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Review

Income inequality and health: A causal review

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ABSTRACT

There is a very large literature examining income inequality in relation to health. Early reviews came to different interpretations of the evidence, though a large majority of studies reported that health tended to be worse in more unequal societies. More recent studies, not included in those reviews, provide substantial new evidence. Our purpose in this paper is to assess whether or not wider income differences play a causal role leading to worse health. We conducted a literature review within an epidemiological causal framework and inferred the likelihood of a causal relationship between income inequality and health (including violence) by considering the evidence as a whole. The body of evidence strongly suggests that income inequality affects population health and wellbeing. The major causal criteria of temporality, biological plausibility, consistency and lack of alternative explanations are well supported. Of the small minority of studies which find no association, most can be explained by income inequality being measured at an inappropriate scale, the inclusion of mediating variables as controls, the use of subjective rather than objective measures of health, or follow up periods which are too short.

The evidence that large income differences have damaging health and social consequences is strong and in most countries inequality is increasing. Narrowing the gap will improve the health and wellbeing of populations.

Key points

- Evidence that income inequality is associated with worse health is reviewed.
- It meets established epidemiological and other scientific criteria for causality.
- The causal processes may extend to violence and other problems with social gradients.
- Reducing income inequality will improve population health and wellbeing.

1. Introduction

World leaders, including the US President, the UK Prime Minister, the Pope and leaders at the International Monetary Fund, the United Nations, World Bank and the World Economic Forum have all described income inequality as one of the most important problems of our time and several have emphasized its social costs (Cameron, 2009; Elliott, 2014; Lagarde, 2013; Moon, 2013; Obama, 2014; Pope Francis, 2013; World Economic Forum, 2014). Inequality is increasing in most regions of the world, rapidly in most rich countries over the past three decades (OECD, 2011; Ortiz and Cummins, 2011). There is a very large literature examining income inequality in relation to health. Early reviews came to different interpretations of the evidence, though a majority of studies reported that health tended to be worse in more unequal societies (Lynch et al., 2004; Macinko et al., 2003; Subramanian and Kawachi, 2004; Wagstaff and van Doorslaer, 2000; Wilkinson and Pickett, 2006). More recent studies, not included in those reviews, provide substantial new evidence.

There is also growing evidence that a wide range of social outcomes, associated with disadvantage within societies, are more common in societies with bigger income differences between rich and poor. Although our objective in this paper is to assess whether or not wider income differences play a causal role leading to worse health (including the public health issue of violence), we consider studies of other social outcomes where they affect interpretation of the health data.

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The first task is to clarify the causal hypothesis, and how it has developed as research has progressed. Research was initially focused simply on whether health was worse in more unequal societies, but there is now growing evidence to suggest that this should be seen as part of a wider tendency for a broad range of outcomes with negative social gradients (i.e. more prevalent where social status is lower) to be more common in societies with bigger income differences between rich and poor. Rather than this pattern being confined to physical health, it may apply also to mental health, and public health issues such as violence, teenage births, child wellbeing, obesity, and more.

Whether causality is tested in relation to a hypothesis confined to a relationship between inequality and physical health, or whether the hypothesis extends to problems with social gradients more generally, has important implications for understanding possible causal mechanisms, mediators and confounders.

In this paper, we will focus on the strongest and most important claim underpinning an effect of inequality on health: that large income differences between rich and poor lead to an increasing frequency of most of the problems associated with low social status within societies. Fig. 1 provides an illustration of the relationships with which this paper is concerned. It shows a cross sectional association between income inequality in developed countries and an index which combines data on: life expectancy, mental illness, obesity, infant mortality, teenage births, homicides, imprisonment, educational attainment, distrust and social mobility. (Raw scores for each variable were converted to z-scores and each country given its average z-score (Wilkinson and Pickett, 2009).)

2. History

The hypothesis that problems (including poor health) associated with low social status are more common in more unequal societies can be traced back to independent roots in papers on homicide rates and on mortality rates. The research literature on homicide and inequality goes back at least 40 years, to a demonstration that they were positively associated among states in the USA (Loftin and Hill, 1974). The earliest paper on mortality and income inequality — some 35 years ago — showed a cross-sectional association between Gini coefficients of income inequality and both infant mortality and life expectancy at age 5, among a group of 56 developed and developing countries (Rodgers, 1979). By 1993, a meta-analysis of some 34 studies concluded that there was a robust tendency for violence to be more common where income differences were larger (Hsieh and Pugh, 1993). The research on income inequality and health expanded rapidly after the first papers were published in journals of epidemiology and public health (Wilkinson, 1992a,b). By 2006, a review of papers on income inequality and health identified 168 analyses, the overwhelming majority of which showed a positive association (Wilkinson and Pickett, 2006). The two literatures — in criminology and sociology on the one hand, and epidemiology and public health on the other — developed independently and unaware of each other until the late 1990s (Wilkinson et al., 1998; Wilson and Daly, 1997).

It was only in 2005 and 2006 (Pickett et al., 2006, 2005a,b), as researchers began to show that the correlates of inequality included teenage birth rates, obesity and mental illness, that it started to look as if a more general explanatory hypothesis was needed than those which had addressed only physical health and violence. On the assumption that social gradients were often evidence that an outcome was sensitive to social status differentiation, we formed the hypothesis that greater inequality might act to strengthen the effects of socioeconomic status differentiation among outcomes with social gradients.

