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Child mortality, socioeconomic position, and one-parent families: independent associations and variation by age and cause of death

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Background Although the association between child mortality and socioeconomic status is well established, it is unclear whether child mortality differences by socioeconomic position are present at all ages. The association of one-parent families with mortality, and whether any such association is due to associated low socioeconomic position, is also not clear.

Methods In all, 480 of 693 (69%) 0–14 year old deaths during 1991–1994 were linked to 1991 census records. Analyses were weighted to adjust for potential linkage bias.

Results There was approximately twofold higher mortality among the lowest compared with the highest socioeconomic categories of education, income, car access, and neighbourhood deprivation. Occupational class differences were weaker. These socioeconomic differences in mortality were strongest among infants (particularly sudden infant death syndrome [SIDS] mortality), but similar across other age groups (1–4, 5–9, and 10–14 years). The socioeconomic differences were of a similar magnitude for unintentional injury, cancer, congenital, and other deaths. Multivariable analyses demonstrated persistent independent associations of education, income, car access, and neighbourhood deprivation with mortality. Rate ratios (adjusted for age and ethnicity) for one-parent families compared with two-parent or other families were 1.2 (95% CI: 1.0, 1.5) and 1.8 (95% CI: 1.2, 2.5) for all-cause and unintentional injury mortality, respectively. Further adjustment for socioeconomic factors reduced these associations to 0.8 (95% CI: 0.6, 1.2) and 1.2 (95% CI: 0.7, 2.2), respectively.

Conclusions There does not appear to be notable variation in relative risk terms of socioeconomic differences in child mortality by age or cause of death. Any association of one-parent families with child mortality is due to associated low socioeconomic position.

Keywords Socioeconomic factors, mortality, child, income, single parent, New Zealand, deprivation

Lower socioeconomic position is associated with increased child mortality,[1–7] but the pattern is variable by cause of death, socioeconomic factor, and age group. By cause of death, socioeconomic differences for unintentional injury deaths are often more marked.[2,8–10] Some studies have found that the all-cause mortality gradient by parental occupational class among school age children is particularly weak, or even absent,[8,11,12] then reappears for 'own' socioeconomic position in early adulthood.[11] Such variation by age might be due to social mobility during childhood and adolescence as parental socioeconomic position wanes in importance as a predictor of health and a young adult's own socioeconomic trajectory

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becomes more important. On examining the possible theoretical processes of equalization in early youth, West[11] argues that the:

> … effects associated with the secondary (high) school, the peer group and youth culture cut across those of the family, home background, and neighbourhood in such a way as to reduce or remove class differences in health. (ref. 11, p. 833)

However, this variation by age is far from conclusive. First, some of the UK evidence relies on unlinked census and mortality data that are prone to numerator—denominator bias,[11] and the studies based on linked census—mortality data are prone to imprecision.[12] Second, occupational class is just one measure of socioeconomic position and many children are often unable to be assigned a class.[3] Third, some of the argument for smaller occupational class differences in mortality is based on smaller absolute differences in mortality during school age.[11] However, 1991–1993 mortality data for England and Wales demonstrates social class mortality gradients in *relative risk terms* during all ages of childhood, although arguably more so among 1–4 year olds than 5–9 and 10–14 year olds.[1]

Children in one-parent families have also been found to have elevated mortality compared with other children[3,9,13] for which the underlying causal mechanisms might be material deprivation, unsafe living environments, and social isolation that may accompany sole parenting.[14] Interestingly, Ostberg[9] simultaneously analyses one-parent families, social class, and other structural factors and finds an independent association of one-parent families with injury deaths but not with non-injury deaths. The reduction in the differential in British infant mortality between the babies of lone mothers and couples has been confined to the neonatal period which suggests the improvement has been more to do with healthcare factors than changes in social and economic factors.[5]

Disentangling the socioeconomic determinants of child mortality is difficult due to death among children being relatively uncommon in developed countries and limited data on child mortality by socioeconomic factors. Few studies measure the association of income with child mortality. The independent effects of socioeconomic position and one-parent families on child mortality are unclear. The New Zealand census collects information on a range of social factors such as income, education, occupational class, car access, small-area deprivation, and family type (i.e. one- and two-parent families). The record linkage of 1991 census and 1991–1994 mortality data, therefore, allows a statistically powerful and unique opportunity to examine social differences in child mortality for the entire New Zealand population. In 1993 child mortality in New Zealand ranked high at 17 out of 21 for OECD countries, in contrast to previously favourable rankings during the 1960s. During the 1980s and 1990s there were rapid and extensive neo-liberal reforms implemented by successive governments in New Zealand, accompanied by a dramatic increase in various measures of inequality among children.[15]

The objectives of this paper are:

- to describe differences in child mortality across a range of socioeconomic and social factors: education, income, car access (a proxy measure of asset wealth and access to community resources[16]), occupational class, labour force status, family type, crowding, and neighbourhood socioeconomic deprivation
- to investigate possible heterogeneity of these differences by age and cause of death
- to investigate the independent effects of household socioeconomic position, neighbourhood deprivation, family type, and parental employment on child mortality.

