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ORIGINAL INVESTIGATION

Long-term exposure to income inequality: implications for physical functioning at older ages

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Abstract The 'inequality hypothesis' proposes that higher levels of societal income inequality have a direct negative causal effect on health. Support for this hypothesis has been mixed; particularly among older people. However, most previous studies have not accounted for people's exposure to inequality over the long-term. We aimed to address this problem by examining the implications of long-term inequality exposure for older people's physical health. Data on individual health and covariates were drawn from three large, comparable surveys of older people, covering 16 countries: the English Longitudinal Study of Ageing, the Survey of Health and Retirement in Europe and the U.S. Health and Retirement Study. Historical inequality information was derived from the Standardised World Income Inequality Database. We used multilevel regression methods to model the association between long-term average inequality and three measures of physical functioning: grip strength, lung function and self-reported activity limitation. Exposure to higher average long-term levels of inequality was significantly negatively related to objectively measured grip strength and lung function, but unrelated to self-reported limitations (although increasing inequality over time was positively related to self-reported limitations). The grip strength and lung function associations were partially explained by between-country differences in height, and in the latter case this factor may fully account for the apparent effect of inequality. We discuss implications of these results for the inequality hypothesis.

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Introduction

The inequality hypothesis proposes that, in economically developed countries, societal income inequality has a detrimental effect on people's health (Wilkinson and Pickett 2006). This hypothesis states that, all other things being equal, someone embedded in a social context of greater inequality is at higher risk of ill-health than someone resident in a more equal context. If this hypothesis is correct, the pronounced increase in income inequality seen in many economically developed countries in recent years (OECD 2008) has significant implications for public health.

Existing research has been neither overwhelmingly supportive nor unsupportive of the inequality hypothesis (Kondo et al. 2009; Lynch et al. 2004; Wilkinson and Pickett 2006). The majority of this research has been based on examining contemporaneous associations between inequality and health. In a recent search of the literature, we identified 146 studies directly testing the association between inequality and health.[1] Of these, 115 were primarily cross-sectional in nature.

A limitation of cross-sectional designs is that they do not account for the effect of past levels of inequality. This is a

[1] This included all studies covered by the most recent comprehensive reviews of the inequality hypothesis literature (Wilkinson & Pickett 2006; Lynch et al. 2004), and all relevant studies indexed on PubMed between January 2006 and January 2011. We counted only studies which statistically tested an association between aggregate income inequality and one or more measures of individual or population health. We excluded studies in which primary outcomes were either violent crime or health related behaviour.

particularly important limitation considering the nature of the causal mechanisms by which inequality is proposed to affect health. These are (i) through chronic psychosocial stress brought about by increased invidious social comparisons, (ii) through a decline in association, trust and reciprocity, in society (social capital) and (iii) through underinvestment in health promoting public goods (Kawachi and Kennedy 1999). Any effect these factors might have on health is not likely to be immediate. Inequality must take time to create chronic stress, or reduce social capital or investment. Most of these factors must also take further time to have a perceptible effect on health. Purely cross-sectional research does not fully account for either of these lag-periods.

A focus on cross-sectional associations between income inequality and health also ignores substantial changes in inequality that have occurred in many economically developed countries. For example, in explanations of the inequality hypothesis, the U.K. is commonly cited as a country with high levels of inequality and correspondingly poor public health (Wilkinson and Pickett 2009). Scandinavian nations like Sweden are often provided as a contrast, as they are much healthier overall, and are also much more equal (Wilkinson and Pickett 2009). However, up to around 1966, Sweden was more economically unequal than the U.K. (data from the Standardised World Income Inequality Dataset; Solt 2009).

Studies of the cross-sectional association between inequality and health, by ignoring potentially dramatic past changes in inequality levels, essentially assume that current inequality exposure is what is most important for people's health. This assumption has no basis in the theoretical framework of the inequality hypothesis (see Wilkinson 2005). This may be why previous studies have most strongly supported a detrimental effect of inequality on infant health (Lynch et al. 2004; Wilkinson and Pickett 2006), and have been more likely to find an association between inequality and the health of younger people (Dorling et al. 2007; LeClere and Soobader 2000), rather than older people who have a longer history of variable exposure to inequality. However, older people are of particular relevance to testing the inequality hypothesis, as, in economically developed countries, they bear the largest burden of disease and mortality. They therefore contribute strongly to the cross-national variation in population health which the inequality hypothesis seeks to explain.

A number of longitudinal investigations have been carried out which have attempted to address the problem of past inequality levels by examining potential lagged effects. Several studies have investigated the association between current health and inequality levels 5–30 years previously (Gadalla and Fuller-Thomson 2008; Kim et al. 2008; Mellor and Milyo 2003). However, while being a useful extension to purely cross-sectional work, this approach still captures inequality exposure at only one or a small number, of time points—not continued exposure over the long-term.

In this study we examined how the health of older people in 16 economically developed countries was related to their overall long-term history of exposure to income inequality (from 1960 to 2006). The inequality hypothesis claims that exposure to higher absolute levels of inequality is harmful for health. We therefore predicted that older people who had been exposed to, on average, higher levels of inequality between 1960 and 2006 would have worse subsequent health than those exposed to lower levels. We tested this prediction using three separate measures of physical functioning.

