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Early-life Exposure to Income Inequality and Adolescent Health and Well-being:

Evidence from the Health Behaviour in School-aged Children Study

Frank J. Elgar and Candace Currie

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EARLY-LIFE EXPOSURE TO INCOME INEQUALITY AND ADOLESCENT HEALTH AND WELL-BEING: EVIDENCE FROM THE HEALTH BEHAVIOUR IN SCHOOL-AGED CHILDREN STUDY

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Abstract: The health of children and adolescents in high income countries negatively relates to income inequality. Theoretical interpretations of this association suggest that inequality intensifies social hierarchies, erodes social or material resources that support health, or impacts socioemotional development in childhood and subsequently harms health. The evidence in support of this causal interpretation is limited by a reliance on cross-sectional, ecological studies. Using multilevel panel data from the Health Behaviour in School-aged Children (HBSC) study, this paper examines lagged and contemporaneous associations between national income inequality and health and well-being during adolescence. Health symptoms and life satisfaction were measured in successive surveys of 11- to 15-year-olds in Europe and North America between 1994 and 2014. These data were linked to country-level income inequality for each survey year (contemporaneous effects) and for earlier developmental periods, at 0-4 years and 5-9 years (lagged effects), dating back to 1979 – the birth year of 15-year-olds in the 1994 survey cycle. Societal growth curve modelling was used to pool data from successive survey cycles and to isolate age, period, and cohort effects.

The results show evidence of lagged effects of income inequality during childhood (5-9 years) on health symptoms and life satisfaction in adolescents (11-15 years), after differences in concurrent income inequality and income per capita, cohort, time period, and individual gender, age, and affluence were held constant. This period of development for income inequality exposure coincides with the early school years when social relationships extend from the family to school and community settings. Inequality may shape child developmental trajectories in ways that later manifest in reduced health and well-being. Though not causal evidence in the strictest sense, these findings establish antecedent-consequence conditions in the association between income inequality and health. The practical and theoretical implications of these results are discussed.

Keywords Income inequality; adolescents; children; health; well-being; causal inference; Health Behaviour in School-aged Children.

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Acronyms

AIC	Akaike's information criterion
BIC	Bayesian information criterion
FAS	Family Affluence Scale
GNI	Gross national income
HBSC	Health Behaviour in School-aged Children
SEP	Socio-Economic Position

1. INTRODUCTION

Social inequalities in children's health and well-being relate to their socioeconomic position (SEP) in society. A large body of empirical evidence shows that growing up in economically disadvantaged conditions worsens health, limits academic achievement, and shortens lifespans.[1,2,3] Children and adolescents living in relative poverty – regardless of overall material conditions – tend to experience more interpersonal violence, family turmoil, and environmental hazards that increase risk of injury, engage in more health compromising behaviours (e.g., physical inactivity, poor nutrition, smoking), report lower subjective well-being, and exhibit more social skills deficits and emotional and behavioural problems.[2,4] Simply put, the likelihood that young people are happy, healthy and doing well in school significantly improves as their SEP rises. These inequalities exist across the full range of SEP in many rich, economically developed countries,[5] and recent evidence suggests that these divisions in health and well-being have widened in recent years.[6]

One interpretation of these differences focuses on children's access to basic material resources that support health, which has been a dominant focus during the past 15 years in the Millennium Development Goals.[7] UNICEF's Report Card 13, Fairness for Children, focuses instead on international differences in "bottom-end" inequality in children's income, education, health, and well-being (i.e., differences between the average below the median and the median).[8] The emphasis here is on relative disparities within high- and middle-income countries and specifically on the experience of growing up excluded from a standard of living that is experienced by the rest of society.