We tested this hypothesis by analyzing whether or not outcomes with steeper social gradients had stronger associations with societal inequality. We selected ten different death rates, some with weaker and some with stronger social gradients, as measured by their correlation with county median income, among the 3139 counties of the USA (Wilkinson and Pickett, 2008). In a multilevel model controlling for the effects of county income, we then estimated the correlations of these death rates with state income inequality. The results, shown in Fig. 2, provided strong confirmation of the hypothesis.

Fig. 1. Index of health and social problems in relation to income inequality in rich countries. Income inequality is measured by the ratio of incomes among the richest compared with the poorest 20% in each country. The index combines data on: life expectancy, mental illness, obesity, infant mortality, teenage births, homicides, imprisonment, educational attainment, distrust and social mobility. Raw scores for each variable were converted to z-scores and each country given its average z-score (Wilkinson and Pickett, 2009).

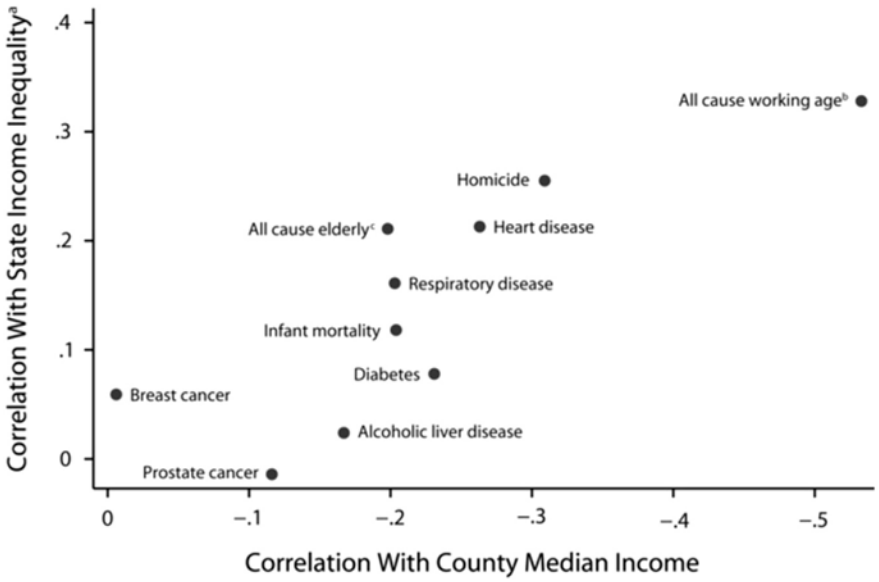

Fig. 2. The effect of county-level median household income in relation to contextual effect of state-level income inequality. *Note.* $r = -0.814$; $P = .004$. [a]Standardized parameter estimates (B) from multilevel model after county-level income was controlled. [b]Aged 25–64 years. [c]Aged ≥65 years.

This was followed by studies that examined the association among rich developed countries between income inequality and a number of health and wellbeing outcomes, including the UNICEF Index of Child Wellbeing and the separate components of the Index of Health and Social Problems shown in Fig. 1 (Pickett and Wilkinson, 2007b; Wilkinson and Pickett, 2007; Wilkinson and Pickett, 2009).

3. Popperian theory testing

The philosopher of science, Sir Karl Popper, taught that the best evidence of the value of a theory was provided by testing its novel predictions (Popper, 2002, 2014). A successful theory was 'corroborated' (but could never be finally proven true) if it accurately predicted the results of scientific observations which had not previously been expected. The initial evidence of a relation between income inequality and population health using international data was first explicitly tested and confirmed in 1996 by two groups working independently at the universities of Harvard and Michigan, who looked to see if the same relationship could be found among the 50 states of the USA (Kaplan et al., 1996; Kennedy et al., 1996). There are now very large numbers — hundreds — of replications of these findings in many different settings in societies at all levels of development. Even the more unequal provinces of China have been found to have significantly less good health (Pei and Rodriguez, 2006). There can now be no doubt that worse health is at least *associated* with greater inequality. The tendency for more unequal societies to have higher homicide rates has also been replicated many times (for one recent review see Rufrancos et al. (2013)). To suggest that a relationship is causal means predicting a subsidiary hypothesis about a mediating mechanism. A testable prediction of a causal mechanism was first suggested, on the basis of qualitative impressions only. The hypothesis was that more equal societies were healthier because they were more cohesive and enjoyed better social relations (Wilkinson, 1996). A year later that prediction was tested quantitatively: path analysis showed that the relationship between greater equality and lower death rates among the US states was mediated by social capital (operationalized as group membership and social trust) (Kawachi et al., 1997).

Another way in which testable predictions have emerged has been when new national data have become available which fit previously established relationships between inequality and an outcome measure. This happened when new data on social mobility and on mental illness rates became available for several additional countries and was found to fit previously established relationships between those outcomes and inequality (Wilkinson and Pickett, 2010b, 288–290).

Lastly, the first papers suggesting that mental illness was more common in more unequal societies used general measures of mental illness from WHO (Pickett et al., 2006; Pickett and Wilkinson, 2010). The picture has since been filled out by papers which show that more specific forms of mental illness, including depression, schizophrenia and psychotic symptoms are all more common in more unequal societies (Burns et al., 2014; Johnson et al., forthcoming; Messias et al., 2011).

There have been a small proportion of negative findings throughout the development of this field. We shall discuss some of the reasons for variations in findings at appropriate points later in this paper.

