

# Seasonal patterns of mortality in relation to social factors

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Summary Statistics New Zealand Security Statement The New Zealand Census-Mortality Study is a study of the relation between social factors and mortality in New Zealand based on the integration of anonymised population census data from Statistics New Zealand and mortality data from the New Zealand Health Information Service. This project was approved by Statistics New Zealand as a Data Laboratory project under the Microdata Access Protocols in 1997. The datasets 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.

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## ABSTRACT

**Background** New Zealand is a temperate country with substantial excess winter mortality. We investigated whether this excess winter mortality varies with social factors.

**Methods** Records from New Zealand censuses in 1981, 1986, 1991, 1996 and 2001 were each anonymously and probabilistically linked to 3 years of subsequent mortality data creating five cohort studies of the New Zealand adult population (age 30–74 years at census) each with 3 years' follow-up. Logistic regression analysis was used to model the risk of dying in winter compared to summer with winter deaths classified '1' and summer deaths '0'. There were 75 138 eligible mortality records with complete data on social variables recorded for 58 683 (78%).

**Results** Adjusting for age, sex, census year, ethnicity and tenure, those in the lowest tertile of income were at increased risk of winter death compared to those in the highest tertile: OR 1.13 (95% CI 1.08 to 1.19). Compared to home owners, people living in rented accommodation were at greater risk of winter death: OR 1.05 (95% CI 1.01 to 1.10). Urban dwellers were also at significantly increased risk. The strongest associations were seen for infectious diseases.

**Conclusions** There was an increased risk of dying in winter for most New Zealanders, but more so among low-income people, those living in rented accommodation and those living in cities. Exact causal mechanisms are not known but possibly include correlated poorer health status, low indoor temperatures and household crowding.

## INTRODUCTION

The effect of outdoor temperature on seasonal patterns of mortality has been widely studied, especially in the UK.<sup>1–8</sup> The relation between daily temperature and mortality varies between countries.<sup>9</sup> In several temperate countries, associations between daily outdoor temperature and mortality appear to have weakened in recent decades.<sup>7 8 10–12</sup>

The complex and varying dose-response patterns of seasonal variations in mortality probably reflect a combination of physiological, social and cultural adaptations to the effects of temperature extremes.<sup>7</sup> The quality of the built environment is of particular interest as a potentially modifiable factor affecting vulnerability to temperature extremes. Well insulated<sup>13</sup> and efficiently heated<sup>14</sup> (or cooled) buildings, along with appropriate outdoor behaviour (especially clothing),<sup>1</sup> can reduce the 'biologically effective' exposure to adverse temperatures.

In temperate countries, mortality rates are typically 10–30% higher during the winter compared to the warmer months.<sup>2 3 6–9 15 16</sup> In New Zealand, the excess winter mortality has previously been reported to be 18%.<sup>16</sup> Excess winter mortality, which is largely attributed to cardiovascular and respiratory diseases, might be related to seasonal changes in ambient exposures (temperature, humidity, ultraviolet light, air pollution), diet, behaviour, infectious disease transmission and other unidentified exposures.<sup>17</sup> There is interest in identifying whether excess winter mortality is more pronounced among lower socio-economic groups, which would strengthen the policy case for place-based and income-targeted policies. The objective of this paper was to investigate social factors potentially associated with excess winter mortality in New Zealand. A priori, we expected ethnicity to modify excess winter mortality since there are strong socio-economic inequalities by ethnicity in New Zealand.

## METHODS

The New Zealand Census-Mortality Study is a population-wide series of cohort studies in which the cohort consists of the entire resident population and the outcome of interest is mortality.<sup>18</sup> Records from censuses in 1981, 1986, 1991, 1996 and 2001 were each anonymously and probabilistically linked to 3 years of subsequent mortality data creating five cohort studies of the New Zealand population each followed up for 3-year periods.<sup>19 20</sup> The proportion of mortality records linked ranged from 70–80% across the cohorts and an estimated 97% of these links are true links. The analysis was limited to those aged 30–74 years. Although all ages were included in the census, up until the 2001–2004 cohort, anonymous record linkage was only available for people aged less than 75 years on census night.

