Does income relate to health due to psychosocial or material factors? Consistent support for the psychosocial hypothesis requires operationalization with income rank not the Yitzhaki Index

Running head: INCOME RANK OR YITZHAKI INDEX

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Abstract

Research on why income influences health has produced mixed findings. Many, but not all, studies suggest that the relationship between income and health is due to income indicating psychosocial position rather than the associated material benefits. The inconsistent findings may be partly due to the use of the Yitzhaki Index, a function which calculates the accumulated income shortfall for an individual relative to those with higher income, in order to represent the psychosocial position conferred by income. The current study tests whether an alternative specification – income rank – provides more consistent conclusions regarding the psychosocial effect of income on health. We used data from two nationally representative samples: 14,224 observations from 9,404 participants across three waves (2004, 2008, and 2012) of the English Longitudinal Study of Aging (ELSA) and 29,237 observations from 8,441 individuals across seven waves (2007-2013) of the Longitudinal Internet Studies for the Social Sciences (LISS). Multilevel regression models indicated that income rank was a stronger and more consistent predictor than both the Yitzhaki Index and actual income of self-rated and objective health. The psychosocial hypothesis is more consistently supported when income rank is used to test it.

Keywords: social rank; relative deprivation; self-rated health; allostatic load; income; Yitzhaki Index; Constant Relative Risk Aversion; Decision by Sampling.

Introduction

A large body of research has investigated why an individual's income negatively relates to their health. Two distinct hypotheses have been offered to explain the association between income and health at the individual level. The materialist hypothesis posits that individuals with lower income are less likely to have good health than individuals with higher income because they lack material resources that are conducive to good health (Lynch, Smith, Kaplan, & House, 2000). This hypothesis can be contrasted with the *psychosocial hypothesis* (Subramanian & Kawachi, 2004; Wilkinson & Pickett, 2006, 2009) which proposes that individuals with less income often have worse health than individuals with higher income due to negative upward social comparisons (Kondo, Kawachi, Subramanian, Takeda, & Yamagata, 2008; Runciman, 1966) which can result in frustration, shame, stress (Kondo et al., 2008) and subsequently ill health.

The literature comparing the materialist and psychosocial effects of an individual's income on their health has mostly used actual income to represent the materialist hypothesis. This is normally contrasted with the psychosocial hypothesis as represented by the Yitzhaki Index (Yitzhaki, 1979). This function represents the average difference between an individual's income and the income of all individuals with higher income within the same reference group. Studies using the Yitzhaki Index to assess the psychosocial hypothesis have yielded mixed results, with many studies finding the Yitzhaki Index relates to health (for example, Eibner & Evans, 2005; Eibner, Sturn, & Gresenz, 2004; Kondo et al., 2008; Subramanyam, Kawachi, Berkman & Subramanian, 2009; Yngwe, Kondo, Hagg, & Kawachi, 2012; Yngwe, Fritzell, Burstrom & Lundberg, 2005; Yngwe, Fritzell, Lundberg, Diderichsen, & Burstrom, 2003), while many others (for example Gravelle & Sutton, 2009; Jones & Wildman, 2008; Li & Zhu, 2006; Lorgelly & Lindley, 2008; Wildman, 2003) find no or only weak evidence for an association (see Adjaye-Gbewonyo & Kawachi, 2012, for a

review of empirical studies published between 2000 and 2010 that test the effect of Yitzhaki Index on health measures). The mixed findings have been attributed to a number of different factors, such as the use of different outcome measures, countries, size and choice of reference groups, statistical methods, different time lags between income and health measures, as well as the presence of a threshold effect of income differences on health (Kondo et al., 2009).

Meanwhile, a new line of evidence (Boyce, Brown, & Moore, 2010; Daly, Boyce, & Wood, 2015; Hounkpatin, Wood, Brown, & Dunn, 2015; Wood, Boyce, Moore, & Brown, 2012) has consistently suggested that it is the rank (ordinal position) of an individual's income that is psychosocially important for their health. For example, Daly, Boyce & Wood (2015) compared the effects of income and income rank on self-rated health, obesity, and allostatic load, and they found that income rank was significantly associated with each health measure in two British populations, even after controlling for the effects of actual income. Moreover, when controlling for income rank, actual income no longer related to health, suggesting that income only relates to health through acting as a proxy for income rank. This parallels findings with mental health and depressive symptoms as the outcome (Elgar et al., 2013; Hounkpatin et al., 2015; Wetherall, Daly, Robb, Wood, & O'Connor, 2015; Wood, Boyce, et al., 2012) as well findings from a study by Subramanyam et al. (2009) which indicated that percentile income rank significantly predicted self-rated health in a US population after controlling for actual income. The income rank specification is consistent with the psychosocial hypothesis but differs from the Yitzhaki Index in that it proposes that health is not necessarily related to the *magnitude* of the difference, but rather the position of income on the income distribution within a comparison group.

The first motivation of the *income rank hypothesis* was from primate studies indicating that low ranking animals in conflict with more dominant members of the same species experience high levels of stress (Sapolsky, 2004; Shivley, Laber-Laird, & Anton,

1997) as evidenced by decreased levels of serotonin in their serum (Raleigh, Brammer, & McGuire, 1983; Yeh, Frickle, & Edwards, 1996). Reduced secretion of serotonin is believed to have allowed the subordinate animal to behave in a hyper vigilant and withdrawn manner so as to increase their chances of survival under hostile conditions. Humans continue to display similar reactions in response to cognitions associated with low social rank (Gilbert, 2006; Price, Sloman, Gardner, Gilbert, & Rohde, 1994). While these hard-wired responses to low rank were adaptive under evolutionary conditions, such reactions may adversely affect health in modern day, particularly if prolonged (Gilbert, 2006; P. J. Taylor, Gooding, Wood, & Tarrier, 2011).

