



Social Determinants of Health

Education inequalities in adult all-cause mortality: first national data for Australia using linked census and mortality data

Rosemary J Korda,^{1*} Nicholas Biddle,² John Lynch,^{3,4}
James Eynstone-Hinkins,⁵ Kay Soga,¹ Emily Banks,¹ Naomi Priest,²
Lynelle Moon⁶ and Tony Blakely⁷

¹National Centre for Epidemiology and Population Health, Research School of Population Health, Australian National University, Canberra ACT, Australia, ²Centre for Social Research and Methods, Research School of Social Sciences, Australian National University, Canberra ACT, Australia, ³School of Public Health, University of Adelaide, Adelaide, Australia, ⁴Population Health Sciences, Bristol Medical School, Bristol, UK, ⁵Health and Vital Statistics Section, Australian Bureau of Statistics, Brisbane, Australia, ⁶Australian Institute of Health and Welfare, Canberra, Australia and ⁷Melbourne School of Population and Global Health, University of Melbourne, Parkville, Victoria, Australia

*Corresponding author. National Centre for Epidemiology and Population Health, Research School of Population Health, Australian National University, Building 62, Mills Road, Acton ACT 2601, Australia. E-mail: rosemary.korda@anu.edu.au

Editorial decision 7 August 2019; Accepted 28 August 2019

Abstract

Background: National linked mortality and census data have not previously been available for Australia. We estimated education-based mortality inequalities from linked census and mortality data that are suitable for international comparisons.

Methods: We used the Australian Bureau of Statistics Death Registrations to Census file, with data on deaths (2011–2012) linked probabilistically to census data (linkage rate 81%). To assess validity, we compared mortality rates by age group (25–44, 45–64, 65–84 years), sex and area-inequality measures to those based on complete death registration data. We used negative binomial regression to quantify inequalities in all-cause mortality in relation to five levels of education [‘Bachelor degree or higher’ (highest) to ‘no Year 12 and no post-secondary qualification’ (lowest)], separately by sex and age group, adjusting for single year of age and correcting for linkage bias and missing education data.

Results: Mortality rates and area-based inequality estimates were comparable to published national estimates. Men aged 25–84 years with the lowest education had age-adjusted mortality rates 2.20 [95% confidence interval (CI): 2.08–2.33] times those of men with the highest education. Among women, the rate ratio was 1.64 (1.55–1.74). Rate ratios were 3.87 (3.38–4.44) in men and 2.57 (2.15–3.07) in women aged 25–44 years, decreasing to 1.68 (1.60–1.76) in men and 1.44 (1.36–1.53) in women aged 65–84 years. Absolute education inequalities increased with age. One in three to four deaths (31%) was associated with less than Bachelor level education.

Conclusions: These linked national data enabled valid estimates of education inequality in mortality suitable for international comparisons. The magnitude of relative inequality is substantial and similar to that reported for other high-income countries.

Key words: Mortality, census, Australia, health inequalities, socioeconomic position, education

Key Messages

- The linked Australian Death Registrations to Census file provides valid data for generating national estimates of education inequality in mortality suitable for international comparisons.
- Australian men aged 25–84 years with low education (no Year 12 and no post-secondary qualification) have a mortality rate around 120% higher, and women 60% higher, than those with high education (university degree), broadly similar to estimates reported for other high-income countries.
- Inequalities differ substantially by age and sex, with relative inequalities highest in young men (25–44 years), where mortality rates are almost 300% higher in low compared with high education, and lowest in older women (65–84 years), with corresponding rates around 40% higher.
- We estimate that the death rate in Australian adults aged 25–84 years in 2011–2012 would have been 30% lower under the counterfactual situation in which everyone has the same mortality rates as those with a university degree.