Methods

Record linkage and census—mortality cohort

Census and mortality records were linked using anonymous and probabilistic methods described elsewhere.[17,18] The matching variables were sex, date of birth, ethnicity and country of birth, and area of residence. Briefly, 480 of 693 (69%) eligible deaths (i.e. children alive on census night, dying in the 3 years following census night and aged <15 years at death) were linked to one of 783 831 census respondents aged 0–14 years. There was no variation in linkage success by age and sex, some by ethnicity, and modest variation by neighbourhood socioeconomic deprivation (see below for details of deprivation index). Therefore, to prevent possible linkage bias in the subsequent cohort analyses we calculated weights so that the linked deaths were representative of all eligible deaths. The calculation of weights is described in detail elsewhere.[19] Briefly, mortality records were stratified according to sex, age, ethnicity, small-area deprivation, region, and cause of death. Within each stratum, the inverse of the proportion of deaths linked was applied as a weight to the linked deaths in the same stratum on the census cohort data-set. For example, if 20 out of 30 injury deaths for Mäori boys living in deprived small areas in the North of New Zealand were linked, these 20 linked deaths were each assigned a weight of 1.5 (30/20) on the cohort data-set.

Socioeconomic variables

The highest educational qualification of any adult in the household was categorized in the following hierarchical order: tertiary (e.g. university degree, nursing), trade (e.g. technical certificates), school (i.e. any school-based qualification), and nil qualifications. Total household income was equivalised using the 'Jensen Index', a New Zealand-specific equivalisation scale that allows for economies of scale in a household and the differential impact on household expenditure of children versus adults.[20] The highest occupational class of any adult in the household was assigned using the New Zealand Socio-Economic Index (NZSEI).[21] The NZSEI uses educational and income values for each occupation to assign a scaled occupational socioeconomic status and six occupational classes. Household car access was categorized as 0,1, or ⩾2 cars. Household labour force status was classified as: 'employed', if one or more adults were employed; 'unemployed', if one or more adults were unemployed (i.e. actively seeking work, and available to start work) and no adult was employed; or was otherwise classified as 'non-active' labour force. Two household composition variables were calculated: crowding (number of people per bedroom) and family type (one parent, and two parent and 'other'). Neighbourhood socioeconomic deprivation was assigned using the New Zealand Index of Deprivation (NZDep91). The components of this index measured for areas of approximately 100 people include

telephone access, car access, means-tested benefits, unemployment, income, one-parent families, qualifications, tenure, and crowding.[22,23]

We were able to assign categories of household education, car access, crowding, and family type to at least 98% of 0–14 year old census respondents at a usual and private residence on census night. However, a household income could only be reliably assigned if all adults were at their usual residence on census night, resulting in 19% of children having a missing household income value. Some 23% of children lived in a household where none of the adults had an occupation during the 4 weeks preceding census night, and therefore were not assigned a household occupational class.

Analyses

To be included in the analyses children had to be at their usual and private residence on census night with at least one adult in the household. This resulted in 742 587 children (94.7% of 0–14 year old census respondents) and 2 013 871 person years of follow-up. This 'full' cohort included 435 linked deaths that corresponded to 627 weighted deaths. The distribution of age and cause of death for the 435 linked deaths within the 'full' cohort are presented in Table 1. Multivariable analyses were restricted to the 566 673 children (76.3% of full cohort; 1 537 824 person years of follow-up) with complete data for all the above socioeconomic factors excluding occupational class. This restricted cohort for multivariable analyses included 309 linked deaths corresponding to 444 weighted deaths.

Analyses were conducted in SAS v8.0 using weighted Poisson regression. Analyses were conducted separately by strata of sex, age, and cause of death to investigate possible effect modification of socioeconomic differences in mortality. We used the general form of the Wald statistic to test the hypothesis of homogeneity of rate ratios across strata (ref. 24, pp. 275–77). The majority of analyses in this paper combine girls and boys for reasons of parsimony, precision, and stability of results, and because there had been no statistically significant presence of effect modification by sex (although such statistical tests tend to be under-powered). The sex of the child cannot confound the association of socioeconomic position and child mortality because although sex is strongly associated with mortality it is not associated with household socioeconomic position. Therefore, we did not control for sex in these combined analyses.