Physical functioning is a particularly important domain of health for older people, and physical frailty has been shown to be a robust predictor of mortality risk (Cooper et al. 2010). Previous studies have also shown an association between (contemporary) inequality and self-reported physical difficulties (De Maio 2008; Fuller-Thomson and Gadalla 2008). In the present study, as well as subjectively reported physical limitations, we investigated two objective measures of physical functioning: grip strength and peak expiratory flow rate (PEF). Both measures separately capture domains of physical health which are important for older people's capabilities and quality-of-life. These measures are less open to the problem of reporting bias than self-reported limitations (Barford et al. 2010; Pfarr et al. 2011).

Methods

Data

Sample

We obtained comparable individual-level information on older people's health (and relevant covariates) in 16 countries by harmonising data from three large-scale, biennial panel studies of ageing: The Survey of Health, Ageing and Retirement in Europe (SHARE; Borsch-Supan et al. 2005), the English Longitudinal Study of Ageing (ELSA; Marmot et al. 2003) and the U.S. Health and Retirement Study (HRS; Juster and Suzman 1995). These surveys employed similar methods and were designed to provide comparable information on the health and circumstances of people over 50 (Kapteyn 2008).

We drew the data for this study primarily from the 2006/7 waves of each survey. The 2006/7 wave of SHARE covered 14 European countries (Austria, Belgium, Denmark, France, Germany, Greece, Italy, the Netherlands, Spain, Sweden, Switzerland, Poland, the Czech Republic and the Republic of Ireland). The initial waves of all three surveys consisted of a probability sample of the non-institutionalised 50+ population in each country, along with co-resident spouses or partners (regardless of age). ELSA also sampled other household members. To compensate for sample ageing and attrition, each survey added 'refresher' samples. In SHARE and ELSA, a refresher sample was added in 2006/7. In HRS, the most recent refresher sample prior to 2006/7 was added in 2004/5. The combined achieved sample across the three surveys in 2006/7 consisted of 62,662 individuals.

A number of these respondents were born outside the country in which they were surveyed. For these respondents, historical inequality in their current country would not reflect their own past exposure. We therefore excluded these respondents from further analysis (3,558 people).

Of the remaining 59,104 respondents 49,605 were eligible for the objective physical measurements. This included all SHARE respondents but only a subset of HRS and ELSA respondents. HRS only sought physical measurements from a randomly selected half of their original sample (8,581 people). The 2006/7 wave of ELSA did not include physical measurements at all, and we therefore carried forward physical measurements from the previous ELSA wave. This meant excluding new ELSA respondents added in 2006/7.

The analyses we conducted included only complete cases. The main sources of missing data were the objectively measured health outcomes. Table 1 shows the number of missing cases in each country for each health measure. Respondents counted as 'missing' for these measures if they declined to participate, or a health condition made participation unsafe. This left a complete case sample of 39,892 people. From this sample we also excluded 338 respondents born after 1960, as they would not have been exposed to the entire period over which inequality was measured.

Alongside core respondents of the three surveys, our final sample included spouses or partners (all three surveys) and other household members (ELSA only) over the age of 45 (extremely few respondents were under the age of 50). Because of this, and other small sampling and non-response differences between countries, our final sample is likely to be broadly, but not completely representative of the 50+ population across the 16 study countries. This should be borne in mind when interpreting the results.

Health outcomes

Grip strength data were collected in the same way in SHARE, ELSA and HRS. Respondents were asked to stand, to hold their arms at 90° to their bodies, and to squeeze the handle of a Smedley spring-type dynamometer as hard as they could. Respondents unable to stand completed the test seated. In SHARE and HRS two measurements were taken for each hand. In ELSA three measurements were taken. In each case we used the maximum valid recorded measurement from the dominant hand.

PEF data were collected in all three surveys using a portable spirometer (a Mini-Wright Peak Flow Meter in SHARE and HRS, and a Vitalograph Escort spirometer in ELSA). Respondents were asked to stand, take a deep breath and blow into the spirometer as hard as they could. Respondents unable to stand completed the test seated. Three measurements were taken in SHARE and ELSA; two in HRS. In each case we took the maximum valid recorded measurement.

We created a binary indicator of self-reported activity limitation using the Activities of Daily Living (ADL) scales from SHARE, ELSA and HRS. These consisted of items assessing subjective difficulty with everyday physical tasks, such as walking short distances, carrying heavy shopping bags or climbing stairs. From the list of 10 items common to SHARE, ELSA and HRS, we created a variable which indicated whether a respondent reported having difficulty with at least one action.

Covariates

We extracted data on individual age in continuous years, gender, education, income and wealth from the 2006/7 waves of SHARE, ELSA and HRS. In order to preserve respondent anonymity, ELSA does not provde the exact age for respondents over 90—we therefore boded these respondents as age 95 in our analyses. We considered that compositional effects of the above factors may confound the association between inequality and health. Previous studies have importantly shown that the compositional effect of income on health may generate a spurious association between inequality and health (Jen et al. 2008). Previous study has also identified a negative association between inequality and education as a potential cause of the association between inequality and health (Muller 2002).

