

RESEARCH REPORT

Excess winter mortality in Europe: a cross country analysis identifying key risk factors

J D Healy

J Epidemiol Community Health 2003;57:784–789

Objective: Much debate remains regarding why certain countries experience dramatically higher winter mortality. Potential causative factors other than cold exposure have rarely been analysed. Comparatively less research exists on excess winter deaths in southern Europe. Multiple time series data on a variety of risk factors are analysed against seasonal-mortality patterns in 14 European countries to identify key relations

Subjects and setting: Excess winter deaths (all causes), 1988–97, EU-14.

Design: Coefficients of seasonal variation in mortality are calculated for EU-14 using monthly mortality data. Comparable, longitudinal datasets on risk factors pertaining to climate, macroeconomy, health care, lifestyle, socioeconomics, and housing were also obtained. Poisson regression identifies seasonality relations over time.

Results: Portugal suffers from the highest rates of excess winter mortality (28%, CI=25% to 31%) followed jointly by Spain (21%, CI=19% to 23%), and Ireland (21%, CI=18% to 24%). Cross country variations in mean winter environmental temperature (regression coefficient (β)=0.27), mean winter relative humidity (β =0.54), parity adjusted per capita national income (β =1.08), per capita health expenditure (β =−1.19), rates of income poverty (β =−0.47), inequality (β =0.97), deprivation (β =0.11), and fuel poverty (β =0.44), and several indicators of residential thermal standards are found to be significantly related to variations in relative excess winter mortality at the 5% level. The strong, positive relation with environmental temperature and strong negative relation with thermal efficiency indicate that housing standards in southern and western Europe play strong parts in such seasonality.

Conclusions: High seasonal mortality in southern and western Europe could be reduced through improved protection from the cold indoors, increased public spending on health care, and improved socioeconomic circumstances resulting in more equitable income distribution.

Correspondence to:
Dr J D Healy, Urban
Institute Ireland, University
College Dublin, Richview
Campus, Dublin 14,
Ireland; J.Healy@ucd.ie

Accepted for publication
26 November 2002

Excess winter mortality has been reported in medical journals for about 150 years,¹ and most countries suffer from 5% to 30% excess winter mortality.² However, there still remains much debate with regard to why certain countries experience dramatically higher rates of seasonal mortality than others. Cold strain from both indoors and outdoors has been implicated on several occasions,^{3–5} however other potential factors (other than cold strain) have rarely been analysed. In addition, there has been far less published research on seasonal variations in mortality in southern Europe.^{6–7} This may be attributable to the perception that such countries are not affected by excess winter deaths because of their mild winter climates. This paper shows that such a perception is highly mistaken.

Besides factors associated with biological and genetic considerations that have been linked with reduced health status,⁸ the health of a population is influenced by a large number of factors that can be grouped into three main categories.⁹ Firstly, environmental factors (social, economic, and natural) play key parts in explaining health inequalities, as mortality rates are negatively associated with a country's macroeconomic health.^{10–11} State expenditure on education has also been shown to be associated with the wellbeing of many populations.^{12–13} If the socioeconomic level of development, as measured by per capita GDP or public expenditure on education, is an important predictor of the health (and, thus, mortality rates) of a population, then it is thought beneficial to see if this relationship holds for excess winter mortality.

Secondly, healthcare provision and health expenditure, in absolute and relative terms, are key variables related to health. Both have been found to be negatively associated with all year mortality rates in a considerably varied literature.^{14–15} This study examines a variety of indicators of healthcare provision to identify whether cross country variations in excess winter mortality are correlated with variations in standards of healthcare services in Europe.