Table 1 Cause of death by sex and age among 435 deaths linked to a 0–14 year old census respondent who was at their usual and private dwelling on census night 1991

		Age (years)				
Cause of death	**Sex**	<1	1–4	5–9	10–14	0–14
Unintentional injury	M	6	33	27	33	93
(ICD codes 800–949)	F	6	24	24	12	63
RTC[a]	M	6	18	9	21	48
	F	6	12	15	9	39
Cancer	M	6	6	15	9	33
(ICD codes 140–209)	F	6	9	15	6	27
Other[b]	M	39	42	15	30	126
	F	18	24	27	24	93
All causes	M	39	84	54	75	252
	F	21	57	66	39	183

Numbers of deaths are random rounded to the nearest multiple of three (minimum released cell size 6) as per Statistics New Zealand protocol.

[a] Road traffic crash deaths (ICD codes 810–825) are also included in the unintentional injury totals.

[b] Other deaths include 39 sudden infant death syndrome deaths (24 males, 15 females; ICD code 798), 48 deaths due to congenital conditions (24, 24; ICD codes 740–759), 9 suicides (ICD codes 950–959, 980–989), and 12 pneumonia and influenza (ICD codes 480–487).

Results

All-cause mortality

There was an approximately twofold higher mortality rate among the lowest compared with the highest socioeconomic categories of education, equivalized household income (for boys only), car access, and area deprivation (Table 2). Regarding the apparent variation in the income association by sex, the reference group (>$50 000) had few deaths. If the <$10 000 group was treated as the reference group the rate ratios for the three middle income groups are more comparable between sexes (i.e. the $10 000–$19 999 level rate ratio for both girls and boys was 0.7, for $20 000–$29 999, 0.8 and 0.5 for girls and boys respectively, and for $30 000–$49 999, 0.5 and 0.6 respectively). Additionally, the Wald statistics testing homogeneity of the rate ratios between girls and boys were not statistically significant ($P > 0.10$) in all four non-referent income levels shown in Table 2.

Both girls and boys living in low occupational class households (classes 5&6) experienced a 40% higher mortality rate when compared with children from high occupational class households (classes 1&2; Table 2). The rate ratios for children living in a household with at least one unemployed adult, compared with at least one employed adult, were 1.9 (95% CI: 1.3, 2.6) for boys and 1.1 (95% CI: 0.7, 1.8) for girls. The Wald statistic comparing these two rate ratios was bordering on statistical significance ($P = 0.07$). There was no apparent association of child mortality with household crowding. The rate ratios for children living in a one-parent family compared with two-parent and other families was 1.3 (95% CI: 1.0, 1.6) for boys and 1.0 (95% CI: 0.7, 1.3) for girls, and there was not a statistically significant difference between boys and girls ($P = 0.15$).

All-cause mortality by age group

Table 3 shows rate ratios by aggregated levels of each socioeconomic factor across four age groups (<1 year, 1–4 years, 5–9 years, and 10–14 years). The education gradient for infant deaths appears stronger than for the three other age groups. To further investigate a possible differential association of socioeconomic position with child mortality according to age, we examined for possible heterogeneity in the rate ratios across age groups. Our null hypothesis that the education rate ratios are homogeneous across these four age groups was rejected ($P = 0.01$) for the nil compared with tertiary qualification rate ratios, but not rejected for the trade and school compared to tertiary rate ratios ($P = 0.23$). For other socioeconomic factors, there was a possible tendency towards stronger differences for infant mortality and weaker differences for 5–9 year old mortality. However, of all levels of the remaining socioeconomic factors, only the rate ratios for children in the $10 000–$29 999 household income group compared with the reference household

Table 2 Age- and ethnicity-adjusted rate ratios (95% CI) of 0–14 year old all-cause mortality by sex by: socioeconomic and labour force status of adults in the household, household composition, and small area deprivation