In SHARE, respondent education was recorded using the 1997 International Standard Classification of Education scale (ISCED-97). We coded ELSA and HRS respondents' highest reported educational qualification on this scale using the coding scheme given in the ISCED-97 manual (UNESCO 2006). Because some SHARE countries did not distinguish between ISCED categories 5 (first stage of tertiary education) and 6 (second stage of tertiary education) we collapsed these categories together.

Total net annual household income [adjusted for household size using the OECD-modified scale (OECD 2009)] and total gross household financial assets were calculated in 2006 USD at purchasing power parity (PPP).

Table 1 Number of cases with missing data for each health outcome (and percentage of total cases), by country ($n = 49{,}605$)

	Grip strength	PEF	ADL	*N*
Austria	169 (12.70 %)	331 (24.87 %)	2 (0.15 %)	*1,331*
Belgium	160 (5.15 %)	261 (8.39 %)	2 (0.06 %)	*3,109*
Czech Republic	150 (5.59 %)	332 (12.30 %)	7 (0.26 %)	*2,700*
Denmark	94 (3.66 %)	224 (8.72 %)	6 (0.23 %)	*2,569*
France	383 (13.81 %)	684 (24.66 %)	42 (1.51 %)	*2,774*
Germany	205 (8.51 %)	352 (14.61 %)	6 (0.25 %)	*2,409*
Greece	302 (9.39 %)	539 (16.75 %)	11 (0.34)	*3,217*
Italy	424 (14.30 %)	762 (25.69 %)	6 (0.20)	*2,996*
Netherlands	145 (5.54 %)	172 (6.58 %)	15 (0.57 %)	*2,615*
Poland	205 (8.57 %)	361 (15.10 %)	12 (0.50 %)	*2,391*
Republic of Ireland	226 (21.46 %)	203 (19.28 %)	7 (0.66 %)	*1,053*
Spain	297 (13.55 %)	404 (18.43 %)	3 (0.14 %)	*2,192*
Sweden	166 (6.23 %)	261 (9.80 %)	4 (0.15 %)	*2,663*
Switzerland	52 (3.92 %)	87 (6.57 %)	6 (0.45 %)	*1,325*
United Kingdom	1,196 (15.57 %)	1,549 (20.17 %)	0	*7,680*
USA	1.975 (23.02 %)	1,816 (21.16 %)	0	*8,581*
Overall	6,149 (12.40 %)	8,338 (16.81 %)	129 (0.26 %)	*49,605*

Where respondents had missing values for these measures, we used the imputed values provided by SHARE, ELSA or HRS. We top-coded income at $500,000, and wealth at $1,000,000. We then square-rooted the income and wealth values to obtain a more normal distribution.

We also obtained measures of yearly GDP per capita for each country from 1960 to 2006 (in constant 2000 USD at PPP) from the 2010 World Bank World Development Indicators (WDI). We calculated both the mean GDP per capita and the GDP trend over this period as we considered that both may be associated with inequality and health. The linear trend in GDP for each country was calculated by regressing GDP on time (in years), giving an estimate of the average yearly change in GDP.

Long-term country-level inequality

As our measure of long-term experience of inequality, we calculated the mean Gini coefficient between 1960 and 2006 for each of the 16 study countries using data from the Standardised World Income Inequality Database v2.0 (SWIID; Solt 2009). We also calculated the linear trend in inequality for each country by regressing Gini on time (in years). The yearly Gini estimates included in the SWIID are adjusted to a common, comparable standard—the Gini coefficient of net equivalised (for household size using the OECD standard scale) household income.

The Czech Republic and Germany did not exist continuously in their present form between 1960 and 2006. For the Czech Republic in years prior to 1993 we used Gini estimates for Czechoslovakia as a whole. For Germany in years prior to 1990 we used estimates derived in the SWIID from a series of income surveys covering the whole country. Further, the SWIID provides Gini estimates only for the U.K. as a whole, whereas the ELSA survey covers only residents of England. In this study we considered inequality at the level of the U.K. as applicable to ELSA respondents.

Finally, the SWIID does not include Gini estimates for Switzerland in 2005–2006. When examining the effects of contemporary inequality, we therefore carried forward the estimate for 2004.

Analyses

We used separate multilevel models (individuals nested within countries) to estimate the association between mean historical country-level inequality and each health outcome. Multilevel linear and logistic regression models were used for the continuous outcomes (grip strength and PEF) and binary outcome (self-reported activity limitation), respectively.

For each outcome, we first fit an empty model (a model with no predictors) to determine the proportion of the outcome variance that could be attributed to differences between countries, rather than between individuals. In order to determine the bivariate association between average historical exposure to inequality and each health outcome, we then added mean country-level inequality (1960–2006) to the model (bivariate model). We then fitted a fully adjusted model including all individual-level (age, gender, education, income, wealth and multiplicative interaction between age and gender) and country-level (GDP and GDP trend) covariates. To preserve statistical power in the fully adjusted model, the effects of individual-level covariates were fixed across countries. All analyses were carried out in Stata v.12.