The second motivation for the rank hypothesis was from cognitive science findings that people always judge relative magnitude based on rank position rather than any other specification (Stewart, Chater, & Brown, 2006). Judgements normally rely on heuristics, rules of thumb that balance cognitive processing cost with accuracy (Kahneman & Tversky, 1979, 2000). It has been suggested that when making relative judgements (such as one's income position relative to others) people first bring a distribution of similar stimuli to mind (e.g., other individual's income) from memory or salient features of the environment, sequentially compare the target (e.g., one's income) with each of the other stimuli in the set (e.g., the incomes of others), and simply keep track of the number of stimuli higher than the target stimuli (that is, one's rank within the income distribution). This ranking process provides a balance between the low cognitive costs (and low informational value) of making non-relative judgements and the high cognitive costs (but high informational value) of calculating both rank position and relative distance (as with the Yitzhaki Index), whilst still capturing most of the relevant information through taking into account the main features of the distribution (e.g., skew). This model has been shown to predict judgements of personality (Wood, Brown, Maltby, & Watkinson, 2012), fairness of sentencing (Aldrovandi, Brown, &

Wood, 2013), indebtedness (Aldrovandi, Wood, Maltby, & Brown, 2015), willingness to pay

for food (Aldrovandi, Brown, & Wood, 2015), educational satisfaction (Brown, Wood,

Ogden, & Maltby, 2015), emotion (Melrose, Brown, & Wood, 2013; Wood, Brown, &

Maltby, 2011), alcohol use (M. J. Taylor, Vlaev, Maltby, Brown, & Wood, in press; Wood,

Brown, & Maltby, 2012), pain (Watkinson, Wood, Lloyd, & Brown, 2013) and health

benefits of exercise (Maltby, Wood, Vlaev, Taylor, & Brown, 2012).

If people have an evolutionary sensitivity to rank position and judge their social

position based on rank position, using the Yitzhaki Index - which measures rank plus the

magnitude of income difference - may erroneously lead to a rejection of the psychosocial

hypothesis. For example, when using the Yitzhaki Index a psychosocial effect of income may

not be apparent for a comparison group of individuals with similar incomes as income

differences will only be minimal. However, a psychosocial effect would be observed for the

same group of individuals when using a pure rank specification. We are unaware of any

previous studies in adults that have directly contrasted the health effects of the Yitzhaki Index

and income rank specifications. Although a study by Elgar et al. (2013) indicated that rank

affluence (within region) better predicted psychosomatic symptoms in an adolescent sample

than actual family affluence or Yitzhaki Index, it is not clear whether such findings might

extend to an adult population and to objectively as well as subjectively measured health

outcomes. In the present study, we directly compare the effects of Yitzhaki Index and income

rank on two health measures, self-rated health and allostatic load, using data from two

nationally representative but culturally different adult samples. Due to co-linearity issues

associated with predicting health jointly from income and income rank or Yitzhaki Index

(Gravelle & Sutton, 2009), we primarily compare the predictive fit of each of the income-

related predictors. We hypothesised that: (H1) A model using income rank will better predict

both self-rated and objective health than one that uses the Yitzhaki Index, suggesting that

income rank is the better representation of psychosocial position, and (H2) use of income rank would provide more consistent support for the psychosocial hypothesis across measures and datasets than the Yitzhaki Index.

Methods

Participants and Procedure

The analysis was performed on two separate datasets: the English Longitudinal Study of Ageing (ELSA) and the Longitudinal Internet Studies for the Social Sciences (LISS) panel.

ELSA. ELSA is a nationally representative sample of non-institutionalized individuals aged 50 years and older and living in England. The ELSA sample was drawn from households who participated in the Health Survey for England (HSE) during 1998, 1999, and 2001. Participants were asked to complete questionnaires about their socio-demographics and health every two years. During Wave 2 (2004), Wave 4 (2008), and Wave 6 (2012), participants who gave consent were also visited by a nurse for assessment of objective measures of health such as blood pressure, lung function and anthropometric indices. Seventy-eight percent of the initial sample (9,432 out of 12,100 participants) completed questionnaires at Wave 2 (2004) and 7,666 participants (63.35% of the initial sample) additionally underwent clinical assessment by a nurse. Eleven thousand and fifty participants completed questionnaires during Wave 4, and 10,601 participants completed questionnaires during Wave 6. Eight thousand six hundred and forty-three and 8,054 participants also underwent clinical assessment at Wave 4 and Wave 6 respectively. We used data from three waves (2004, 2008, and 2012) for the current study. Our analytic sample consisted of 9,404 participants (mean age 68.28 years, 56.54% female) who completed self-report questionnaires on at least one occasion and 5,596 participants (mean age 67.90 years, 55.44% female) who underwent clinical assessment on at least one occasion. Our analytic

sample was slightly older and had slightly higher average level of income than those who did

not respond to measures of interest.