	Females				Males			
	Person years	Linked deaths	Weighted deaths	Rate ratio (95% CI)	Person years	Linked deaths	Weighted deaths	Rate ratio (95% CI)
Socioeconomic status of adults in household								
Highest adult qualification in household[a]								
Tertiary	295 497	33	45	1	308 459	63	84	1
Trade	272 460	60	84	2.0 (1.4, 3.0)	284 354	72	102	1.3 (0.9, 1.7)
School	218 187	39	57	1.6 (1.1, 2.5)	227 919	48	69	1.0 (0.7, 1.5)
Nil	194 529	48	72	2.3 (1.5, 3.5)	200 384	69	105	1.8 (1.3, 2.5)
Highest adult occupational class in household[a]								
Classes 1&2	205 904	27	39	1	214 643	36	51	1
Class 3	140 088	18	21	0.8 (0.5, 1.3)	145 382	24	33	0.9 (0.5, 1.3)
Class 4	150 989	27	42	1.3 (0.9, 2.1)	158 814	36	51	1.3 (0.9, 1.9)
Classes 5&6	214 764	42	63	1.4 (0.9, 2.1)	223 924	57	84	1.4 (1.0, 2.0)
No occupation	207 739	54	75	1.6 (1.0, 2.5)	215 298	78	111	1.9 (1.3, 2.8)
Equivalized household income								
⩾$50 000	90 474	15	21	1	95 335	12	21	1
$30–$49 999	180 161	21	27	0.8 (0.4, 1.4)	187 205	42	57	1.4 (0.8, 2.3)
$20–$29 999	198 082	33	51	1.1 (0.6, 1.9)	208 024	39	54	1.2 (0.7, 2.0)
$10–$19 999	254 583	45	66	1.0 (0.6, 1.7)	263 664	69	102	1.7 (1.0, 2.7)
<$10 000	74 029	21	30	1.4 (0.8, 2.7)	77 376	33	48	2.4 (1.4, 4.1)
Car access[a]								
⩾2	426 710	54	78	1	444 699	99	135	1
1	458 572	96	138	1.5 (1.1, 2.0)	477 842	102	147	1.0 (0.8, 1.4)
0	86 202	30	45	2.2 (1.4, 3.5)	89 213	48	75	2.6 (1.8, 3.7)
Labour force status of adults in household[a]								
⩾1 employed	760 079	126	177	1	792 957	174	246	1
⩾1 unemployed	74 428	15	21	1.1 (0.7, 1.8)	77 913	33	48	1.9 (1.3, 2.6)
All non-active	151 265	45	63	1.4 (0.9, 2.1)	155 455	48	69	1.3 (0.9, 1.9)
Small area socioeconomic deprivation[b]								
Quintile 1	185 852	24	33	1	193 510	33	45	1
Quintile 2	183 882	33	42	1.3 (0.8, 2.1)	191 557	30	42	1.0 (0.7, 1.6)
Quintile 3	180 841	24	33	0.9 (0.6, 1.5)	190 074	45	57	1.3 (0.9, 2.0)
Quintile 4	190 840	42	60	1.6 (1.0, 2.5)	198 298	45	69	1.6 (1.1, 2.4)
Quintile 5	244 353	63	93	1.8 (1.1, 2.7)	252 947	99	150	2.5 (1.7, 3.6)
Household composition								
People per bedroom (crowding)								
⩽1	240 878	45	63	1	248 340	60	87	1
>1–⩽1.5	398 327	63	93	1.0 (0.7, 1.3)	413 549	93	135	1.0 (0.7, 1.3)
>1.5–⩽2	271 734	54	78	1.0 (0.7, 1.4)	285 822	84	123	1.1 (0.8, 1.5)
>2	75 652	21	27	1.1 (0.7, 1.8)	79 569	15	21	0.7 (0.4, 1.1)
Family type								
2 parent and other	776 491	138	198	1	810 264	189	267	1
One parent	210 100	42	60	1.0 (0.7, 1.3)	217 016	66	99	1.3 (1.0, 1.6)

Numbers of deaths are random rounded to the nearest multiple of three (minimum released cell size 6) as per SNZ protocol, but rate ratios are calculated with exact data. Ethnicity was dichotomized as Mäori and Pacific combined versus non-Maori non-Pacific. The number of children included for each variable varies due to missing data.

[a] Also adjusts for number of adults in household.

[b] Quintile 1 is the least deprived, and quintile 5 is the most deprived.

income group (⩾$30 000) were statistically significantly different ($P = 0.02$). Whilst not included elsewhere in this paper, additional results for 15–19 year olds are presented in the final column of Table 3 for comparison. The 15–19 year old rate ratios tended to be intermediary between those for 5–9 and 10–14 year olds, except for car access and equivalized household income, where the 15–19 year old association was null.

Cause-specific mortality

Cancer, unintentional injury, congenital, and 'other' cause of death rate ratios for 0–14 year olds are shown in Table 4. All causes of death were associated with most socioeconomic factors, although CI were wide. There was a tendency towards a stronger association of socioeconomic factors with congenital deaths. However, within all levels of each socioeconomic factor the null hypothesis of homogeneity of the rate ratios across causes of death was not rejected (P-values all > 0.05), although P-values for 'trade or school' level of education, 'occupational classes 4, 5 & 6', households with 'one car', and 'one parent' family type ranged from 0.06 to 0.11. The final column shows the rate ratios for sudden infant death syndrome (SIDS) among infants. (Data was too sparse to analyse infant congenital deaths separately.) There was a tendency for strong socioeconomic differences in SIDS mortality—particularly by education. Given that SIDS deaths account for 64% of infant deaths, this probably explains the tendency to a stronger association of socioeconomic position with infant mortality (compared with other ages) shown in Table 3.