We assigned each respondent to a mutually exclusive ethnic group using a prioritisation system commonly used in New Zealand: Māori, if any one of the responses was Māori; of the remainder, Pacific if any one response was Pacific; of the remainder, Asian if any one response was Asian; and the remainder non-Māori, non-Pacific, non-Asian (mostly New Zealand European). Socioeconomic position was characterised as total household income, with adjustment for the number of children and adults in the household to allow for economies of scale using the Jensen index<sup>21</sup>; highest educational qualification (higher than secondary school, secondary school or none); and neighbourhood

deprivation measured by the NZDep index.<sup>22</sup> This index of deprivation within small geographic areas was calculated using census data on socioeconomic characteristics (eg, car access, tenure and receipt of benefits) at aggregations of about 100 people. Housing tenure, a proxy for asset wealth and perhaps housing conditions, was categorised as rental or owner-occupied. Place of residence was classified as urban or rural based on Statistics New Zealand definitions.

The proportion of mortality records linked to a census record varied by sex, age, ethnicity and the deprivation index.<sup>19</sup> Therefore, weights were applied to adjust for linkage bias. For example, if 20 of 30 Māori men who died aged 45–64 years and living in moderately deprived small areas of New Zealand were linked to a census record, each of the 20 linked records received a weight of 1.5 (30/20).

We used logistic regression analyses, weighted as described above, to model the risk of dying in winter compared to summer in adults aged 30–74 years living in a private dwelling at the time of census. People dying in the winter months (June, July, August) were classified 1 and those dying in the summer months (December, January, February) 0. Data for deaths occurring in the spring or autumn months were discarded. Thus, we employed a type of case-control analysis of deaths to determine risk factors for winter mortality. This is an efficient study design undertaking analyses only on deaths and generating regression coefficients (and hence ORs) that directly estimate variation in excess winter mortality. For example, an OR of 1.1 for low compared to high income means that low income people have 10% higher odds of winter mortality than high income people. A full cohort analysis would give actual rates of death, but because there are no obvious differences in person-time between winter and summer it is not necessary to model the full cohort. Further, a full cohort analysis would require interaction terms of social factors with an additional winter:summer independent variable, whereas modelling deaths only gives interaction effects.

Separate models were analysed for all causes of death and for subgroups of cause based on the International Classification of Diseases (ICD) 9 three-digit codes as follows: infections ICD 001–139, 320–323, 390–392, 460–466, 480–487, 590, 595, 614–616, 680–686, 711, 771; cardiovascular causes ICD 393–438; respiratory causes ICD 470–478, 490–519; cancers ICD 140–209; and accidents ICD 800–949. Initial models used dummy variables for age (classified by decade), sex, prioritised ethnicity, census year, educational status, marital status, housing tenure, income, urban-rural status and NZDep decile. Analyses were repeated by ethnic group. We directly investigated interaction between age, census period, ethnicity, housing tenure, income and rurality by addition of interaction terms to the regression model.

For final analyses, we included participants with complete data on all covariates. We performed sensitivity analyses in which participants with missing data were included.

All analyses were undertaken in the Data Laboratory at Statistics New Zealand on unit-level data. Tabular output data of counts were randomly rounded to a near multiple of 3 to meet privacy requirements.

## RESULTS

Table 1, column 1, shows the number of deaths during winter or summer in the census cohort. Column 2 shows the number of deaths with complete data. The remaining columns show the number of deaths by subgroup of cause (after weighting). There were 75 138 mortality records linked to census information for

persons who were aged 30–74 years on census night and living in a private dwelling at the time of the census. Initial models of mortality from all causes suggested that there were consistent associations between the risk of dying in winter and age, income, tenancy status and urban-rural status. There were no significant independent effects of education, marital status or neighbourhood deprivation on excess winter mortality and removal of these variables did not materially alter the effects of income, tenancy or urban-rural status. Therefore, we dropped education, marital status and deprivation from further analysis, but retained sex, age, ethnicity and census cohort a priori. This left 58 683 observations with complete data (table 1).