Background

Addressing socioeconomic inequalities in mortality within countries is a key public health priority globally.¹ Apart from being inherently unjust² and resulting in significant financial cost to societies,³ socioeconomic inequalities are potentially avoidable and hence point to opportunities for intervention to improve the overall health of the population. Thus, accurate quantification of these inequalities alongside average mortality rates is necessary, to better monitor population health, formulate policy and target resources.³

Integral to monitoring inequalities is the ability to make comparisons over time and across countries. To this end, the OECD has recommended using standardized approaches, preferably using a longitudinal design incorporating linked census and mortality data, with education as the socioeconomic indicator.⁴ Education is recommended, as it is reported with reasonable reliability, can be harmonized across countries, has little missing data, is a relatively stable measure across the adult lifespan and is less subject to ‘reverse causality’ than other measures such as income.^{4,5} Inequalities in health by education are now being systematically monitored in other countries, including in the USA and Europe, and several countries, such as England, Finland and Lithuania, have adopted national targets for the reduction of socioeconomic inequalities in mortality based on such estimates.^{6–8}

In Australia, the ability to quantify and compare inequalities in mortality has to date been limited by the

available data. Estimates have been based on cross-sectional mortality data using area-based socioeconomic measures, typically the Australian Bureau of Statistics (ABS) Socio-Economic Indexes for Areas (SEIFA) Index of Relative Disadvantage.^{9–13} However, the ABS has recently created a resource by linking death registration data with individual-level data from the Australian census. This national linked data file for the first time enables quantification of mortality by education in Australia. The primary aim of this study was to use these data to quantify education inequalities in all-cause mortality in Australia using recommended methodology to enable international comparisons.⁴ This included estimating both absolute and relative inequalities in relation to five levels of education, separately by sex and age group, adjusting for age and correcting for linkage bias and missing education data. As this is a new resource, we also provide validation data to accompany the analyses.

Methods

Data

We used the linked ABS Death Registrations to Census file, which contains records of all deaths registered up to 30 September 2012 and occurring between 10 August 2011 and 27 September 2012 inclusive, linked probabilistically to data from the 2011 Census of Population and Housing, which took place on 9 August 2011.¹⁴ The ABS initially

linked death and census data as part of the 2011 Census Data Enhancement program, using name and address information, along with other personal characteristics, creating a 'gold standard' record linkage. In that linkage, 142 697 of the 153 455 death registration records (93%) were successfully matched to census records. However, as dissemination of this file to external users was precluded under the Enhancement program due to privacy and confidentiality concerns, the reconstructed Death Registrations to Census record linkage was subsequently carried out probabilistically without using name-and-address information, but with personal characteristics including date of birth, sex and area of residence (based on Meshblocks, which are designed to be socioeconomically homogenous and contain, where possible, a dwelling count of between 30 and 60), as well as country of birth and year of arrival in Australia, similar to methods used in other countries (e.g. the New Zealand Census-Mortality Study¹⁵). The linked data file contains 123 910 records (81% of registered deaths), of which 95.3% were linked to the same census record as the gold standard linkage.¹⁶ For each sociodemographic strata that could be characterized on both the linked data file and full death registration file [sex, age cohort (born >1945/<1946), migrant status (born in Australia/Europe/elsewhere) and city residence (yes/no)], the linkage rate was calculated and its inverse used as a weight in analyses to restore population representativeness. Further details of the linkage methods and weighting are available elsewhere.¹⁶

Given the linked file was only deaths, we obtained denominator counts by strata for the total 2011 Census population through ABS TableBuilder.¹⁴

Variables

The socioeconomic variable of interest for this study—education—was derived from two of the census variables—*highest year of school completed* [Year 12 or equivalent (the highest level of schooling) down to Year 8 or below, or Never attended school] and *level of highest non-school qualification* (Postgraduate Degree, Graduate Diploma/Graduate Certificate, Bachelor Degree, Advanced Diploma/Diploma, Certificate III/IV, Certificate III, Certificate not further defined and No non-school qualification). Using a combination of these two variables, we created five mutually exclusive categories, which correspond to categories used in the International Standard Classification of Education (ISCED, 2011)¹⁷: I. Bachelor degree or higher (whether completed Year 12 or not) (equivalent to ISCED levels 6, 7 and 8); II. Other post-secondary school qualification and completed Year 12; and III. Other post-secondary school qualification but did not complete Year 12 (together corresponding to

ISCED levels 4 and 5); IV. No post-secondary school qualification, but completed Year 12 (ISCED level 3); and V. No post-secondary school qualification and did not complete Year 12 (ISCED levels 0, 1 and 2).