Results

Descriptive statistics

46.63 % of the final analysis sample ($n = 38{,}162$) were male. The median age of the sample was 64, their median net equivalised household income was $16,914 and their median gross household wealth was $23,446. The modal education group was ISCED category 3 (upper secondary education).

Table 2 gives the long-term mean level of inequality in each of the sample countries from 1960 to 2006, the long-term trend over this period and contemporary (2006) inequality levels (it should be noted that the SWIID does not provide Gini estimates for Switzerland for 2005–6, therefore we carried forward the estimate for 2004). The country with the highest average inequality from 1960 to 2006 was the USA (mean Gini = 33.86). The country with the lowest was the Czech Republic (mean Gini = 21.95). The USA also had the highest contemporary level of inequality (Gini = 37.86).

In general, countries with high contemporary inequality also tended to have experienced high historical levels. However, a number of countries experienced pronounced changes in inequality between 1960 and 2006; meaning that current levels would not fully represent residents' overall level of exposure during this period. For example, Poland experienced a pronounced upward trend in inequality from 1960 to 2006. By 2006 there was therefore a relatively high level of inequality in Poland. However, Polish residents will have, on average, experienced a lower level of inequality than residents of other countries that have lower 2006 levels (e.g. France or Germany).

Table 2 also gives the mean GDP per capita of each country from 1960 to 2006, along with the extent and direction of the trend over this period. Previous studies have emphasised the need to adjust for GDP as an indicator of country-level wealth to account for the fact that more unequal countries also tend to be poorer (e.g. Lynch et al. 2004). However, in the present sample, the correlation between average inequality and average GDP is actually slightly positive, although non-significant ($r = 0.11$, $p = 0.68$).

Finally, Table 2 also gives country-level aggregates for each health outcome. Table 2 shows that the country with the lowest mean grip strength (30.29 kg) and PEF (306.08 L/min) was Spain. Germany had the highest mean grip strength (37.34 kg), and Sweden the highest mean PEF (426.89 L/min). The country with the highest prevalence of self-reported activity limitation was the U.K. (18.48 %). The country with the lowest was Greece (3.50 %).

Associations between long-term country-level inequality and individual health

To help contextualise the multilevel model results, Figs. 1, 2 and 3 show the bivariate ecological association between long-term average inequality in each country and the aggregate levels of each health outcome. Consistent with our hypothesis, Figs. 1 and 2 show negative relationships between inequality and grip strength and PEF, respectively. Countries with higher average levels of historical inequality tend to have lower population average grip strength and PEF. In the case of grip strength, this ecological-level association was large and statistically significant (Pearson's $r = -0.67$, $p < 0.01$). However, for PEF the association was smaller and not significant ($r = 0.37$, $p = 0.07$). Contrary to our hypothesis, Fig. 3 shows no real association between inequality and the proportion of the population reporting an activity limitation ($r = 0.10$, $p = 0.72$).

In the empty models, 2.61 % of the variance in grip strength, 4.37 % of the variance in PEF and 6.84 % of the variance in activity limitation was explained by differences between countries, rather than differences between individuals.

Table 3 shows the results when adding (i) country-level mean inequality from 1960 to 2006, and (ii) country and individual-level covariates. For grip strength, adding mean inequality explained a large fraction (45.20 %) of the country-level variance. In this bivariate model, mean inequality also had a highly statistically significant negative association with grip strength. This association was slightly attenuated in the fully adjusted model, but remained highly significant.

Mean inequality explained a smaller fraction (13.60 %) of the country-level variance in PEF, and the negative bivariate association between mean inequality and PEF was not statistically significant. However, when adjusted for covariates, this association became statistically significant at the 5 % level. Step-wise addition of the covariates to the bivariate model showed that the association became significant when mean GDP was added to the model.

Table 3 also shows that mean country-level inequality explained <1 % of the country-level variance in activity limitation. There was no association, in either the bivariate or fully adjusted models, between mean inequality and the odds of reporting an activity limitation.

Table 2 Descriptive statistics (mean/% and standard deviations) for inequality, GDP and health outcomes for each country ($n = 38,162$)