LISS. The LISS panel is a sample of approximately 5,000 households in the

Netherlands who were randomly selected from municipal registers in 2007. Refreshment

samples were recruited during 2009, 2011-2012, and 2013-2014 to ensure the

representativeness of the sample. Participants completed online surveys each month which

asked questions about their socio-demographic and income status. Internet service and

personal computers were provided to households who did not have access to the internet or a

computer. During the months of November and December of 2007-2013 participants were

additionally asked to rate their health. Participants were included in our analyses if they

provided data on socio-demographics, income and self-rated health during at least one of the

7 waves. Six thousand six hundred and ninety-eight individuals (78.90% of the initial sample)

provided data on their subjective health during November and December 2007 (Wave 1),

5,961 participants provided data on their self-rated health during November and December

2008 (Wave 2). After refreshment samples were added in 2009, data on self-rated health was

available for 6,109, 5,718, 5,072, 5,780 and 5,379 participants during waves 3- 7

respectively. The final sample for our analyses consisted of 8,441 individuals (mean age

49.49 years, 53.20% female) who provided a total of 29,237 observations across all waves.

Individuals who were included in our study were generally older, had slightly lower income

and more likely to be married but did not differ in levels of self-rated health. Table 1 provides

the means and standard deviations of the variables of interest for the two analytic samples.

Measures

Self-rated health. In ELSA, self-rated health was assessed using a single item:

"Would you say your health is...", to which participants responded with either "excellent",

"very good", "good", "fair" or "poor". Scores were reverse coded and treated as a continuous

measure ranging from 1 ("poor") to 5 ("excellent"). Similarly, in LISS, participants were asked "How would you describe your health, generally speaking?", to which they responded on a 5-Likert scale ranging from 1 ("poor") to 5 ("excellent").

Allostatic load. For ELSA an indicator of high risk allostatic load was calculated using selected biomarkers of immune function (C-reactive protein and fibrinogen), cardiovascular functioning (systolic and diastolic blood pressure), respiratory functioning (peak expiratory flow), metabolic functioning (the ratio of total blood cholesterol to high density lipoprotein (HDL) cholesterol, triglycerides, glycated haemoglobin), and an index of body fat (waist measurement). A binary variable indicating high risk levels was generated for each biomarker. Levels of C-reactive protein, fibrinogen, systolic blood pressure, total blood cholesterol to HDL cholesterol, triglycerides, glycated haemoglobin and waist measurement in the upper quartile were considered high risk. Levels of diastolic blood pressure and peak expiratory flow in the lowest quartile were considered high risk. The binary variables indicating risk of each biomarker was calculated separately for each gender by fasting status. The nine binary variables were then summed to generate a continuous measure of high risk allostatic load, ranging from 0 (does not belong to high risk group for any of the biomarkers) to 9 (belongs to high risk group for all biomarkers). Only individuals who provided measures for all nine biomarkers were included in the analysis. This measure of allostatic load has been used in previous studies by Read & Grundy (2012) and Daly, Boyce & Wood (2015).

Actual income, the Yitzhaki Index, and income rank. Data on total household income was available for every wave in both datasets. ELSA additionally contained data on 'equivalised total income', which is the total income adjusted for family size. In ELSA, equivalised total income was used rather than total household income since the former accounts for increased demand on resources for larger families. Individuals with negative equivalised income values in ELSA (referred to as income henceforth) were assigned a value

income of £0 (in ELSA) so that they would be included in the analysis. Income was then

transformed to a Constant Relative Risk Aversion (CRRA) utility function using the formula:

$$u = \frac{y^{1-\rho} - 1}{1 - \rho}$$

where for values of ρ not equal to 1, u is utility, y is income and ρ is the elasticity of

marginal utility with respect to income and is assumed to be constant. When $\rho = 1$, the

function is equal to log-transformed income. This function has been used to more adequately

account for the highly non-linear association between income and well-being (for example

Layard, Nickell, & Mayraz, 2008; Hounkpatin, Wood, Brown & Dunn, 2015), which may not

be captured by the commonly used logarithmic function. Using the CRRA function allows us

to represent the exact shape of the relationship between income and health. This is important

in order to ensure that any significant coefficient on the income rank or Yitzhaki Index is not

due to these variables representing non-linearites in the relationship between income and

health that are not fully captured by the logarithmic function. Use of the CRRA function

therefore allows a more accurate estimation of the association between actual income and

health as well as preventing bias on the coefficient on the relative income measures.

The Yitzhaki Index (RD; Yitzhaki, 1979) and income rank (R; Brown, Gardner,

Oswald, & Qian, 2008; Stewart, Chater, & Brown, 2006) within education group and region

were calculated as the social psychology literature suggests individuals compare themselves

to these groups (Goethals & Darley, 1977; Singer, 1981). In LISS, only education was used

as a reference group since geographical data was not available. The Yitzhaki Index of an

individual i was calculated as:

$$RD_i = \frac{1}{N} \sum_u (y_u - y_i), \forall (y_u > y_i)$$

where y_i is the income of the individual i, y_u is the income of an individual u with higher

income than individual i and N is the total number of individuals within the reference group.

RD is therefore the average difference in income between individual i and other members in the same reference group who have higher income. The income rank, R, of an individual i is given by:

$$R_i = \frac{j-1}{n-1}$$

where $j - 1$ is the number of individuals within individual i's reference group who have incomes lower than individual i and n is the number of people within that reference group.

Potential covariates. Age, gender, household size (log-transformed), employment status (employed or unemployed), retirement status (retired or not retired), marital status (married, remarried, legally separated, divorced, widowed, never married in ELSA; married, separated, divorced, widowed, never married in LISS) and level of education achieved (no qualifications, foreign/other qualifications, National Vocational Qualification [NVQ] 1, GCE 'O' level or NVQ 2 , 'A' level or NVQ3, below degree, university degree or NVQ 4 or NVQ 5 in ELSA; not yet started education, primary school, intermediate secondary school/junior high school, higher secondary education or senior high school, intermediate vocational education or junior college, higher vocational education or college, university level in LISS) and year were controlled for in all analyses. In ELSA, government office region (North East, North West, Yorkshire and the Humber, East Midlands, West Midlands, East of England, London, South East, South West) was additionally controlled for in all analyses.

