

# Correcting for numerator/denominator bias when assessing changing inequalities in occupational class mortality, Australia 1981–2002

Gail M Williams,<sup>a</sup> Jake M Najman,<sup>b</sup> & Alexandra Clavarino<sup>a</sup>

**Objective** Comparisons of the changing patterns of inequalities in occupational mortality provide one way to monitor the achievement of equity goals. However, previous comparisons have not corrected for numerator/denominator bias, which is a consequence of the different ways in which occupational details are recorded on death certificates and on census forms. The objective of this study was to measure the impact of this bias on mortality rates and ratios over time.

**Methods** Using data provided by the Australian Bureau of Statistics, we examined the evidence for bias over the period 1981–2002, and used imputation methods to adjust for this bias. We compared unadjusted with imputed rates of mortality for manual/non-manual workers.

**Findings** Unadjusted data indicate increasing inequality in the age-adjusted rates of mortality for manual/non-manual workers during 1981–2002. Imputed data suggest that there have been modest fluctuations in the ratios of mortality for manual/non-manual workers during this time, but with evidence that inequalities have increased only in recent years and are now at historic highs.

**Conclusion** We found that imputation for missing data leads to changes in estimates of inequalities related to social class in mortality for some years but not for others. Occupational class comparisons should be imputed or otherwise adjusted for missing data on census or death certificates.

**Keywords** Mortality/trends; Socioeconomic factors; Occupational health; Australia (*source: MeSH, NLM*).

**Mots clés** Mortalité/orientations; Facteur socioéconomique; Hygiène professionnelle; Australie (*source: MeSH, INSERM*).

**Palabras clave** Mortalidad/tendencias; Factores socioeconómicos; Salud ocupacional; Australia (*fuentes: DeCS, BIREME*).

## Arabic

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Voir page 202 le résumé en français. En la página 203 figura un resumen en español.

## Introduction

While there is consistent evidence for socioeconomic inequalities in mortality in Australia,<sup>1,2</sup> studies that seek to “track” the changing magnitude of those inequalities over time confront substantial methodological problems. Data on occupational categories and on area characteristics have been used to assess changes related to social class in mortality over time. Occupational data have provided the longest time-series which, for England and Wales, provide comparisons from 1921 to the 1990s.<sup>3</sup> These data point to substantial temporal changes in class-related inequalities in mortality in England and Wales, with inequalities being lowest during the 1940s and increasing since that time.

The validity of data on occupational mortality has, however, been a source

of increasing concern. The basis of this concern involves changes in patterns of workforce participation over time (for example, in recent years there has been a substantial reduction in the number and proportion of manual workers in the workforce). Time-related changes in patterns of employment are likely to be associated with time-related changes in the numerator and denominator used to calculate rates of occupational mortality. Numerator/denominator bias in studies comparing socioeconomic inequalities in mortality over time has been described by a number of researchers.<sup>4–6</sup> The main concern involves the different criteria used to record occupation at census and on death certificates. The number of persons “exposed” is derived from successive censuses. In Australia (and generally else-

where), the relevant census question notes the current occupation, which is ascribed a class (or socioeconomic) category. In contrast, occupation as recorded at death certification is based on the last known (or, depending upon particular government requirements, sometimes “usual”) occupation of the deceased.

Class inequalities in mortality are likely to reflect changes in the rate of workforce participation over time, particularly if those persons who are out of the workforce are disproportionately from a particular socioeconomic group. Changing demographic trends in Australia clearly point to a substantial increase in female employment over time, to changes in the types of work available and to an increase in the numbers of people who have left the

<sup>a</sup> School of Population Health, University of Queensland, Brisbane, Australia.

<sup>b</sup> Schools of Population Health and Social Science, University of Queensland, Brisbane, Australia. Correspondence to this author (j.najman@uq.edu.au).

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Table 1. Australian male population (workforce) by age and occupation category, as recorded in successive censuses

Year	Age group (years)	Occupation category (%)			Total (n)
		Non-manual	Manual	Not currently employed <sup>a</sup>	
1981	15–24	21.7	41.8	36.5	1 273 121
	25–59	42.2	43.2	14.7	3 233 099
	60–64	22.9	25.0	52.1	287 588
1986	15–24	19.6	37.4	43.0	1 321 714
	25–59	42.7	38.9	18.4	3 548 109
	60–64	20.0	10.0	60.1	341 142
1991	15–24	18.8	30.7	50.5	1 346 893
	25–59	41.2	33.8	25.1	3 912 445
	60–64	21.1	19.5	59.4	354 792
1996	15–24	21.2	30.6	48.2	1 321 378
	25–59	44.1	32.1	23.7	4 272 781
	60–64	22.6	15.6	61.8	343 022
2001	15–24	23.2	28.7	48.2	1 331 877
	25–59	44.4	32.0	23.6	4 566 383
	60–64	25.4	17.3	57.3	398 207