	Mean Gini (1960–2006)	Gini trend (1960–2006)	2006 Gini	Mean GDPpc (1960–2006; $)	GDPpc trend (1960–2006; $)	Mean grip strength (Kg)	Mean PEF (L/min)	% with activity limitation
Austria	25.95 (1.56)	+0.16/y	27.14	16,630 (5,551)	+401.33/y	35.50 (11.95)	358.12 (148.98)	8.25
Belgium	25.42 (2.37)	0.00/y	26.76	16,002 (4,967)	+363.19/y	35.63 (12.17)	351.60 (155.95)	10.06
Czech Republic	21.95 (2.84)	+0.19/y	25.53	5,507 (683.24)	+120.89/y	36.31 (11.53)	339.24 (137.75)	6.17
Denmark	24.52 (1.71)	−0.10/y	23.87	21,587 (5,998)	+434.85/y	35.09 (12.43)	400.97 (147.60)	6.16
France	28.96 (2.43)	−0.18/y	27.14	16,274 (4,825)	+335.37/y	34.25 (11.76)	361.97 (165.45)	7.83
Germany	27.53 (1.41)	0.00/y	29.65	18,299 (3,905)	+350.97/y	37.34 (11.65)	373.18 (147.75)	6.95
Greece	32.96 (1.00)	+0.04/y	33.77	10,202 (3,116)	+184.88/y	34.41 (11.30)	355.01 (123.28)	3.50
Italy	33.54 (2.17)	−0.07/y	34.01	13,514 (4,416)	+325.06/y	33.67 (11.47)	316.89 (174.75)	4.87
Netherlands	25.90 (1.49)	−0.02/y	27.15	16,836 (4,924)	+362.13/y	36.13 (11.42)	390.10 (154.50)	4.72
Poland	26.64 (3.07)	+0.18/y	30.79	4,032 (859)	+167.75/y	33.89 (11.81)	310.57 (144.16)	17.25
Republic of Ireland	32.29 (0.75)	0.00/y	32.18	13,206 (7,630)	+643.52/y	33.73 (11.74)	335.05 (141.07)	10.59
Spain	31.46 (2.45)	+0.13/y	30.96	9,707 (3,999)	+244.80/y	30.29 (11.36)	306.08 (219.19)	7.49
Sweden	23.87 (3.21)	−0.13/y	24.20	20,422 (5,149)	+385.35/y	37.01 (12.08)	426.87 (140.20)	7.00
Switzerland	29.65 (1.34)	−0.18/y	27.42	28,445 (4,642)	+289.84/y	35.80 (11.43)	386.41 (144.85)	5.33
United Kingdom	29.97 (3.51)	+0.23/y	35.66	17,528 (4,986)	+388.03/y	31.48 (11.68)	374.14 (143.43)	18.48
USA	33.86 (2.37)	+0.11/y	37.86	24,786 (6,921)	+517.54/y	32.03 (11.44)	371.44 (133.52)	13.29
Overall	29.82 (2.38)	+0.07/y	32.41	17,888 (6,244)	+381.78/y	34.07 (11.87)	364.25 (152.43)	9.93

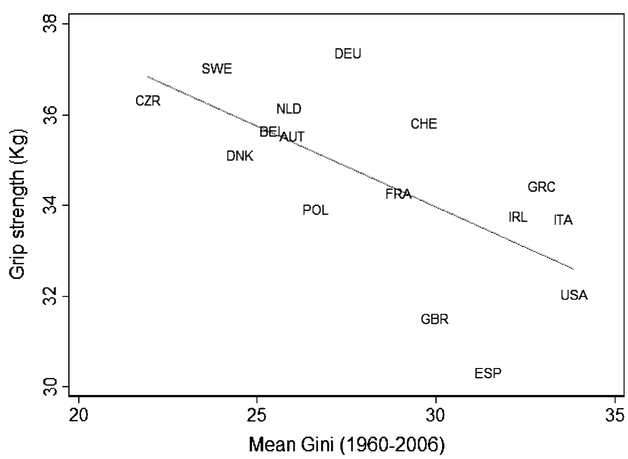

Fig. 1 Mean country grip strength and mean inequality (Gini) from 1960 to 2006

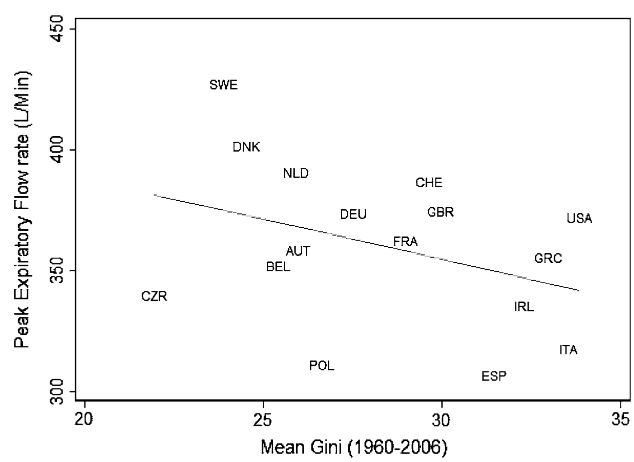

Fig. 2 Mean country PEF and mean inequality (Gini) from 1960 to 2006

The effect of change in inequality over time

Although the inequality hypothesis posits a negative health effect of *absolutely* high levels of inequality, it is possible that experiencing a dramatic increase or decrease in inequality may also have an effect on health—either directly, or as an indicator of substantial social or political change. To address this possibility, we added indicators of the direction and extent of change in inequality (from 1960 to 2006) to the fully adjusted models. This had no significant effect on either grip strength or PEF, and did not alter the association between average inequality and these outcomes. However, the inequality trend was significantly related to activity limitation, such that people living in countries where the inequality trend was more positive were more likely report a limitation. An increase from the strongest negative slope (Switzerland) to the strongest positive slope (the UK) would predict a 4.83× increased odds of reporting an activity limitation.