Finally, environment and lifestyles are both strongly linked with a country's level of economic development.¹⁵ There is a large literature analysing lifestyle risk factors with non-seasonal mortality (for example, smoking rates have been demonstrated to be highly associated with impaired health and premature mortality,^{16–17} as has obesity^{18–19}), but few studies examine the potential influence of such factors on seasonal variations in mortality. Furthermore, there is a considerable epidemiological literature showing various degrees of (positive) relationships between all year mortality and socioeconomic indicators, such as income poverty,^{20–21} inequality,^{22–23} and deprivation.^{24–25} A smaller medical literature is evident regarding the association between fuel poverty (and poor domestic thermal efficiency) and excess winter mortality.^{3–5–26} The relative importance of all of these factors on seasonal variations in mortality has not been explored hitherto. The basis of this paper is to present a macro analysis of the broad relationship between these factors and excess winter mortality by using, for the first time, a pan-European analysis in which longitudinal winter mortality in 14 European countries is examined and multiple time series

data on a variety of risk factors are regressed against seasonal mortality to identify associations.

METHODS

A recent 10 year time series (1988–97) was chosen for the baseline analysis; data for years post-1997 were not available for all 14 countries. Excess winter mortality is defined as the surplus number of deaths occurring during the winter season (December to March inclusive) compared with the average of the non-winter seasons; adjustments were made for leap years. This four month period suited the climatic characteristics of the 14 countries best. A relative definition of seasonal mortality is used in this paper,²⁷ which enables meaningful cross country comparisons of excess winter mortality to be achieved. The coefficient of seasonal variation in mortality is calculated using the following formula, which acts as a lower bound estimate of seasonal mortality:

$$CSVM = \frac{[f_{deaths} (Dec+Jan+Feb+Mar)] - [f_{deaths} (Apr+May+Jun+Jul) + f_{deaths} (Aug+Sep+Oct+Nov)/2]}{[f_{deaths} (Apr+May+Jun+Jul) + f_{deaths} (Aug+Sep+Oct+Nov)/2]}$$

all divided by

$$[f_{deaths} (Apr+May+Jun+Jul) + f_{deaths} (Aug+Sep+Oct+Nov)/2]$$

All 14 European countries used in the analysis, being relatively alike in economic and social characteristics, exhibit similar crude mortality rates (9–11 deaths per thousand population). Monthly mortality data were originally obtained through the United Nations Databank. Individual countries were contacted subsequently to obtain missing monthly mortality data.

A Poisson regression model is considered most suitable for the data, and it is used on each risk factor to identify associations with seasonality over time. Mean monthly climatic data (precipitation, relative humidity, and environmental temperature) were obtained using the Meteotest Meteororm V.4.0 CD ROM, a meteorological computer program that contains reliable 30 year averages for several hundred weather stations globally. Weather stations were selected carefully on the basis that they were most climatically representative of a given country with regard to respective population dispersals. After extensive discussions with meteorologists, the weather stations used were often those found in a country's capital city, as these captured, for most cases, the largest share of the country's population. However, for those countries with particularly dispersed populations and discernible climatic variations (Italy, France), a north-south gradient was used, that is, the average of two weather stations—each climatically representative and with high population densities—was used.

Longitudinal datasets on macroeconomic indicators were obtained from the United Nations Statistics Division and the World Bank. Time series datasets were also obtained from the World Bank regarding lifestyle risk factors such as smoking and obesity, and on health service provision. Data on four socioeconomic variables were calculated using the European Community Household Panel longitudinal users' database covering the four years 1994–97; this survey is the first comparable, cross country database on social indicators in the EU. As it only started in 1994, there are no cross country data available in Europe regarding such socioeconomic indicators prior to this year. In this regard, relative excess winter mortality is re-calculated for all 14 countries in the model for the socioeconomic section of the analysis using a comparable time series (1994–97). Income poverty is calculated for these years by assigning a poverty threshold of 60% of median equivalised income adjusted for purchasing power, as is often used in cross country poverty studies.^{28–29} Income inequality is

calculated using the Gini coefficient measure. Deprivation is calculated using a composite index of multiple indicators of material and social deprivation.³⁰ Levels of fuel poverty are taken from a recent pan-European analysis of fuel poor households in which estimates were calculated using a suite of indicators of housing conditions, affordability of home heating and energy efficiency levels based on a consensual approach.³¹ Data on thermal efficiency standards of European housing were obtained from Eurostat and updated using a new household survey of Ireland^{32–33}; Norway and Sweden are included in this analysis as thermal data were not available for Spain or Italy.