Our aim in this review is to go beyond the 'counting' methodology of previous major reviews — these mostly divided studies into supportive, mixed and unsupportive of the income inequality—health relationship, and counted them. Among mixed studies, which showed some but not all relationships to be significant, results within a study might vary by geographic scale, or by health outcome, measure of inequality, gender or age of subjects, etc. — merely counting these adds nothing to interpretation, even if we count more. Instead we conduct a causal review to give a more structured and coherent framework to our examination of the literature. We have aimed to incorporate all new studies that illuminate relevant causal processes.

4. Epidemiological criteria for causality

In observational epidemiology, causality cannot be proven or disproven by any single study — there are no 'black swans' — just because income inequality might not affect some health outcomes, or not in some times or places or for some populations, does not

mean that it isn't a causal relationship in other contexts. Instead, in epidemiology, a body of evidence needs to be considered, usually including non-epidemiological studies, to judge whether or not an exposure–outcome relationship is causal. Causal criteria were first proposed in the Surgeon General's Report of 1964, and refined by Sir Austin Bradford Hill in 1965, in the context of examining the evidence linking cigarette smoking to lung cancer (Hill, 1965; Terry, 1964). The use of causal criteria, indeed even the term 'criteria', has been contentious, especially if they are used as a simple checklist or algorithm; however when used as a framework for thoughtful inference, and used to consider competing causal theories by focusing on crucial observations, they offer a useful organizing structure for critical review (Bhopal, 2002; Rothman et al., 2008). Bradford Hill's original 9 'criteria' have been further refined with modern usage and, as indicated in Table 1, 4 are considered of major importance (Gordis, 2013).

4.1. Consistency

There are now perhaps as many as 300 peer-reviewed studies of the relation between income inequality and measures of health or homicide. They include both ecological and multilevel studies using cross-sectional, cohort and time-series designs in many time periods. Looking at bivariate correlations before the use of control variables, the most recent full review found only 6 per cent (8 of 128) of studies did not find at least one significant association between greater inequality and worse health (Wilkinson and Pickett, 2006). After the use of many different kinds of control variables, many of which might be on the causal pathway, 70 per cent of the studies reporting either positive or negative (but not "mixed") results, found only significant associations between higher inequality and worse outcomes.

These relationships have been found in a wide variety of settings. Much research has focused on the rich, developed, market economies (UK, USA, western Europe, Japan, Singapore, Australia and New Zealand) and analyses of the 50 US states (Wilkinson and Pickett, 2007; Wilkinson and Pickett, 2009). Some studies have included developing, emerging and developed nations, or focused on developing countries in particular. Infant mortality is the health outcome most often shown to be positively correlated with income inequality in less developed nations (Babones, 2008; Flegg, 1982; Hales et al., 1999), although there are also associations with lower life expectancy, higher HIV prevalence and higher homicide rates (Babones, 2008; Drain et al., 2004; Fajnzylber et al., 2002). Some studies have focused on particular world regions. For example, Marmot and Bobak found larger declines in life expectancy in the more unequal countries of Eastern Europe following the dissolution of the Soviet Union (Marmot and Bobak, 2000). Biggs and colleagues studied 22 Latin American countries from 1960 to 2007 and found a substantial relationship between income inequality, life expectancy, infant mortality and tuberculosis mortality rates; they also reported that when inequality was rising, economic growth was related to only a modest improvement in health, whereas during periods of decreasing inequality, there was a very strong effect of rising Gross Domestic Product (Biggs et al., 2013). Other studies have shown an association between income inequality and health across states/regions within nations, including, for example, in Argentina (De Maio et al., 2012), Canada (Daly et al., 2001), Brazil (Rasella et al., 2013), Chile (Subramanian et al., 2003), China (Pei and Rodriguez, 2006), Ecuador (Larrea and Kawachi, 2005), India (Rajan et al., 2013), Italy (De Vogli et al., 2005), Japan (Kondo et al., 2008), and Russia (Walberg et al., 1998).

Table 1
Epidemiological framework for causal inference (major criteria are in bold) (Gordis, 2013).

Consistency	**The association has been replicated in different methodological, geographical and time settings**
Temporality	**The putative cause must precede the effect, this is an indisputable criterion for causality**
Strength of association	The stronger an association is the less likely it is that there is some alternative unknown explanation
Specificity	There is a high probability that an exposure is causally linked to some outcomes more than to others (many epidemiologists believe this criterion should be dropped)
Dose response Relationship	Increased exposure is related to increased outcomes
Cessation of exposure	If exposure changes, positively or negatively, the incidence of the outcome will rise or fall
Consideration of alternative explanations	**The association is not confounded by one or more other factors**
Biological plausibility	**The association fits with existing biological knowledge**
Coherence	The association is supported by other scientific knowledge

The geographical scale at which income inequality is measured is, however, an important methodological issue because it points to a distinction between the large majority of supportive studies and the unsupportive minority. In one review, researchers found that after the use of controls, the proportion of analyses classified as wholly supportive of an income inequality effect on health was 83 per cent among international studies, but fell to 73 per cent in large subnational areas, and to 45 per cent in studies of small areas such as neighborhoods (Wilkinson and Pickett, 2006). A similar pattern was noted in an earlier meta-analysis of studies of income inequality and violent crime, including homicide (Hsieh and Pugh, 1993) and a later meta-analysis of multilevel studies (Kondo et al., 2012). Hsieh and Pugh concluded that "homogenous estimates of association between income inequality and homicide were reported by studies using states and nations as their sampling units, but not by studies using smaller sampling units."