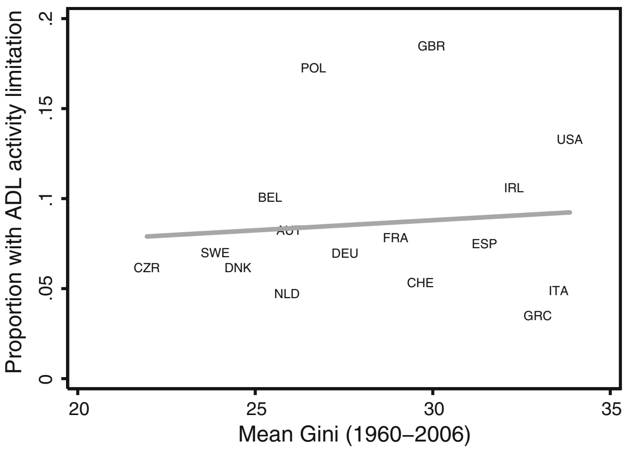

Fig. 3 Proportion of people in each country reporting difficulty with at least one activity of daily living (ADL) and mean inequality (Gini) from 1960 to 2006

Comparing historical and contemporary inequality

As noted in the Methods section, average historical levels of inequality (1960–2006) are highly positively correlated with contemporary (2006) levels. We argue in the introduction that taking account of past levels of inequality is important for getting a more accurate picture of its health effects. We therefore re-ran the fully adjusted models described above, replacing average levels of inequality with the single year estimate for 2006.

Adjusted for covariates, contemporary inequality was significantly negatively associated with grip strength. However, beginning from a model containing only the covariates, adding contemporary inequality explained a smaller proportion of the between-country variance in this outcome (39.15 %) than did adding average inequality from 1960 to 2006 (50.52 %). The association between contemporary inequality and grip strength was also weaker ($\beta = -0.23$, $p < 0.01$).

For PEF, contemporary inequality also explained a smaller proportion of the country-level variance (8.92 vs. 24.42 %), and was not significantly negatively associated with the outcome ($\beta = -1.63$, $p = 0.21$).

Consistent with the results from the main models, contemporary inequality was not associated with the odds of reporting activity limitation.

Sensitivity analyses

In order to check the robustness of our results we conducted a number of additional analyses.

First, in order to determine whether any apparent effects of inequality were being driven by any individual country were-ran the fully adjusted models excluding and replacing each country in turn. In all of these models the direction and statistical significance of the primary associations was unchanged.

Second, in order to determine whether the negative association between inequality and grip strength, or between inequality and PEF, were driven by patterns of missing data in the outcome measures we examined the ecological association between mean country-level inequality and the proportion of missing grip strength and PEF cases per country. There was a positive and statistically significant correlation between mean inequality and both the proportion of missing grip strength cases and PEF cases. Respondents who would have performed very poorly on these physical function tests were also less likely to take the test. This implies that any bias introduced by these missing data is likely to have been conservative.

Third, in order to facilitate a more straightforward comparison between the outcome measures, we created binary indicators of low grip strength and low PEF (indicating scorers in the bottom fifth of the distribution for these outcomes). Adjusting for covariates, average inequality was positively related to the odds of having low grip strength (OR = 1.07, $p < 0.01$) and low PEF (OR = 1.06, $p = 0.08$). However, for the latter the association was not statistically significant.

Finally, we attempted to determine whether the negative associations between inequality and the two physically measured outcomes could be explained by differences in height. It should be noted that measurement of height was not consistent across the three surveys used in the present analysis. ELSA and HRS collected objective measurements, whereas SHARE relied on subjective reports. Nevertheless, adding height to the fully adjusted models did attenuate the negative associations between average inequality and grip strength, and between inequality and PEF. The proportional attenuation was similar in both cases—a reduction in the magnitude of the coefficient of 37 and 43 %, respectively. However, the grip strength association remained statistically significant ($\beta = -0.19$, $p < 0.01$), whereas the PEF association did not ($\beta = -1.87$, $p = 0.14$).

Discussion

Based on the inequality hypothesis, we predicted that older people who had been exposed to higher average levels of inequality over the long term would suffer worse subsequent physical health. Consistent with this prediction, we found that older people living in countries with higher long-term average levels of inequality had significantly worse physical functioning, in terms of both manual grip strength and PEF. These associations were independent of individual age, gender, education, income, wealth and country-level average GDP. The magnitude of these

Table 3 Associations between mean country-level inequality (1960–2006) and grip strength and PEF (β coefficients and 95 % CIs), and between inequality and the odds of reporting an activity limitation (odds ratios and 95 % CIs); derived from separate multi-level regression models; individuals (n = 38,162) nested within counties (n = 16)