RESULTS

Excess winter mortality in EU-14

The results show that, between 1988 and 1997, Portugal has the highest seasonal variation in mortality in Europe, with a winter increase of some 28% above the average mortality rate; this amounts to some 8800 premature winter deaths each year. Ireland also fares particularly poorly with an increase of some 21% (or 2000 excess winter deaths annually). Spain also exhibits the same coefficient (21%, 19 000 deaths). England, Wales, Northern Ireland, and Scotland—both collectively (as the UK) and separately—all share very high seasonality coefficients. The highest level is found in England (19%, 31 000 excess deaths), followed by Wales (17%, 1800 deaths), Northern Ireland (also 17%, 800 deaths), and Scotland (16%, 3100 deaths). Overall, the UK exhibits an average seasonality rate of 18%, which represents about 37 000 annual excess winter deaths. Greece exhibits similarly high rates of relative excess winter mortality (18%), representing 5700 premature winter deaths annually. Furthermore, Italy demonstrates a level of 16%, which accounts for some 27 000 excess deaths. Conversely, Finland, Germany, and the Netherlands appear to suffer far less from excess winter mortality. Confidence intervals of the mean coefficients are also reported in table 1.

Excess winter mortality and climate

Mean winter measurements of environmental temperature, rainfall, and humidity are analysed against the results for relative excess winter mortality. The results demonstrate that climatic variables such as mean winter environmental temperature and mean winter precipitation are found to be positively associated with levels of relative excess winter mortality in Europe. A highly significant regression coefficient of 0.27 is found ($p < 0.001$) with regard to environmental temperature. This positive relation can be termed the "paradox of excess winter mortality". The paradox

Table 1 Coefficient of seasonal variation in mortality (CSVM) in EU-14 (mean, 1988–97)

	CSVM	95% CI
Austria	0.14	(0.12 to 0.16)
Belgium	0.13	(0.09 to 0.17)
Denmark	0.12	(0.10 to 0.14)
Finland	0.10	(0.07 to 0.13)
France	0.13	(0.11 to 0.15)
Germany	0.11	(0.09 to 0.13)
Greece	0.18	(0.15 to 0.21)
Ireland	0.21	(0.18 to 0.24)
Italy	0.16	(0.14 to 0.18)
Luxembourg	0.12	(0.08 to 0.16)
Netherlands	0.11	(0.09 to 0.13)
Portugal	0.28	(0.25 to 0.31)
Spain	0.21	(0.19 to 0.23)
UK	0.18	(0.16 to 0.20)
Mean	0.16	(0.14 to 0.18)

consists of the fact that higher mortality rates are generally found in less severe, milder winter climates where, all else equal, there should be less potential for cold strain and cold related mortality. This result indicates that the typical, inverse relation normally found between cold exposure and rates of (all year) mortality does not hold for excess winter mortality. Housing standards have been linked as a potential, causative factor behind this paradox.³⁻⁵ Countries with comparatively warm all year climates tend to have poor domestic thermal efficiency. Because of this, these countries find it hardest to keep their homes warm when winter arrives. This is especially the case in Portugal, Spain, and Ireland, where winter temperatures are comparatively mild and excess mortality rates in winter are very high. Conversely, countries with severe climates—such as those in Scandinavia—have to maintain high levels of thermal efficiency, as temperatures demand that houses must retain warmth.

Studies on the relative importance of damp (or humidity) on mortality rates are less frequently found, though some associations have been found with impaired health generally.²⁹ This study finds some relationship between the overall level of relative humidity and relative excess winter mortality across Europe; a significant regression coefficient of 0.23 ($p = 0.02$) is reported. The relationships between mean winter rainfall and excess deaths is also found to be significant (a regression coefficient of 0.54, $p < 0.001$).

