

EVIDENCE BASED PUBLIC HEALTH POLICY AND PRACTICE

Do places affect the probability of death in Australia? A multilevel study of area-level disadvantage, individual-level socioeconomic position and all-cause mortality, 1998–2000

Gavin Turrell, Anne Kavanagh, Glenn Draper, S V Subramanian

J Epidemiol Community Health 2007;61:13–19. doi: 10.1136/jech.2006.046094

Background: In Australia, studies finding an association between area-level socioeconomic disadvantage and mortality are often based on aggregate-ecological designs which confound area-level and individual-level sources of socioeconomic variation. Area-level socioeconomic differences in mortality therefore may be an artefact of varying population compositions and not the characteristics of areas as such.

Objective: To examine the associations between area-level disadvantage and all-cause mortality before and after adjustment for within-area variation in individual-level socioeconomic position (SEP) using unlinked census and mortality-register data in a multilevel context.

Setting, participants and design: The study covers the total Australian continent for the period 1998–2000 and is based on decedents aged 25–64 years (n=43 257). The socioeconomic characteristics of statistical local areas (SLA, n=1317) were measured using an index of relative socioeconomic disadvantage, and individual-level SEP was measured by occupation.

Results: Living in a disadvantaged SLA was associated with higher all-cause mortality after adjustment for within-SLA variation in occupation. Death rates were highest for blue-collar workers and lowest among white-collar employees. Cross-level interactions showed no convincing evidence that SLA disadvantage modified the extent of inequality in mortality between the occupation groups.

Conclusions: Multilevel analysis can be used to examine area variation in mortality using unlinked census and mortality data, therefore making it less necessary to use aggregate-ecological designs. In Australia, area-level and individual-level socioeconomic factors make an independent contribution to the probability of premature mortality. Policies and interventions to improve population health and reduce mortality inequalities should focus on places as well as people.

See end of article for authors' affiliations

Correspondence to:
Dr G Turrell, School of Public Health, Queensland University of Technology, Victoria Park Road, Kelvin Grove, Brisbane, Queensland 4059, Australia;
g.turrell@qut.edu.au

Accepted 11 May 2006

Although it has long been known that individual-level socioeconomic position (SEP) is associated with mortality, in the past decade or so, researchers have turned their attention to the question of whether the socioeconomic characteristics of places are also important.^{1–3} Multilevel analysis is increasingly being used to investigate this issue,^{4–6} and the findings of most studies suggest that area-level socioeconomic disadvantage increases mortality risk over and above an individual's own SEP.^{7–10}

We identified 16 Australian studies that had investigated the association between an area's socioeconomic characteristics and its mortality and/or morbidity profile, and all found mortality and poorer health in disadvantaged areas.^{11–26} Each of these studies used an aggregate ecological design, the conceptual and statistical problems of which are well documented.^{27–28} Ecological studies that use data aggregated to a single geographical scale cannot provide a quantification of the variation between areas in terms of their mortality profiles, and then, more importantly, indicate whether the variation is probably due to the clustering of individuals (ie, a composition effect) or the environmental characteristics of the areas as such (ie, a context effect). Thus, even though previous Australian studies found higher mortality in disadvantaged areas, this does not mean that areas as such are important in terms of influencing the probability of death of the area's residents. Ecological studies leave open the possibility that geographical variations in mortality are an artefact of varying population compositions, and unless these are taken into account (which aggregate studies cannot do), individual-level and area-level sources of variation remain confounded.²⁹ It is therefore an

open question as to whether places are important (independent) determinants of mortality in Australia.

International studies investigating the multilevel relationship between area disadvantage and mortality are usually based on designs that involve linking census data^{9–34} or survey data^{7–10 35–36} to death records contained in mortality registers. In Australia, legislation related to privacy and confidentiality effectively prohibits the first type of study, and there are no known area-based population surveys that would facilitate the second approach. These two factors may explain why area-based studies of inequality in mortality in Australia have been restricted to ecological designs.

Of the 12 multilevel studies of mortality reviewed for this paper, 10 were based on designs that took account of variation in mortality at only two levels (ie, individuals and one spatial unit), and their geographical coverage was often limited to one region or city in a country. Given our limited understanding of how and at what geographical scale area-level factors influence mortality, many of these studies possibly overestimated the mortality variation at level 2 because variation between spatial units at higher or lower levels of aggregation were unaccounted for. Multilevel studies that are more inclusive of multiple geographical scales are clearly needed to investigate this issue.²⁹

Abbreviations: ABS, Australian Bureau of Statistics; ASCO, Australian Standard Classification for Occupations; ASGC, Australian Standard Geographical Classification; IRSD, index of relative socioeconomic disadvantage; SEP, socioeconomic position; SLA, statistical local area; SSD, statistical subdivision

We describe the first known multilevel investigation of the relative contribution of area-level and individual-level socioeconomic factors to all-cause mortality in Australia using a method that does not require record linkage, or use an ecological approach. Moreover, our study is based on a five-level design, thus allowing us to capture mortality variation at many different geographical scales, and it covers the whole of the Australian continent. The dataset pertains to men and women aged 25–64 years for the period 1998–2000, and uses the four primary spatial units comprising the Australian Standard Geographical Classification (ASGC)—states/territories, statistical divisions, statistical subdivisions (SSD) and statistical local areas (SLA).³⁷ Using SLA as the primary focus (but taking into account mortality variation at each of the other levels) we deal with three questions using a sex-stratified analysis:

- (a) What is the relationship between area-level socioeconomic disadvantage and mortality before and after adjustment for within-SLA variation in individual-level SEP (ie, occupation)?
- (b) Does the relationship between occupation and mortality differ by area-level socioeconomic disadvantage?
- (c) What is the variation in all-cause mortality at each of the four geographical levels comprising the ASGC before and after adjustment for within-SLA variation in occupation and between-SLA variation in area disadvantage?