Analysis

We accessed the Death Registrations to Census file through the ABS virtual DataLab. We included all deaths in people aged 25–84 years old occurring in the full year following the census date, thus excluding deaths occurring after this time (10 412 deaths) and individuals aged <25 years (1246 deaths) or ≥85 years (41 477 deaths), leaving 70 775 linked death records (equivalent to 88 177 weighted deaths). We summed the weighted number of deaths (numerators for mortality rates) and person-years at risk (death date minus census date, because those who die are then no longer at risk), by single year of age, sex and education.

To calculate total person-years at risk (denominators for mortality rates), we used Census 2011 data to obtain counts for each age-sex-education subgroup (each person = 1 year at risk). We adjusted for the shorter time at risk in the deceased by subtracting the number of people who died and adding the person-years at risk for these people, as ascertained from the Death Registrations to Census file.

Deaths and person-years with education missing (22.3 and 11.8%, respectively, [Supplementary Table 1](#), available as [Supplementary data](#) at *IJE* online) were separately assigned to education categories probabilistically based on sex, single year of age and area-based education (SEIFA Index of Education and Occupation population-based deciles¹⁸).

For validation purposes, we generated crude death rates for each age–sex group in the analysis data set and compared these with rates derived from published complete death registration data for a similar period (January 2011–December 2012; details, [Supplementary Table 2](#), available as [Supplementary data](#) at *IJE* online). We also generated age-group–sex-specific area-based inequality estimates based on the SEIFA IRSD quintile,¹⁸ the standard area-based socioeconomic measure used to report on inequality estimates for Australia, and compared these to official published estimates, which were based on (near-complete) death registration data¹³ (details, [Supplementary Table 3](#), available as [Supplementary data](#) at *IJE* online).

To quantify inequality in mortality rates in relation to education, we used negative binomial regression to accommodate overdispersion in the data. We calculated rate ratios (RRs) and rate differences (RDs) with 95% confidence intervals (CIs), using the highest education category (Bachelor degree or higher) as the reference category. We also estimated the total number of excess deaths associated

with less than Bachelor education by multiplying the RD by the number of people in each education group and summing them. In addition, as recommended,⁴ we also report the relative index of inequality (RII). The RII converts categorical data into continuous measures, incorporating all education levels into the one estimate and allowing the size of the education groups to be taken into account. The RII can be interpreted as the ratio of the mortality rate predicted for the hypothetical lowest end of the socioeconomic continuum to the rate predicted for the hypothetical highest end.¹⁹ All else being equal, the RII will increase if the proportion of disadvantaged people increases in a population.

All analyses were performed separately for men and women and by broad age group (25–44, 45–64, 65–84 and 25–84 years) and were adjusted for single year of age.

We performed supplementary analyses to allow broader international comparisons⁴: we re-ran the analyses with education categories aggregated into low (Group V), middle (Groups II, III and IV) and high (Group I) and reported these for men and women by 10-year age brackets (25–34 up to 75–84).

We used Stata version 15.1 for all analyses. We obtained ethics approval for this study from the Australian National University Human Research Ethics Committee.

Results

Crude data, including number of people, deaths and person-years for men and women by age group and education level, are shown in [Table 1](#). The crude mortality rate was 5.2% higher (3.11 per 10 000 higher) than the rate estimated from published ABS data for 2011–2012 ([Supplementary Table 1](#), available as [Supplementary data at IJE online](#)). This difference (in percentage terms) was similar across age–sex groups, except among the 25–44 years age group, in which the mortality rates were around 5–10% lower in the analysis file compared with ABS data. The age–group–sex-specific area-based inequality (SEIFA IRSD) estimates derived from the analysis file compared favourably to official published estimates ([Supplementary Table 2](#), available as [Supplementary data at IJE online](#)).

Education gradients in all-cause mortality were evident in all age groups, for both men and women—as education levels increased, mortality rates declined ([Table 1](#) and [Supplementary Table 3](#), available as [Supplementary data at IJE online](#)). Among men aged 25–84 years, the age-adjusted mortality rate among the lowest educated (no post-secondary school qualification and no Year 12, 102 per 10 000 person-years) was 2.20 (95% CI: 2.08–2.33) times the mortality rate of those with the highest education

(Bachelor degree or higher, 46.3 per 10 000 person-years)—a RD equal to 55.5 (51.3–59.8) per 10 000 person-years. The corresponding mortality rates for the lowest and highest educated women were 59.4 and 36.2 per 10 000 person-years—a RR of 1.64 (1.55–1.74) and RD of 23.1 (20.4–25.8) per 10 000 person-years.