Excess winter mortality and macroeconomic factors

The results of the study show that the state of the macroeconomy is strongly associated with the level of excess winter deaths across Europe ($p < 0.001$). The relationship indicates that more affluent countries with higher per capita GDP (Luxembourg, Germany, Denmark) exhibit lower seasonal variations in mortality. The converse is also true; the four “cohesion” countries of the EU (Greece, Ireland, Spain, and Portugal) demonstrate the largest mortality variations during winter. This study demonstrates that excess winter mortality does not follow non-seasonal mortality in its relationship with public spending on education. Public per capita expenditure on both primary and secondary education is found to have an insignificant association with variations in excess winter mortality ($p = 0.07, 0.06$ respectively) (see table 2).

Excess winter mortality and healthcare provision

This study finds strong associations between various indicators of healthcare provision and seasonal variations in

mortality across Europe. Total health expenditure as a percentage of per capita GNP is found to be moderately associated with rates of excess winter mortality. Countries that dedicate relatively high proportions of their national income to health care (Germany, France) are found to exhibit lower seasonality in mortality rates than those with relatively low health expenditure (Portugal, Ireland). Disaggregating the data shows that public health expenditure is far more strongly associated with seasonal mortality (a regression coefficient of 0.6, $p = 0.001$), while private health expenditure is found to be a less significant variable in the model ($p = 0.11$). Again, countries like Portugal, Ireland, and Greece (which all dedicate about 5% or less of per capita GNP on public health expenditure) demonstrate the highest variations in excess winter mortality in Europe. Per capita health expenditure (adjusted for purchasing power parity) is found to have the strongest association with relative excess winter mortality in Europe, with a regression coefficient of -1.19 ($p < 0.001$). However, the number of hospital beds (per 1000 population) is found to be insignificantly associated with the coefficient of seasonal variation in mortality ($p = 0.44$), and similarly the number of GPs (per 1000 population) is not found to be associated with variations in relative excess winter deaths ($p = 0.67$) (see table 3).

Excess winter mortality and lifestyle risk factors

The findings in this section indicate no relationship between lifestyle risk factors at the macro level and levels of seasonal mortality across Europe. Firstly, smoking rates are found to be insignificantly related to relative excess winter mortality in 13 countries ($p = 0.34$). This implies that, while smoking is found to be strongly associated with mortality and health status using non-seasonal mortality rates, it does not seem to be a significant lifestyle risk factor for seasonal mortality rates. The same test is now carried out for obesity levels—another key risk factor for impaired health status and premature mortality. Again, a similar result is found, with no apparent association between obesity and excess winter mortality. Thus, the hypothesis that the level of excess winter mortality is associated with lifestyle risk factors is rejected.

Excess winter mortality and socioeconomic factors

The study now examines four key socioeconomic indicators across EU-14. The latest data from the longitudinal European Community Household Panel (1994–97) are used to examine levels of income poverty, income inequality, multiple deprivation, and fuel poverty. The coefficient of seasonal variation in mortality is re-calculated for this section using a

Table 2 Coefficient of seasonal variation in mortality and climatic and macroeconomic variables in EU-14

	CSVM	Mean winter temperature (°C)	Mean winter rainfall (mm)	Mean winter relative humidity (%)	PPP adjusted GDP per capita (\$)	Per capita expenditure on primary education (% of per capita GNP)	Per capita expenditure on secondary education (% of per capita GNP)
Austria	0.14	1.4	14	78	20100	20	25
Belgium	0.13	3.7	68	85	20300	16	23
Denmark	0.12	2.1	41	86	20400	27	34
Finland	0.10	-3.5	39	86	17600	23	29
France	0.13	7.0	50	78	18800	13	24
Germany	0.11	1.6	49	82	20600	—	31
Greece	0.18	11.6	51	71	12200	11	13
Ireland	0.21	5.8	65	81	14100	14	22
Italy	0.16	6.4	80	78	18600	19	—
Luxembourg	0.12	1.5	71	83	27300	—	24
Netherlands	0.11	4.3	60	87	18800	—	21
Portugal	0.28	13.5	100	77	12200	18	20
Spain	0.21	6.5	40	73	13700	14	—
UK	0.18	5.4	58	84	17700	—	24