We performed sensitivity analyses in which participants with missing data were included as further categories. Participants with missing data were significantly more vulnerable to excess winter mortality than the respective baseline groups for ethnicity, income and tenure (data not shown). However, the overall results for categories with complete data were qualitatively unchanged.

### All causes of death

There was a total of 41 325 winter and 33 810 summer deaths for the 15 years of observation from 1981–2004—an excess winter mortality of 22%. In our logistic regression modelling, the overall reference group is European women aged 70–74 years at the time of the census, who died between 1981 and 1984, owned their own home, had higher income and lived in a rural area. Among this high socio-economic reference group, the excess winter mortality is near null as given by the exponent of the intercept in the main model (table 2; OR = 1.001).

Table 2 also shows the coefficients and ORs for a range of social variables where the outcome variable is winter or summer death. These ORs describe the variation in excess winter mortality odds across levels of social groups. There were no significant associations with census period, sex or ethnicity. Those of European/other ethnicity appeared to have slightly higher excess winter mortality compared to the other ethnicities, but none of the associations were significant. Compared to people on high incomes, those on middle and lower incomes were at increased risk of dying in winter and there was a dose response: middle income OR 1.052 (95% CI 1.001 to 1.106) and lower income OR 1.133 (95% CI 1.083 to 1.186). Compared to people owning their home, people living in rented accommodation were at increased risk of winter death (OR 1.054, 95% CI 1.009 to 1.100). Those living in cities were at increased risk of winter death compared to those living in rural areas (OR 1.056, 95% CI 1.015 to 1.097).

Figure 1 depicts the OR of winter to summer mortality by level of income and housing tenure for a modified reference person who is European, male, aged 60–69 years, living in an urban area and dying in 1981–1984. (This modified reference group was deliberately selected to have a moderate excess winter mortality, even before considering income and tenure.) To do this, we sum the appropriate regression coefficients (including the intercept) in table 2. Thus, these ORs refer to the winter to summer mortality comparison not comparisons between levels of social variables. For a European male, aged 60–69 years and dying in 1981–1984, and who also owned his own house and had a high income, his odds of dying in winter were 1.14 times greater than dying in summer. If he both rented and had a low income, his odds of dying in winter were 1.36 times greater than dying in summer (ie,  $1.36 = 1.14 \times 1.133 \times 1.054$ ). That is, the odds of excess winter mortality are clearly modified by both income and tenure.

**Table 1** Distribution of deaths by sociodemographic characteristics and by cause of death. Only deaths occurring during winter or summer are included

	Number of deaths (unweighted, rounded)*		Number of deaths (weighted, rounded)						
	Deaths linked to a census (N = 75138)	Linked deaths with complete data (N = 58683)	All causes (N = 75672)	Infection (N = 1509)	Respiratory (N = 4992)	Cancer (N = 27435)	Injury (N = 2607)	Circulatory (N = 30213)	Other (N = 8925)
Age (decade)									
30s	2457	1884	2904	75	69	744	714	468	834
40s	5499	4197	5847	129	153	2106	561	1740	1155
50s	12258	9402	12378	198	525	5319	489	4401	1449
60s	25908	20505	26019	423	1848	10131	468	10560	2592
70s	29016	22698	28518	684	2394	9135	375	13035	2895
Female									
Female	44940	35385	45798	867	2964	15084	1875	19713	5301
Male									
Male	30204	23298	29871	642	2028	12351	732	10497	3624
Māori									
Māori	7884	5373	7866	198	573	2415	411	3087	1179
Pacific									
Pacific	1857	1134	1632	42	108	459	60	630	336
Asian									
Asian	687	510	708	27	18	228	57	258	120
European/other									
European/other	64047	51669	65466	1239	4293	24333	2076	26241	7287
Missing									
Missing	663								
Income:									
Low									
Low	33336	32211	41322	885	3315	13992	1053	17139	4944
Middle									
Middle	15135	14634	18969	354	1083	7029	789	7521	2193
High									
High	12258	11838	15378	267	594	6417	762	5553	1785
Missing									
Missing	14412								
Own home									
Own home	54585	47361	60726	1149	3756	22812	2034	24177	6801
Rented									
Rented	14079	11322	14946	357	1233	4623	573	6036	2121
Missing									
Missing	6480								
Rural									
Rural	18747	14574	19194	336	1233	6936	831	7626	2232
Urban									
Urban	56388	44109	56478	1173	3756	20499	1773	22587	6693