Table 3 Age-specific all-cause mortality rate ratios (95% CI) by socioeconomic position, labour force status, family type, and small area deprivation

	Age group (years)						
	<1	1–4	5–9	10–14	0–14[a]	1–14[a]	15–19
Highest qualification[b]							
Tertiary	1	1	1	1	1	1	1
Trade or school	2.3 (1.1, 4.8)	1.7 (1.2, 2.6)	1.1 (0.7, 1.7)	1.2 (0.8, 1.8)	1.4 (1.1, 1.8)	1.3 (1.1, 1.7)	1.2 (1.0, 1.4)
Nil	4.7 (2.1, 10.8)	2.7 (1.7, 4.3)	1.1 (0.7, 1.9)	1.6 (1.0, 2.5)	2.0 (1.5, 2.6)	1.8 (1.3, 2.3)	1.4 (1.1, 1.8)
Highest class[b,c]							
Classes 1 2 &3	1	1	1	1	1	1	1
Classes 4 5 &6	1.2 (0.7, 2.3)	1.8 (1.3, 2.7)	1.0 (0.7, 1.5)	1.7 (1.2, 2.5)	1.5 (1.2, 1.8)	1.5 (1.2, 1.9)	1.4 (1.2, 1.6)
No occupation	2.2 (1.1, 4.4)	2.1 (1.3, 3.3)	1.6 (1.0, 2.6)	1.8 (1.1, 2.9)	1.9 (1.5, 2.5)	1.8 (1.4, 2.4)	1.7 (1.3, 2.2)
Equivalized income							
⩾$30 000	1	1	1	1	1	1	1
$10–$29 999	0.8 (0.4, 1.5)	2.1 (1.3, 3.2)	1.2 (0.8, 1.8)	0.9 (0.6, 1.3)	1.2 (1.0, 1.5)	1.3 (1.0, 1.6)	1.1 (1.0, 1.4)
<$10 000	1.5 (0.7, 3.3)	3.1 (1.8, 5.6)	1.4 (0.8, 2.6)	1.5 (0.9, 2.7)	1.8 (1.3, 2.5)	1.9 (1.3, 2.6)	1.0 (0.7, 1.5)
Car access[b]							
⩾2	1	1	1	1	1	1	1
1	1.3 (0.7, 2.3)	1.3 (0.9, 1.8)	1.0 (0.7, 1.4)	1.3 (0.9, 1.9)	1.2 (1.0, 1.5)	1.2 (1.0, 1.5)	0.9 (0.8, 1.1)
0	3.9 (1.9, 8.2)	2.0 (1.2, 3.3)	1.7 (1.0, 3.0)	3.2 (1.8, 5.4)	2.4 (1.8, 3.2)	2.2 (1.6, 3.0)	1.1 (0.8, 1.6)
Labour force status[b]							
⩾1 employed	1	1	1	1	1	1	1
Nil employed	1.9 (1.1, 3.3)	1.3 (0.9, 2.0)	1.7 (1.2, 2.6)	1.0 (0.6, 1.6)	1.4 (1.2, 1.8)	1.4 (1.1, 1.7)	1.4 (1.1, 1.7)
Area deprivation[d]							
Deciles 1–5	1	1	1	1	1	1	1
Deciles 6–10	2.0 (1.1, 3.4)	1.5 (1.1, 2.1)	1.2 (0.8, 1.6)	1.9 (1.3, 2.7)	1.5 (1.3, 1.9)	1.5 (1.2, 1.8)	1.3 (1.1, 1.6)
Family type							
2 parent and other	1	1	1	1	1	1	1
One parent	1.6 (1.0, 2.6)	1.3 (0.9, 1.8)	1.1 (0.7, 1.5)	0.9 (0.6, 1.3)	1.1 (0.9, 1.4)	1.1 (0.9, 1.3)	1.2 (1.0, 1.4)

All analyses are adjusted for ethnicity.

[a] Adjusted for age.

[b] Adjusts for number of adults in household.

[c] Average NZSEI score of occupations held by adults in household <50 (low and medium low) and >50 (medium-high to high).

[d] Deciles 1 to 5 are the least deprived half of the population, and deciles 6 to 10 the most deprived.

Multivariable analyses

Table 5 presents the rate ratios for each socioeconomic factor controlling for age and ethnicity and for a multivariable model that adjusts for all other variables in the Table. We explored the possibility of selection bias by comparing the single variable rate ratios of all-cause and injury mortality for nil qualifications and car access in the restricted cohort (Table 5) with the comparable rate ratios in the full cohort (Table 3; at least 98% of children had non-missing data for these variables in the full cohort). The patterns for these variables were similar, arguing against selection bias. However, the one-parent rate ratio for injury increases from 1.3 in the full cohort (Table 4) to 1.8 in the restricted cohort (Table 5) suggesting some selection bias.

