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Relation between income inequality and mortality: empirical demonstration

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Abstract

Objective To assess the extent to which observed associations at population level between income inequality and mortality are statistical artefacts.
Design Indirect "what if" simulation by using observed risks of mortality at individual level as a function of income to construct hypothetical state level mortality specific for age and sex as if the statistical artefact argument were 100% correct.
Setting Data from the 1990 census for the 50 US states plus Washington, DC, were used for population distributions by age, sex, state, and income range; data disaggregated by age, sex, and state from the Centers for Disease Control and Prevention were used for mortality; and regressions from the national longitudinal mortality study were used for the individual level relation between income and risk of mortality.
Results Hypothetical mortality, while correlated with inequality (as implied by the logic of the statistical artefact argument), showed a weaker association with states' levels of income inequality than the observed mortality.
Conclusions The observed associations in the United States at the state level between income inequality and mortality cannot be entirely or substantially explained as statistical artefacts of an underlying individual level relation between income and mortality. There remains an important association between income inequality and mortality at state level over and above anything that could be accounted for by any statistical artefact. This result reinforces the need to consider a broad range of factors, including the social milieu, as fundamental determinants of health.

Introduction

Considerable debate surrounds the impact of socioeconomic circumstances on individuals' health. Recent results suggest that there is a link not only between individual socioeconomic circumstances and health but also between the socioeconomic milieu in which individuals live and their health. Research has shown that higher levels of inequality in income among nations, states, or cities in the United States, or other geographically defined populations, are associated with higher mortality.[1–4]

Concerns have been raised by Gravelle, however, that these results may be no more than a statistical artefact.[5] Gravelle points out, as others have noted previously,[6 7] that a "diminishing returns" protective effect of higher individual income on individual risk of death is sufficient to account for differences in mortality between populations if there are differences in the extent of wealth and poverty, hence in the degree of income inequality.

The logic of this argument is correct. At the individual level, higher income (or some closely related but unmeasured factor, such as social status, for which income is a proxy) is causally associated with greater longevity.[8] Moreover, while an extra dollar or pound of income is protective, the amount of protective effect tails off as total income rises.[8 9]

At the level of a population there is always some mixture of people with low, middle, and high incomes. If one population has a more equal distribution of income than another, this is equivalent to there being fewer individuals with either very high or very low incomes and more with incomes closer to the middle. But if a poorer individual is £1000 better off in a second population the beneficial effect on his or her risk of mortality is larger than the adverse impact on the risk of some richer person being £1000 worse off because of the diminishing protective returns of additional income. Thus, a population with a more equal distribution of income can have a lower mortality, other things being equal, solely as a result of a generic curvilinear individual level causal relation between income and risk of mortality.

This logical possibility, however, is not a sufficient reason to dismiss the potential importance of inequality in income as an independent determinant of population level mortality. This remains an empirical question.

We approached this question indirectly by first estimating a generic individual level relation between income and mortality. We then simulated the extent to which variations in the distribution of income across populations can account for the observed population

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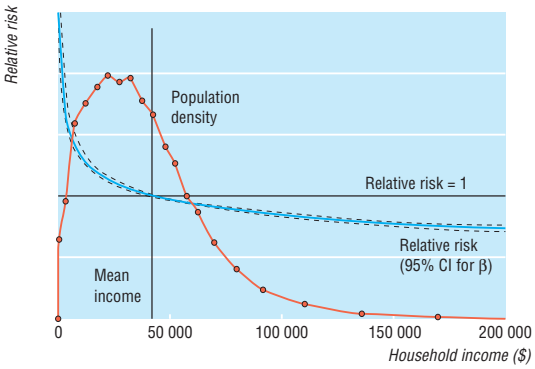

Fig 1 Relative risk of dying and population distribution for US individuals by household income ($)

level relation between income inequality and mortality. In other words, we asked "what if" our well specified relation between individual level income and mortality were fully causal, the key step in Gravelle's argument. We therefore applied this relation to all individuals in a population group based on its actual income distribution and then calculated expected mortality. The extent to which we reproduce the observed population level association between income inequality and mortality is then an empirical test of the statistical artefact hypothesis.

Method

The argument that the association between income inequality and mortality is artefactual depends on bringing together information at two levels. One is the level of individuals; the other level is that of populations such as US states.