SLA are often based on the incorporated bodies of local governments and councils, and these are responsible for service and infrastructure provision at the local and regional level; hence, SLA are spatial entities that are likely to be socially and economically relevant to their residents. On the basis of the findings of international studies,^{7–10} we hypothesise that living in socioeconomically disadvantaged SLA will be associated with a higher probability of mortality independent of its occupational composition. If confirmed, this relationship will suggest that SLA in Australia are differentiated on the basis of area-level factors important for health, and that disadvantaged SLA

are less conducive to the attainment and maintenance of good health. By extension, confirmation of the hypothesis will also suggest that policies and programmes to improve population health and reduce mortality inequalities should focus on places as well as people.

METHODS

Analytical approach and units of analysis

We compiled a 5-level structure comprising cells at level 1 which were nested in SLA at level 2, nested in SSD at level 3, nested in statistical divisions at level 4 and nested in states/territories at level 5. Figure 1 presents a diagrammatic representation of the data structure.

Cells consist of individuals grouped as types (eg, male professionals aged 60–64 years) and each cell contains the number of deaths for all causes that occurred during 1998–2000 (numerator) and the estimated population counts in 1996 corresponding to the sex/occupation/age profile of each particular cell (denominator). Mortality in each cell is expressed as a proportion—that is, the number of deaths in each sex/occupation/age group relative to the population in each subgroup: this proportion forms the outcome variable. The other four levels comprise spatial units from the ASGC to which mortality data are coded. SLA aggregate to form SSD, which in turn aggregate to statistical divisions and these form states and territories. Each of these spatial units covers the whole of Australia without gaps or overlaps.

In 1996, the ASGC comprised 1336 SLA, 194 SSD, 66 subdivisions and 9 states and territories. Of the 1336 SLA, we excluded 7 special areas defined as “Offshore, Shipping and Migratory” (eg, people who were living on offshore oil rigs, drilling platforms, on ships between Australian ports, or in transit on trains, buses or aircraft) and 12 SLA with small populations and thus not assigned an area-level socioeconomic score by the Australian Bureau of Statistics (ABS). The final data structure used in this analysis consisted of 9 states and territories (100%), 59 statistical divisions (89.4%), 187 SSD (96.4%) and 1317 SLA (98.6%).

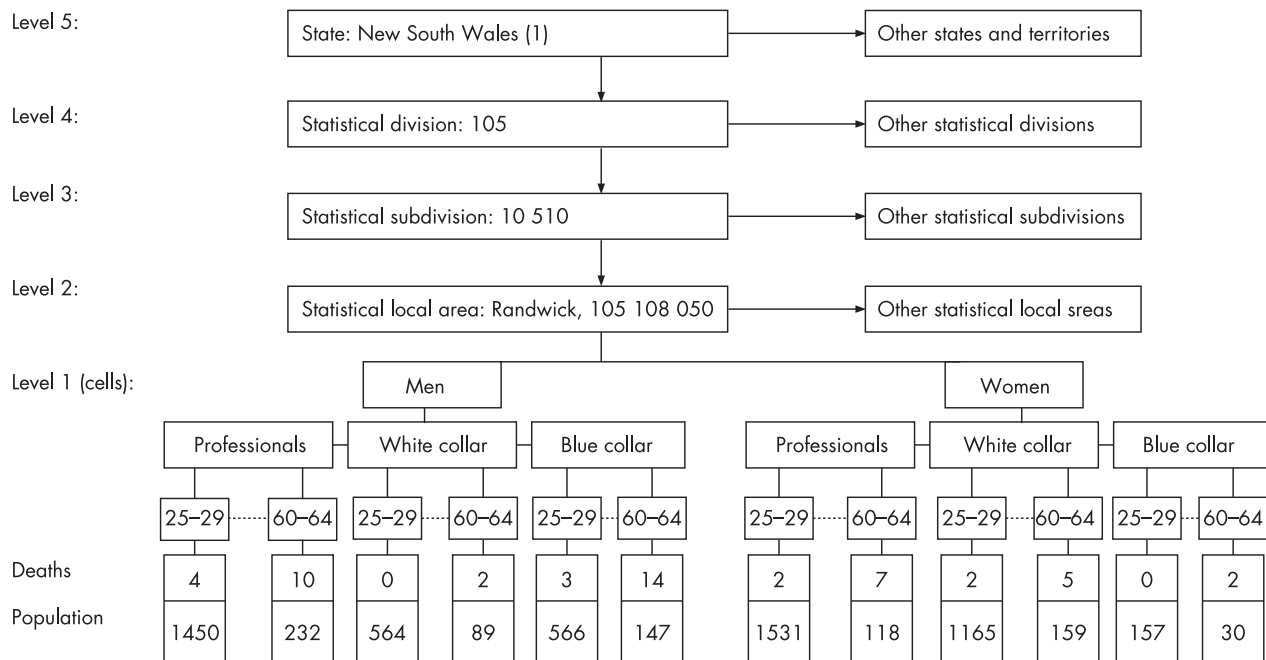


Figure 1 Diagrammatic representation of the multilevel data structure.