Statistical Analysis

Analysis was performed using STATA Version 11 (StataCorp, 2009). Given the clustered nature of the data (observations clustered within individuals who are nested in regions in ELSA and observations clustered within individuals who are nested within households in LISS), we fitted 3-level multilevel models to assess the association between health measures and each of the income-related predictors (CRRA-transformed actual income, Yitzhaki Index and income rank). To make full use of the longitudinal nature of the

data, we additionally modelled the association between each health outcome and lagged

income-related predictors. Values of income-related predictors at four-year and one-year time

lag were used for the analysis in ELSA and LISS respectively, since data on our variables of

interest were collected every four years in ELSA and yearly in LISS. The lagged models

contained significantly fewer observations (N = 14,224 for analyses on self-rated health in

ELSA; N = 7,310 for analyses on allostatic load in ELSA; N = 29,237 for analyses on self-

rated health in LISS) as subjects who did not provide data on income at both current and

lagged periods were dropped from the analysis. We use the maximum likelihood estimation

option of the *xtmixed* command in STATA to account for missing data (Rabe-Hesketh &

Skrondal, 2008). Maximum likelihood estimation borrows information about the correlation

between variables from complete cases to derive the most likely parameter estimates

(Allison, 2012).

We first derived the CRRA specification that best explained the effect of actual

income on each health variable by varying the values of ρ used to construct the CRRA

function. Goodness of fit statistics indicated that the best-fitting specification to represent the

effect of contemporaneous actual income on self-rated health across all time waves was ρ =

.70 in ELSA and ρ = .70 in LISS. In ELSA, the best-fitting specification for the effect of

actual income on allostatic load was achieved when income was CRRA-transformed using ρ

= .70. Goodness of fit statistics indicated the best-fitting CRRA specification for the effect of

lagged actual income on self-rated health in ELSA and LISS was ρ = .50 and ρ = .70

respectively. The best-fitting CRRA specification for the effect of lagged actual income on

allostatic load in ELSA was ρ = .30. We then, for each combination of income measure (the

potential predictor) and outcome, compared the fit of three models to assess whether the

association between health and income was best explained by contemporaneous income,

lagged income, or both. Model 1 predicted health from current income plus covariates, Model

2 predicted health from lagged income plus covariates and Model 3 predicted health from both current and lagged income plus covariates. All models were compared primarily using the Bayesian Information Criterion (BIC). BIC is a goodness of fit test which penalizes models for added parameters (Burnham & Anderson, 2004; Raftery, 1996) – a lower value indicating a better fit. Both the BIC and an alternative fit statistic, Akaike Information Criterion (AIC) are presented here for completeness. A BIC/AIC difference of 2 is considered weak evidence that the model with the lowest BIC/AIC explains the data better than the competing model and BIC/AIC differences of 4-7 provide moderate evidence that the model with the lowest BIC/AIC performs better.

Results

Our first set of analyses were concerned with establishing; (a) whether health was best predicted from contemporaneous or lagged income, and (b) which income-related predictor (absolute, Yitzhaki, or rank) best accounted for this relationship. Considering each income-related predictor, in turn, we first fitted 3 regression models for each outcome variable in each sample. Model 1 predicted an outcome variable from contemporaneous values of one income-related predictor, plus covariates. Model 2 predicted an outcome variable from lagged values of the same income-related predictor, plus covariates. Model 3 predicted an outcome variable jointly from contemporaneous and lagged values of the income-related predictor, plus covariates. Each model indicated that both contemporaneous and lagged values of each income-related significantly predicted each health outcome (except for lagged actual income in LISS) before controlling for the remaining income-related predictors (Table I of the Appendix). Goodness of fit statistics (the BIC and AIC) indicated that regardless of which of Models 1, 2 and 3 were considered, income rank (normally within region) consistently outperformed predictions using either actual income or the Yitzhaki Index (Table 2).

The choice of model (1, 2 or 3; whether health is most influenced by only contemporaneous, only lagged, or contemporaneous and lagged income specifications), however, was not so clear cut. The best-fitting model for the association between self-rated health and each income-related predictor in ELSA was the model predicting self-rated health from both contemporaneous and lagged values of the specified income-related predictor (Model 3). The best-fitting model for the association between allostatic load and each income-related predictor in ELSA was generally the model predicting allostatic load from both contemporaneous and lagged values of the specified income-related predictor (Model 3). The best-fitting model for the association between self-rated health and each income-related predictor in LISS was the model predicting self-rated health from contemporaneous values of the specified income-related predictor, although the improvement on Model 3 (particularly when using income rank) was trivial. All further analyses were based on Model 3.

We next assessed whether Yitzhaki Index or rank remained significantly associated with health after controlling for actual income (see Table 3). Predicting self-rated health jointly from income and Yitzhaki Index within region in ELSA indicated Yitzhaki Index did not uniquely predict self-rated health after controlling for actual income. Predicting self-rated health jointly from income and rank within region in ELSA indicated rank uniquely predicted self-rated health after controlling for actual income. Jointly regressing self-rated health on income and Yitzhaki Index within education group in ELSA indicated Yitzhaki Index had an independent lagged but not contemporaneous effect on self-rated health, whilst jointly regressing self-rated health on income and rank within education group indicated rank had both an independent contemporaneous and lagged effect on self-rated health. In LISS, predicting self-rated health jointly from income and Yitzhaki Index within education group indicated Yitzhaki Index uniquely predicted self-rated health. Predicting self-rated health jointly from income and income rank within education group indicated rank uniquely

predicted self-rated health. Predicting allostatic load jointly from income and Yitzhaki Index within region in ELSA indicated Yitzhaki Index did not uniquely predict allostatic load. Predicting allostatic load jointly from income and rank within region in ELSA indicated rank uniquely predicted allostatic load. Similar results were observed using education as a reference group in ELSA.