<sup>a</sup> Includes unemployed and those who could not be classified as either non-manual and manual workers on information available.

workforce, or are not attached to it on a full-time basis.<sup>7</sup> All of these changes may have an impact on comparisons of class-related inequalities in mortality over time. For example, in periods of high unemployment, there would be a decrease in the number of people employed in particular occupations, but no commensurate decrease in the number of deaths of persons previously employed in those occupations. An occupation may be included on the death certificate (because the person was employed in the past), but the same person may not be described as employed according to their replies to questions about occupation on the census (e.g. unemployed, retired). The effect of such a bias could be to inflate the rate of mortality for the most economically disadvantaged groups of people in periods of higher unemployment.

De Looper & Magnus<sup>2</sup> provide the longest time-series trends in male mortality by occupational group available in Australia. Comparing age-standardized mortality ratios for 1966–2001, they found that the rate of mortality for male manual workers in 1966 was 20% higher than that for non-manual workers and that this difference had increased to 60% by 2001.<sup>2</sup> The rate of increase was not steady over this period of time; there was a narrowing

of “class” inequalities in the mid 1990s. Of course, it would be useful to know whether these inequalities were affected by the changing demographic patterns in Australia during this time period.

This paper uses data derived from the Australian Bureau of Statistics to develop a method for calculating imputed age-standardized rates of occupational class mortality for the Australian male workforce over the period 1981–2002. All data are derived from official collections by the Australian Bureau of Statistics during 1981–2002.

## Methods

The Australian Bureau of Statistics provided the numbers of cause-specific deaths in each year (1981–2002 inclusive) and population counts for each census year (1981, 1986, 1991, 1996 and 2001) for males only, by age and occupation group. Population counts for non-census years were estimated by assuming a constant annual rate of population growth between census years within each age–occupation group, calculating this rate from the census data, and applying this to each non-census year. Rates were standardized to the population age distribution of Australian males in 1996.

Population (denominator) data are limited to those persons in the labour force. The labour force is defined as persons aged 15 years and above who are employed, or who are looking and available for work.<sup>8</sup> Occupation as described

Table 2. All-cause male deaths, Australia (selected years)<sup>a</sup>

Year	Age group (years)	Occupation category (%)			Total (n)
		Non-manual	Manual	Not currently employed <sup>a</sup>	
1981	15–24	14.6	59.2	26.2	1 830
	25–59	28.6	47.1	24.3	13 170
	60–64	25.8	36.8	37.4	5 786
1986	15–24	15.1	50.1	34.9	1 772
	25–59	30.6	45.9	23.5	11 828
	60–64	25.6	40.8	33.6	6 307
1991	15–24	14.6	42.1	43.2	1 524
	25–59	35.9	44.5	19.6	11 341
	60–64	33.4	42.2	24.4	5 659
1996	15–24	14.6	42.1	43.2	1 407
	25–59	35.9	44.5	19.6	11 433
	60–64	33.4	42.2	24.4	4 636
2001	15–24	15.1	36.9	48.0	1 122
	25–59	32.0	41.9	26.1	11 205
	60–64	30.4	35.8	33.7	4 280

<sup>a</sup> Not employed, or insufficient information to allocate occupational code from death certificate.

on death certificate (numerator) data are derived, in Australia, from information generally supplied by the next-of-kin and includes details of the most recent or usual occupation (this varies according to Australian state). Between 1981 and 2002, changes in the definition of numerator and denominator have occurred. This may introduce error or bias into comparisons of occupational mortality over time.

Occupations for males were grouped into two categories — non-manual and manual workers. The residual category, which comprised those not currently employed and those unemployed, was only used for imputation. Between 1981 and 2001, there have been substantial changes in the workforce (Table 1). While the male “workforce” has increased at each successive census, this increase primarily comprises persons not currently in paid employment and, to a lesser extent, non-manual workers. Of the approximately 1.5 million males that have joined the workforce since 1981, well over half (858 629 men) were classified as not currently employed. In 1981, males not currently employed constituted 22.7% of the male population. By 2001, males not currently employed comprised 30.9% of the male population.

In contrast, the number of male deaths over the same period of time declined from 20 786 in 1981 to 16 607 in 2001 (Table 2). Males not employed comprised 28.1% of the male deaths in 1981 and 29.5% in 2001.