For all-cause mortality, the multivariable model demonstrated an independent effect of nil qualification, nil car access, and a remaining gradient of mortality across levels of area deprivation, and is suggestive of an independent association with very low income (rate ratio 1.4, 95% CI: 0.9, 2.3). However, household labour force status had no independent association with mortality and the modest 20% higher mortality among one-parent families became a 20% lower mortality—but CI included 1.0 in both instances. The pattern of multivariable rate ratios for unintentional injury deaths had some variations: education was no longer an independent predictor; there was an independent gradient across income levels; and what was a notable association of one-parent families, adjusting for just age and ethnicity (rate ratio 1.8, 95% CI: 1.2, 2.5), became a null association in the multivariable analyses (1.2, 95% CI: 0.7, 2.2). Regarding one-parent families and injury deaths, controlling for the potential confounder education (in addition to age and ethnicity) reduced the rate ratio from 1.8 to 1.5 (95% CI: 0.8, 2.5). Further control for income (as a potential mediating variable) did not further reduce the rate ratio.

Discussion

This study confirms the general observation that the socioeconomic circumstances of children's lives influence their health.[1,4,25,26] Because of the large study size and range of social factors our study adds specific information. First, our estimate of a 40% greater mortality among low compared with high occupational classes is consistent with that found by occupational class in other countries.[1,2,8] However, the socioeconomic differences in our study were stronger for the other measures of parental or household socioeconomic position—education, income, car access, and neighbourhood deprivation. There was a suggestion of a social exclusion or poverty effect over and above a background gradient of mortality for these socioeconomic factors. Child mortality steadily increased with decreasing socioeconomic position but then tended to jump

Table 4 Cause-specific mortality rate ratios (95% CI) by socioeconomic position, labour force status, family type, and small area deprivation

Cause of death	All-causes	Unintentional injury	Cancer	Congenital	Other	SIDS[a]
Age group (years)	0–14	0–14	0–14	0–14	0–14	<1
Highest qualification[b]						
Tertiary	1	1	1	1	1	1
Trade or school	1.4 (1.1, 1.8)	1.1 (0.8, 1.6)	1.4 (0.8, 2.5)	3.9 (1.6, 9.5)	1.4 (1.0, 2.0)	4.3 (1.3, 14.6)
Nil	2.0 (1.5, 2.6)	1.6 (1.0, 2.4)	2.0 (0.9, 4.1)	4.1 (1.5, 11.4)	2.1 (1.4, 3.3)	7.9 (2.1, 29.1)
Highest class[b,c]						
Classes 1 2 &3	1	1	1	1	1	1
Classes 4 5 &6	1.5 (1.2, 1.8)	1.5 (1.1, 2.2)	1.3 (0.7, 2.3)	3.3 (1.5, 6.9)	1.2 (0.9, 1.7)	1.7 (0.7, 4.3)
No occupation	1.9 (1.5, 2.5)	1.6 (1.1, 2.5)	2.7 (1.4, 5.2)	2.6 (1.0, 6.5)	1.9 (1.3, 2.8)	3.2 (1.2, 8.2)
Equivalized income						
⩾$30 000	1	1	1	1	1	1
$10–$29 999	1.2 (1.0, 1.5)	1.4 (1.0, 2.1)	1.3 (0.7, 2.3)	1.5 (0.7, 3.0)	0.9 (0.7, 1.3)	0.5 (0.2, 1.2)
<$10 000	1.8 (1.3, 2.5)	2.3 (1.4, 3.8)	1.3 (0.5, 3.5)	2.6 (1.0, 6.5)	1.5 (0.9, 2.4)	1.8 (0.7, 4.3)
Car access[b]						
⩾2	1	1	1	1	1	1
1	1.2 (1.0, 1.5)	1.0 (0.8, 1.4)	1.5 (0.9, 2.5)	2.6 (1.4, 5.0)	1.1 (0.8, 1.5)	1.2 (0.5, 2.5)
0	2.4 (1.8, 3.2)	2.2 (1.4, 3.5)	2.4 (0.9, 6.0)	2.4 (0.9, 6.8)	2.6 (1.7, 4.0)	3.6 (1.4, 9.1)
Labour force status[b]						
⩾1 employed	1	1	1	1	1	1
Nil employed	1.4 (1.2, 1.8)	1.2 (0.9, 1.8)	2.2 (1.2, 4.0)	1.0 (0.5, 2.0)	1.6 (1.1, 2.2)	2.3 (1.2, 4.7)
Area deprivation[d]						
Deciles 1–5	1	1	1	1	1	1
Deciles 6–10	1.5 (1.3, 1.9)	1.6 (1.2, 2.1)	1.0 (0.6, 1.7)	1.3 (0.7, 2.2)	1.9 (1.4, 2.6)	2.7 (1.3, 5.7)
Family type						
2 parent and other	1	1	1	1	1	1
One parent	1.1 (0.9, 1.4)	1.3 (1.0, 1.8)	0.6 (0.3, 1.2)	0.8 (0.4, 1.5)	1.2 (0.9, 1.7)	2.1 (1.2, 3.8)

All analyses are adjusted for age and ethnicity.