Jointly regressing each of our health outcomes on actual income and rank or actual income and Yitzhaki Index resulted in VIFs with final values ranging from 2.89 to 7.19. Given that the parameter estimates of our joint regression models may be biased by co-linearity (Tu & Gilthorpe, 2012) and following on from recent recommendations (Hounkpatin et al., 2015), we compared the fit of the models predicting health from actual income plus Yitzhaki Index to the fit of the models predicting health from actual income and rank. Across both samples, health measures and reference groups, the model predicting health from actual income plus rank provided better fit on the data than the model predicting health from actual income plus Yitzhaki (see Table 4). Moreover, the best fitting model was alternatively that which predicted health from actual income plus rank or that which predicted health from rank alone.

We additionally repeated all analysis using age (<50, 50-59, 60-69, 70-79, 80-89, >89 in ELSA; 10-year age bands ranging from 0 to 100 years in LISS) as a reference group. The results are reported in Tables A and B of the Online Appendix. Rank was a better predictor of self-rated health in LISS and allostatic load in ELSA than both the Yitzhaki Index and actual income. However, the best-fitting model to explain the association between self-rated health and income in ELSA was the model predicting self-rated health from both current and lagged income. Both rank and Yitzhaki Index within age group uniquely predicted both health outcomes after controlling for actual income in ELSA. In LISS, rank within age group had an

independent contemporaneous and lagged independent effect on self-rated health, while Yitzhaki Index had only an independent contemporaneous effect on health.

Discussion

This study explored differences in the predictive value of two competing indicators of relative deprivation- the Yitzhaki Index and income rank position- on self-rated health and allostatic load. The findings contribute to the debate on the material and psychosocial effects of an individual's income on their health by suggesting that the psychosocial effect (as a complete or additive explanation of the link between income and health) is strongly supported when modelled by the rank but not Yitzhaki specification.

The results support both of our hypotheses. Income rank was a better predictor of self-rated health and allostatic load than the Yitzhaki Index for both samples and across two reference groups. In line with our second hypothesis, income rank more consistently predicted self-rated health and allostatic load than Yitzhaki Index in both samples after controlling for actual income, whereas whether Yitzhaki Index remained a predictor of health was variable, model, and sample specific. The findings demonstrate how support for the psychosocial hypothesis over the material hypothesis may depend on the specification used to model relative deprivation. Contrasting the associations of actual income and Yitzhaki Index with self-rated health and allostatic load may lead to the conclusion that material factors better explain the association between health and income, while contrasting the associations of actual income and income rank leads to the conclusion that psychosocial factors uniquely predict health outcomes and relate more strongly to health than material factors.

The results here support the role of income rank on health. Income rank negatively relates to both self-report and objective measures of health. Our findings are consistent with a growing body of literature comparing the material and psychosocial processes on health (for example Martikainen, Adda, Ferrie, Smith, & Marmot, 2003; Elgar et al., 2013; Daly, Boyce,

& Wood, 2015; Boyce, Brown, & Moore, 2010; Wood, Boyce, et al., 2012), and contrast the studies by Eibner & Evans (2005) and Li & Zhu (2006) who report mixed findings for an effect of rank on health. A failure to find a significant effect of rank in the two outlier studies may be the result of using datasets in which information on individual income was only collected being within in a broad income band (as in the case of the study by Eibner & Evans, 2005), rather than the actual income level, which is less suitable for forming the rank variable, or the use of a deflated income per capita household income variable (as in the case of the study by Li & Zhu, 2006), which assumes that people compare relative spending power rather than simply how much they are earning relative to others. The current study additionally provides evidence to suggest that the association between an individual's income and health is more closely related to their income rank position within a reference group than the magnitude of the difference in their income relative to those with higher income within the reference group. Previous studies that failed to find an effect of relative income on health using the Yitzhaki Index may have found a significant association had they used the income rank specification as a measure of relative deprivation instead. We suggest, as future research, that these earlier studies are revisited to see whether the results change if a rank measure of relative deprivation is used.

There are a number of limitations that must be considered. Firstly, although we use longitudinal data we do not make strong causal inferences about the association between income rank and health. It is possible that an individual's health predicts their income. Additional statistical procedures such as instrumentation and the use of natural experiments would be needed to determine any causal association between income (rank) and health. Such instrumentation however is difficult as it requires data not commonly available in datasets. Certainly issues of causality are key to address in future work. Secondly, we use a composite measure of allostatic load since a summary score of biomarkers has been found to be more