Relative inequality was highest in the youngest age cohorts [25–44 years, men: RR = 3.87 (95% CI: 3.38–4.44); women: RR = 2.57 (2.15–3.07)] and lowest in the oldest age cohorts [65–84 years, men: RR = 1.68 (1.60–1.76); women: RR = 1.44 (1.36–1.53)]. This was also reflected in the RII estimates ([Table 1](#)). Absolute inequality was lower in the younger age groups than in the older age groups, reflecting the markedly higher mortality rates in the older age groups [men: 25–44 years, RD = 13.6 (12.0–15.1), 65–84 years, RD = 140 (129–152); women: 25–44 years, RD = 5.79 (4.54–7.04), 65–84 years, RD = 66.3 (56.6–76.1); [Table 1](#)]. These age-related patterns are also evident in the estimates based on 10-year age brackets ([Supplementary Table 3](#), available as [Supplementary data at IJE online](#)).

The total number of excess deaths associated with lower than Bachelor education (25–84 years) was 27 127/88 177 deaths (31%), 66% of which were male deaths. Excess deaths were highest in the 65–84 years age group (66% of total excess deaths for ages 25 to <85 years) and lowest in the 25–44 years age group (7%) ([Supplementary Table 4](#), available as [Supplementary data at IJE online](#)).

Discussion

This is the first study to report on education inequalities in mortality in Australia using whole-of-population linked census and mortality data. After applying weights to correct for linkage bias and imputing missing education data, the ABS probabilistically linked Census to Death Registrations data appear to be of sufficient quality for quantifying inequalities. Using these data, we estimated that, among Australian adults aged 25–84 years, the mortality rate of men who had not completed Year 12 and did not have post-school qualifications was more than twice that of men with a university degree; among women, it was 1.6 times. For younger people, these relative inequalities were greater, although the total excess deaths associated with lower education were higher in the older age cohorts due to the much higher death rates at these ages. We estimate that the death rate in Australian adults aged 25–84 years in 2011–2012 would have been around 30% lower under the counterfactual situation in which everyone has the same mortality rates as those with a university degree. This scenario, however, assumes no confounding and complete risk reversibility, which is an unlikely case.

Table 1. Crude data and age-adjusted mortality rates, rate differences, rate ratios and relative index of inequality (RII) in relation to education for Australian adults aged 25–84 years, separately by age group and sex, 2011–2012