Table 3 Coefficient of seasonal variation in mortality and healthcare provision in EU-13

	CSVM	Total health expenditure as a % of GNP pc	Public health expenditure as a % of GNP pc	Private health expenditure as a % of GNP pc	Health expenditure per capita (PPP \$)	GPs (per 1000 population)	Hospital beds (per 1000 population)
Austria	0.14	8.3	6.0	2.2	1896	2.8	9.2
Belgium	0.13	7.6	6.8	0.9	1759	3.4	7.2
Denmark	0.12	8.0	6.7	1.3	1931	2.9	4.7
Finland	0.10	7.4	5.7	1.8	1520	2.8	9.2
France	0.13	9.6	7.1	2.5	2026	2.9	8.7
Germany	0.11	10.7	8.3	2.5	2364	3.4	9.6
Greece	0.18	8.9	5.3	3.6	1226	3.9	5.0
Ireland	0.21	6.3	4.9	1.5	1293	2.1	3.7
Italy	0.16	7.6	5.3	2.3	1539	5.5	6.5
Netherlands	0.11	8.5	6.1	2.3	1874	2.6	11.3
Portugal	0.28	5.9	4.7	3.2	1142	3.0	4.1
Spain	0.21	7.4	5.6	1.8	1182	4.2	3.9
UK	0.18	6.8	5.9	1.0	1391	1.6	4.5

comparable time series, but relative excess winter mortality remains relatively static, although Greek data demonstrate a 4% point fall in the level of seasonality. Strong cross country relationships are found between excess mortality and relative income poverty, inequality using the Gini coefficient, composite, multiple deprivation levels and composite levels of fuel poverty. Countries with high levels of income poverty and inequality (Greece, Ireland, Portugal) also demonstrate the highest coefficient of seasonal variation in mortality (see table 4).

Excess winter mortality and household thermal efficiency

If housing standards have been at least part blamed for levels of excess winter mortality evident in western Europe,³⁻⁵ then it is useful to analyse data on domestic thermal efficiency to identify if there is an empirical relationship between variations in seasonal mortality and differing housing standards. Table 5 demonstrates the results of this exercise. Exemplary levels of thermal efficiency are found in Scandinavian countries. Sweden, Norway, and Finland have very high energy efficiency standards in their homes to combat the comparatively severe outdoor environments experienced in these countries. However, available data on southern and western European thermal standards illustrate low penetration of energy saving measures such as cavity wall insulation, roof insulation, floor insulation, and double glazed windows; this is especially the case in Portugal and

Table 5 Coefficient of seasonal variation in mortality and domestic thermal efficiency in EU-13

	CSVM	Cavity wall insulation (% houses)	Roof insulation (% houses)	Floor insulation (% houses)	Double glazing (% houses)
Austria	0.14	26	37	11	53
Belgium	0.13	42	43	12	62
Denmark	0.12	65	76	63	91
Finland	0.10	100	100	100	100
France	0.13	68	71	24	52
Germany	0.11	24	42	15	88
Greece	0.18	12	16	6	8
Ireland	0.21	42	72	22	33
Netherlands	0.11	47	53	27	78
Norway	0.12	85	77	88	98
Portugal	0.28	6	6	2	3
Sweden	0.12	100	100	100	100
UK	0.18	25	90	4	61

Greece, though Ireland and the UK also fare relatively poorly. While provisional correlation analysis yielded moderate associations between the variables, the regression test indicates less robust relations between excess winter deaths and energy efficiency levels, although cross country levels of cavity wall insulation, double glazing, and floor insulation are all significant at the 5% level in the model (p = 0.02, p = 0.02, p = 0.03 respectively).