Table 3 presents age and year by per-

centage of census population and deaths for males classified as not (currently) employed for the five successive census collections from 1981 to 2001.

Two features of Table 3 are important. Firstly, for the age group 15–24 years, more recent census data indicate that almost half the population are out of the workforce, an increase of about one third since 1981. Interestingly, for the same age group, the number of deaths of persons categorized as not (currently) employed has almost doubled. The age group 60–64 years is also of concern; the percentage of males not (currently) employed in the population is almost twice that of male deaths similarly classified. The data suggest that changes in the numerator and denominator for men not (currently) employed over the period 1981 to 2001 are substantial for those men aged 15–24 years, and that there remain major concerns regarding the classification of males aged 60–64 years. To enable consistent comparisons of socioeconomic inequalities in mortality over time to be made, it would seem appropriate to limit the comparisons to men aged 25–59 years.

Even if comparisons are limited to the age group 25–59 years, the proportion of males not (currently) employed varies over time depending upon whether one is considering census numbers or death registrations. However, these variations are not as great as in the other age groups, and could be addressed by making imputations based upon other available data.

Given that the relative proportion of the population and deaths of those not (currently) employed varies over time, how might these variations affect estimates of inequalities in mortality? The Australian Bureau of Statistics publishes periodic workforce surveys that include questions related to the last job for persons no longer in the labour force. Such data are available for 1981–2002, in some instances disaggregated by the age of the respondent. An inspection of this data indicates that manual workers comprise about 60% of those not in the workforce. This percentage varies only slightly over the 22 years for which we have data. Using this workforce survey data, all males not in the workforce were proportionately redistributed (imputed) to manual or non-manual categories and all age-standardized rates of mortality were recalculated.<sup>1</sup>

## Results

Table 4 presents manual/non-manual mortality ratios for three sets of comparison. The first comparison is the “usual” presentation of age-standardized rates of mortality for males aged 15–64 years, excluding all males “out of the workforce”. While rates of mortality have decreased for both manual and non-manual workers, the decrease for non-manual workers is consistently greater. The second comparison is similar to the first, but with the exclusion of males aged 15–24 and 60–64 years. This exclusion has no apparent effect on trends in the relative mortality of manual/non-manual workers over time. The third comparison is for males aged 25–59 years with inclusion of those “out of the workforce”. Imputation is used to reallocate those males who in either the numerator or denominator are categorized as not (currently) employed. It is interesting to note here that this process has only a marginal impact on the age-standardized rates of mortality in recent years. However, this process of imputation clearly has a substantial impact on rates of mortality at some times (e.g. in the early 1980s and in the early 1990s) when there were substantial shifts in the relative proportion of males in the numerator and denominator who were not in the workforce. The overall consequence of this process of adjustment for those not in the workforce is to reduce the magnitude of manual/non-manual

Table 3. Age and year by percentage of census population and deaths for males not currently employed

Year		Age group (years)		
		15–24	25–59	60–64
1981	Population	36.5	14.7	52.1
	Deaths	26.2	24.3	37.4
1986	Population	43.0	18.4	60.1
	Deaths	34.9	23.5	33.6
1991	Population	50.1	25.1	59.4
	Deaths	43.2	19.6	24.4
1996	Population	48.2	23.7	61.8
	Deaths	44.8	20.2	21.9
2001	Population	48.2	23.6	57.3
	Deaths	48.0	26.1	33.7

Table 4. Rates of all-cause mortality (per 100 000 population per year) for Australian males in the workforce, according to occupational class

Year	All ages, 15–64 years		Ages 25–59 years		Ages 25–59 years	
	ASMR <sup>a</sup>		ASMR		Imputed <sup>b</sup> ASMR	
	Manual	Non-manual	Manual	Non-manual	Manual	Non-manual
1981	535.2	364.4	443.5	294.0	480.8	304.9
1982	554.0	366.1	455.6	288.6	478.0	294.0
1983	523.3	350.2	415.6	277.5	444.1	285.3
1984	494.1	337.5	392.7	263.4	419.1	269.9
1985	532.6	348.8	414.8	261.2	435.6	265.7
1986	554.2	348.0	411.9	263.0	411.8	260.3
1987	570.3	368.7	432.1	270.5	406.3	259.8
1988	555.3	359.2	426.0	261.0	407.4	252.2
1989	569.7	350.7	440.0	259.8	399.6	245.5
1990	564.0	360.4	436.1	270.8	372.4	249.4
1991	534.0	366.4	419.4	279.1	347.4	252.3
1992	553.6	349.5	423.8	263.9	348.2	238.1
1993	542.3	335.7	411.3	259.5	334.9	233.1
1994	544.0	328.9	407.5	247.9	333.8	224.3
1995	544.9	314.3	405.8	239.7	330.9	217.0
1996	542.7	290.0	399.4	224.0	335.1	206.1
1997	542.7	267.3	379.6	210.4	334.4	197.1
1998	569.4	241.9	373.8	196.5	338.1	186.2
1999	434.5	230.5	362.1	190.3	331.1	181.3
2000	411.8	206.4	346.5	177.3	325.5	171.4
2001	389.2	208.3	346.5	177.3	325.5	171.4
2002	375.2	205.4	316.8	169.7	298.0	164.3

<sup>a</sup> ASMR, age-standardized mortality rate.