strongly associated with health than single biomarkers (Karlamangla, Singer, McEwen, Rowe, & Seeman, 2002). Future work may want to examine the relationship between income and specific health conditions. Thirdly, we model the effects of relative deprivation using measures of income rank and the Yitzhaki Index that we estimated from income levels within each reference group. If subjective self-report measures had been used for both relative deprivation and health then any results may have been caused by shared method (response) bias; we were able to rule this out here, through showing the results hold with an objective measure of relative deprivation combined with both subjective and objectively measured health. However, it is unclear whether such 'objective' measures of relative deprivation translate to perceived sense of relative deprivation or the extent to which each individual is affected by having lower income (rank). Further studies such as those by Pham-Kanter (2009) and Miething (2013) that additionally ask participants to provide self-report measures of their income rank and indicate the extent to which they worry about their income rank may provide an alternate measure of the effect of relative deprivation on health. We encourage more widespread inclusion of these measures in large scale dataset collections. In conclusion, this study supports the role of psychosocial processes on health and highlights the effect of psychosocial factors is most evident when modelled using the income rank specification than the Yitzhaki Index. Our findings are broadly consistent with the separate but related income inequality literature (Wilkinson & Pickett, 2006), which shows that individuals in less equal societies have worse health than individuals in more equal societies, even after controlling for individual-level actual income. In less equal societies, differences in rank will likely be more salient, as each income rank position would be more noticeable through being associated with larger differences in absolute income. As a result, individuals in unequal societies may be more likely to make social comparisons and compete on income rank rather than other domains (such as exercise) on which comparisons may be more health promoting. Further, to

the extent that people spend time and energy pursuing income rank, this will crowd out more intrinsically motivating activities. Income rank may therefore relate more strongly to health in less equal societies (as suggested by Wood et al., 2012). These are testable hypotheses that we encourage future work to investigate to fully integrate the relative income and inequality literatures.

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Table 1[a] Descriptive Statistics Across Time Waves for ELSA and LISS

ELSA

	Wave 4		Wave 6	
	N	Mean (SD)	N	Mean (SD)
Age	6246	68.52 (9.56)	7978	68.1 (9.23)
Female	6246	0.57 (0.49)	7978	0.56 (0.50)
No qualifications (proportion)	6246	0.30 (0.46)	7978	0.26 (0.44)
Married (proportion)	6246	0.54 (0.50)	7978	0.55 (0.50)
Employment status	6246	0.25 (0.43)	7978	0.01 (0.08)
Retired	6246	0.63 (0.48)	7978	0.99 (0.08)
Equivalised Income (£)	6246	323.02 (246.24)	7978	398.43 (542.70)
Self-rated health	6246	3.15 (1.08)	7978	3.15 (1.11)
Allostatic load	5393	2.18 (1.49)	6717	2.75 (1.50)

LISS

	Wave 2		Wave 3		Wave 4		Wave 5	
	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)
Age	4996	46.77 (16.07)	4615	47.71 (16.77)	5162	49.37 (17.23)	4616	50.53 (17.24)
Female	4996	0.54 (0.50)	4615	0.53 (0.50)	5162	0.53 (0.50)	4616	0.53 (0.50)
Primary education (proportion)	4996	0.00 (0.03)	4615	0.00 (0.04)	5162	0.00 (0.05)	4616	0.00 (0.05)
Married (proportion)	4996	0.62 (0.49)	4615	0.60 (0.49)	5162	0.58 (0.49)	4616	0.58 (0.49)
Employment status	4996	0.52 (0.50)	4615	0.48 (0.50)	5162	0.47 (0.50)	4616	0.46 (0.50)
Retired	4996	0.15 (0.36)	4615	0.17 (0.38)	5162	0.20 (0.40)	4616	0.22 (0.41)
Net Income (€)	4996	3186.39 (7119.02)	4615	3019.80 (6055.37)	5162	2913.25 (3316.23)	4616	2902.22 (2974.07)
Household size	4996	2.78 (1.31)	4615	2.73 (1.35)	5162	2.60 (1.32)	4616	2.60 (1.33)
Self-rated health	4996	3.18 (0.75)	4615	3.14 (0.75)	5162	3.10 (0.76)	4616	3.08 (0.75)

	Wave 6		Wave 7	
	N	Mean (SD)	N	Mean (SD)
	5960	50.85 (17.31)	4818	51.72 (17.42)
	5060	0.53 (0.50)	4818	0.53 (0.50)
	5060	0.00 (0.05)	4818	0.00 (0.05)
	5060	0.59 (0.49)	4818	0.59 (0.49)
	5060	0.45 (0.50)	4818	0.43 (0.50)
	5060	0.22 (0.42)	4818	0.24 (0.43)
	5060	2972.58 (3485.07)	4818	2916.04 (2944.36)
	5060	2.60 (1.30)	4818	2.55 (1.28)
	5060	3.10 (0.77)	4818	3.08 (0.76)

[a]N = number of observations. SD = standard deviation.

Table 2[b] *Fit Statistics Comparing Contemporaneous and Lagged Models of the Association Between Income-Related Predictors and Health*

	Contemporaneous model		Lagged model		Contemporaneous + Lagged model	
	BIC	AIC	BIC	AIC	BIC	AIC
ELSA						
Self-rated health						
Actual income	36435.73	36201.29	36403.92	36169.48	36337.61	36095.61
Yitzhaki Index (region)	36437.56	36203.11	36424.94	36190.50	36361.36	36119.35
Yitzhaki Index (education)	36439.40	36204.96	36479.17	37244.73	36406.47	36164.47
Rank (region)	**36422.11**	**36187.67**	**36383.48**	**36149.03**	**36322.94**	**36080.94**
Rank (education)	36427.17	36192.72	36410.00	36175.55	36347.79	36105.79
Allostatic load						
Actual income	17039.60	16825.79	**17023.47**	**16809.67**	17027.15	16806.44
Yitzhaki Index (region)	17034.89	16821.08	17032.30	16818.49	17031.74	16811.04
Yitzhaki Index (education)	17036.45	16822.64	17042.41	16828.60	17040.72	16820.02
Rank (region)	**17030.11**	**16816.31**	**17023.76**	**16809.95**	**17022.77**	**16802.07**
Rank (education)	17031.22	16817.41	17028.29	16814.48	17027.19	16806.49
LISS						
Self-rated health						
Actual income	66912.42	66705.34	66917.16	66710.08	66919.10	66703.73
Yitzhaki Index (education)	66890.53	66683.45	66897.01	66689.93	66893.12	66677.76
Rank (education)	**66879.02**	**66671.94**	**66882.61**	**66675.53**	**66879.31**	**66663.95**