Table 4 Coefficient of seasonal variation in mortality, socio economic indicators and lifestyle risk factors in EU-14

	CSVM	Smoking rate (%)	Obesity rate (%)	Income-poverty rate (%)	Income inequality (Gini)	Deprivation rate (%)	Fuel poverty rate (%)
Austria	0.14	35	6	-	-	-	6
Belgium	0.13	25	8	17	29	22	10
Denmark	0.12	37	6	11	22	17	4
Finland	0.10	23	9	-	-	-	5
France	0.13	34	5	16	29	28	10
Germany	0.11	30	5	18	29	19	5
Greece	0.18	37	11	21	34	58	33
Ireland	0.21	29	6	21	35	28	9
Italy	0.16	32	5	19	31	37	14
Luxembourg	0.12	-	8	14	31	14	5
Netherlands	0.11	33	5	10	27	16	6
Portugal	0.28	27	8	24	37	56	50
Spain	0.21	37	8	19	33	40	32
UK	0.18	27	10	20	34	27	9

Table 6 Results of regression model: cross country relations with relative excess winter mortality (regression coefficients and significance)

	β	p Value
Mean winter environmental temperature	0.27	<0.001
Mean winter precipitation	0.23	0.017
Mean winter relative humidity	0.54	<0.001
Purchasing power adjusted per capita GDP	1.08	<0.001
Per capita spend on primary education as a % of per capita GNP	0.12	0.070
Per capita spend on secondary education as a % of per capita GNP	-0.27	0.061
Total health expenditure as a % of per capita GNP	0.63	0.069
Public health expenditure as a % of per capita GNP	0.60	0.001
Private health expenditure as a % of per capita GNP	0.90	0.011
Purchasing power adjusted per capita health expenditure	-1.19	<0.001
GPs per 1000 population	0.59	-0.437
Hospital beds per 1000 population	-0.23	0.067
Smoking rate	0.40	0.344
Obesity rate	0.30	0.512
Income poverty rate (60% median equivalised income)	-0.47	0.008
Income inequality (Gini coefficient)	0.97	0.020
Deprivation rate (composite)	0.11	0.048
Fuel poverty rate (composite)	0.44	0.005
Cavity wall insulation (% of housing stock equipped)	-2.56	0.022
Roof insulation (% of housing stock equipped)	1.36	0.110
Floor insulation (% of housing stock equipped)	1.01	0.029
Double glazed windows (% of housing stock equipped)	-0.31	0.024

DISCUSSION

Using data from 1988 to 97, relative excess winter mortality is found to be highest in southern Europe, Ireland, and the UK, where seasonality in mortality of 18%–28% is calculated (see table 6). Scandinavian and other northern European countries are relatively unaffected by the problem. Such results are startling, especially for southern Europe where virtually no published work exists regarding seasonal variations in mortality. Paradoxically, countries with the mildest winter climates, where mean environmental temperatures remain above 5°C, exhibit the highest variations in seasonal mortality. Other climatic variables, such as mean winter precipitation levels and relative humidity, are not significantly related to cross country variations in excess winter deaths. However, the strong relationship demonstrated between mean cross country winter environmental temperatures and levels of relative excess winter mortality indicates that certain populations are far more vulnerable to cold exposure than others. Moreover, available data on cross country thermal efficiency standards in housing indicate that those countries with the poorest housing (Portugal, Greece, Ireland, the UK) demonstrate the highest excess winter mortality. If the ability of a population to protect themselves from cold spells is a key factor in such pronounced seasonality in southern and western Europe, as has been mentioned previously,^{3–5 26} then it would seem that improving the thermal standards of housing could be an effective preventative intervention in curbing excess deaths. Such a health strategy would also assist in the alleviation of fuel poverty, which, this study shows, is also highest in those countries in southern and western Europe with the poorest energy efficiency.³⁴

Socioeconomic indicators of wellbeing (poverty, income inequality, deprivation, and fuel poverty) are also associated with cross country levels of excess winter mortality. This suggests that levels of excess winter mortality could be reduced through socioeconomic progress, as was found in a longitudinal analysis of the Netherlands,³⁵ especially in countries with more unequal income distribution. Macroeconomic data indicate that levels of relative excess winter mortality are associated with per capita GNP, but not state expenditure on education. Lifestyle risk factors are also not associated with seasonal variations in mortality, unlike

all year mortality rates. However, a number of indicators of healthcare provision are significantly associated with cross country variations in seasonal mortality. Strong associations are reported for public health expenditure as a proportion of per capita GNP, purchasing power adjusted health expenditure per capita, and hospital bed ratios. The last indicator is especially worrying, as it indicates that potential bed shortages could be resulting in increased seasonal mortality in winter when resources are at their most stretched. Such findings are cause for concern for those countries with relatively low hospital bed ratios and short average durations of stay, most notably Ireland and Spain.