Another line of research on the structural determinants of health examines the association between inequalities in income and inequalities in health. Studies have found that children and adults who live in countries with smaller income differences tend to have better health and social outcomes.[9,10] An analysis of adolescent health in 34 mostly high-income countries found that income inequality related to higher body mass indices, less physical activity, and more mental and physical health symptoms.[6] These associations held up to numerous controls including national income per capita and individual SEP. Similar research on children and adolescents has found that income inequality relates to alcohol misuse,[11] school bullying,[12,13] physical assaults,[14] teenage pregnancy,[15] and child maltreatment.[16] Using country data shown in previous Unicef Report Cards, Pickett and Wilkinson have found that international differences in child well-being correlate with income inequality more strongly than with country wealth.[17,18] Based on these and similar studies on inequality, these authors concluded that further improvements in child well-being in rich countries may depend more on reductions in income inequality than on further economic growth.[18]

While the link between national income inequality and child well-being has been replicated in several independent studies, the mechanisms underlying this association remain unclear. The prevailing psychosocial interpretation is that income inequality is socially corrosive.[10] It intensifies social hierarchies, erodes social capital that supports health, and consequently contributes to stress-related health problems and social disorder.[10,19,20] This explanation is consistent with developmental perspectives that describe how early life exposure to inequality shapes social and moral development in children. Arsenio and Gold proposed that children's

exposure to unfairness biases how social information is processed such that instrumental goals are valued more than relational goals and violence and intimidation are learned to be effective ways to succeed in an unjust world.[21] This explanation helps to explain the robust association between income inequality and prevalence of school bullying.[12,13] An alternative, "materialist" explanation of the association focuses on the relation between income inequality and the quality of public services and infrastructure that support health and well-being, like benefits and cash transfers to families and good quality public schools and public health services. The idea here is that as income inequality increases, social expenditures decline due to increased support for conservative governments and opposition to taxation among the upper classes who stand to benefit less from wealth redistribution for the common good,[22] all leading to an economic rift in society that economist Robert Evans calls "private affluence and public squalor."[23]

There is a lack of consensus about the relative importance of these psychosocial and material pathways, and it is possible that both are involved in linking income inequality to poor health. For policymakers, a more significant question about this area of research is the lack of robust causal evidence. A criterion of causal inference is *temporality*; the putative cause must precede the effect.[24,25] A limitation in the available evidence is that most studies of income inequality and health have used a cross-sectional research design. Any causal interpretation of the health impacts of income inequality implies antecedent-consequence conditions that have not yet been thoroughly tested. Other limitations of previous studies are their reliance on aggregate health indicators and the limited number of country observations. Ecological studies sometimes lack the statistical power needed to detect macro-level contextual effects on health and adequately control differences in country wealth, individual SEP, and other individual characteristics.

The goal of the present study was to address the issue of temporality using panel data on national income inequality and health data from the World Health Organisation's Health Behaviour in School-aged Children (HBSC) study. We hypothesised that early life exposure to income inequality has a lagged effect on health and well-being in adolescence. Our hypothesis for such an effect was based on developmental consequences of early childhood stress and socioeconomic disadvantage. Developmental and epigenetic studies have traced the origins of SEP differences in mental and physical health to early life experiences, specifically to neuroendocrine stress pathways,[26] neuroregulatory centres of the brain that govern attention, social interaction, and emotion,[27] and the cumulative nature of chronic stress and its risks to health.[28] For example, longitudinal studies by Evans and colleagues found that low SEP at age 9 prospectively predicts physiological stress dysregulation, emotion dysregulation, and emotional and behavioural problems in adolescence (ages 13 and 17) after differences in concurrent SEP were controlled.[29,30] The 'biological embedding' of childhood poverty and the durability of socioeconomic differences in health across the life course both suggest that early life stressors – like income inequality – could impact health and well-being through similar stress pathways and sensitive periods of development.[31]

Additional support for this lagged effect hypothesis comes from adult studies of income inequality on health in later life. Karlsson et al. studied income inequality and adult health, activities of daily living, and life expectancy in 19 countries in 1990 and 2006 and found a significant lagged effect of

income inequality on health but only in rich countries.[32] Another study of national income inequality and physical health in old age in 16 countries found a significant relation between averaged inequality over a 46-year period (1960 to 2006) and later health.[33] Blakely et al. used US state-level data on income inequality and self-reported adult health and found that in adults aged 45 years and older, income inequality experienced up to 15 years previously related more strongly to poor health than inequality measured contemporaneously.[34] More recently, Lillard et al. reported on small but statistically significant effects of early life exposure (0 to 4 years) to national income inequality on health later in life.[35] However, this study involved a single cohort in just one country and thus confounded age, cohort, and period effects because income inequality varied synchronously over time with developmental stages and not between settings or individuals. Not all studies have found such effects. Leigh and Jencks examined life expectancy, infant mortality, homicide, and suicide in a sample of 12 countries and found no association (concurrently or with a 5-year lag) with income inequality.[36] Similarly, Mellor and Milyo found no significant lagged effects of US state-level income inequality on adult self-rated health after controlling for state fixed-effects.[37]