\*Values were randomly rounded to a near multiple of 3 to meet privacy requirements of Statistics New Zealand.

### Subgroups of cause of death

There was a similar pattern of results for deaths from infectious causes, circulatory diseases and cancers. Among these causes of death, there was an increased odds of winter death among those in the lowest tertile of income compared to those in the highest tertile. In most instances, CIs by cause of death (table 3) overlapped the corresponding CI for all causes combined (table 2). However, for deaths from infectious diseases, the risk of dying in winter was significantly increased during 1996–1999 compared to the risk in 1981–1984 (OR 1.986, 95% CI 1.292 to 3.050). Those of Asian ethnicity appeared at significantly reduced risk of winter death compared to the baseline group. Compared to the high income group, there was a two-thirds or greater odds of winter death from infectious disease for both low income (OR 1.664, 95% CI 1.150 to 2.408) and middle income groups (OR 1.816, 95% CI 1.206 to 2.736).

### DISCUSSION

We found that excess winter mortality varied by income, housing tenure and rurality. The strongest association between income and excess winter mortality was seen for infectious diseases. Conversely, we found little evidence that gender, ethnicity, education, marital status or neighbourhood deprivation modified the association.

### Neighbourhood deprivation and income

The evidence that social factors, measured at the individual level, can affect excess winter mortality is surprisingly limited.<sup>17</sup>

In the USA, but not in Denmark, excess winter mortality varied by level of education with a greater excess among those with less education.<sup>23</sup> There was no significant association with education in our study. Consistent with previous studies that used area neighbourhood deprivation indices,<sup>2 8 16 17 24–28</sup> we did not find an association between neighbourhood deprivation and excess winter mortality. While there is an established link between overall mortality and socioeconomic status, the proportional difference does not appear to increase during winter.

Not all people living in a deprived area are individually deprived<sup>29</sup> or have low income.<sup>29</sup> Thus, it is of interest that we found that excess winter mortality varied by household income. A number of causal mechanisms may link income to variation in excess winter mortality. There is likely to be an income gradient in housing quality in New Zealand.<sup>30</sup> Poorer people are more likely to be suffering from fuel poverty, unable to afford to heat their home to World Health Organisation recommended levels and more likely to be at home for longer hours and exposed to low temperatures.<sup>31</sup> Such problems may contribute to excess winter mortality (see below). Household crowding is strongly associated with poverty and with an increased risk of several important infectious diseases in New Zealand.<sup>32 33</sup> Chronic illness may also link low income to excess winter mortality, as lower income groups generally have poorer health.<sup>34</sup> The majority of excess winter mortality is related to cardiovascular thrombosis and/or respiratory disease. Pre-existing illness, in particular respiratory disease, increases the risk for influenza-related mortality and

**Table 2** Logistic regression model results where the outcome is winter versus summer death, and coefficients and ORs are shown for a number of social factors (for all causes, N=75672)