We have previously suggested that studies of income inequality are more supportive in large areas because in that context income inequality serves as a measure and determinant of the scale of social stratification, or how hierarchical a society is (Wilkinson and Pickett, 2006). Income inequality in small areas is affected by the degree of residential segregation of rich and poor and the health of people in deprived neighborhoods is likely to be poor — not because of the inequality within each of those small areas — but because they are deprived in relation to the wider society. Studies from the USA and Sweden, which have compared the strength of association at different levels of aggregation, support this interpretation and the need to think carefully about scale before conducting studies (Chen and Gotway Crawford, 2012; Franzini et al., 2001; Rostila et al., 2012). Another factor which might contribute to the same picture is the possibility that more unequal societies may give rise to greater residential segregation between rich and poor, so increasing the inequality between areas and diminishing the inequality within them.

Together, the studies provide overwhelming evidence that greater inequality is linked to worse health and more violence. Factors such as the size of area (Chen and Gotway Crawford, 2012) and the use of conceptually inappropriate controls, may provide plausible explanations of the minority of unsupportive studies.

4.2. Temporality

The large number of cross-sectional studies, undertaken over several decades, which link health and violence to income inequality, imply that there are relationships over time. As neither

income distribution nor health are invariant over time, the fact that cross-sectional associations between them have been reported so many times is in itself an indication that they move together.

The preponderance of cross-sectional studies is partly a reflection of the limited availability of time series estimates of income inequality and, for some countries, for health outcomes. But there are now a growing number of studies of these relationships over time.

A meta-analysis of multi-level studies by Kondo and colleagues included data covering almost 60 million individuals from 9 cohort studies from Denmark, Finland, Norway, New Zealand, Sweden and the USA, with follow-up periods ranging from 1 to 28 years (Kondo et al., 2009). The overall cohort relative risk (95% confidence interval) per 0.05 unit increase in the Gini coefficient, a measure of income inequality, was 1.08 (1.06–1.10). Studies with baseline data collection after 1990 and a length of follow-up greater than 7 years had a marginally higher relative risk, these interactions were not modified by the size of the area in which inequality was measured (Kondo et al., 2012).

In an international panel study of 21 developed countries over 30 years, controlling for serial correlation, and stratifying by age and sex, Torre and Myrskylä, found that high inequality was associated with increased mortality of males and females aged 1–49 and older women, but not older men (Torre and Myrskyla, 2014).

Zheng (2012) reviewed 79 studies of income inequality in relation to mortality: 4 aggregate and 7 multi-level studies examined lagged effects up to 10 years, with mixed results, but all of these studies tested the lagged effect of income inequality in a particular year, treating it as a time-invariant variable and failing to control for a series of previous, subsequent and contemporaneous income inequalities. Zheng also reviewed 8 similar studies of self-rated health – 7 found a significant effect, with 2 suggesting the strongest effect persisting through 15 years, however, again none of these studies looked at serial measures of inequality. Zheng's reviews included studies published through 2008 and contained in four previously published reviews (Kondo et al., 2009; Lynch et al., 2004; Subramanian and Kawachi, 2004; Wilkinson and Pickett, 2006).

We have conducted a further primary systematic search for time-series and panel studies of income inequality and health, and identified an additional 9 studies, containing 53 analyses, including studies of mortality, life expectancy, infant mortality, under-5 survival rate and self-rated health (see Supplementary Table S1). Of these, 55% support a longitudinal effect of income inequality on health (60% of within-country studies in USA, UK and Norway), 37.5% do not and 7.5% had mixed results, but all of these studies also suffer from the same methodological problem of not considering time-variant income inequality.

Studies also varied in the inclusion of control variables in the analyses of income inequality and health, including measures of aggregate or individual income or education, ethnic mix, unemployment, alcohol or tobacco consumption, birth, fertility and divorce rates, benefit payments, health expenditure, etc. As some of these may be mediating or moderating factors in a causal pathway leading from income inequality to health, the inclusion of some is questionable and the estimates of the effect of inequality would be under-estimated.

Zheng went on to conduct a discrete time-hazard analysis of US national-level income inequality on mortality, controlling for individual income, in 701,179 individuals with a 21 year follow-up; a detrimental effect of rising inequality began to affect mortality after 3–5 years and the effect size increased until mortality plateaued at a higher level after 12 years. This finding was robust to different model specifications and different measures of inequality. This study probably provides the best estimates of the *average* lag time between changes in inequality and mortality. It seems to accord well with other studies, though of course lag times will vary between age groups and causes of death.

A review of time-series and panel studies of income inequality and crime, that included 7 studies examining homicide rates, 5 conducted in the USA, Canada or by international cross-country comparisons, found a significant increase in the murder rate with rising income inequality (Rufrancos et al., 2013). A study in West Germany found no association, as did a single international study, although the statistical methods of this study were criticized.

Clarkwest analyzed state-level data within the USA, from 1970 to 2000, to examine the effects of initial levels and change in income inequality on 10-year changes in life expectancy, finding that states with higher levels of inequality experienced less subsequent improvement in life expectancy (Clarkwest, 2008).

It is important to note that, for reasons which are not well understood, health continues to improve over time in most developed countries, with life expectancy rising by approximately 2–3 years with each decade. Against this background rate of improvement, the effect of changes in income inequality is to speed up or slow this background rate. Only when there are catastrophic rises in inequality, as in Russia and Eastern Europe during the transition, does life expectancy actually fall (Marmot and Bobak, 2000).