The first step is to derive a reliable individual level relation between income and risk of mortality. This generic relation was estimated for the US population by using the national longitudinal mortality study. [10] This data set matched files containing household income and other demographic information from the US Census Bureau's current population survey to the National Death Index to provide about 7.6 million person years of mortality exposure from 10 years of follow up.

The downward sloping curves (close together) in figure 1 show the results—the estimated relation between household income and the relative risk of mortality, plus a 95% confidence interval, after age and sex were controlled for. The relation is highly significant both statistically and substantively and is clearly consistent with a diminishing returns individual level relation between income and risk of mortality. (While we assumed logarithmic specification, other analyses determined that this was a reasonable functional form.)

The remaining steps in the analysis complement this individual level relation with consistent population level data from the 1990 census on income inequality and mortality for each of the 50 US states plus Washington, DC. Special Census Bureau tabulations provided counts of the numbers of individuals living in households by state, sex, detailed age groupings, and detailed income ranges. The other "humped" curve in figure 1 shows the resulting distribution of individuals by household income for the whole of the United States. Finally, 3 years of mortality data by state, sex, and age centred on 1990 were downloaded from the Centers for Disease Control and Prevention CDC Wonder site (http://wonder.cdc.gov/).

Given these data, a series of hypothetical standardised mortalities specific for states was constructed. For each state, the generic relation between individual level income and risk of mortality, shown by the income-mortality curve in figure 1, was applied to the actual income distribution within the state. In other words, a set of expected relative risks of mortality was calculated for each detailed age-sex-income-state category. These relative risks were next averaged over income groups, within each age-sex-state group, taking account of number of individuals in each income interval (within age-sex-state groups). The result is a set of relative risks of dying as if the only reason for differences between states in risks of mortality were differences in income inequality between states (that is, differences in the composition of each state's population by income group).

We then multiplied these relative risks by corresponding national mortality specific for age-sex and then standardised the rates by age-sex to the overall US population. The result is a set of hypothetical state specific mortalities where the only reason a state's mortality experience should differ from the national pattern is that its population has a different income distribution. These hypothetical mortalities are thus, by construction, exactly those we should observe if Gravelle's artefact hypothesis were 100% correct.

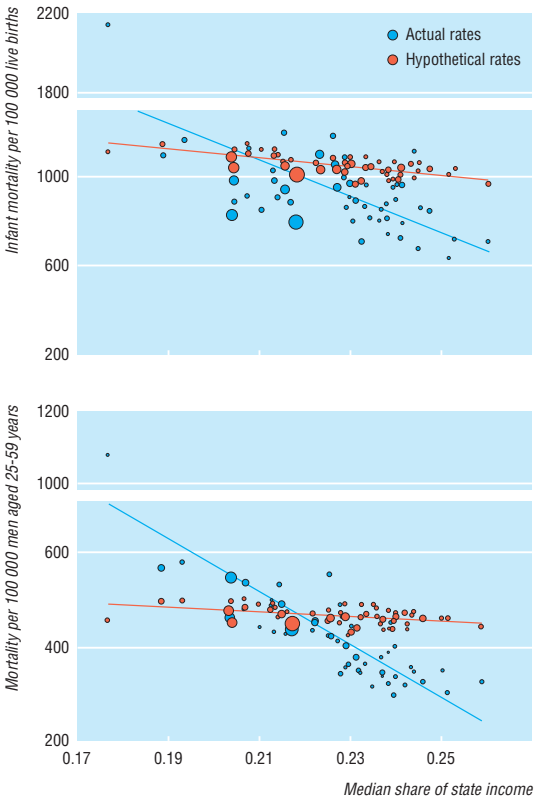

Fig 2 Actual and hypothetical mortality for infants and working age men by income inequality. Solid and dashed lines are ordinary least squares regression fits through the actual and hypothetical data points, respectively

Results

Some of the main results are shown in figures 2a-b for mortality in infants and working age (25 to 59) men, respectively. Mortality is on the y axis, with income inequality, measured by the proportion of total household income accruing to the bottom half of the population (the "median share") along the x axis. Each point in these scatter plots represents one of the 50 US states plus Washington, DC, with the area of each circle proportional to the state's population.

Discussion

The pattern of mortality generated from a literal application of Gravelle's artefact hypothesis provides a poor fit with the observed data in the United States. If the observed association between state level standardised mortality and income inequality were completely artefactual then the two scatters of points (actual and hypothetical, solid and open circles) would be on top of one another and the two regression lines would be superimposed. This is clearly not the case. Mortality based on the artefact hypothesis shows some slope in the expected direction—a higher share of income accruing to the bottom half of the population, indicating lower inequality, is associated with lower mortality. But these slopes are considerably less than the slopes of actual mortality in relation to income inequality.