Data

Unit record mortality data were obtained from the ABS, the national statutory authority that compiles death statistics from information made available by the registrars of births, deaths and marriages in each state and territory. Population data pertaining to age, sex and occupation were also obtained from the ABS, and comprised the 1996 census for men and women aged 25–64 years in 5-year age groups.

During the period 1998–2000, there were 47 067 deaths from all causes among men and 26 053 deaths among women. Decedents who did not have an occupation at the time of death, or whose occupation was unknown or could not be ascertained due to insufficient information, and those who could not be assigned a place of usual residence before death, were excluded from the analysis. The final dataset consisted of 43 257 death records and 5 995 661 population counts (table 1).

Measurement of area-level disadvantage

Area-level disadvantage for each SLA was measured using its index of relative socioeconomic disadvantage (IRSD) score. IRSD scores are derived by the ABS and they reflect the overall level of disadvantage of an area measured on attributes such as low income, low educational attainment, high levels of public-sector housing and high unemployment.³⁸ The IRSD scores were calculated using data from the 1996 Australian Census. For analysis, we ranked the 1317 SLA on the basis of their IRSD scores and categorised them into quintiles such that Q1 contained the 20% least-disadvantaged areas and Q5 the 20% most disadvantaged.

Measurement of occupation

Occupation data forming the numerator pertain to the decedent's job at the time of death, whereas occupation information forming the denominator pertains to the main job held in the previous week. Both sources of occupation information were coded by the ABS to the first edition of the Australian Standard Classification of Occupations (ASCO).³⁹ ASCO is a skill-based measure that groups together occupations

requiring similar levels of education, knowledge, responsibility, on-the-job training and experience, and comprises eight occupation categories:

- 1 managers and administrators,
- 2 professionals,
- 3 para-professionals,
- 4 tradespersons,
- 5 clerks,
- 6 salespersons and personal service workers,
- 7 plant and machine operators and drivers and
- 8 labourers and related workers.

We recoded the ASCO measure into three categories for analysis: managers and professionals (1–3), white-collar employees (5 and 6) and blue-collar workers (4, 7 and 8). Similar three-level classifications have been used in previously published Australian articles^{40–41} and reports on population-health monitoring,⁴² and the classification is sufficiently sensitive to discriminate between occupation groups in terms of a range of health and social outcomes.

Analysis

The data were analysed using MLwiN V.2.1c.⁴³ Specifically, we fitted a multilevel binomial logit-link model with the predictive-penalised quasi-likelihood procedure and second-order linearisation, using the iterative generalised least squares algorithm.⁴⁴ As proportions are not always best represented as a binomial distribution owing to overdispersion or underdispersion,⁴⁵ allowance for this was made by using the extra binomial distribution assumption in MLwiN.

A five-level random coefficient model was used to examine the association between area-disadvantage and mortality (model 1), occupation and mortality (model 2) and simultaneous adjustment for both disadvantage and occupation (model 3). The regression output for each of these models is expressed as mortality per 100 000 population (relative to a reference age group of 50–54 years), and mortality risk ratios (RRs) and their 95% confidence intervals (CIs). This analysis was extended to test for cross-level interactions between area-level disadvantage and occupation (model 4); these examine whether relative differences between occupation groups in their probability of mortality vary across the IRSD quintiles. The extent of area variation in all-cause mortality was assessed initially by allowing the probability of death to vary across SLA conditional only on age-variation within SLA (model 5). This model was expanded by allowing for variation at the SSD, statistical division and state/territory levels (model 6); and further extended by adjustment for within-SLA variation in occupation and between-SLA variation in area-disadvantage (model 7) and then for a cross-level interaction between occupation and area-disadvantage (model 8). The significance of the random variation at each level was tested with “Wald-like” tests^{43–44} and p values were based on a χ^2 distribution.

RESULTS

For both men and women, rates of all-cause mortality were highest among those who lived in the most socioeconomically disadvantaged SLA, and among blue-collar workers (table 2, models 1 and 2). For men, simultaneous adjustment for area disadvantage and occupation (model 3) resulted in a moderate attenuation of the relative mortality inequalities among the IRSD quintiles but negligible reductions among the occupation groups. For women, simultaneous adjustment for area disadvantage and occupation resulted in little change in the magnitude of the mortality inequalities for either socioeconomic indicator (model 3).

Table 1 Description of the data used for the multilevel analysis

	Population	Deaths
Area-disadvantage (men)		
Q1 (least disadvantaged quintile)	852 497	6086
Q2	582 044	5017
Q3	711 681	7275
Q4	742 412	8130
Q5 (most disadvantaged quintile)	504 603	5912
Area-disadvantage (women)		
Q1 (least disadvantaged quintile)	718 375	2781
Q2	456 276	1752
Q3	530 880	2252
Q4	543 553	2396
Q5 (most disadvantaged quintile)	353 340	1656
Occupation (men) cells, n = 29 696		
Professionals	1 497 812	10 384
White collar	467 419	2890
Blue collar	1 428 006	19 146
Occupation (women) cells, n = 29 110		
Professionals	1 072 799	4450
White collar	1 147 359	4232
Blue collar	382 266	2155

Level 2: statistical local areas, n = 1317

Level 3: statistical subdivisions, n = 187

Level 4: statistical divisions, n = 59

Level 5: states and territories, n = 9

Australia, all-cause mortality, males and females 25–64 years, 1998–2000.