There are a number of limitations due mainly to the ecological design of the study. Cross country analyses are often problematic as standardised datasets are difficult to obtain. A number of assumptions and approximations have to be made when dealing with such large scale macro datasets and these carry errors. However, great care was undertaken in obtaining the highest quality longitudinal data in an effort to offset potential uncertainties associated with multi-country ecological comparisons. Although this study has not proved causality, the strong, positive relation with environmental temperature and the equally strong associations with thermal standards in housing indicate that improving the thermal efficiency of housing in southern and western Europe could play a strong part in reducing the large seasonal variations in mortality found in these countries. The results corroborate the work of multicentre studies⁵ indicating greater impacts on mortality in southern and western Europe than in colder northern regions.

ACKNOWLEDGEMENTS

I wish to thank Seiffe Tadesse for kindly providing me with UN mortality datasets. For furnishing me with additional mortality data, I am grateful to Allan Baker, Silvia Bruzzone, Caroline Capocci, Ursula Jung, Joëlle Kaiser, Juhani Leskinen, Glenn Meredith, Marie Rodgers, and Jolanda van der Meer. I also thank Niamh Moore and Gerald Mills for their advice and I pay special thanks to Dr Mills for generously providing very useful climatic data. Thanks to Vivienne Brophy for providing vital data on domestic thermal efficiency. I also thank Peter Clinch for his assistance funding the European Community Household Panel users' database. Thanks also to Frank Convery and Erna O'Connor for useful comments and to Finbarr Brereton for statistical advice. Many thanks to an anonymous referee for very useful remarks and clarifications.

Funding: I am grateful to the Irish Research Council for the Humanities and Social Sciences for financial support, and to the Environmental Institute and Urban Institute of Ireland, University College Dublin, for additional funding.

Conflicts of interest: none declared.