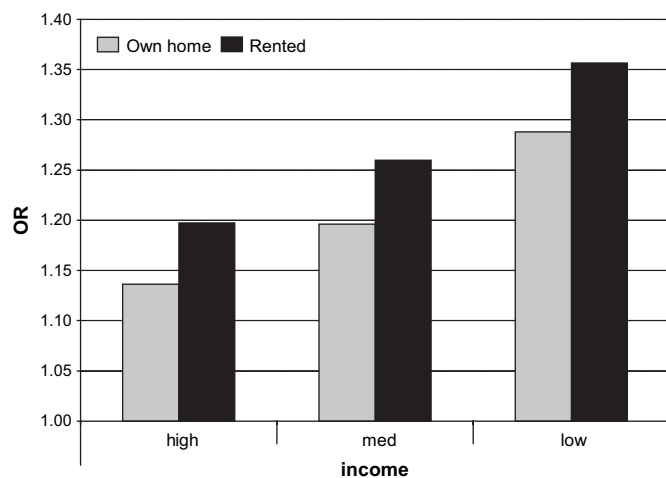
Variable	Coefficient (95% CI)	OR (95% CI)
Constant	-0.001 (-0.068 to 0.066)	
Age (base 70s)		
30s	-0.089 (-0.186 to 0.009)	0.915 (0.830 to 1.009)
40s	-0.053 (-0.122 to 0.016)	0.948 (0.885 to 1.016)
50s	0.011 (-0.040 to 0.062)	1.011 (0.960 to 1.064)
60s	0.065 (0.026 to 0.103)**	1.067 (1.026 to 1.109)**
Period (base 1981–1984)		
1986–1989	0.002 (-0.050 to 0.053)	1.002 (0.951 to 1.055)
1991–1994	0.005 (-0.048 to 0.057)	1.005 (0.953 to 1.058)
1996–1999	0.026 (-0.027 to 0.080)	1.027 (0.973 to 1.083)
2001–2004	0.014 (-0.040 to 0.068)	1.015 (0.961 to 1.071)
Sex (base female)		
Male	0.0100 (-0.024 to 0.043)	1.010 (0.976 to 1.044)
Ethnicity (base European/other)		
Māori	-0.010 (-0.070 to 0.050)	0.990 (0.933 to 1.051)
Pacific	-0.063 (-0.185 to 0.059)	0.939 (0.831 to 1.061)
Asian	-0.108 (-0.287 to 0.071)	0.898 (0.750 to 1.073)
Tenure (base owned)		
Rented	0.052 (0.009 to 0.095)*	1.054 (1.009 to 1.100)*
Income (base high)		
Lower	0.125 (0.080 to 0.171)**	1.133 (1.083 to 1.186)**
Middle		
Rurality (base rural)		
Urban	0.054 (0.015 to 0.093)**	1.056 (1.015 to 1.097)**

\*p<0.05; \*\*p< 0.01.

excess winter mortality.<sup>4 35</sup> Differing levels of access and use of healthcare services might also provide a mechanism for mediating the association between income and excess winter mortality.

### Tenure

Living in rented housing was significantly associated with higher excess winter mortality in this study. The association between rented housing and winter mortality may reflect socioeconomic characteristics of tenants that are not captured by other variables (such as asset wealth). It is tempting to speculate that poorer quality of rental houses compared to owner-occupied



**Figure 1** ORs of winter compared to summer mortality by income and tenure, among urban European males aged 60–69 years, dying in 1981–1984.

houses, and crowding, may contribute to this association. Studies of the association between housing quality and excess winter mortality have produced inconsistent results.<sup>3 4 6 17</sup> Nevertheless, there is some evidence from Europe to suggest that actual housing conditions (eg, low indoor temperatures, poor heating, lack of insulation and/or fuel poverty) can contribute to excess winter mortality, particularly in the elderly, although other factors such as outdoor cold stress are also important.<sup>1–3 6</sup>

A recent analysis also found an association of housing conditions with excess winter hospital admissions in New Zealand,<sup>36</sup> although findings with regards to excess winter mortality were inconclusive (personal communication, Lucy Telfar-Barnard, University of Otago, Wellington, New Zealand, 2009). Excess winter hospital admissions was higher for those living in ‘poor’ condition dwellings compared to those living in ‘superior’ condition dwellings, and rates of winter hospital admissions were increased in areas with a higher proportion of rental households.

