. Sloan RP, Huang MH, Sidney S, Liu K, Williams OD, Seeman T. Socioeconomic status and health: is parasympathetic nervous system activity an intervening mechanism? Int J Epidemiol 2005;34:309-15.
65. Sessa F, Anna V, Messina G, et al. Heart rate variability as predictive factor for sudden cardiac death. Aging (Albany NY) 2018;10:166–77.
66. Cheng A, Brown LL, Duff JP, et al. International network for simulation-based pediatric innovation R and education CPRI. Improving cardiopulmonary resuscitation with a CPR feedback device and refresher simulations (CPR CARES Study): a randomized clinical trial. JAMA Pediatr 2015;169:137–44.
67. Cornwell EY, Currit A. Racial and social disparities in bystander support during medical emergencies on US streets. Am J Public Health 2016;106:1049–51.
68. Hsia RY, Huang D, Mann NC, et al. A US national study of the association between income and ambulance response time in cardiac arrest. JAMA Netw Open 2018;1:e185202.
69. Ross CE. Collective threat, trust, and the sense of personal control. J Health Soc Behav 2011;52:287–96.
70. Evans GW, Kantrowitz E. Socioeconomic status and health: the potential role of environmental risk exposure. Annu Rev Public Health 2002;23:303–31.
71. Ahn KO, Shin SD, Hwang SS. Sex disparity in resuscitation efforts and outcomes in out-of-hospital cardiac arrest. Am J Emerg Med 2012;30:1810–6.
72. Andrew E, Nehme Z, Bernard S, Smith K. The influence of comorbidity on survival and long-term outcomes after out-of-hospital cardiac arrest. Resuscitation 2017;110:42–7.
73. Hirlekar G, Jonsson M, Karlsson T, Hollenberg J, Albertsson P, Herlitz J. Comorbidity and survival in out-of-hospital cardiac arrest. Resuscitation 2018;133:118–23.
74. Stecker EC, Teodorescu C, Reinier K, et al. Ischemic heart disease diagnosed before sudden cardiac arrest is independently associated with improved survival. J Am Heart Assoc 2014;3:e001160.
75. Diez Roux AV, Mair C. Neighborhoods and health. Ann N Y Acad Sci 2010;1186:125–45.
76. Govindarajan A, Schull M. Effect of socioeconomic status on out-of-hospital transport delays of patients with chest pain. Ann Emerg Med 2003;41:481–90.
77. Herd P. Do functional health inequalities decrease in old age?: Educational status and functional decline among the 1931-1941. Birth Cohort 2006;28:375–92.