We are unaware of any previous research on lagged effects of income inequality in childhood on health and well-being in adolescence. The small number of studies that have investigated early life exposures to income inequality has involved different sample characteristics, analytic approaches, statistical controls, and measures of income inequality and health. None of these studies used datasets that provided sufficient heterogeneity in income inequality between populations, time periods, and age groups. This study aims to address this knowledge gap using a series of repeated, cross-national surveys of adolescent health that were carried out in 40 countries as part of the HBSC study (www.hbsc.org). We link individual records on the health and well-being of 11, 13 and 15-year-olds from six survey cycles (1994 to 2014) to country-level data on income inequality for each survey year (contemporaneous effects) and earlier developmental periods, at 0-4 years and 5-9 years (lagged effects). These two early age groups were chosen to distinguish infancy and early childhood stages of development when social influences on health and well-being begin to extend from the family to school and community settings. We apply Fairbrother's 'societal growth curve model' of country-level changes in income inequality in order to maximize the statistical sensitivity of our analysis to contextual-level effects. This multilevel design pools repeated cycles of complex survey data while retaining their multilevel structure, which helps to delineate age, cohort, and period effects.[38] Our hypothesis is that exposure to income inequality in infancy and early childhood relates to health symptoms and low well-being in adolescence, after controlling differences in contemporaneous income inequality, national wealth, and individual-level family affluence.

2. METHODS

Data sources

Health Behaviour in School-aged Children Study. Self-report data on health symptoms and family affluence were collected in the 1994, 1998, 2002, 2006, 2010, and 2014 cycles of the HBSC study. Data on life satisfaction were collected in the 2002, 2006, 2010, and 2014 cycles. Each cycle included

nationally representative samples of 11-, 13- and 15-year-olds from a growing network of countries in Europe and North America. The analysis of health symptoms involved a pooled sample of 888,841 adolescents from 180 country/survey year groups. The analysis of life satisfaction involved a sample of 678,031 adolescents from 137 country/survey year groups. Greenland was omitted from the study due to the lack of publicly available economic data. Survey data from England, Scotland and Wales were combined with equal weight to correspond to economic data on the United Kingdom and data from French and Flemish samples in Belgium were also combined.

Health and well-being. In all HBSC survey cycles, an eight-item health symptom checklist measured four psychological symptoms (irritability or bad temper, feeling low, feeling nervous, and difficulty sleeping) and four physical symptoms (headache, stomach ache, back ache, and feeling dizzy).[39] Respondents reported the frequency of each symptom during the previous six months (0 = rarely or never, 1 = every month, 2 = every week, 3 = more than once a week, 4 = every day). These scores were summed to create a health symptom scale that ranged from 0 to 32 points. The validity of this health symptom checklist was supported by cross-national studies and qualitative interviews with adolescents.[39,40] Since 2002, the HBSC survey included Cantril's life satisfaction ladder to measure how respondents felt about their life at present on an 11-point scale ranging from 0 (worst possible life) to 10 (best possible life).[41]

Socioeconomic position. The HBSC Family Affluence Scale (FAS) was used in our study to account for some socioeconomic variation at the individual level. The FAS is an index of material assets or common indicators of wealth.[42,43] It has been validated alongside measures of SEP that solicit adolescents' reports of parental occupation, educational attainment, or household income, and has been found to have better criterion validity and to be less affected by non-response bias than these other measures.[42,44] The FAS had two items in the 1994 survey, "Does your family own a car, van or truck?" (No = 0, Yes = 1, Yes, two or more = 2); "Do you have your own bedroom for yourself?" (No = 0, Yes = 1). A third item was added to the scale in 1998: "During the past 12 months, how many times did you travel away on holiday with your family?" (Not at all = 0, Once = 1, Twice or more = 2); A fourth item was added for the 2002, 2006, and 2010 surveys: "How many computers does your family own?" (None = 0, One = 1, Two or more = 2). Finally, two more items were added for the 2014 survey, thus creating a 6-item scale: "At home, do you have a dishwasher (No = 0, Yes = 1); How many bathrooms (room with a bath) are in your home (None = 0, One = 1, Two = 2, More than two = 3)." Total summary scores on these items were transformed to country- and year-specific ridit scores, thus representing a relative family affluence score for each country/year group that ranged from 0 (least affluent) to 1 (most affluent). The ridit is a proportional rank score that represents the proportion of observations with lower scores, effectively transforming ordinal data to de facto interval scale.[45,46]