	Grip strength		PEF		Activity limitation	
	Bivariate	Fully adjusted	Bivariate	Fully adjusted	Bivariate	Fully adjusted
Mean Gini	**−0.36***** (−0.55, −0.16)	**−0.30***** (−0.45, −.0.15)	−3.29 (−7.36, 0.79)	**−3.01*** (−5.63, −0.39)	1.01 (0.94, 1.08)	0.98 (0.91, 1.04)
Age	–	**−0.32***** (−0.33, −0.31)	–	**−4.11***** (−4.28, −3.93)	–	**1.05***** (1.05, 1.06)
Male gender	–	**30.77***** (29.77, 31.77)	–	**246.75***** (230.00, 263.49)	–	1.14 (0.69, 1.87)
Male*Age	–	**−0.23***** (−0.24, −0.21)	–	**−1.81***** (−2.07, −1.56)	–	1.00 (0.99, 1.00)
ISCED category						
0	–	**−2.02***** (−2.56, −1.48)	–	**−34.66***** (−43.70, −25.62)	–	**2.23***** (1.80, 2.77)
1	–	**−0.87***** (−1.10, −0.65)	–	**−19.85***** (−23.58, −16.12)	–	**1.37***** (1.24, 1.52)
2	–	−0.21 (−0.46, 0.04)	–	**−12.61***** (−16.82, −8.40)	–	**1.21**** (1.06, 1.37)
3 (reference)	–	–	–	–	–	–
4	–	**0.70***** (0.35, 1.05)	–	**9.63**** (3.71, 15.55)	–	0.88 (0.74, 1.04)
5/6	–	0.10 (−0.11, 0.32)	–	**18.24***** (14.59, 21.89)	–	**0.75***** (0.67, 0.85)
(sqrt) hhd income (net $1000 s)	–	**0.08***** (0.04, 0.11)	–	**0.94**** (0.36, 1.52)	–	**0.97**** (0.96, 0.99)
(sqrt) hhd wealth (gross, $1000 s)	–	**0.07***** (0.06, 0.09)	–	**1.78***** (1.54, 2.02)	–	**0.97***** (0.96, 0.97)
Mean GDPpc (1960–2006, $1000 s)	–	0.06 (−0.03, 0.15)	–	**2.66**** (1.07, 4.25)	–	0.99 (0.95, 1.03)
GDP trend (1960–2006, $1000 s per year)	–	−1.26 (−6.28, 3.75)	–	−0.74 (−90.16, 88.68)	–	9.64 (1.00, 92.93)
Var(u)	2.00	1.05	887.96	337.32	0.24	0.21
Var(e)	136.65	54.08	22469.98	15211.62	–	–
ρ (%)	1.45	1.91	3.80	2.17	6.82	6.05
Δ var(u) (%)	−45.20	−46.37	−13.60	−62.01	−0.23	−12.06
Δ var(e) (%)	0.00	−60.43	0.00	−32.30	–	–
AIC	296021.70	261075.50	490758.70	475885.80	23732.25	22240.13

Bold text indicates statistical significance, asterisks indicate level of significance (* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$); var(u/e): variance in the outcome at the country/individual-level; ρ(%): country-level variance as a percentage of the total outcome variance; Δ var(u/e): change in variance from previous model (for bivariate model this is change from empty model); *AIC* Aikake's Information Criterion of model fit association were such that an increase of 11.94 in the average Gini coefficient from 1960 to 2006 (the difference between the average of the USA and the Czech Republic) would predict a 3.58 kg reduction in grip strength, and a 35.94 L/min reduction in PEF. In both cases this is roughly equivalent to an 8 year increase in age.

Inconsistent with the inequality hypothesis, we found no association between average inequality and the likelihood of reporting a physical activity limitation. Further, we found that accounting for country differences in height explained a large proportion of the apparent inequality effect. In terms of PEF, this attenuation rendered the association non-significant.

There are several possible explanations for these mixed results. In terms of height, it is possible that this lies on the causal pathway between inequality and health. Previous studies have found associations between inequality and low birth-weight (Kaplan et al. 1996; Shi et al. 2004), which suggests that pre-natal exposure to inequality may have a detrimental effect on physical development, and potentially therefore on attained height. It is also possible that development could be affected by post-natal stress caused by inequality (Mascie-Taylor 1991).

This possibility highlights an empirical and theoretical gap in the existing literature with respect to the potentially differential effects of inequality exposure at different points in the life-course. Existing work on the health effects of psychosocial stress has suggested that infancy and early childhood may be a particularly sensitive period for exposure, as this is when the body's stress response system is being 'calibrated' for later life (Flinn 2006). However, the potentially more complex processes by which income inequality may affect health during this, or other periods of the life-course have not been explored in the literature so far. If we are to more fully understand the effects of inequality on health, a thorough theoretical exploration of how its effects might change across life is required to inform future empirical work.

Unfortunately, for the majority of our sample, we have no information on inequality exposure during childhood and it was therefore impossible to examine the effects of this potentially sensitive period. It is plausible that the countries in our sample with high average levels of inequality from 1960 to 2006 also had high levels in previous years. However, as we have emphasised in the introduction, this cannot be assumed.

As to role of height in our results; physical development during childhood may indeed be a pathway through which inequality affects health at older ages. This would make our original results (excluding height from the model) a better reflection of the true effect of inequality. However, until this possibility has been more fully investigated it is likely safer to assume that differences between countries in average height are primarily determined by other factors. In this light, our results provide no strong evidence of a meaningful association between inequality and older people's lung function in particular.