Education	Population (%)	Deaths (n)	Person-years	Rate per 10 000 person-years (95% CI)	Rate difference per 10 000 person-years (95% CI)	Rate ratio (95% CI)	RII (95% CI)
Men							
Age 25–44 years							
Bachelor degree or higher	836 011 (28%)	386	835 790	4.72 (4.19–5.24)	–	–	–
Other post-secondary + Year 12	631 997 (21%)	435	631 757	7.14 (6.39–7.90)	2.43 (1.51–3.35)	1.51 (1.30–1.77)	1.51 (1.30–1.77)
Other post-secondary + No Year 12	503 209 (17%)	507	502 943	9.53 (8.56–10.5)	4.81 (3.71–5.92)	2.02 (1.74–2.35)	2.02 (1.74–2.35)
No post-secondary + Year 12	479 800 (16%)	482	479 558	10.4 (9.35–11.5)	5.70 (4.51–6.88)	2.21 (1.90–2.57)	2.21 (1.90–2.57)
No post-secondary + No Year 12	524 814 (18%)	1004	524 308	18.3 (16.8–19.7)	13.6 (12.0–15.1)	3.87 (3.38–4.44)	5.27 (4.39–6.33)
Age 45–64 years							
Bachelor degree or higher	559 145 (21%)	1476	558 339	27.4 (26.0–28.8)	–	–	–
Other post-secondary + Year 12	368 964 (14%)	1483	368 188	41.1 (39.0–43.2)	13.7 (11.2–16.3)	1.50 (1.39–1.61)	1.50 (1.39–1.61)
Other post-secondary + No Year 12	684 146 (25%)	3070	682 595	45.5 (43.9–47.2)	18.1 (16.0–20.3)	1.66 (1.56–1.77)	1.66 (1.56–1.77)
No post-secondary + Year 12	304 842 (11%)	1414	304 145	46.4 (43.9–48.8)	19.0 (16.2–21.8)	1.69 (1.57–1.82)	1.69 (1.57–1.82)
No post-secondary + No Year 12	771 246 (29%)	5225	768 703	65.2 (63.3–67.2)	37.8 (35.4–40.3)	2.38 (2.24–2.53)	2.80 (2.55–3.07)
Age 65–84 years							
Bachelor degree or higher	155 062 (13%)	2818	153 564	206 (197–214)	–	–	–
Other post-secondary + Year 12	138 819 (11%)	3242	137 111	246 (236–255)	39.7 (26.9–52.5)	1.19 (1.13–1.26)	1.19 (1.13–1.26)
Other post-secondary + No Year 12	295 720 (24%)	7895	291 685	282 (274–290)	76.3 (64.6–87.9)	1.37 (1.30–1.44)	1.37 (1.30–1.44)
No post-secondary + Year 12	122 876 (10%)	3463	121 122	289 (278–301)	83.5 (69.6–97.5)	1.41 (1.33–1.49)	1.41 (1.33–1.49)
No post-secondary + No Year 12	526 815 (43%)	18 786	517 671	346 (338–355)	140 (129–152)	1.68 (1.60–1.76)	1.89 (1.77–2.02)
Age 25–84 years							
Bachelor degree or higher	1 550 218 (22%)	4681	1 547 694	46.3 (44.4–48.2)	–	–	–
Other post-secondary + Year 12	1 139 780 (17%)	5160	1 137 056	61.9 (59.4–64.4)	15.6 (12.5–18.7)	1.34 (1.26–1.42)	1.34 (1.26–1.42)
Other post-secondary + No Year 12	1 483 075 (21%)	11 473	1 477 224	72.3 (69.7–74.9)	26.0 (22.8–29.2)	1.56 (1.48–1.65)	1.56 (1.48–1.65)
No post-secondary + Year 12	907 518 (13%)	5359	904 825	75.0 (72.0–78.1)	28.8 (25.2–32.3)	1.62 (1.53–1.72)	1.62 (1.53–1.72)
No post-secondary + No Year 12	1 822 875 (26%)	25 015	1 810 682	102 (98.0–106)	55.5 (51.3–59.8)	2.20 (2.08–2.33)	2.65 (2.47–2.85)
Women							
Age 25–44 years							
Bachelor degree or higher	1 090 247 (36%)	385	1 090 044	3.68 (3.21–4.15)	–	–	–
Other post-secondary + Year 12	609 880 (20%)	200	609 780	3.44 (2.89–3.99)	–0.24(–0.96–0.48)	0.93 (0.76–1.15)	0.93 (0.76–1.15)
Other post-secondary + No Year 12	298 623 (10%)	170	298 538	5.32 (4.39–6.25)	1.64 (0.59–2.69)	1.45 (1.16–1.80)	1.45 (1.16–1.80)
No post-secondary + Year 12	527 332 (17%)	290	527 180	5.62 (4.82–6.41)	1.94 (1.02–2.85)	1.53 (1.26–1.85)	1.53 (1.26–1.85)
No post-secondary + No Year 12	528 190 (17%)	549	527 915	9.47 (8.31–10.6)	5.79 (4.54–7.04)	2.57 (2.15–3.07)	3.64 (2.78–4.75)

(Continued)