A number of studies have suggested that death rates among the elderly show little or no relation to current inequality, see for example, Torre and Myrskyla (2014). However, analyses have shown that the health of older people is independently influenced by socioeconomic class at three different points in the life course, by fetal health and perhaps also by social security provisions in childhood (Hoynes et al., 2012; Johnson and Schoeni, 2011; Smith et al., 1997). If health in later life is similarly affected by lifetime exposure to inequality, we will need lifelong measures of exposure before we know whether the health of the elderly really is insensitive to their life time's experience of inequality.

4.3. Strength of association

In general, the stronger an association between putative cause and effect, the less likely it is that the relationship can be explained by other factors. But with health outcomes which are multifactorial, not all causes will have strong effects if they are necessary but not sufficient to cause the outcome alone. Nevertheless, at a population level, even moderate effects can have large impacts.

In international, cross-sectional, unadjusted studies of income inequality in relation to health and social problems in rich countries, the strength of the statistically significant associations vary (Pickett and Wilkinson, 2007a; Wilkinson and Pickett, 2010b; Wilkinson and Pickett, 2007; Wilkinson and Pickett, 2009). Correlations with income inequality are higher for mental illness and teenage birth rates (both, $r = 0.73$), drug use and child wellbeing (both, $r = 0.63$) than for life expectancy, infant mortality, obesity and homicides (all, $r < 0.5$). However, when we treated income inequality as a common cause of many health and social problems and combined them in one index, which tends to emphasize their common variance, the correlation with an index of problems was so high ($r = 0.87$) that any alternative explanations would need to have extraordinarily strong effects (Fig. 1).

When estimated in multilevel models, the size of the effect of inequality usually looks much smaller – as described above in the section on Consistency. The difference is a matter of what is included as an effect of inequality. Some of the early multilevel studies of the effects of inequality were based on the assumption that the relationship between individual income and health was a reflection of the direct effects of what people's material circumstances did for their health regardless of anyone else in society. The

desire was to separate out such effects, before looking at the broader contextual effects of inequality, which were assumed to work through quite different pathways involving psychosocial processes hinging on relativities and social comparisons. However, a great deal of research attests to the likelihood that individual income is related to health because it is a marker of individual social status (Adler et al., 2000; Marmot, 2004) and that subjective social status may be more important than objective measures (Singh-Manoux et al., 2006). There is also evidence that greater inequality worsens outcomes such as math and literacy scores, social mobility, dropping out of high school teenage birth rates and mental illness, all of which might create feedback from higher inequality to increased numbers of people on low incomes (Messias et al., 2011; OECD, 2009; Wilkinson and Pickett, 2010b). If so, this would mean that multilevel models controlling out the effects of individual income risk seriously underestimating the effects of inequality.

4.4. Specificity

In some contexts, specificity is an outmoded causal criterion which dates from when the main health focus was on infectious diseases which could only be caused by exposure to a specific pathogen. It is less relevant in a context where most health and social problems have multiple, interacting causes and many outcomes share causes. However, there is an aspect of specificity in the relationship between income inequality and health that is helpful when considering causality and the pathways from one to the other. As we outlined in the History section above, the adverse effects of income inequality seem to be specific to outcomes which have an inverse social gradient (Wilkinson and Pickett, 2008). For example, there was no social gradient for breast or prostate cancer mortality, and no effect of income inequality, whereas there was a steep social gradient in working age all-cause mortality, and a strong association with income inequality. This would explain why the social outcomes included in Fig. 1 are more common in unequal societies.

Broadly similar results have been found for child health (Bird, 2014). In 29 OECD countries, income inequality was positively related to post-neonatal mortality and teenage overweight, both of which have steep social gradients, whilst there was no association for suicide, which did not have clear evidence of a social gradient in some countries. One interpretation of this specificity is that income inequality intensifies the health effects of social hierarchy and social comparisons, thus increasing socioeconomic disparities in health. However, there was no association between income inequality and child asthma or adolescent smoking, both of which have some evidence of social gradients.

In international comparative studies there is also a degree of specificity with regard to income inequality being associated with objective measures of health, rather than subjective measures. This is because, internationally, there is no correlation between life expectancy and subjective health measures such as the proportion of the population with good self-rated health, although these measures are correlated within countries (Barford et al., 2010; Dorling and Barford, 2009).

4.5. Dose–response relationship

A very large number of studies demonstrate statistically significant linear relationships between income inequality and health. The effects on inequality increase step by step from the most unequal of the 50 states of the USA and the most unequal countries to the most equal. However, Kondo and colleagues find a threshold effect, with higher relative risk of mortality in cohort studies with higher levels of income inequality (Gini coefficient >0.30) at baseline (Kondo et al., 2012). In other analyses of health and social problems among developed countries the relationships tend to appear linear, with no evidence of a step change above some threshold level of inequality (see Fig. 1). According to the World Bank World Development Indicators database, few nations have Gini coefficients below 0.30 (World Bank, 2014), the threshold identified by Kondo and colleagues. Among developing nations there is only Afghanistan. Several former Soviet republics (Belarus, Bulgaria, Czech Republic, Kazakhstan, Romania, Slovak Republic, Ukraine) have Gini coefficients between 0.25 and 0.29, as do the Scandinavian countries (Denmark, Finland, Norway, Sweden), Austria, Germany and Japan. Among OECD countries, only the Netherlands has not experienced a rise in income inequality since the mid-1980s. Thus most of the world's population is exposed to income inequality above the threshold suggested by Kondo et al., and the proportion exposed continues to rise (Smeeding et al., 2014).