[a] Sudden infant death syndrome.

[b] Adjusts for number of adults in household.

[c] Average NZSEI score of occupations held by adults in household less than 50 (low and medium low) and greater than 50 (medium-high to high).

[d] Deciles 1 to 5 are the least deprived half of the population, and deciles 6 to 10 the most deprived.

notably amongst the lowest socioeconomic strata. However, there was insufficient study power to make confident conclusions. We will further investigate this possibility of a threshold effect by pooling data from this study with recently linked census-mortality data for the 1981, 1986, and 1996 censuses in New Zealand.

Second, our findings are consistent with a strong association of socioeconomic factors with mortality at *all ages* in childhood supporting recent findings in the UK,[1] although the association was probably strongest for infant mortality (Table 3). Third, we found strong associations of a range of socioeconomic factors with unintentional injury and SIDS consistent with previous research.[27] We also found higher risks of childhood cancer and congenital death among lower socioeconomic households according to most socioeconomic factors—although 95% CI often included 1.0. It is unclear whether these findings for congenital and cancer deaths are due to varying incidence or case fatality rates by socioeconomic position.

Fourth, households with no adult in employment and one-parent families tended to be associated with increased child mortality adjusting for just age and ethnicity (Table 2), but controlling for socioeconomic position largely removed these associations (Table 5). Our analyses for household labour force status and one-parent families should be interpreted cautiously due to small effect sizes, statistical imprecision, possible residual linkage bias, and some apparent selection bias for the multivariable analyses of one-parent families and injury. Regarding linkage bias, all analyses in this paper used weights that allow for linkage of child deaths by small-area deprivation and demographic factors. We are confident that this weighting performs well to adjust for the (small) linkage bias by socioeconomic position.[17,19] However, we need to be more cautious regarding one-parent families as they are a residentially mobile population and our linkage success was highly dependent on geocodes. It is possible that we underestimated the association of one-parent families (and households with no adult in employment) with child mortality. However, the notable relative reductions in the rate ratios for one-parent families when controlling for other socioeconomic factors is a valid observation—even if we might have underestimated the actual rate ratios. Our two main conclusions are, first, that there is a modest association of one-parent families and parental unemployment with child mortality when controlling for just age and ethnicity. Second, any increased child mortality in these households and families appears to be due to correlated socioeconomic factors. For example, our multivariable analyses for one-parent families suggest that education was a notable confounder, however (somewhat surprisingly) income did not appear to explain much of this association over and above education.

Fifth, household crowding is a major independent risk factor for infectious disease morbidity,[28] but given that infection is not a major cause of death among children it does not emerge as an independent risk factor for mortality analyses.

Table 5 Multivariable mortality rate ratios (95% CI) for all-cause and unintentional injury among 566 673 children with complete data (1 537 824 person-years)

	All deaths		Unintentional injury deaths	
	Single socio-economic variable (controlling for age and ethnicity)	Multivariable (plus controlling for variables in Table)	Single socio-economic variable (controlling for age and ethnicity)	Multivariable (plus controlling for for variables in Table)
Education				
Tertiary	1	1	1	1
Trade	1.5 (1.2, 2.0)	1.4 (1.1, 1.9)	1.1 (0.7, 1.7)	1.0 (0.6, 1.5)
School	1.2 (0.9, 1.6)	1.0 (0.8, 1.4)	1.1 (0.7, 1.7)	0.9 (0.6, 1.5)
Nil	2.0 (1.5, 2.6)	1.5 (1.1, 2.1)	1.4 (0.9, 2.3)	1.1 (0.7, 1.8)
Income				
⩾$50 000	1	1	1	1
$30–$49 999	1.1 (0.7, 1.6)	1.0 (0.6, 1.4)	1.6 (0.8, 3.5)	1.5 (0.7, 3.2)
$20–$29 999	1.2 (0.8, 1.8)	0.9 (0.6, 1.4)	1.9 (0.9, 4.0)	1.7 (0.8, 3.8)
$10–$19 999	1.4 (1.0, 2.0)	1.0 (0.6, 1.5)	2.3 (1.1, 4.8)	1.7 (0.8, 3.8)
<$10 000	2.1 (1.4, 3.3)	1.4 (0.9, 2.3)	3.3 (1.5, 7.4)	2.3 (0.9, 5.8)
Car access				
⩾2	1	1	1	1
1	1.3 (1.0, 1.6)	1.1 (0.9, 1.4)	1.2 (0.8, 1.8)	1.1 (0.7, 1.6)
0	2.4 (1.7, 3.3)	1.9 (1.3, 2.7)	2.5 (1.4, 4.3)	2.1 (1.2, 3.7)
Labour force				
⩾1 employed	1	1	1	1
⩾1 unemployed	1.4 (1.0, 2.0)	1.0 (0.7, 1.4)	1.3 (0.8, 2.3)	1.0 (0.5, 1.7)
All non-active	1.3 (0.9, 1.8)	0.9 (0.6, 1.2)	1.1 (0.7, 1.9)	0.8 (0.4, 1.4)
Area deprivation[a]				
Quintile 1	1	1	1	1
Quintile 2	1.3 (0.9, 1.9)	1.3 (0.9, 1.8)	1.5 (0.8, 2.7)	1.4 (0.7, 2.5)
Quintile 3	1.2 (0.9, 1.8)	1.1 (0.8, 1.7)	1.3 (0.7, 2.4)	1.1 (0.6, 2.2)
Quintile 4	1.9 (1.3, 2.7)	1.7 (1.2, 2.4)	2.8 (1.6, 4.8)	2.3 (1.3, 4.1)
Quintile 5	2.3 (1.6, 3.2)	1.8 (1.2, 2.6)	1.8 (1.0, 3.3)	1.3 (0.7, 2.5)
People/bedroom				
⩽1	1	1	1	1
>1–⩽1.5	1.1 (0.8, 1.4)	1.0 (0.8, 1.4)	0.9 (0.6, 1.3)	0.9 (0.6, 1.4)
>1.5–⩽2	1.2 (0.9, 1.5)	1.1 (0.8, 1.4)	0.5 (0.3, 0.9)	0.5 (0.3, 0.9)
>2	1.1 (0.7, 1.7)	0.9 (0.6, 1.4)	1.1 (0.6, 2.0)	1.1 (0.6, 2.2)
Family type				
2 parent	1	1	1	1
One parent	1.2 (1.0, 1.5)	0.8 (0.6, 1.2)	1.8 (1.2, 2.5)	1.2 (0.7, 2.2)