Table 1. Continued

Education	Population (%)	Deaths (n)	Person-years	Rate per 10 000 person-years (95% CI)	Rate difference per 10 000 person-years (95% CI)	Rate ratio (95% CI)	RII (95% CI)
Age 45–64 years							
Bachelor degree or higher	604 364 (22%)	1147	603 762	20.2 (19.1–21.4)	–	–	–
Other post-secondary + Year 12	333 279 (12%)	730	332 907	23.7 (22.0–25.4)	3.45 (1.37–5.53)	1.17 (1.07–1.28)	
Other post-secondary + No Year 12	389 706 (14%)	957	389 214	25.6 (24.0–27.3)	5.40 (3.40–7.40)	1.27 (1.16–1.38)	
No post-secondary + Year 12	341 396 (12%)	1045	340 889	31.9 (29.9–33.8)	11.6 (9.37–13.9)	1.57 (1.45–1.71)	
No post-secondary + No Year 12	1 097 781 (40%)	3963	1 095 820	33.4 (32.4–34.5)	13.2 (11.6–14.8)	1.65 (1.55–1.76)	2.11 (1.88–2.37)
Age 65–84 years							
Bachelor degree or higher	138 184 (10%)	1679	137 281	150 (142–158)	–	–	–
Other post-secondary + Year 12	88 128 (6%)	1177	87 508	154 (145–164)	4.08 (–8.24–16.4)	1.03 (0.95–1.11)	
Other post-secondary + No Year 12	105 575 (8%)	1491	104 783	163 (154–172)	13.0 (0.96–25.0)	1.09 (1.01–1.17)	
No post-secondary + Year 12	152 681 (11%)	2880	151 213	190 (181–198)	39.9 (28.4–51.4)	1.27 (1.18–1.36)	
No post-secondary + No Year 12	885 834 (65%)	19 827	876 088	216 (210–222)	66.3 (56.6–76.1)	1.44 (1.36–1.53)	1.77 (1.63–1.93)
Age 25–84 years							
Bachelor degree or higher	1 832 795 (25%)	3211	1 831 086	36.2 (34.6–37.9)	–	–	–
Other post-secondary + Year 12	1 031 287 (14%)	2107	1 030 196	38.8 (36.8–40.8)	2.55 (0.05–5.05)	1.07 (1.00–1.14)	
Other post-secondary + No Year 12	793 904 (11%)	2618	792 535	43.4 (41.3–45.5)	7.16 (4.55–9.76)	1.20 (1.12–1.28)	
No post-secondary + Year 12	1 021 409 (14%)	4214	1 019 283	51.3 (49.0–53.5)	15.0 (12.3–17.7)	1.41 (1.33–1.50)	
No post-secondary + No Year 12	2 511 805 (35%)	24 339	2 499 824	59.4 (57.2–61.6)	23.1 (20.4–25.8)	1.64 (1.55–1.74)	2.13 (1.97–2.31)
Total persons, age 25–84	14 094 666	88 177	14 050 405				

^aAge as recorded on Census.^bPopulation percentage is within age group.

Nevertheless, it points to the health burden and lost lives from socioeconomic inequalities in health and the potential for population health gain regardless of the mechanisms underlying these inequalities.^{6,20,21}

Other countries, including New Zealand, Canada, Colombia and many European countries, have for some time used census linked to mortality data to quantify inequalities in mortality, universally demonstrating educational gradients.^{7,22–30} Our estimates of RRs for the lowest compared with the highest education groups were similar to the most recent published estimates (covering periods up to the late 2010s) reported for Canada (men 1.97; women 1.90),²⁶ Italy (men 2.06, women 1.59),²⁷ Belgium (men 1.88; women 1.59)²⁸ and Lithuania (men 1.99; women 1.84)²⁹ and appear lower than estimates from Colombia (men 2.60; women 2.36).²⁴ Australian RIs of 2.65 and 2.13 for men and women aged 25–84 years are broadly similar to the age- and sex-adjusted RIs reported for countries in Scandinavia and Western Europe based on data from the early 2000s (e.g. Sweden 2.01; Belgium 1.95; Switzerland 2.28) and are substantially lower than those reported for Eastern European countries (e.g. Hungary 4.21; Czech Republic 4.36).²⁵

Our finding of lower relative and higher absolute inequalities in older age cohorts is reported for other countries (e.g.^{29,30}) and is not an unexpected finding.³¹ This reflects the mathematical limits of relative differences in the face of large absolute rates, increasing non-preventable deaths and compositional changes in the education groupings—as successive cohorts become more educated over time, disadvantage is likely to be more highly concentrated in the lower-education groups.^{21,32}