Country data. Data on country wealth, gross national income per person (Atlas method, US dollars) were retrieved for every HBSC survey cycle year from the World Bank Databank.[47] Data on national income inequality were retrieved from Frederick Solt's Standardized World Income Inequality Database.[48] This database contains estimated Gini indices of post-taxation income inequality based on the UN University's World Income Inequality Database and Luxembourg Income Study.

The Gini index has a theoretical range of 0 (perfect equality with everyone having equal income) to 1 (perfect inequality with one person having all the income). We retrieved Gini indices from 1979 to 2014 to cover all early life exposures for adolescents aged 11, 13 and 15 years in the HBSC study, including Eastern European countries that were once part of the USSR, Yugoslavia, and Czechoslovakia. 1979 is the earliest year that we chose as it is the birth year for the oldest age group (15-year-olds) in the first HBSC survey cycle in 1994.

Statistical analysis. According to Fairbrother, our analytic design is a variation of growth curve modelling because it examines change in countries through repeated cross-sectional surveys.[38] Our country/year groups were nested within each country in a 3-level framework. Time (in years) was modelled as a random effect. Age (in years) was modelled as a fixed effect.[38] We did not include schools as a fourth level of variation due to computational limitations. Intraclass correlations at the school level were 0.07 for health symptoms and 0.08 for life satisfaction. Therefore, most of the observed variation in symptoms and life satisfaction were attributed to individual, country, and temporal differences. The time variable was anchored at the first HBSC survey cycle in 1994 and ranges from 0 to 20 years. Then, individual records from the HBSC were linked to a table of annual income inequality "exposures" from birth to the age at the time of HBSC data collection. The advantage of staggering age groups and survey years in this way is that it guards against confounding age, cohort, and period effects. In the main analysis, we use the averages in national income inequality from ages 0 to 4 and from age 5 to 9 as the two early exposure variables. The goodness-of-fit of these models is reported using Akaike's information criterion (AIC), which is a measure of model deviance (d) adjusted for the number of parameters (q) in the model (AIC = d + 2q), and the more conservative Bayesian information criterion (BIC), which also corrects for differences in the number of observations (n) in the model (BIC = d + log(n)*q).[49] We then examine the contributions of each year of income inequality exposure from age 0 to 10 to attempt to hone in on a developmental period that is most sensitive to income inequality in terms of adolescent health and well-being.

3. RESULTS

Descriptive statistics on the individual-level variables used in the study are summarised in Table 1 (page 12). The gender and age distributions of the samples were about equal in all six survey cycles. During HBSC survey years, per capita income ranged from $4,570 (Ukraine, 2002) to $65,970 (Norway, 2014) and income inequality ranged from 0.175 (Finland, 1994) to 0.416 (Macedonia). Figure 1 (page 11) shows the high variability in income inequality between countries and during the 35-year period from 1979 to 2014. Thirty-five of the 40 countries in the study experienced a rise in income inequality. Gini indices rose by approximately 21%, from an average of 0.263 (SD = 0.060) in 1979 (or first observation thereafter) to 0.308 (SD = 0.049) in 2014.