Table 2 Modelling the association between area-level socioeconomic disadvantage, occupation and all cause mortality

	Model 1* (area disadvantage)		Model 2 (occupation)		Model 3 (occupation and area-disadvantage), rate ratio (95% CI)
	Rate†	Rate ratio (95% CI)	Rate†	Rate ratio (95% CI)	
Men					
Area-disadvantage					
Q1 (least disadvantaged quintile)	304.3	1.00			1.00
Q2	397.4	1.31 (1.23 to 1.39)			1.22 (1.14 to 1.30)
Q3	439.9	1.45 (1.36 to 1.54)			1.29 (1.20 to 1.37)
Q4	478.2	1.57 (1.48 to 1.68)			1.35 (1.27 to 1.45)
Q5 (most disadvantaged quintile)	578.3	1.91 (1.78 to 2.04)			1.59 (1.48 to 1.70)
Occupation					
Professionals			319.2	1.00	1.00
White collar			290.0	0.91 (0.87 to 0.95)	0.90 (0.86 to 0.95)
Blue collar			634.3	1.99 (1.94 to 2.05)	1.96 (1.90 to 2.02)
Women					
Area-disadvantage					
Q1 (least disadvantaged quintile)	179.0	1.00			1.00
Q2	200.3	1.12 (1.03 to 1.22)			1.11 (1.02 to 1.20)
Q3	221.1	1.24 (1.14 to 1.35)			1.22 (1.12 to 1.32)
Q4	230.8	1.29 (1.19 to 1.40)			1.26 (1.16 to 1.37)
Q5 (most disadvantaged quintile)	273.5	1.53 (1.39 to 1.68)			1.48 (1.35 to 1.63)
Occupation					
Professionals			220.5	1.00	1.00
White collar			198.3	0.90 (0.86 to 0.94)	0.89 (0.85 to 0.94)
Blue collar			268.1	1.22 (1.14 to 1.29)	1.19 (1.12 to 1.26)

*All models also adjusted for within-statistical local area variation in age (reference age category 50–54 years).
 †Mortality per 100 000 population among 50–54-year-olds.
 Data are for men and women aged 25–64 years, 1998–2000.

Figures 2 and 3 examine whether mortality inequality by occupation varied by area-level socioeconomic disadvantage for men and women, respectively. A joint χ^2 test of the interaction terms indicated that the inclusion of cross-level interactions significantly improved model fit for both sexes (men, $p = 0.017$; women, $p = 0.035$). For men, no significant cross-level interactions were found among blue-collar workers; however, a significant interaction was found for white-collar employees living in the most disadvantaged quintile (RR 0.78, 95% CI 0.66 to 0.91). This indicates that the relative mortality inequality between professionals and white collar employees was larger in the most disadvantaged quintile (Q5) compared with the least disadvantaged (Q1), and that the mortality for white-collar employees was significantly lower than professionals in Q5, whereas there was no significant difference between these occupation groups in Q1. For women, significant cross-level interactions were found for white-collar employees living in quintile 5 (RR 1.20, 95% CI 1.03 to 1.40) and for blue-collar workers in quintile 3 (RR 1.26, 95% CI 1.04 to 1.52).

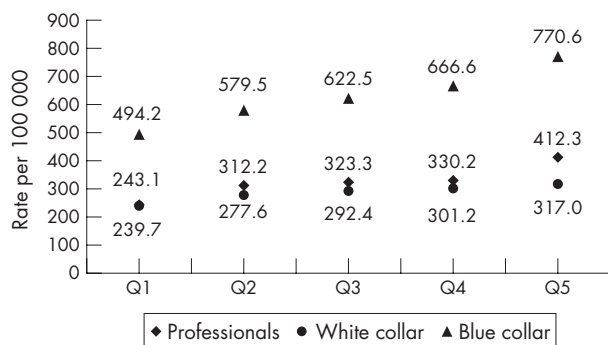


Figure 2 Plot of a cross-level interaction between occupation, area-level socioeconomic disadvantage and all-cause mortality per 100 000 population (model 4): men 25–64 years, 1998–2000. Q1 and Q5 = 20% most socioeconomically advantaged and disadvantaged statistical local areas in Australia, respectively.

Table 3 shows the area variation in the probability of all-cause mortality for each of the geographical levels comprising the ASGC. In model 5, the mortality variation was constrained to the SLA level: for both men and women the SLA random term was significant ($p \leq 0.01$) indicating that the average probability of death was not constant across the 1317 SLA. The SLA variation was larger for men. After allowing for mortality variation at the SSD, statistical divisions and state and territory levels (model 6), the variance of the SLA random term was markedly reduced: by 65.3% for men and by 85.2% for women. Moreover, Wald-like tests performed on the random terms for SSD, statistical division and states and territories indicated that the probability of death varied systematically at each of these levels (more notably so for women than for men). Model 7 extends model 6 and examines the extent of mortality variation at the SLA level after adjustment for within-SLA variation in occupation, and between-SLA differences in area socioeconomic disadvantage. For men, the SLA random term was