REFERENCES

- Guy WA. On the annual fluctuations in the number of deaths from various diseases, compared with like fluctuations in crime and in other events within and beyond the control of human will. *Journal of the Statistical Society* 1858;**21**:52–86.
- Curwen M. Excess winter mortality: a British phenomenon? *Health Trends* 1991;**22**:169–75.
- Clinch JP, Healy JD. Housing standards and excess winter mortality. *J Epidemiol Community Health* 2000;**54**:719–20.
- Eng H, Mercer J. Seasonal variations in mortality caused by cardiovascular disease in Norway and Ireland. *J Cardiovasc Risk* 1998;**5**:89–95.
- Eurowinter Group. Cold exposure and inter mortality from ischaemic heart disease, cerebrovascular disease, respiratory disease, and all causes in warm and cold regions of Europe. *Lancet* 1997;**349**:1341–6.
- Ballester-Diez F, Corella-Piquer D, Perez-Hoyos S, et al. Seasonal variation in mortality in the city of Valencia, Spain. [In Spanish]. *Salud Publica Mex* 1997;**39**:95–101.
- Zauli-Sajani S, Garaffoni G, Goldoni CA, et al. Mortality and bioclimatic discomfort in Emilia-Romagna, Italy. *J Epidemiol Community Health* 2002;**56**:536–7.
- Goldberg EM, Morrison SL. Schizophrenia and social class. *Br J Psychiatry* 1963;**109**:785.
- Townsend P. *Poverty in the United Kingdom*. London: Penguin Books, 1979.
- Cumper GE. National incomes and health: implications of some recent additions to the data. *J Trop Med Hygiene* 1981;**84**:49–61.
- Brainerd E. Market reform and mortality in transitional economies. *World Development* 1998;**26**:2013–27.
- Muller A. Education, income inequality and mortality: a multiple regression analysis. *BMJ* 2002;**324**:23–5.
- Backlund E, Sorlie PD, Johnson NJ. A comparison of the relationships between education and income with mortality: the national longitudinal mortality study. *Soc Sci Med* 1999;**49**:1373–84.
- Elola J, Daponte A, Navarro V. Health indicators and the organisation of health care systems in western Europe. *Am J Public Health* 1995;**85**:1397–401.
- Poikolainen K, Eskola J. Health services resources and their relation to mortality from causes amenable to health care intervention: a cross-national study. *Int J Epidemiol* 1988;**17**:86–9.
- Kondo K, Iwamoto T, Hirano R. Factors affecting longevity. *Southeast Asian J Tropical Med Public Health* 1997;**28**:88–93.
- Boyle P, Maisonneuve P. Lung cancer and tobacco smoking. *Lung Cancer* 1995;**12**:167–81.
- Elia M. Obesity in the elderly. *Obes Res* 2001;**9**:244–85.
- Visscher TL, Seidell JC, Malarious A, et al. A comparison of body mass index, waist-hip ratio and waist circumference as predictors of all-cause mortality among the elderly: the Rotterdam study. *Int J Obes Relat Metab Disord* 2001;**25**:1730–5.
- Shibuya K, Hashimoto H, Yano E. Individual income, income distribution and self-rated health in Japan: cross-sectional analysis of nationally representative sample. *BMJ* 2002;**324**:16–19.
- Wildman J. The impact of income inequality on individual and societal health: absolute income, relative income and statistical artefacts. *Health Econ* 2001;**10**:357–62.
- Kennedy BP, Kawachi I, Prothrow-Stith D. Income distribution and mortality: cross-sectional ecological study of the Robin Hood index in the United States. *BMJ* 1996;**312**:1004–7.
- Wolfson M, Kaplan G, Lynch NR, et al. Relation between income inequality and mortality: empirical demonstration. *BMJ* 1999;**319**:953–5.
- Wilkinson RG. *Unhealthy societies: the afflictions of inequality*. London: Routledge, 1996.
- Deaton A. *Relative deprivation, inequality and mortality*. NBER working paper 8099. Cambridge, MA: Center for Health and Well-Being, Princeton University, 2001.
- Gemmell I, McLoone P, Boddy FA, et al. Seasonal variation in mortality in Scotland. *Int J Epidemiol* 2000;**29**:274–9.
- Laake K, Sverre JM. Winter excess mortality: a comparison between Norway and England plus Wales. *Age Ageing* 1996;**25**:343–8.
- Duncan GJ, Gustafsson B, Hauser R, et al. Poverty dynamics in eight countries. *J Population Econ* 1993;**6**:215–34.
- Callan T, Nolan B, Whelan CT. Resources, deprivation and the measurement of poverty. *Journal of Social Policy* 1993;**22**:141–72.
- Healy JD. *Multiple deprivation in Europe: longitudinal results using the European Community Household Panel*. Environmental Studies Research Series Working Paper 02/12. Dublin: Department of Environment Studies, University College Dublin, 2002.
- Healy JD, Clinch JP. *Fuel poverty in Europe: a cross-country analysis using a new composite measurement*. Environmental Studies Research Series Working Paper 02/06. Dublin: Department of Environment Studies, University College Dublin, 2002.
- Eurostat. *Energy consumption in European households*. Luxembourg: Office for official Publications of the European Union, 1999.
- Healy JD, Clinch JP. Quantifying the severity of fuel poverty, its relationship with poor housing and reasons for non-investment in energy-saving measures in Ireland. *Energy Policy* 2003;**32**:207–20.
- Clinch JP, Healy JD. Cost-benefit analysis of domestic energy efficiency in Ireland. *Energy Policy* 2001;**29**:113–24.
- Kunst AE, Looman CWN, Mackenbach JP. The decline in winter excess mortality in the Netherlands. *Int J Epidemiol* 1990;**20**:971–7.