<sup>b</sup> Imputed for males not (currently) employed.

inequalities in mortality for some of the years being compared.

Table 5 presents the manual/non-manual mortality ratios for 1981–2002. These parallel the findings in Table 4, suggesting that restricting the manual/non-manual comparison to males aged 25–59 years makes no material difference to the findings, while the reallocation of those “out of the workforce” to manual/non-manual categories changes some of the estimates of mortality inequalities but not others. The effect of imputation is to suggest that inequalities in mortality of manual/non-manual workers were not as great as indicated in other estimates, nor did they increase in the way that these estimates suggested. Taking the mean ratios as a guide, for the age group 15–64 years the ratio of manual to non-manual mortality has increased from 1.53 in the 1980s to 1.73 in the 1990s and to 1.90 in 2000–02. Imputation for the “not (currently) in employment” group suggests that there was little change in socioeconomic inequalities in

mortality ratios in the 1980s and 1990s, but an increase in the period 2000–02. The data are consistent in suggesting that socioeconomic inequalities in occupational mortality are at historic highs.

## Discussion

Changes in socioeconomic inequalities in mortality are a way of monitoring the overall consequences of the social, economic and political changes that occur in a society. Despite concerns with numerator/denominator bias associated with estimates of occupational mortality over time, unadjusted data continue to be published.<sup>1,2</sup> Without adjustment, some findings are likely to be misleading.

In order to understand the impact of changes in the numerator/denominator over time, we have presented three sets of mortality calculations. Firstly we have presented age-standardized rates of mortality for males aged 15–64 years. These indicate that while there has been a decline in rates of mortality for manual and non-manual

workers, the decline for non-manual workers has been substantially greater. The data here points to a linear increase in manual/non manual mortality ratios during 1981–2002. This finding is consistent with recent publications.<sup>1,2</sup>

Secondly, we compared age-standardized mortality rates for males aged 25–59 years. The exclusion of those aged 15–24 and 60–64 years was intended to address the two age groups containing the largest proportions of males who were out of the workforce, and for which concerns about numerator/denominator were most evident. Restricting comparisons to those aged 25–59 years, in effect, produces identical findings to those derived without the exclusion of these age groups.

Thirdly, for the age group 25–59 years, we have presented imputed age-standardized mortality rates and ratios. The process of imputation involved redistributing those males not in the workforce both in the numerator and denominator according to proportions derived from national workforce surveys

of those “out of the workforce”. Here the effect of imputation was to change estimates of mortality inequalities in the early 1980s, and 1990s, with the consequence that there is little evidence for changes in mortality inequality between manual/non-manual workers until the late 1990s and early 2000s. Overall, one could still conclude that there had been increasing occupational class mortality inequalities over the period 1981–2002, but with the caveat that the increases were of a modest magnitude and only evident from about 1998 onwards.

## Conclusion

There is evidence that numerator/denominator bias influences comparisons of rates of socioeconomic (occupational) mortality over time. While all estimates of socioeconomic inequalities in mortality are affected by the different ways in which the census and death certificates derive occupational data, the magnitude of this effect changes over time, rendering comparisons subject, in some instances, to substantial bias. This paper presents a method for imputing occupational categories to those not (currently) employed, arguably minimizing the impact of the occupational coding problems noted above. The imputed data broadly confirm the findings derived from the non-imputed data, although the former differ in a number of specific details. ■

**Competing interests:** none declared.

Table 5. All-cause mortality ratios for manual/non-manual workers, Australian males in the workforce