The Deaths Registration to Census data file has enabled the first Australian whole-of-population estimates of mortality inequalities in relation to education useful for international comparisons and as a baseline for comparisons over time. When using these data, however, several limitations should be borne in mind. The first relates to the reliance on probabilistic linkage without the benefit of name-and-address information, leading to a loss of data and accuracy. Data for some subpopulations are less likely to be linked and while use of the ABS-derived weights addresses this to some extent, these weights do not explicitly factor in education. If linkage, and hence ascertainment of death, varies by education after adjusting for linkage bias based on other subpopulations, inequality estimates will be biased. Given vulnerable populations are less likely to be linked, if anything, it is more likely than not that there will be a relative under-ascertainment of deaths among those with lower education levels, hence mortality inequality will have been underestimated (although this was not apparent in the area-based inequality estimates, expect perhaps in younger men). Further, younger people remain under-represented in the Death Registrations to Census file, suggesting that the age groups used for weighting are too

broad. This under-representation likely reflects to some degree the higher proportion of coronial cases among younger people, which are less likely to be captured in the linked data file due to delay in registration and residential mobility. Second, while self-reported education is considered valid,^{4,5} accuracy of this measure cannot be verified and it may vary across subpopulations. Third, while our probabilistic method of imputing missing education data is likely to have minimized bias, it does not take into account the extra variance caused by the missing data imputation and thus our CIs are likely to be too narrow. Fourth, only deaths registered up until a month after the 12-month follow-up were included in the file and estimates would be more stable if based on several years of data rather than a single year.

Conclusions

The 2011 Death Registrations to Census file, despite imperfect linkage, has provided a mechanism for generating valid estimates of inequality in mortality in Australia, suitable for international comparisons, thus adding to the available data for international benchmarking. The magnitude of relative inequality in mortality is substantial and similar to that reported for other high-income countries. Future census to deaths linkage will likely use name and address identifiers, making for more precise linkage, and analysis files should include all census records (people who did and did not die), which will improve the quality and scope of analyses. Smaller time lags in the availability of these linked data would also assist monitoring, although inequalities are unlikely to change rapidly. Quantifying inequalities is a crucial component of monitoring the population's health and doing so more accurately, in a timelier way and with more nuance, will make these more visible and for better public policy.

Supplementary data

Supplementary data are available at *IJE* online.

Funding

This work was supported by the National Health and Medical Research Council of Australia Partnership Project Grant (grant number 1134707), in conjunction with the Australian Bureau of Statistics, the Australian Institute of Health and Welfare and the National Heart Foundation of Australia.

Acknowledgements

We acknowledge the contributions of members of the Whole-of-population Linked Data Project team, in particular Jennifer Welsh, Lauren Moran, Melonie Martin and Talei Parker.

Conflict of interest: None declared.