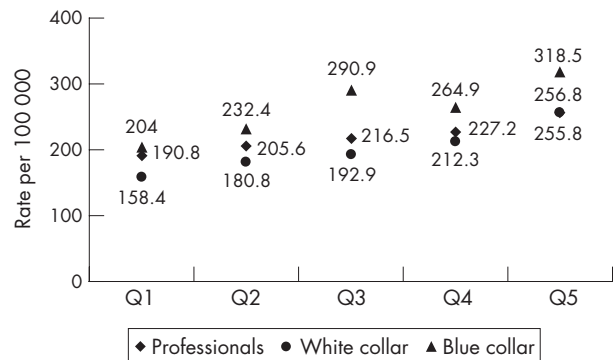


Figure 3 Plot of a cross-level interaction between occupation, area-level socioeconomic disadvantage and all-cause mortality per 100 000 population (model 4): women 25–64 years, 1998–2000. Q1 and Q5 = 20% most socioeconomically advantaged and disadvantaged statistical local areas in Australia, respectively.

attenuated after adjustment; however, it remained significant at $p \leq 0.01$. Mortality variation at each of the other levels was also attenuated. For women, no significant variation was found at the SLA level ($p \leq 0.05$) after adjustment for occupation and area disadvantage, although significant variation in the probability of mortality was evident among SSD and statistical divisions. Further adjustment for a cross-level interaction between occupation and area disadvantage (model 8) had no effect on the extent of mortality variation at any of the geographical levels for either men or women.

DISCUSSION

The results of this study add to a growing body of international evidence which show that living in a socioeconomically disadvantaged area significantly increases the probability of premature death over and above the socioeconomic characteristics of the residents of the areas.^{7–10} Specifically, we found that socioeconomically disadvantaged SLA had higher all-cause mortality even after adjustment for within-SLA variation in occupation. Importantly, our approach to structuring and analysing unlinked census and mortality data showed how this relationship could be examined in a multilevel context in countries where record linkage is not routinely conducted, using a method that makes it less necessary to rely on aggregate-ecological designs.

A further contribution of this study is that although it focused on between-area and within-area variation in mortality at the SLA level, variation at three higher geographical levels was also allowed for. In analyses that modelled only variation at the SLA level, we found that the random term was highly significant; however, its magnitude was reduced markedly when geographical variation at higher levels was accounted for. Had we therefore based our analysis on a two-level model, we would have greatly overestimated the variance at the SLA level, and by extension, overemphasised the potential contribution of SLA-level socioeconomic disadvantage (and other ecological factors) to variations in all-cause mortality. These results suggest that previous multilevel studies based on only two spatial scales^{7 9 10 30–36} may have mis-estimated the magnitude of area variation in mortality.

Consistent with international^{46–48} and Australian studies,^{40 49 50} we found a strong association between occupation and mortality: compared with professionals, blue-collar workers had significantly higher mortality and white-collar

employees significantly lower rates. This is the first Australian study to report on occupational mortality inequalities for women. Occupational data on female decedents were not collected on death certificates before the mid-1980s,⁴² and data collected in the decade immediately after were incomplete and considered too unreliable for meaningful analysis.

The cross-level interactions did not provide convincing evidence that the nature and extent of association between occupation and mortality was differentially affected by varying degrees of area-level socioeconomic disadvantage. Only 3 of 20 cross-level interactions were significant; thus, in most cases, mortality inequality between professionals, white-collar employees and blue-collar workers was similar irrespective of the socioeconomic environment. The cross-level analysis did indicate, however, that death rates for all three occupation groups increased monotonically across the socioeconomic quintiles such that they were lowest in the least disadvantaged SLA and highest in the most disadvantaged.

Our examination of mortality variation between states and territories, statistical division, SSD and SLA showed that the average probability of premature death varied systematically at each geographical scale, suggesting that contextual factors at each level made a measurable contribution to mortality. At the state and territory level, mortality variation possibly reflects historical differences in macrolevel political governance, which manifests in different policies (eg, social, economic, environmental, taxation and welfare) that either protect and promote population health or make its attainment more difficult. Understanding mortality variation at the statistical division and SSD levels is problematic, as these are primarily statistical units with no obvious social or cultural significance. SLA, by contrast, are often based on incorporated bodies of local governments and councils, hence mortality variation at this level might reflect differences in availability and access to health-related infrastructure and services (eg, recreational opportunities, public transport, housing and healthcare) or differences in local regulations and ordinances influencing such things as the number and location of take-away stores or shops selling healthy food.

Study limitations

Several data limitations and potential sources of bias need to be considered when interpreting this study's findings. Firstly, bias is inherent in the estimates of mortality inequality owing to the

Table 3 Area-level variation in all-cause mortality for each spatial unit comprising the Australian Standard Geographical Classification: men and women aged 25–64 years, 1998–2000

	Model 5		Model 6		Model 7		Model 8	
	Est	SE	Est	SE	Est	SE	Est	SE
Men								
Level 5: states and territories			0.058	0.033*	0.052	0.028*	0.052	0.028*
Level 4: statistical divisions			0.013	0.007*	0.006	0.004	0.006	0.004
Level 3: SSD			0.017	0.006†	0.007	0.004*	0.007	0.004*
Level 2: SLA	0.153	0.012†	0.053	0.007†	0.033	0.005†	0.033	0.005†
Level 1: cell dispersion	1.31	0.011	1.37	0.011	1.22	0.010	1.22	0.010
Women								
Level 5: states and territories			0.053	0.03*	0.059	0.034*	0.059	0.033*
Level 4: statistical divisions			0.005	0.006	0.018	0.009‡	0.017	0.009‡
Level 3: SSD			0.026	0.008†	0.016	0.006†	0.016	0.006†
Level 2: SLA	0.108	0.013†	0.016	0.006†	0.009	0.005*	0.008	0.005*
Level 1: Cell dispersion	1.21	0.010	1.26	0.01	1.19	0.010	1.19	0.010

Est, estimate; SLA, statistical local areas; SSD, statistical subdivisions.