The observed associations in the United States at the state level between income inequality and mortality therefore cannot be entirely, or even substantially, explained as statistical artefacts of an underlying individual level relation between income and risk of mortality. There remains an important association between state level income inequality and mortality, over and above anything that could be accounted for by statistical artefact.

Key messages

- Evidence is accumulating that living in a society with higher inequality in income predisposes its members to higher mortality; at the same time, there is widespread evidence that, for individuals, higher income is protective
- This individual level relation could "explain" the former societal level relation
- The strength of observed levels of association between income inequality and mortality, however, may go well beyond what can be explained as a statistical artefact of an individual level relation between income and mortality
- The empirical analysis reported here, based on 1990 data for US states, suggests that the association between income inequality and mortality is considerably stronger than can be accounted for by any statistical artefact
- Research underpinning public health policy should therefore take a broad view of the importance of the social milieu as a fundamental determinant of health

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Contributors: MCW conceived the methods used for assessing empirically the artefact hypothesis, specified, acquired, and analysed the US census data, and developed and wrote the software for constructing the hypothetical counterfactual. GK and JL inspired the analysis and participated in the framing and writing of the final paper. NR undertook the statistical analysis of the state level data, prepared the graphical results, and participated in the writing of the papers. EB undertook the special regression analyses for the individual level relation between mortality and income and participated in the writing of the paper. MCW is guarantor.

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Diminishing returns to aggregate level studies

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The suggestion that the health of individuals depends on the characteristics of the society in which they live, as well as on their own characteristics, is important. Almost all the empirical work it has prompted has examined the aggregate level relation between income inequality and population mortality. But if the individual level relation between risk of mortality and income is curvilinear at least part of any association between population mortality and income inequality is artefactual in the sense that it could arise even if individual risk was due only to individual income and not to its distribution.

The paper by Wolfson et al is an ingenious attempt to estimate how much of the variation in cross sectional US state level mortality could be due to the curvature of the relation between individual level mortality and income interacting with differences in the

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distribution of income within states. The authors estimate the hypothetical state level mortality that would arise if individuals' relative risks of mortality depended non-linearly on their incomes and income distributions differed across states. They argue that if there was no direct effect of income distribution on individual mortality then state level actual and hypothetical mortality should coincide. Their figures show that actual and hypothetical mortality diverge considerably and that regression lines relating actual and hypothetical state mortality to income equality have different slopes. The authors conclude that the artefact explanation is not the main reason for the frequently documented correlations between population mortality and income distribution.

There are two difficulties with this conclusion. Firstly, in the absence of any detailed information on the regressions it is difficult to determine if the difference between actual and hypothetical mortality is significantly related to income equality. The points plotted seem to have a wide scatter. Furthermore, one outlier state with an actual mortality around twice the mean and with a low measure of income equality seems to be exerting a considerable influence on the slope of the regression line of actual mortality against income equality.

Secondly, individual risk of mortality is affected by several other individual characteristics, such as education,[1] and possibly by state level characteristics, such as climate or public health infrastructure. In testing for a relation between income distribution and the difference between actual and hypothetical state mortality, it is necessary to allow for the potentially confounding effect of other factors measured at state level, such as mean education level, expenditure on public health, climate, etc.

The authors are right to suggest that investigations of the determinants of individual health ought to test for the effect of societal factors and that such testing requires both individual level and aggregate data. The fact that the few studies that have used appropriate data yield contradictory conclusions[2-4] should not be used to support further aggregate level analysis. Investigators need to collect better individual level data and to formulate their models clearly to take account of the complexities arising from the multiple influences on health, the two way causation between income and health, and the lags in the relations. The authors' clear demonstration of diminishing returns in the effect of individual income on individual health in figure 1 reinforces the argument that aggregate level analysis of population health and income distribution is subject to rapidly diminishing intellectual returns.

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Two pathways, but how much do they diverge?