'Single socio-economic variable' results are all adjusted for age and ethnicity, and also adjusted for number of adults in the dwelling in the case of highest qualification, car access, and labour force status. All multivariable models adjust for age, ethnicity, and number of adults in the dwelling, in addition to variables shown in table. The total number of linked all-cause deaths was 309 (weighted = 444) and injury deaths was 105 (weighted 159).

[a] Quintile 1 is the least deprived, and quintile 5 the most deprived.

The final major finding of our study is the importance of small area socioeconomic deprivation on childhood mortality *over and above* individual or household level socioeconomic position as a predictor of childhood mortality. The association of small area socioeconomic deprivation with all-cause mortality was halved, but not removed, after adjusting for household socioeconomic position (Table 5). For example, the rate ratio for the most deprived quintile reduced from 2.3 (95% CI: 1.6, 3.2) to 1.8 (95% CI: 1.2, 2.6). While suggestive of an independent ecological or contextual effect of neighbourhood socioeconomic deprivation on childhood mortality, this finding is difficult to interpret due to possible residual confounding by household socioeconomic position.[29] Interestingly, the notable association of small area socioeconomic deprivation with unintentional injury death in the multivariable analyses (Table 5), taken together with other research demonstrating a differential distribution of environmental causes of childhood injury by socioeconomic position,[14,30] points to a true contextual effect of neighbourhood socioeconomic deprivation on child injury mortality.

It seems likely that the marked social inequalities in child mortality in New Zealand, accompanied by increasing social inequalities, are key explanations for the low ranking of child health status in New Zealand relative to other industrialized countries. Broad population-based policies (including education, social assistance, labour market, and taxation policies) are required to reduce social inequalities that, in turn, should reduce the health gradient.[31]

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SUMMARY STATISTICS NEW ZEALAND SECURITY STATEMENT

The New Zealand Census-Mortality Study (NZCMS) is a study of the relationship between socioeconomic factors and mortality in New Zealand, based on the integration of anonymized population census data from Statistics New Zealand and mortality data from the New Zealand Health Information Service. The project was approved by Statistics New Zealand as a Data Laboratory project under the Microdata Access Protocols in 1997. The data-sets created by the integration process are covered by the Statistics Act and can be used for statistical purposes only. Only approved researchers who have signed Statistics New Zealand's declaration of secrecy can access the integrated data in the Data Laboratory. (A full security statement is in a technical report at http://www.wnmeds.ac.nz/nzcms-info.html.) For further information about confidentiality matters in regard to this study please contact Statistics New Zealand.

KEY MESSAGES

- Socioeconomic position is associated with child mortality at all ages and for all major causes of child death.
- Four socioeconomic factors (household income, parental education, car access, and neighbourhood deprivation) were all strongly associated with child mortality, but the association of occupational class was weaker.
- Modest associations of household labour force status and family type (one-parent families) with child mortality are probably due to confounding by socioeconomic position.
- Neighbourhood socioeconomic deprivation had an independent association with child mortality over and above the contribution of household and parent socioeconomic position.

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