Model 5: adjusted for within-SLA variation in age only.

Model 6: adjusted for within-SLA variation in age and variation at the SSD, statistical division and state/territory levels.

Model 7: model 6 adjusted for within-SLA variation in occupation and between-SLA variation in area-disadvantage.

Model 8: model 7 and a cross-level interaction between occupation and area-disadvantage.

* $p \leq 0.1$; † $p \leq 0.01$; ‡ $p \leq 0.05$. Significance based on Wald-like tests.^{43 44}

What this paper adds

- Multilevel studies have found that area-level disadvantage increases mortality risk independent of individual-level socioeconomic position.
- Most of these studies have been based on designs that link census or survey data to death records in mortality registers.
- In Australia, studies on record-linkage mortality are not routinely conducted; instead, studies are usually based on aggregate-ecological designs which confound area-level and individual-level sources of variation.
- This makes it difficult to know whether mortality differences between advantaged and disadvantaged areas are due to contextual (place) effects, or are artefacts of varying population compositions (eg, poor people living in poor places).
- This study shows how routinely available unlinked census and mortality data can be examined in a multilevel context, thereby making ecological studies of mortality less necessary.
- We found that the place of residence influences the probability of premature death over and above individual-level characteristics.
- More specifically, living in a socioeconomically disadvantaged area increases the risk of early death irrespective of one's own socioeconomic position.

numerator and denominator data arising from different sources.^{40–51} Numerator data pertain to the decedent's last occupation which may not reflect their primary lifetime occupation. This information is usually provided by a relative or acquaintance and the tendency is to report jobs that are more socially desirable, or to raise (promote) the occupational position or status of the deceased. The denominator data pertain to a person's current job, or a job held in the previous week, and these data are self-reported using a standardised collection procedure. Numerator–denominator bias tends to attenuate rather than widen occupational mortality inequalities, thus estimates reported here are likely to be smaller than the true magnitude of occupational differences in mortality in the Australian population.⁴⁰

Secondly, the use of the IRSD to measure area-level disadvantage was adequate in terms of quantifying the nature and extent of mortality inequality between SLA; however, composite socioeconomic indexes tell us little about the specific area-level factors that produce the inequalities. Measures such as the IRSD, therefore, are somewhat limited in terms of their capacity to inform policies and interventions to reduce health inequalities,⁵² although they do serve to indicate that places are important (or not) for health.

Thirdly, our finding of an association between area-level disadvantage and mortality might be confounded by individual-level socioeconomic factors not included in the models. However, we included one of the most widely used indicators of a person's SEP (ie, occupation), and given the correlation among socioeconomic measures⁵³ this indicator was probably capturing the unmeasured influences of other socioeconomic factors excluded from the models. Alternatively, the inclusion of occupation may have resulted in overadjustment, which argues for the possibility of an even stronger contextual effect on mortality than was observed in this study. If occupation represents part of the pathway via which area-level

Policy implications

- Policies and programmes to improve population health and reduce mortality inequalities need to focus on the social and economic characteristics of places as well as people.

disadvantage influences the probability of mortality of the residents of the areas, then simultaneously modelling occupation (or other markers of SEP) may inappropriately attenuate the variation that is more correctly attributable to area-level disadvantage.⁶

Fourthly, this study estimated the extent of mortality inequality among people who were economically active at the time of death (ie, full and part-time employed). Analyses based exclusively on this group, and hence exclusive of the economically inactive (eg, unemployed, working-aged on pensions and homeless), underestimate the actual extent of socioeconomic mortality in the wider population.⁵⁴ Our results, therefore, represent a partial but nevertheless important picture of how all-cause mortality in Australia is patterned by individual-level SEP.

Conclusions

In Australia, the average probability of premature death varies non-randomly across each of the ASGC spatial units to which mortality data are coded; hence each level in the hierarchy seems to make an important contribution to mortality. Both SLA disadvantage and occupation independently influenced the probability of death; however, there was limited support for different socioeconomic environments having a differential effect on the extent of mortality inequality between occupation groups. Future research needs to investigate the reasons for socioeconomic differences in mortality at the area level. This is a necessary step if place-based policies and interventions to reduce mortality inequality at the individual level are to be developed and effectively implemented. Finally, we showed how unlinked census and mortality data can be used in a multilevel context to examine area-based mortality inequalities. We recommend that this method be used (where possible) instead of aggregate-ecological designs, thus avoiding the methodological and interpretative problems associated with this approach.