[b]For each health outcome, the fit of contemporaneous models of the association between each income-related predictor and health and the fit of lagged models of the association between each income-related predictor and health is compared to models predicting health from contemporaneous and lagged actual income -related predictor simultaneously. The best fitting parameter within each model is indicated in bold. N = 14,224 for models of self-rated health in ELSA, N= 7,310 for models of allostatic load in ELSA and N = 29,237 for models of self-rated health in LISS.

Table 3[c] Parameter Estimates of Models Jointly Predicting Health from Actual Income and Relative Deprivation

	f(income) + Yitzhaki Index		f(income) +Rank	
	b (standard error)	p-value	b (standard error)	p-value
Self-rated health				
ELSA				
Actual income	0.05 (0.02)	0.003	0.04 (0.02)	0.030
Lagged actual income	0.07 (0.02)	<0.001	0.03 (0.02)	0.058
Yitzhaki Index (region)	-0.02 (0.02)	0.188		
Lagged Yitzhaki Index (region)	-0.03 (0.02)	0.092		
Rank (region)			0.15 (0.06)	0.016
Lagged rank (region)			0.22 (0.06)	<0.001
Actual income	0.05 (0.02)	0.003	0.04 (0.02)	0.009
Lagged actual income	0.12 (0.01)	<0.001	0.06 (0.02)	<0.001
Yitzhaki Index (education)	-0.03 (0.02)	0.075		
Lagged Yitzhaki Index (education)	0.03 (0.01)	0.025		
Rank (education)			0.12 (0.06)	0.031
Lagged rank (education)			0.11 (0.05)	0.033
LISS				
Actual income	-0.01 (0.01)	0.474	-0.01 (0.01)	0.304
Lagged actual income	-0.00 (0.01)	0.986	-0.01 (0.01)	0.485
Yitzhaki Index (education)	-0.05 (0.02)	0.002		
Lagged Yitzhaki Index (education)	-0.03 (0.01)	0.037		
Rank (education)			0.17 (0.05)	0.001
Lagged rank (education)			0.13 (0.05)	0.004
Allostatic load				
ELSA				
Actual income	0.01 (0.02)	0.051	0.02 (0.02)	0.272
Lagged actual income	-0.05 (0.02)	0.004	-0.04 (0.02)	0.057
Yitzhaki Index (region)	0.04 (0.02)	0.074		
Lagged Yitzhaki Index (region)	0.01 (0.02)	0.733		
Rank (region)			-0.19 (0.08)	0.011
Lagged rank (region)			-0.06 (0.06)	0.293
Actual income	0.00 (0.02)	0.912	0.02 (0.02)	0.410
Lagged actual income	-0.07 (0.02)	<0.001	-0.04 (0.02)	0.017
Yitzhaki Index (education)	0.03 (0.02)	0.123		
Lagged Yitzhaki Index (education)	-0.02 (0.01)	0.160		
Rank (education)			-0.16 (0.07)	0.020
Lagged rank (education)			-0.02 (0.05)	0.662

Table 4[d] *Fit Statistics Competing Models of the Association Between Income-Related*

Predictors and Self-rated Health and Allostatic Load

	Rank		Rank + Actual Income		Yitzhaki + Actual Income	
	BIC	AIC	BIC	AIC	BIC	AIC
ELSA, self-rated health						
Region	**36322.94**	36080.94	36333.59	**36076.45**	36351.71	36094.57
Education	36347.79	36105.79	**36346.93**	**36089.80**	36349.04	36091.91
ELSA, allostatic load						
Region	**17022.77**	16802.07	17036.07	**16801.57**	17041.36	16806.87
Education	**17027.19**	16806.49	17038.86	**16804.37**	17041.01	16806.51
LISS, self-rated health						
Education	**66879.31**	**66663.95**	66897.55	66665.62	66913.07	66681.14

[d]For each health outcome, the fit of the rank model is compared to models predicting health

(1) jointly from rank and actual income (2) jointly from Yitzhaki and actual income. N =

14,224 for models of self-rated health in ELSA, N= 7,310 for models of allostatic load in

ELSA and N = 29,237 for models of self-rated health in LISS. The best fitting of the

combinations of the income parameters are indicated in bold.

Online Supplementary

Table I[a] *Parameter Estimates of the Association between Health, Contemporaneous and Lagged Income-Related Predictors*