### Urban-rural status

Our study also found that living in an urban setting was associated with a greater risk of excess winter mortality than rural living. Our finding differs from that of a UK study that did not find any association between rurality and excess winter mortality.<sup>28</sup> The rural environment may provide less opportunity for infectious disease transmission than urban environments<sup>37</sup> and household crowding is less common in rural areas.<sup>33</sup> Urban air pollution is higher in cities and higher in winter in most New Zealand cities. Indoor air pollution from heating is also likely to be higher in winter when temperatures are lower and windows are more often closed.

### Demographic factors

As has previously been reported in New Zealand,<sup>16</sup> with the exception of a single sub analysis, excess winter mortality was not significantly related to ethnicity in this study on a relative scale. Mortality rates are significantly higher for Māori and Pacific Islanders than for Europeans in New Zealand.<sup>38 39</sup> Thus, while the proportional increase in excess winter mortality was similar between ethnic groups, the absolute increase in Māori mortality rates will be about twice that for European/other. Our findings indicate that relative differences in excess winter mortality may be related to lower household income, which is more common among non-European ethnic groups, rather than to the individual’s ethnicity per se.

### Study strengths and weaknesses

The strengths of this study include large datasets for all deaths linked to census data in New Zealand for 15 years of deaths traversing a 25-year period. Linkage of mortality and census data enabled access to individual-level data on social factors. Our study further extends upon the previous study of excess winter mortality in New Zealand by Davie *et al*,<sup>16</sup> which used only national mortality data. However, we did not have data on seasonal environmental exposures such as ambient or indoor temperature, air quality, and housing conditions or heating sources that may vary by social factors. We also did not have data on variables that might influence vulnerability to climate and vary by social group, such as health status, comorbidities and behaviour (both traditional health risk factors such as diet and smoking and behavioural adaptations or responses to climate).

It is notable that household crowding can be linked to all three social factors associated with excess winter mortality in this study (low income, rental accommodation and urban

**Table 3** Logistic regression model results where the outcome is winter versus summer death. ORs (95% CI) are shown for a number of social factors and by specific causes of death