Authors' affiliations

G Turrell, School of Public Health, Queensland University of Technology, Brisbane, Queensland, Australia

A Kavanagh, Key Centre for Women's Health in Society, School of Population Health, University of Melbourne, Melbourne, Australia

G Draper, Epidemiology Branch, Western Australia Department of Health, Perth, Australia

S V Subramanian, Department of Society, Human Development and Health, Harvard School of Public Health, Boston, Massachusetts, USA

Funding: GT is supported by a National Health and Medical Research Council/National Heart Foundation Career Development Award (CR 01B 0502) and AK is supported by a Victorian Health Promotion (VicHealth) Senior Research Fellowship. SVS is supported by a National Institutes of Health and National Heart, Lung, and Blood Institute Career Development Award (1 K25 HL081275-01).

Competing interests: None.

Ethical approval: Institutional ethical approval was not required for this manuscript or the data on which it is based. The study comprises an analysis of publicly available data that are released in a de-identified, anonymous form.

REFERENCES

- 1 Kawachi I, Berkman LF, eds. *Neighbourhoods and health*. New York: Oxford University Press, 2003:1–19.
- 2 Kaplan G. People and places—contrasting perspectives on the association between social class and health. *Int J Health Services* 1996;**26**:507–19.
- 3 Macintyre S, Ellaway A, Cummins S. Place effects on health: how can we conceptualise, operationalise, and measure them? *Soc Sci Med* 2002;**55**:125–39.
- 4 Subramanian SV. The relevance of multilevel statistical methods for identifying causal neighbourhood effects. *Soc Sci Med* 2004;**58**:1961–7.
- 5 Diez-Roux AV. Investigating neighbourhood and area effects on health. *Am J Public Health* 2001;**91**:1783–9.
- 6 Diez-Roux AV. Estimating neighbourhood health effects: the challenges of causal inference in a complex world. *Soc Sci Med* 2004;**58**:1953–60.
- 7 Bosma H, van de Mheen HD, Borsboom GJJM, et al. Neighbourhood socioeconomic status and all-cause mortality. *Am J Epidemiol* 2001;**153**:363–71.
- 8 Pickett KE, Pearl M. Multilevel analyses of neighbourhood socioeconomic context and health outcomes: a critical review. *J Epidemiol Community Health* 2001;**55**:111–22.
- 9 Martikainen P, Kauppinen TM, Valkonen T. Effects of the characteristics of neighbourhoods and the characteristics of people on cause specific mortality: a register based follow-up study of 252000 men. *J Epidemiol Community Health* 2003;**57**:210–17.
- 10 Marinacci C, Spadea T, Biggeri A, et al. The role of individual and contextual socioeconomic circumstances on mortality: analysis of time variations in a city of north west Italy. *J Epidemiol Community Health* 2004;**58**:199–207.
- 11 Gibberd RW, Dobson AJ, duVe Florey C, et al. Differences and comparative declines in ischaemic heart disease mortality among subpopulations in Australia, 1969–1978. *Int J Epidemiol* 1984;**13**:25–31.
- 12 Siskind V, Copeman R, Najman JM. Socioeconomic status and mortality: a Brisbane area analysis. *Community Health Studies* 1987;**11**:15–23.
- 13 Siskind V, Najman JM, Veitch C. Socioeconomic status and mortality revisited: an extension of the Brisbane area analysis. *Aust J Public Health* 1992;**16**:315–20.
- 14 Burnley IH. Mortality from respiratory system cancer in New South Wales and Sydney. *Aust J Public Health* 1992;**16**:251–61.
- 15 Taylor R, Quine S, Lyle D, et al. Socioeconomic correlates of mortality and hospital morbidity differentials by local government areas in Sydney 1985–1988. *Aust J Public Health* 1992;**16**:305–14.
- 16 Burnley IH. Differential and spatial aspects of suicide mortality in New South Wales and Sydney, 1980–1991. *Aust J Public Health* 1994;**18**:293–304.
- 17 Burnley IH. Socioeconomic and spatial differentials in mortality and means of committing suicide in New South Wales, Australia, 1985–91. *Soc Sci Med* 1995;**41**:687–98.
- 18 Quine S, Taylor R, Hayes L. Australian trends in mortality by socioeconomic status using NSW small area data, 1970–89. *J Biosoc Sci* 1995;**27**:409–19.
- 19 Burnley IH. Socio-demographic and spatial aspects of male mortality from HIV-AIDS related diseases in New South Wales, Australia, 1990–1994. *Soc Sci Med* 1999;**49**:751–62.
- 20 Siahpush M, Singh GK. Social integration and mortality in Australia. *Aust NZ J Public Health* 1999;**23**:571–7.
- 21 Taylor R, Chey T, Bauman A, et al. Socio-economic, migrant and geographic differentials in coronary heart disease occurrence in New South Wales. *Aust NZ J Public Health* 1999;**23**:20–6.
- 22 Yu XQ, Robertson C, Brett I. Socioeconomic correlates of mortality differentials by local government area in rural northern New South Wales, 1981–1995. *Aust NZ J Public Health* 2000;**24**:365–9.
- 23 Turrell G, Mathers C. Socioeconomic inequalities in all-cause and specific-cause mortality in Australia: 1985–1987 and 1995–1997. *Int J Epidemiol* 2001;**30**:231–9.