Year	All ages, 15–64 years	Ages 25–59 years	Ages 25–59 years
	ASMR <sup>a</sup>	ASMR	Imputed <sup>b</sup> ASMR
1981	1.47	1.51	1.58
1982	1.51	1.58	1.63
1983	1.49	1.50	1.56
1984	1.46	1.49	1.55
1985	1.53	1.59	1.64
1986	1.59	1.57	1.58
1987	1.55	1.60	1.56
1988	1.55	1.63	1.62
1989	1.62	1.69	1.63
1990	1.56	1.61	1.49
1991	1.46	1.50	1.38
1992	1.58	1.61	1.46
1993	1.62	1.58	1.44
1994	1.65	1.64	1.49
1995	1.73	1.69	1.52
1996	1.87	1.78	1.63
1997	2.03	1.80	1.70
1998	1.94	1.90	1.82
1999	1.89	1.90	1.83
2000	1.99	1.95	1.90
2001	1.87	1.95	1.90
2002	1.83	1.87	1.81
Mean, 1981–89	1.53	1.57	1.59
Mean, 1990–99	1.73	1.70	1.58
Mean, 2000–02	1.90	1.92	1.87

<sup>a</sup> ASMR, age-standardized mortality rate.

<sup>b</sup> Imputed for males not (currently) employed.

## Résumé

### Correction du biais lié au rapport numérateur/dénominateur dans l'appréciation de l'évolution des inégalités en matière de mortalité professionnelle liées à la classe sociale en Australie pendant la période 1981-2002

**Objectif** L'un des moyens de suivre la progression vers les objectifs fixés au plan de l'équité consiste à comparer les différents modes d'évolution des inégalités en matière de mortalité professionnelle. Malheureusement, dans les comparaisons effectuées jusqu'ici, on n'a pas corrigé le biais lié au rapport numérateur/dénominateur qui tient au fait que les données professionnelles ne sont pas enregistrées de la même manière sur les certificats de décès et les formulaires de recensement. La présente étude a pour objet d'évaluer l'influence de ce biais sur l'évolution des taux et des ratios de mortalité.

**Méthodes** En nous basant sur les données fournies par l'Office australien de la statistique (Australian Bureau of Statistics), nous avons recherché des preuves d'un tel biais dans les données relatives à la période 1981-2002 et procédé par imputation pour le corriger. Nous avons comparé les taux de mortalité non corrigés aux taux corrigés chez les travailleurs manuels et non manuels.

**Résultats** Selon les données non corrigées, il y a eu augmentation

des inégalités dans les taux de mortalité corrigés de la structure d'âge entre les travailleurs manuels et les travailleurs non manuels au cours de la période 1981-2002. Selon les données imputées il semblerait qu'en fait les ratios de mortalité des travailleurs manuels et non manuels n'aient présenté que de modestes fluctuations pendant cette période, les inégalités n'ayant progressé qu'au cours des dernières années pour atteindre aujourd'hui un sommet historique.

**Conclusion** Nous avons constaté que l'imputation des données manquantes a pour effet de modifier l'estimation des inégalités en matière de mortalité qui sont liées à la classe sociale et ce, pour certaines années mais pas pour d'autres. Si l'on veut faire des comparaisons entre catégories professionnelles, il faut procéder par imputation ou utiliser d'autres modes de correction pour traiter le problème des données manquantes dans les formulaires de recensement et les certificats de décès.

## Resumen

### Corrección del sesgo numerador/denominador en la evaluación de las desigualdades en mortalidad ocupacional, Australia, 1981–2002

**Objetivo** La comparación a lo largo del tiempo del perfil de las desigualdades en mortalidad ocupacional es una manera de controlar los objetivos de equidad. Sin embargo, en las comparaciones realizadas hasta ahora no se ha corregido el sesgo numerador/denominador que se produce como consecuencia de los distintos métodos utilizados para registrar los datos ocupacionales en los certificados de defunción y en los formularios de los censos.

**Métodos** Empleando datos proporcionados por la Oficina de Estadísticas de Australia, examinamos la evidencia de posibles sesgos durante el periodo 1981–2002 y aplicamos métodos de imputación para introducir los ajustes correspondientes. Comparamos las tasas de mortalidad no ajustadas con las imputadas para trabajadores manuales y no manuales.

**Resultados** Los datos no ajustados muestran una desigualdad creciente en las tasas de mortalidad ajustadas por edad para los trabajadores manuales y no manuales durante 1981–2002. Los datos imputados llevan a pensar que se han producido fluctuaciones moderadas de las razones de mortalidad para los trabajadores manuales y no manuales durante este tiempo, pero hay indicios de que las desigualdades han aumentado sólo en los últimos años y se encuentran ahora en máximos históricos.

**Conclusión** Hallamos que la imputación de datos faltantes altera las estimaciones de las desigualdades en mortalidad relacionadas con la clase social en algunos años pero no en otros. Las comparaciones por clase ocupacional deberían realizarse tras imputar o ajustar de otro modo los datos que faltan en los censos o los certificados de defunción.

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