Our analysis of health symptoms is summarized in Table 2 (page 14). Four regression models were fitted to the data. Model 1 included gender, age group, family affluence, time, and country-level income inequality and per capita income at the time of the survey. Model 2 contained Model 1 variables plus income inequality at ages 0 to 4 years. Model 3 contained Model 1 variables plus

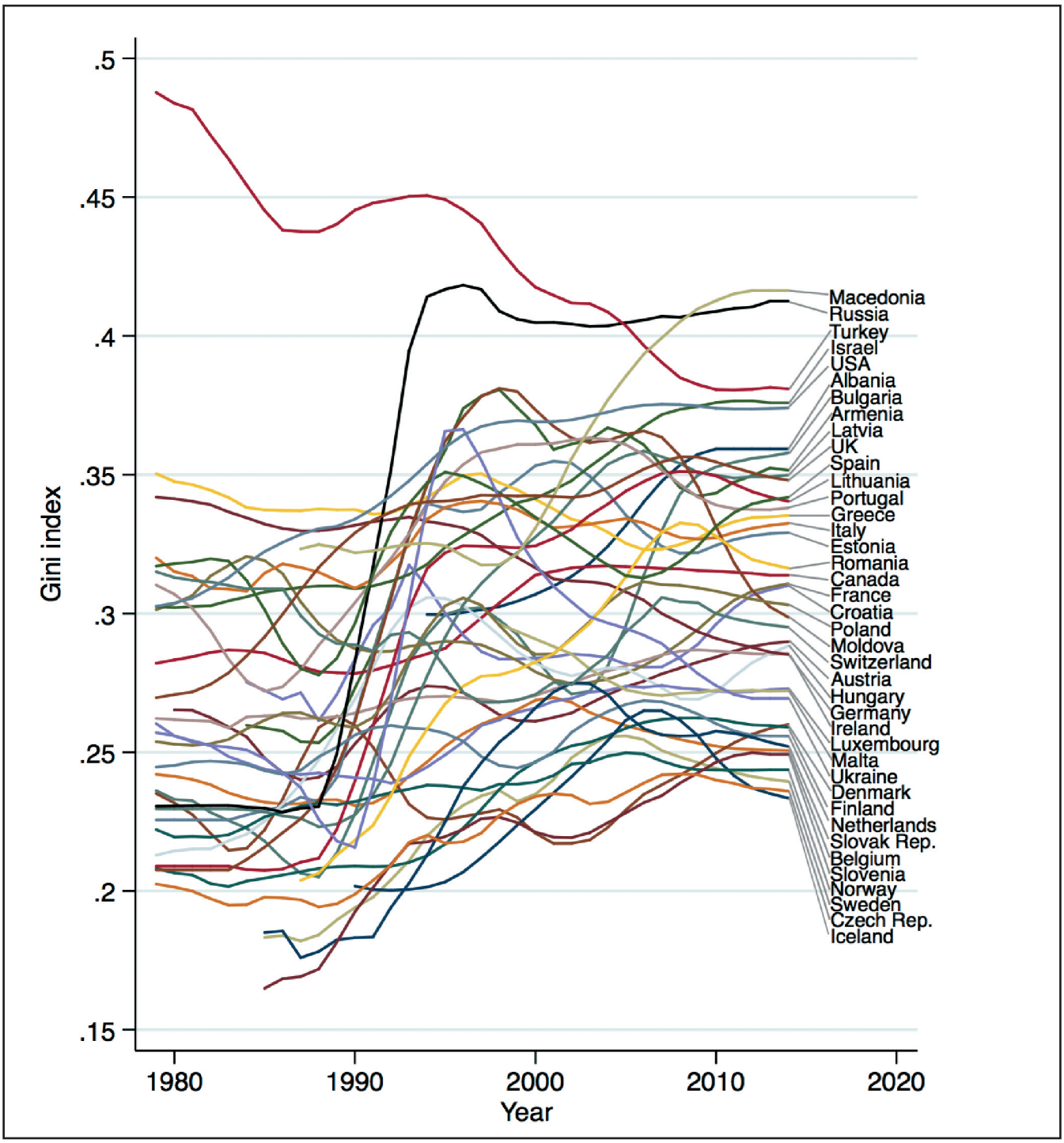

Figure 1 - ***Income inequality (Gini index) in 40 countries, 1979 to 2014. The data were smoothed using a 5-year rolling average.***

Table 1 - ***Summary statistics on individual-level variables by HBSC survey year***