- 24 Cass A, Cunningham J, Wang Z, et al. Social disadvantage and variation in the incidence of end-stage renal disease in Australian capital cities. *Aust NZ J Public Health* 2001;**25**:322–6.
- 25 Wilkinson D, Ryan P, Hiller J. Variation in mortality rates in Australia: correlation with indigenous status, remoteness and socioeconomic deprivation. *J Public Health Med* 2001;**23**:74–7.
- 26 Hayes LJ, Quine S, Taylor R, et al. Socio-economic mortality differentials in Sydney over a quarter of a century, 1970–94. *Aust NZ J Public Health* 2002;**26**:311–17.
- 27 Greenland S. Ecologic versus individual-level sources of bias in ecologic estimates of contextual health effects. *Int J Epidemiol* 2001;**30**:1343–50.
- 28 Milyo J, Mellor JM. On the importance of age-adjustment methods in ecological studies of social determinants of mortality. *Health Serv Res* 2003;**38**:1781–90.
- 29 Subramanian SV, Duncan C, Jones K. Multilevel perspectives on modeling census data. *Environ Plann A* 2001;**33**:399–417.
- 30 Blomgren J, Martikainen P, Makela P, et al. The effects of regional characteristics on alcohol-related mortality—a register-based multilevel analysis of 1.1 million men. *Soc Sci Med* 2004;**58**:2523–35.
- 31 Jaffe DH, Eisenbach Z, Neumark YD, et al. Individual, household, and neighborhood status and mortality: a study of absolute and relative deprivation. *Soc Sci Med* 2005;**60**:989–97.
- 32 Veugelers PJ, Yip AM, Kephart G. Proximate and contextual socioeconomic determinants of mortality: multilevel approaches in a setting with universal health care coverage. *Am J Epidemiol* 2001;**154**:725–32.
- 33 Borrell C, Rodriguez M, Ferrando J, et al. Role of individual and contextual effects in injury mortality: new evidence from small area analysis. *Inj Prev* 2002;**8**:297–302.
- 34 Sloggett A, Joshi H. Higher mortality in deprived areas: community or personal disadvantage? *BMJ* 1994;**309**:1470–4.
- 35 Yen IH, Kaplan GA. Neighborhood social environment and risk of death: multilevel evidence from the Alameda County Study. *Am J Epidemiol* 1999;**149**:898–907.
- 36 Malstrom M, Johansson S, Sundquist J. A hierarchical analysis of long-term illness and mortality in socially deprived areas. *Soc Sci Med* 2001;**53**:265–75.
- 37 Australian Bureau of Statistics. *Statistical geography: volume 1. Australian Standard Geographical Classification (ASGC)*, Catalogue number 1216.0. Canberra: Australian Government Publishing Service, 1996.
- 38 Australian Bureau of Statistics. *Socioeconomic indexes for areas, 1996*, Catalogue number 2039.0. Canberra: Australian Government Publishing Service, 1998.
- 39 Australian Bureau of Statistics. *Australian Standard Classification of Occupations*, 2nd edn. Catalogue number 1220.0. Canberra: Australian Government Publishing Service, 1997.
- 40 Bennett S. Socioeconomic inequality in coronary heart disease and stroke mortality among Australian men. *Int J Epidemiol* 1996;**25**:266–75.
- 41 Burton N, Turrell G. Occupation, hours worked, and leisure-time physical activity. *Prev Med* 2000;**31**:673–81.
- 42 Draper G, Turrell G, Oldenburg B. *Health inequalities in Australia: mortality*, Health Inequalities Monitoring Series Number 1, AIHW Catalogue number PHE 55. Canberra: Queensland University of Technology, 2004.
- 43 Rasbash J, Browne W, Goldstein H, et al. *A user's guide to MLwiN*. Version 2.1, multilevel models project, Institute of Education. London: University of London, 2000.
- 44 Goldstein H. *Multilevel statistical models*. London: Arnold, 2003.
- 45 Collet D. *Modelling binary data*. London: Chapman and Hall, 1991.
- 46 Barnett E, Armstrong DL, Casper ML. Social class and premature mortality among men: a method for state-based surveillance. *Am J Public Health* 1997;**87**:1521–4.
- 47 Davey Smith G, Hart C, Hole D, et al. Education and occupational social class: which is the more important indicator of mortality risk? *J Epidemiol Community Health* 1998;**52**:153–60.
- 48 Diderichsen F, Hallqvist J. Trends in occupational mortality among middle-aged men in Sweden 1961–1990. *Int J Epidemiol* 1997;**26**:782–7.
- 49 Dobson A, Halpin S, Alexander H. Does the occupational structure of the Hunter region explain the high rates of ischaemic heart disease among its men? *Aust J Public Health* 1991;**15**:172–7.
- 50 Burnley IH. Disadvantage and male cancer incidence and mortality in New South Wales 1985–1993. *Soc Sci Med* 1997;**45**:465–76.
- 51 Blakely T, Fawcett J. Bias measuring mortality gradients by occupational class in New Zealand. *NZ Med J* 2005;**118**:U1253.
- 52 McCracken K. Into a SEIFA SES cul-de-sac? *Aust NZ J Public Health* 2001;**25**:305–6.
- 53 Turrell G, Hewitt B, Patterson C, et al. Measuring socioeconomic position in dietary research: is choice of socioeconomic indicator important? *Public Health Nutr* 2003;**6**:191–200.
- 54 Martikainen P, Valkonen T. Bias related to the exclusion of the economically inactive in studies on social class differences in mortality. *Int J Epidemiol* 1999;**28**:899–904.