	f(income)		Yitzhaki Index		Rank	
	b (standard error)	p-value	b (standard error)	p-value	b (standard error)	p-value
<u>Self-rated health</u>						
ELSA						
Actual income	0.10 (0.01)	<0.000				
Lagged actual income	0.10 (0.01)	<0.000				
Yitzhaki Index (region)			-0.08 (0.01)	<0.000		
Lagged yitzhaki Index (region)			-0.09 (0.01)	<0.000		
Rank (region)					0.27 (0.03)	<0.000
Lagged rank (region)					0.33 (0.03)	<0.000
Yitzhaki Index (education)			-0.08 (0.01)	<0.000		
Lagged yitzhaki Index (education)			-0.07 (0.01)	<0.000		
Rank (education)					0.25 (0.03)	<0.000
Lagged rank (education)					0.29 (0.03)	<0.000
LISS						
Actual income	0.02 (0.01)	0.044				
Lagged actual income	0.01 (0.01)	0.087				
Yitzhaki Index (education)			-0.04 (0.01)	<0.000		
Lagged yitzhaki Index (education)			-0.03 (0.01)	0.006		
Rank (education)					0.14 (0.04)	<0.000
Lagged rank (education)					0.11 (0.04)	0.002
<u>Allostatic load</u>						
ELSA						
Actual income	-0.04 (0.02)	0.019				
Lagged actual income	-0.06 (0.01)	<0.000				
Yitzhaki Index (region)			0.03 (0.01)	0.003		
Lagged Yitzhaki Index (region)			0.05 (0.01)	<0.000		
Rank (region)					-0.12 (0.04)	0.003
Lagged rank (region)					-0.18 (0.04)	<0.000
Yitzhaki Index (education)			0.04 (0.01)	<0.000		
Lagged Yitzhaki Index (education)			0.03 (0.01)	0.002		
Rank (education)					-0.11 (0.04)	0.003
Lagged rank (education)					-0.16 (0.04)	<0.000

Table II[b] *Fit Statistics Comparing Contemporaneous and Lagged Models of the Association Between Income-Related Predictors and Health*

	Contemporaneous model		Lagged model		Contemporaneous + Lagged model	
	BIC	AIC	BIC	AIC	BIC	AIC
ELSA						
Self-rated health						
Actual income	**32279.26**	**32056.07**	32258.87	32035.69	**32193.43**	**31962.80**
Yitzhaki Index (age)	32285.15	32061.96	32280.50	32057.32	32216.67	31986.05
Rank (age)	32290.07	32066.88	**32250.48**	**32027.29**	32205.73	31975.11
Allostatic load						
Actual income	15112.66	14909.42	15105.73	14902.49	15108.16	14898.14
Yitzhaki Index (age)	15112.33	14909.09	15111.94	14908.69	15112.73	14902.71
Rank (age)	**15109.46**	**14906.21**	**15104.60**	**14901.35**	**15106.36**	**14896.34**
LISS						
Self-rated health						
Actual income	66911.14	66704.06	66915.87	66708.79	66917.82	66702.45
Yitzhaki Index (age)	66896.48	66689.40	66913.63	66706.55	66905.56	66690.20
Rank (age)	**66871.01**	**66663.93**	**66878.89**	**66671.81**	**66872.10**	**66656.74**

[b]For each health outcome, the fit of contemporaneous models of the association between each income-related predictor and health and the fit of lagged models of the association between each income-related predictor and health is compared to models predicting health from contemporaneous and lagged actual income -related predictor simultaneously. The best fitting parameter within each model is indicated in bold. N = 12,576 for models of self-rated health in ELSA, N= 7,310 for models of allostatic load in ELSA and N = 29,236 for models of self-rated health in LISS.

Table III[c] *Parameter Estimates of the Association between Health, Contemporaneous and Lagged Income-Related Predictors Using Age as a Reference group*

	f(income) + Yitzhaki Index		f(income) + Rank	
	b (standard error)	p-value	b (standard error)	p-value
Self-rated health				
ELSA				
Actual income	0.04 (0.02)	0.009	0.06 (0.02)	<0.001
Lagged actual income	0.08 (0.02)	<0.001	0.06 (0.02)	0.001
Yitzhaki Index (age)	-0.04 (0.02)	0.008		
Lagged Yitzhaki Index (age)	-0.01 (0.02)	0.347		
Rank (age)			0.04 (0.06)	0.466
Lagged rank (age)			0.14 (0.05)	0.008
LISS				
Actual income	-0.00 (0.01)	0.974	-0.02 (0.01)	0.139
Lagged actual income	0.01 (0.01)	0.117	-0.01 (0.01)	0.543
Yitzhaki Index (age)	-0.04 (0.01)	0.001		
Lagged Yitzhaki Index (age)	-0.00 (0.01)	0.880		
Rank (age)			0.21 (0.05)	<0.001
Lagged rank (age)			0.13 (0.05)	0.007
Allostatic load				
ELSA				
Actual income	0.02 (0.02)	0.363	0.02 (0.02)	0.282
Lagged actual income	-0.05 (0.02)	0.003	-0.04 (0.02)	0.051
Yitzhaki Index (age)	0.05 (0.02)	0.010		
Lagged Yitzhaki Index (age)	0.00 (0.02)	0.768		
Rank (age)			-0.18 (0.07)	0.009
Lagged rank (age)			-0.06 (0.06)	0.302

Table IV[d] *Fit Statistics Competing Models of the Association Between Income-Related Predictors and Self-rated Health and Allostatic Load*

	Rank		Rank + Actual Income		Yitzhaki + Actual Income	
	BIC	AIC	BIC	AIC	BIC	AIC
ELSA, self-rated health						
Age	32205.73	31975.11	**32202.23**	31956.73	32205.13	**31954.79**
ELSA, allostatic load						
Age	**15106.36**	**14896.34**	15122.25	14898.68	15124.49	14900.93
LISS, self-rated health						
Age	**66872.10**	**66656.74**	66889.01	66657.08	66923.23	66691.30

[d]For each health outcome, the fit of the rank model is compared to models predicting health (1) jointly from rank and actual income (2) jointly from rank and Yitzhaki Index and (3) jointly from rank + actual income + Yitzhaki Index. N = 12,576 for models of self-rated health in ELSA, N= 6,469 for models of allostatic load in ELSA and N = 29,236 for models of self-rated health in LISS. The best fitting of the combinations of the income parameters are indicated in bold.