However, even within more equal countries, inequality seems to matter. A recent study from Norway (Elstad, 2011) found an independent effect of regional income inequality on mortality, after adjustment for regional-level social and economic characteristics. A study from Finland (Aittomaki et al., 2014) suggested that widening differences in income inequality account for almost half of the increase in health inequalities, and one from Sweden found a detrimental effect of municipal income inequality on self-rated health (Rostila et al., 2012).

Whether each additional increment of inequality above a Gini of 0.3 has a greater effect than it does below that level remains unclear, but there is substantial agreement that there is a dose–response relationship above that level.

4.6. Cessation of exposure

There can be no examples of cessation of exposure to inequality – only of exposure to more or less inequality. Interesting evidence comes from a study by Hamilton and Kawachi (2013), which assessed whether or not individuals who migrated to the USA from countries with greater income inequality than the USA have better health than those who migrated from countries with less income inequality. Among immigrants who lived in the USA between 6 and 20 years, those for whom moving to the USA was a move towards greater equality had better self-reported health than those for whom it was a move towards greater inequality. Similarly, Auger and colleagues found that income inequality was associated with mortality among non-immigrant Canadians but not migrants, although for long-term immigrants the effects tended to approach those of the Canadian born population (Auger et al., 2012).

Also relevant is the striking reversal in international rankings in income inequality and population health between the USA and Japan in the three or four decades following the Second World War (Bezruchka et al., 2008). In the post-war period, the USA had much lower inequality than it does today and ranked high in the international league table for life expectancy, whereas Japan was highly unequal, with lower life expectancy. But by the end of the 1980s, Japan had become one of the most equal countries and had the highest life expectancy in the world. In contrast, the USA became rapidly more unequal from the late 1960s and is now among the most unequal societies in the developed world. During that period its position slipped in the international life expectancy league tables and it now ranks 40th according to the United Nations (United Nations Department of Economic and Social Affairs (UN DESA) Population Division, 2011).

4.7. Consideration of alternative explanations

Given that the epidemiological criteria examined so far support a causal interpretation for the role of inequality, we should ask whether there are any other possible explanations.

A paper by Deaton in 2003 (Deaton and Lubotsky, 2003), reported that the proportion of black residents in states and Metropolitan Statistical Areas of the USA explained the income inequality–health association. This paper continues to be cited as evidence that income inequality does not affect health, despite the fact that several more recent studies find that ethnic heterogeneity does *not* confound the income inequality–health association in the USA (Ash and Robinson, 2009; Ram, 2005; Subramanian and Kawachi, 2003a; Subramanian and Kawachi, 2003b, 2004). International comparisons also show that income inequality is significantly related to health even after adjustment for ethnic heterogeneity (Ram, 2006). Nor does ethnicity explain the income inequality–homicide relationship in US states. To clarify this, one analysis of homicides in the 50 states confined attention to white perpetrators of homicides and showed they were significantly related to income inequality measured only among the white populations of each state (Daly and Wilson, 2010). It seems likely that ethnic differences attract more attention and seem more important not only when they become markers of social status differences but also when greater inequality makes social status differentiation more powerful, increasing the importance of 'downward' social prejudices whether by class or ethnicity (Andersen and Curtis, 2012; Kennedy et al., 1997).

Another proposed alternative explanation suggests not only that the relationship between individual income and health is curvilinear, such that a rise in income for the poor has a greater impact on health than an equivalent rise in income for the rich, but also that this effect reflects only the direct influence of material living standards on health — not inequality as such. The suggestion is that greater equality would improve average health but only for reasons related to what individual material circumstances do to health, regardless of other incomes and position in the income hierarchy. The assumption is that someone's health is affected only by their own income and is unaffected by where they are in the income hierarchy. Studies within the USA (Wolfson et al., 1999), UK (Wood et al., 2012) and international comparisons (Babones, 2008) disprove this explanation, as do the many multilevel studies of income inequality and health reviewed by Kondo et al., which control for individual income and socioeconomic status (Kondo et al., 2009). Such studies show a contextual effect of inequality over and above the effects of individual income.

Income inequality is, and can only be, an ecological variable describing the scale of income differences across a population. Because inferences are usually made only to other ecological variables such as rates of health or social problems across the same population, the possibility of an ecological fallacy does not arise: inferences are not made from ecological variables to individual risk. However, studies which ask 'whose health is affected by inequality?' suggest that although effects are probably strongest among the least well off, they extend to the majority of the population (Subramanian and Kawachi, 2006; Wilkinson and Pickett, 2010b).

It has also been suggested that the income inequality–health association reflects reverse causality — in other words, income inequality is a result of a larger proportion of the population being unhealthy, rather than a cause. The time series studies described above, which show that there are substantial lag periods between changes in inequality and changes in health, disprove this interpretation, as do the findings of cohort studies. In addition, income inequality has been related to many infant and child outcomes, including infant mortality, low birth weight, child wellbeing and child mental health problems, which would not be expected to affect inequality (Pickett and Wilkinson, 2007b).

The suggestion of reverse causality faces two other difficulties. The first is that more unequal countries appear to do badly on a wide range of health and social outcomes while more equal countries do well. If income inequality were a result of worsening outcomes, then it would be necessary to find an alternative explanation for why so many disparate problems — ranging from health to homicides, child wellbeing, mental illness and drug abuse — all tend to be worse in some countries than others. As they are such different outcomes, yet all with similar social gradients, it would be necessary to posit another, very deep-seated, explanation closely related to social status differentiation. Lastly, a good deal is known of the economic policies which came in from the late 1970s onwards that led directly to wider income differences.