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Whether narrower differences in income lead to better population health through the effects of individual income or through the wider effects of inequality in society, it is surely mischievous to call either pathway "artefactual." The argument is about how, rather than whether, narrower income differences are related to better population health. The pathway does not alter the reality of the health benefits or the central policy implications. In addition, the difference between the pathways may be less important than some suppose because, as Wolfson et al rightly point out, we cannot assume that individual and societal pathways map neatly on to the distinction between material and psychosocial processes. We know from experiments among monkeys that low social status is itself a risk factor for poor health that works through biologically plausible psychosocial pathways. As similar processes seem to contribute to inequalities in human health[1] it seems right to regard individual income partly as a marker for social status. At the societal level it is also possible—though perhaps less probable—that inequality could be generated by material risk factors. In future let us refer to individual and societal components of the inequality effect.

My view of what might lie behind the relation with income inequality has changed substantially over the years. The curvature of the relation between individual income and mortality was what initially led me to see whether a society's health was related to its income distribution. Because the incomes of only a small proportion of the population are low enough to put them on to the steeply rising part of the curve (see Wolfson et al fig 1), however, the inequality effect looked too large to be explained by curvature alone.[2] In addition, the fact that income and health are so much more closely related within developed countries than between them implied that curves within countries reflect a relation with relative rather than absolute income. After all, even the poor in the United States (those below half the average US income) still fall on the flatter part of the international curve.

On top of the individual effects of relative deprivation and low social status, there are probably also cultural processes by which less egalitarian societies develop more aggressive and less supportive social environments.[3] The deeper and more concentrated relative deprivation becomes, the more society's institutions and prosocial norms of behaviour will lose respect and legitimacy. Although a rise in the more socially antagonistic, delinquent, and risky forms of behaviour—which often accompany high levels of deprivation—may be felt throughout society, these processes are likely to increase health inequalities as they are driven by relative deprivation and concentrated in the poorest areas.[4]

The balance between individual and societal pathways is likely to vary from one country to another, from one period to another, and with the size of the areas over which inequality is measured. But regardless of the pathway, the relation between income inequality and population health suggests that reducing health inequalities need not conflict with the desire to raise health standards throughout society. Instead of redistributing a given amount of health or health producing goods in a zero sum game, we can be confident that increased wellbeing among the least well off need not be matched by losses among the rich.

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Effect of station design on death in the London Underground: observational study

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Injury and death after a fall or jump under a train (known colloquially as a "one under") are common on the London Underground.[1] Emergency teams noticed that both severity of injury and survival seemed to be related to the design of the station, with a drainage pit (often called the "suicide pit") giving a protective effect. This pit is located under the railway tracks for the length of the platform in about half of underground stations. It is usually about a metre deep and was originally intended to drain water away from the platform.

We carried out this study to assess mortality in patients hit by London Underground trains at platforms with and without a drainage pit.

Methods and results

For each incident from January 1996 to March 1997 the "record of incident" made in compliance with the Railway Regulations Act of 1893 was retrospectively examined. The platform of each incident and the outcome (lived or died) were recorded. The presence of a drainage pit was ascertained from the station manager or by personal inspection. The outcome with and without a drainage pit was compared with Fisher's exact test.

Fifty eight cases occurred over the 15 months, but the exact platform concerned could not be ascertained for five incidents. Thirty three patients died (overall mortality 57%). The table shows that the mortality was 44% for platforms with a pit compared with 76% for platforms without a pit. This difference was significant ($P = 0.026$).

Comment

This study shows that the presence of a pit halves the number of deaths in patients who are hit by a train. The overall mortality (at 57%) was similar to the previously reported figures of 55%[2] and 45%.[1] Many attempts have been made to reduce the number of deaths on the London Underground.[3–5] The association between the pit and increased survival[2] is purely fortuitous as pits were introduced for engineering reasons. The pit increases the clearance between the train and the ground, probably allowing a casualty to fall away from the train's wheels. Even when a pit is present, if the casualty has not fallen into it then he or she is unlikely to survive.

In the design of rolling stock little attention is paid to the interaction between a human body and the train. New carriages at present being introduced on the Jubilee line have less ground clearance, and therefore there is even less room for a body to escape the wheels. The ultimate method of preventing death under trains is the complete separation of moving trains and passengers by the introduction of sliding doors along the platform edge that open only when the train has come to a halt. This feature has been incorporated into some new stations but would probably be prohibitively expensive to introduce at existing stations.

Being hit by a train is an important cause of death from trauma in London, but the presence of a pit under the rails halves the mortality. The mechanics of the interaction of the human body with the train are poorly studied, and so present rolling stock and stations are not designed to maximise survival.

Outcome in 58 incidents according to whether platform did or did not have pit

	Pit	No pit	Unknown	Total
Dead	14	16	3	33
Alive	18	5	2	25

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