References

1. WHO. *Closing the Gap in a Generation: Health Equity through Action on the Social Determinants of Health*. Geneva: The World Health Organization and Commission on Social Determinants of Health, 2008.
2. Braveman PA, Kumanyika S, Fielding J *et al*. Health disparities and health equity: the issue is justice. *Am J Public Health* 2011; **101**(Suppl 1):S149–155.
3. Mackenbach JP, Meerding WJ, Kunst AE. Economic costs of health inequalities in the European Union. *J Epidemiol Community Health* 2011; **65**:412–19.
4. Mackenbach J, Menvielle G, Jasilionis D, Gelder R. *Measuring Educational Inequalities in Mortality Statistics*. OECD Statistics Working Papers, No. 2015/08. Paris: OECD Publishing, 2015.
5. Duncan GJ, Daly MC, McDonough P, Williams DR. Optimal indicators of socioeconomic status for health research. *Am J Public Health* 2002; **92**:1151–57.
6. Cutler D, Lleras-Muney A. *Education and Health: Evaluating Theories and Evidence*. NBER Working Paper No. 12352, Cambridge: National Bureau of Economic Research, Inc, 2006.
7. Mackenbach JP, Kulhánová I, Artnik B *et al*. Changes in mortality inequalities over two decades: register based study of European countries. *BMJ* 2016; **353**:i1732.
8. Crombie I, Irvine L, Elliott L, Wallace H. *Closing the Health Inequalities Gap: An International Perspective*. Geneva: World Health Organisation, 2005.
9. Wilkinson D, Ryan P, Hiller J. Variation in mortality rates in Australia: correlation with Indigenous status, remoteness and socio-economic deprivation. *J Public Health Med* 2001; **23**: 74–77.
10. Glover J, Hetzel D, Glover L, Tennant S, Page A. *A Social Health Atlas of South Australia*, 3rd edn. Adelaide: The University of Adelaide, 2006.
11. Australian Institute of Health and Welfare. *Australian Burden of Disease Study: Impact and Causes of Illness and Deaths in Australia 2011*. Canberra: AIHW, 2016.
12. Stephens AS, Gupta L, Thackway S, Broome RA. Socioeconomic, remoteness and sex differences in life expectancy in New South Wales, Australia, 2001–2012: a population-based study. *BMJ Open* 2017; **7**:e013227.
13. Australian Institute of Health and Welfare. *Mortality Inequalities in Australia 2009–2011*. Bulletin No. 124. Cat. No. AUS 184. Canberra: AIHW, 2014.
14. Australian Bureau of Statistics. *2011 Census Data*. Canberra: ABS, 2018 (updated 17 July 2017). http://www.abs.gov.au/web_sitedbs/censushome.nsf/home/historicaldata2011 (10 May 2019, date last accessed).
15. Blakely T, Disney G, Atkinson J, Teng A, Mackenbach JP. A typology for charting socioeconomic mortality gradients: ‘Go Southwest’. *Epidemiology* 2017; **28**:594–603.
16. Australian Bureau of Statistics. *1351.0.55.058—Research Paper: Death Registrations to Census Linkage Project—a Linked Dataset for Analysis*. Canberra: ABS, 2016.
17. UNESCO. *International Standard Classification of Education ISCED 2011*. Montreal: UNESCO Institute for Statistics, 2012.
18. Australian Bureau of Statistics. *Socio-Economic Indexes for Areas (SEIFA)—Technical Paper, 2011, Cat. No. 2039.0.55.001*. Canberra: ABS, 2013.
19. Mackenbach JP, Kunst AE. Measuring the magnitude of socioeconomic inequalities in health: an overview of available measures illustrated with two examples from Europe. *Soc Sci Med* 1997; **44**:757–71.
20. Braveman P. Health disparities and health equity: concepts and measurement. *Annu Rev Public Health* 2006; **27**:167–94.
21. 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.
22. Wilkins R, Tjepkema M, Mustard C, Choinière R. The Canadian census mortality follow-up study, 1991 through 2001. *Health Rep* 2008; **19**:25–43.
23. Fawcett J, Blakely T, Kunst A. Are mortality differences and trends by education any better or worse in New Zealand? A comparison study with Norway, Denmark and Finland, 1980–1990s. *Eur J Epidemiol* 2005; **20**:683–91.
24. Arroyave I, Burdorf A, Cardona D, Avendano M. Socioeconomic inequalities in premature mortality in Colombia, 1998–2007: the double burden of non-communicable diseases and injuries. *Prev Med* 2014; **64**:41–7.
25. Stirbu I, Kunst AE, Bopp M *et al*. Educational inequalities in avoidable mortality in Europe. *J Epidemiol Community Health* 2010; **64**:913–20.
26. Kumar M, Evra R. *Linking the 2006 Census of Population to the Canadian Mortality Database: Descriptive and Validation Study*. Ottawa: Statistics Canada, 2018. Contract No.: Catalogue no. 11–633-X—No. 014.
27. Alicandro G, Frova L, Sebastiani G, Boffetta P, La Vecchia C. Differences in education and premature mortality: a record linkage study of over 35 million Italians. *Eur J Public Health* 2018; **28**:231–37.
28. Renard F, Gadeyne S, Devleeschauwer B, Tafforeau J, Deboosere P. Trends in educational inequalities in premature mortality in Belgium between the 1990s and the 2000s: the contribution of specific causes of deaths. *J Epidemiol Community Health* 2017; **71**:371–80.
29. Kalediene R, Prochorskas R, Sauliune S. Socio-economic mortality inequalities in Lithuania during 2001–2009: the record linkage study. *Public Health* 2015; **129**:1645–51.
30. Disney G, McDonald A, Atkinson J, Blakely T. *New Zealand Census Mortality and Cancer Trends Study Data Explorer*, 2016. <http://www.uow.otago.ac.nz/NZCMS-CT-dataexplorer> (10 May 2019, date last accessed).
31. Harper S, Lynch J. Health inequalities: measurement and decomposition. In: Oakes M, Kaufman J (eds). *Methods in Social Epidemiology*. San Francisco: Jossey Bass, 2017.
32. Bound J, Geronimus AT, Rodriguez JM, Waidmann TA. Measuring recent apparent declines in longevity: the role of increasing educational attainment. *Health Aff (Millwood)* 2015; **34**:2167–73.