In terms of pathways from income inequality to health, it has been suggested that more generous welfare regimes, public spending (e.g., on health or transport), more comprehensive social security, and investment in human capital development (e.g., education) are all characteristic of more equal societies and that the relation between income inequality and health may therefore be mediated by these 'neo-material' factors. From a neo-material perspective, the association between income inequality and health reflects people's lack of resources, as well as societal underinvestment in such things as "education, health services, transportation, environmental controls, availability of food, quality of housing, [and] occupational health regulations" (Lynch et al., 2000).

However, explicit tests of "neo-material" vs. psychosocial pathways from income inequality to healthy life expectancy, mortality, mental health and homicide rates conclude that psychosocial factors, such as social capital and trust, mediate the relationship, whereas neo-material factors, such as public expenditure on health or social services, have little or no explanatory role (Elgar, 2010; Elgar and Aitken, 2011; Layte, 2012). Of course, in so far as welfare regimes, social security, etc. redistribute income, it is difficult to disentangle the independent effects of income inequality and welfare regimes.

Lastly, there is a frequent tendency to imagine that cultural differences lie behind and are the real reason for associations between income inequality and a poorer performance on a wide range of health and social outcomes. Any such hypotheses about the role of culture would of course have to be compatible with the evidence that shows that health changes follow changes in income distribution after a lag of some years. It would also have to be compatible with the evidence of associations in different parts of the world, at different levels of development and with different cultures. So, for instance, Mexico, Russia and South Africa all have very high levels of income inequality and very high levels of violence, but their cultural identities are very different. Similarly, societies like Japan and the Scandinavian countries have low levels of inequality and low levels of violence despite obvious cultural differences between them. Also interesting is the cultural similarity between Portugal and Spain. They were both dictatorships until the mid 1970s and share a border. However, their performance on the Index of Health and Social Problems reflects, as Fig. 1 shows, their substantial differences in income distribution.

4.8. Biological plausibility

A psychosocial explanation of the effect of income inequality on health and behavioral outcomes is consistent with the biology of chronic stress, new studies of the neuroscience of social sensitivity, and concepts from evolutionary biology. Income inequality is

linked to lower levels of social cohesion and generalized trust, suggesting that inequality acts as a social stressor (Uslaner and Brown, 2005); Lancee and Van de Werfhorst, 2012 #3006; Delhey and Dragolov, 2014 #3574}.

Chronic stress impairs memory and increases risk of depression, lowers immune responses, elevates blood pressure and risk of cardiovascular disease, and affects hormonal systems (Sapolsky, 2005). Research shows that measures of how we relate to one another, such as friendship, social support and social networks, are as protective for health as smoking is deleterious (Holt-Lunstad et al., 2010). If we have friends, we are less likely to contract a common cold infection in randomized controlled trials (Cohen et al., 1997), if we have a difficult relationship with our spouses or partners we heal more slowly in trials of experimental wound healing (Kiecolt-Glaser et al., 2005). A meta-analysis of 208 laboratory studies of acute psychological stressors and cortisol responses shows that stronger cortisol responses were elicited if tasks were uncontrollable or characterized by "social-evaluative threat" (threats to self-esteem or social status) (Dickerson and Kemeny, 2004). Even low levels of psychological distress were found to be related to mortality in a meta-analysis of 10 large prospective cohort studies (Russ et al., 2012). Telomere length, a measure of cell aging, is shorter by age 9 among African American boys who lived in highly disadvantaged environments compared to those who were raised in more affluent environments (Mitchell et al., 2014).

Neuroscience studies also highlight the importance of psychosocial factors for human physiology. A neuroimaging study showed that social pain (exclusion) activated the same areas of the brain as physical pain. The anterior cingulate cortex (ACC) was more active during experiences of social exclusion and was positively correlated with self-reported distress (Eisenberger et al., 2003). In another study, baseline sensitivity to physical pain predicted sensitivity to social rejection and social exclusion was associated with more sensitivity to physical pain (Eisenberger et al., 2006). In two experiments, participants received either acetaminophen (a pain suppressant) or a placebo for 3 weeks. Acetaminophen reduced daily reports of social pain, and functional magnetic resonance imaging showed that acetaminophen reduced neural responses to social pain in areas of the brain previously shown to be related to both social and physical pain (DeWall et al., 2010).

Evolutionary explanations of human sensitivity to social relationships and hierarchies stress the importance of belonging and people's need for positive relationships and connectedness. Social exclusion affects cognitive, emotional, and behavioral outcomes, and adaptations to low social rank in both animals and humans include altered levels of hormones and behaviors, such as withdrawal, apathy, or hypervigilance (DeWall et al., 2011). A theory linking submission and subordination to depression suggests that it results from an inability to stop, or escape from, a submissive defeat strategy, and the evidence reviewed by Johnson and colleagues supports this; people with depression were more likely to report feeling inferior, or experiencing shame, in more than 20 research studies (Johnson et al., 2012).

4.9. Coherence

In rich countries there is no association between average levels of income (e.g. gross national income per capita) and measures of health, such as life expectancy (Cutler et al., 2006; Kenny, 2011; Preston, 2007; Wilkinson and Pickett, 2010a). Yet within rich countries there are strong associations between individual income and life expectancy. This pattern suggests that it is relative income within societies that is important for health in rich countries, in turn suggesting that psychosocial mechanisms are relevant.