An additional aspect of our findings which requires explanations is the discrepancy between the results for objectively measured grip strength and subjectively reported activity limitation. Low grip strength among older people is considered to be a good indicator of poor underlying physical capability (Rantanen et al. 1999). Therefore a negative effect of inequality on grip strength should also likely be reflected in an increased risk of reporting difficulties with physical activities. This is particularly notable as our sensitivity analyses showed that inequality was not only negatively associated with continuous grip strength scores but also with an increased risk of having very low grip strength.

One explanation for these divergent findings is that there may be differences between countries in the likelihood that people will report having difficulty with everyday activities, independent of their underlying level of functioning. There is substantial evidence that such reporting heterogeneity exists between many of the countries in our sample. Using data from the first wave of SHARE, Jurges (2007) found that, independent of underlying health, there were significant differences between countries in the proportion of people who reported their overall health as 'good'. Similarly, Pfarr et al. (2011) showed (also using SHARE data) significant differences in the proportion of people reporting their health as 'poor', independent of their 'true' health status. More importantly for the present study, Pfarr et al. (2011) also showed differences between countries in the likelihood that people would report being physically limited by the same specific disease. For example, they found that Greek women with a chronic physical condition (osteoporosis) were less likely to report being physically limited than were German women with the same condition. In the present study, such reporting differences could have obscured an association between inequality and physical activity limitation. This may explain not only why, for example, Italy had low aggregate grip strength and PEF in the present study but also a low prevalence of self-reported activity limitation. Spain, also, had the lowest aggregate grip strength and PEF, but only a moderate prevalence of self-reported activity limitation. Some previous studies *have* shown an association between inequality and significant physical activity limitation (De Maio 2008; Fuller-Thomson and Gadalla 2008; Gadalla and Fuller-Thomson 2008). However, these studies have all been carried out in sub-national contexts (Argentinean provinces or U.S. states), which may have ameliorated the problem of reporting heterogeneity.

We did nevertheless find a positive association between increasing inequality and self-reported activity limitation. A possible explanation for this finding is that steeply rising or falling inequality could reflect macro-economic or social policy changes which have a bearing on activity limitation and disability. For example, a sharp increase in inequality could parallel a decrease in taxation, and a consequent decrease in healthcare investment.

Conclusions

What bearing do the results of this study have on the ongoing debate surrounding the inequality hypothesis? Overall they are neither strongly supportive nor unsupportive of the inequality hypothesis. We have shown a robust association between long-term exposure to inequality and a specific aspect of physical health (manual grip strength), but weak or non-existent associations with two other aspects (PEF and activity limitations). As with the overwhelming majority of investigations of the inequality hypothesis, certain limitations mean that there are several potential explanations for our results, aside from a causal effect of inequality.

First, although we have discussed plausible explanations for why inequality might not have been associated with activity limitation, and why the negative associations with grip strength and PEF were strongly attenuated when accounting for differences in height, these explanations cannot be fully tested with our data. It therefore remains for future work to systematically investigate the influence of reporting heterogeneity across countries, and to investigate the potential effect of inequality on childhood physical development.

Second, and most importantly, we cannot discount the possibility of residual confounding by unmeasured or poorly controlled factors. It is possible, for example, that cultural and historical factors may lead to a country being both more unequal over time, and more unhealthy, without there being a causal association between inequality and health (Lynch et al. 2004). Similarly, other macro-economic factors, not adequately measured by GDP (such as levels of unemployment, social mobility or national spending priorities) might influence both inequality over time and subsequent health.

Residual confounding is a particular problem when studying factors as causally distant as societal inequality and individual health (Zimmerman 2008). In order to progress further in our attempts to identify a causal link between inequality and health, a great deal more theoretical and empirical work is required to untangle the manifold influences of (particularly) other macro-economic factors which may influence and interact with both.

Finally, in this study we measured health at only one time point. Combining data on both inequality and health over time would allow us to exclude the effects of potentially time-invariant characteristics of individuals, such as affect or response style. However, many of the most important potential covariates of inequality, such as other macro-economic factors, are time-varying. Further, as we note in the introduction, longitudinal analyses of this type must also assume, a priori, a lag-time for inequality's effects.

Despite the outlined limitations, the present study represents an important contribution to the inequality hypothesis debate. To our knowledge, it is one of the first studies to focus specifically on the potential effects of inequality on older people—the population bearing the strongest burden of disease in economically developed countries. It is also one of the first studies to demonstrate a highly robust association between inequality and an objectively measured indicator of physical health. This is particularly important as the majority of the existing literature has focused either on mortality or self-reported health. The latter of which is subject to substantial problems of reporting bias, as we, and others (Barford et al. 2010; Jurges 2007; Pfarr et al. 2011) have noted.

We have taken a first step in accounting for the influence, not simply of contemporary exposure to inequality, but of long-term exposure across the life-course. Further, we have shown that long-term average exposure is a superior predictor of older people's current physical functioning (in terms of grip strength) than is contemporary exposure alone. This study opens up substantial opportunities for future work, for example in investigating the potentially differential effect of exposure to inequality during specific periods of the life-course.

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