	Infection (N = 1509)	Circulatory (N = 30213)	Cancer (N = 27435)	Respiratory (N = 4992)	Injury (N = 2607)
Variable					
Age (base 70s)					
30s	0.952 (0.496 to 1.829)	1.140 (0.903 to 1.439)	1.064 (0.890 to 1.272)	0.972 (0.501 to 1.886)	0.947 (0.690 to 1.300)
40s	0.760 (0.470 to 1.231)	0.996 (0.880 to 1.128)	1.092 (0.976 to 1.222)	0.701 (0.466 to 1.054)	1.005 (0.725 to 1.393)
50s	1.170 (0.762 to 1.795)	1.013 (0.932 to 1.102)	1.062 (0.980 to 1.151)	1.179 (0.927 to 1.500)	1.017 (0.724 to 1.428)
60s	1.188 (0.865 to 1.633)	1.124 (1.059 to 1.193)**	1.072 (1.005 to 1.142)*	1.087 (0.940 to 1.258)	0.961 (0.695 to 1.328)
Period (base 1981–1984)					
1986–1989	1.019 (0.708 to 1.465)	1.019 (0.945 to 1.100)	1.032 (0.943 to 1.130)	0.893 (0.721 to 1.107)	0.818 (0.607 to 1.103)
1991–1994	0.850 (0.585 to 1.235)	0.978 (0.904 to 1.057)	1.056 (0.966 to 1.154)	1.077 (0.862 to 1.347)	1.000 (0.731 to 1.367)
1996–1999	1.986 (1.292 to 3.050)**	1.044 (0.960 to 1.136)	1.061 (0.970 to 1.160)	1.032 (0.831 to 1.282)	0.736 (0.538 to 1.007)
2001–2004	1.312 (0.822 to 2.092)	1.042 (0.954 to 1.138)	1.082 (0.989 to 1.183)	1.115 (0.894 to 1.391)	0.747 (0.548 to 1.018)
Sex (base female)					
Male	1.007 (0.772 to 1.313)	1.031 (0.975 to 1.089)	1.018 (0.964 to 1.074)	1.113 (0.970 to 1.277)	0.918 (0.742 to 1.135)
Ethnicity (base European/ other)					
Maori	0.969 (0.637 to 1.473)	0.945 (0.858 to 1.040)	0.975 (0.880 to 1.081)	0.952 (0.752 to 1.206)	0.940 (0.701 to 1.263)
Pacific	0.632 (0.283 to 1.412)	0.905 (0.746 to 1.098)	0.894 (0.712 to 1.122)	0.829 (0.507 to 1.357)	1.039 (0.539 to 2.000)
Asian	0.209 (0.075 to 0.582)**	0.910 (0.677 to 1.223)	0.853 (0.629 to 1.158)	1.088 (0.325 to 3.641)	1.042 (0.498 to 2.180)
Tenure (base owned)					
Rented	1.179 (0.853 to 1.630)	1.010 (0.944 to 1.080)	1.011 (0.939 to 1.089)	1.136 (0.968 to 1.334)	1.106 (0.865 to 1.413)
Income (base high)					
Lower	1.664 (1.150 to 2.408)**	1.095 (1.017 to 1.179)*	1.148 (1.068 to 1.233)**	0.904 (0.727 to 1.124)	1.040 (0.812 to 1.332)
Middle	1.816 (1.206 to 2.736)**	1.04 (0.959 to 1.127)	1.093 (1.012 to 1.181)*	0.878 (0.688 to 1.121)	0.987 (0.766 to 1.271)
Rurality (base rural)					
Urban	1.368 (1.000 to 1.873)	1.061 (0.998 to 1.128)	1.030 (0.968 to 1.097)	1.013 (0.866 to 1.185)	1.055 (0.853 to 1.305)

\*p &lt; 0.05; \*\*p &lt; 0.01.

environment). As well as issues of affordability, in New Zealand, household crowding can be a reflection of cultural values within some ethnic groups, although reducing housing costs appears to be the main driver.<sup>40</sup> Various agencies are working on initiatives to provide affordable housing appropriate for large, extended

families,<sup>33</sup> which may also have implications for excess winter mortality rates if infection transmission rates are reduced.

Lower income, living in rental accommodation and living in an urban environment were found to be associated with a higher risk of excess winter mortality, but there was no association with neighbourhood deprivation, education or ethnicity in mutually adjusted analyses. The potential causal pathways of these associations need to be further elucidated. These findings strengthen the evidence that low income and associated housing tenure (perhaps as a proxy for asset wealth or via associated differences in indoor temperatures and household crowding) increase the risk of dying in winter. The recently initiated programme in New Zealand to increase energy efficiency of housing may provide a natural experiment of the importance of housing quality in excess winter mortality.

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## What is already known on this subject

In temperate countries, mortality rates are typically 10–30% higher during the winter compared to the warmer months. The underlying causes are likely to be complex and multifactorial, but many seasonal exposures are plausibly influenced by social factors, including those related to housing. Well insulated and efficiently heated buildings, along with appropriate outdoor behaviour, can reduce the 'biologically effective' exposure to cold temperatures. There is policy interest in social interventions to reduce excess winter mortality, but existing evidence of the effectiveness of interventions is conflicting.

## What this study adds

In this record-linkage study of the New Zealand population, there was an increased risk of dying in winter among low-income people, those living in rented accommodation and those living in cities. These findings strengthen the evidence that low income and rental housing tenure (a proxy for asset wealth and/or housing conditions, such as low indoor temperatures and household crowding) are associated with an increased risk of dying in winter.

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