Recent studies of income inequality in relation to psychological states and traits and sociological outcomes lend coherence to a psychosocial explanation of the health and social effects of income inequality. International comparisons show that status anxiety is higher in more unequal countries, for all socioeconomic groups (Layte and Whelan, 2013). Status anxiety and trust were found to mediate the association between income inequality and subjective wellbeing (Delhey and Dragolov, 2014). In more unequal countries, people exhibit higher levels of self-enhancement, i.e., believing themselves to be better than average (Loughnan et al., 2011). In both ecological and multi-level analyses, people in more unequal US states scored lower on a measure of agreeableness — reflecting less concern for social harmony and getting along with others (de Vries et al., 2011). In more unequal European countries people show less solidarity — they are less willing to help others (Paskov and Dewilde, 2012).

5. Discussion and conclusions

The body of evidence on income inequality and health points strongly to a causal connection. The major criteria of temporality, biological plausibility, consistency and lack of alternative explanations are well supported. Of the small minority of studies which find no association, most can be explained by income inequality being measured at an inappropriate scale, the inclusion of mediating variables as controls, the use of subjective rather than objective measures of health, or follow up periods which are too short.

Suicides seem to stand as an important exception to the general pattern: they tend to be more common in more equal societies despite the evidence that depression is more common in more unequal societies (Daly et al., 2011; Messias et al., 2011). A possible explanation is that social gradients in suicides are not always consistent internationally (Burrows and Laflamme, 2010). However, another possibility is that there may be some truth in the view that violence can be directed either outwards or inwards against oneself. If suicide is, like homicide, often a response to adversity, we think it likely that greater equality increases a tendency to blame oneself rather than others for what goes wrong.

Epidemiological causal criteria are not exhaustive. A good test of the validity of a scientific theory is its ability to make successful, testable predictions. The theory that more equal societies were healthier arose from one international study (Rodgers, 1979), and has now been tested in many different contexts. The search for a mechanism led to the discovery that social relationships (social cohesion, trust, involvement in community life and low levels of violence) are better in more equal societies. This suggested inequality and health were linked through psychosocial processes related to social differentiation and relative deprivation (Kondo et al., 2008). That inequality does have powerful psychosocial effects is now amply confirmed.

We suggest that the most parsimonious explanation for the effects of income inequality is that larger income differences increase social distances, accentuating social class or status differences. This would explain why income inequality is most closely related to health when measured across whole societies coterminous with social class hierarchies (Kondo et al., 2011; Wilkinson and Pickett, 2006). Rather than income inequality being a new and independent determinant of health, it is likely to act by strengthening the many causal processes (known and unknown) through which social class imprints itself on people throughout life. This would suggest why, not only health, but a wide range of other outcomes with social gradients are also related to inequality. It also suggests that if class and status are to become a less powerful influence both on individual lives and on whole societies, it will be

necessary to reduce the material differences which are so often constitutive of the cultural markers of social differentiation.

As whole populations are exposed to societal income inequality, estimates of the population attributable risk will be high even if, for some outcomes, the causal effect on some outcomes is modest. Kondo and colleagues estimated that upwards of 1.5 million deaths (9.6% of total adult mortality for the 15–60 age group) could be averted in 30 OECD countries if each country reduced its Gini coefficient below 0.3. If individual income is also related to health partly through psychosocial mechanisms involving relative deprivation, then multilevel models which control out its effects may substantially underestimate the effects of inequality (Pickett and Wilkinson, 2009). It has been estimated that if the UK reduced its inequality to the average in other OECD countries, the expenditure savings on physical and mental illness, violence and imprisonment alone, would amount to £39 billion per year (The Equality Trust, 2014).

Future research should move beyond mere replication of these findings in different samples, towards more explicit attempts to clarify the causal relationships, including studies of (1) different measures of income inequality (top- and bottom-sensitive measures, for example) in relation to different health and social outcomes, (2) time lags for different outcomes and (3) further modeling and testing of specific causal pathways, and (4) whether inequalities in wealth are as much part of the picture as inequalities in income. The number of countries for which comparable measures of wealth inequality are available is limited, but initial explorations of the relationships with life expectancy are interesting. Life expectancy in Denmark, which appears to be an outlier in relation to its more equal distribution of income, appears to fall into place in relation to its large inequalities in wealth (Nowatzki, 2012).

The evidence that large income differences have damaging health and social consequences is already far stronger than the evidence supporting policy initiatives in many other areas of social and economic policy, and the message is beginning to reach politicians. The world leaders we mentioned at the start of this paper have all referred to inequality as a cause of social and economic harm. But to recognize the problem is not the same as tackling it effectively. The gap between the richest and poorest 20 per cent of households in countries like the USA and UK is not only very much wider than it used to be in the 1970s, but is still twice as large as in some other successful market democracies. The reason why politicians do not do more is almost certainly a reflection of the undemocratic power of money in politics and the media (Gilens and Page, 2014). Narrowing the gap will require not only redistributive tax policies but also a reduction in income differences before tax. The halving of top tax rates since the 1970s has led not only to a widening of income differences after tax but, more surprisingly, to a more rapid rise in pre-tax incomes at the top — particularly in the private sector where CEO pay seems unrelated to company performance (Chemi, 2014; Piketty et al., 2011; Tosi et al., 2000).

Schrecker has written about the risks of policy makers requiring unachievable standards of proof in social epidemiology before they are willing to act and Popper emphasized that scientific theories are never finally proven true (Popper, 2014; Schrecker, 2013). Adopting too high a standard of evidence may mean that it is never considered strong enough. Schrecker quotes Michael Marmot as saying "While we should not formulate policies in the absence of evidence to support them, we must not be paralyzed into inaction while we wait for the evidence to be absolutely unimpeachable" (Marmot, 2000).

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.socscimed.2014.12.031.

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