	1994	1998	2002	2006	2010	2014
n	102,779	135,732	162,305	205,938	213,595	219,460
Gender (n)						
Male	49,911	61.522	78,936	101,047	105,099	108,161
Female	52,888	64,210	83,369	104,891	108,496	111,299
% Female	51.45	51.07	51.37	50.93	50.80	50.71
Age group (n)						
11 years	35,138	43,137	54,857	66,707	67,924	70,293
13 years	34,691	42,971	55,539	69,954	71,975	75,385
15 years	32,776	39,624	50,580	67,872	71,652	71,941
Mean age (SD)	13.52 (1.65)	13.58 (1.65)	13.54 (1.66)	13.60 (1.65)	13.56 (1.64)	13.57 (1.63)
Mean symptoms (SD)	7.89 (5.79)	8.33 (6.05)	7.90 (6.21)	8.04 (6.45)	8.09 (6.55)	8.23 (6.82)
Mean life satisfaction (SD)	–	–	7.55 (1.92)	7.57 (1.94)	7.59 (1.93)	7.64 (1.95)
Mean family affluence (SD)	0.50 (0.27)	0.50 (0.28)	0.50 (0.28)	0.50 (0.28)	0.50 (0.28)	0.50 (0.27)

SD = Standard deviation.

income inequality at ages 5 to 9 years. Finally, Model 4 contained Model 1 variables plus income inequality at both 0 to 4 years and 5 to 9 years. In supplementary analyses not reported here, we tested modified effects of income inequality by gender, age group, and family affluence. No evidence was found of differential effects of income inequality on symptoms and life satisfaction by these compositional characteristics. Therefore, we present here the most parsimonious set of results in which the effects of income inequality on health and well-being are adjusted for fixed effects of gender, age, and family affluence.

The results from Model 1 show a positive contemporaneous association between income inequality and reported health symptoms. The full theoretical range of the Gini index, from 0 (perfect equality) to 1 (perfect inequality), corresponded to a 6.14-point difference (95% confidence interval [CI] = 0.18, 12.11) in symptoms. No association was found between per capita income and symptoms, and no significant trend in symptoms was found over the 20-year period. Symptoms were about 2 points higher in females than in males and were higher in older age groups and lower affluence groups. The results of Model 2 show that average income inequality from birth to age 4 had no lagged effect on adolescent health symptoms after the Model 1 variables were entered. However, Model 3 results show a significant association between average income inequality from age 5 to age 9 and health symptoms (b = 4.39, 95% CI = 2.57, 6.21). The contemporaneous association with income inequality was no longer significant once this early exposure variable was entered. The results of Model 4, which had all three income inequality variables entered, confirmed that exposure to inequality at age 5 to 9 is the dominant determinant of adolescent health symptoms (b = 4.33, 95% CI = 2.48, 6.20).

The analysis of life satisfaction is presented in Table 3 (page 14). Life satisfaction was measured in the four most recent survey cycles of the HBSC, so the time series in this analysis ranged from 1987 (the birth year of 15-year-olds in the 2002 survey) to 2014. Four models analogous to those shown in Table 2 were fitted to life satisfaction scores. Model 1 results show no contemporaneous

Table 2 - ***Regression analysis of health symptoms in 11- to 15-year-olds in 40 countries (1994 to 2014)***

Variable	Model 1 b (95% CI)	Model 2 b (95% CI)	Model 3 b (95% CI)	Model 4 b (95% CI)
Constant	2.56 (0.66, 4.46)	2.31 (0.37, 4.25)	2.10 (0.19, 4.02)	2.02 (0.08, 3.96)
Gender (female)	2-05 (2.02, 2.07)	2.05 (2.02, 2.07)	2.05 (2.02, 2.07)	2.05 (2.02, 2.07)
Age group				
11 years	ref.	ref.	ref.	ref.
13 years	1.04 (1.01, 1.07)	1.04 (1.01,1.08)	1.05 (1.02, 1.08)	1.05 (1.02, 1.08)
15 years	1.81 (1.77, 1.84)	1.82 (1.78, 1.86)	1.84 (1.80, 1.87)	1.84 (1.80, 1.87)
Family affluence	-0.81 (-0.85, -0.76)	-0.81 (-0.86, -0.77)	-0.81 (-0.85, -0.76)	-0.81 (-0.86, -0.77)
Time (years)	-0.01 (-0-04, 0.02)	-0.02 (-0.05, 0.02)	0.02 (-0.05, 0.01)	-0.02 (-0.06, 0.01)
Income inequality				
Current	6.14 (0.18,12.11)	6.19 (0.20, 12.18)	3.45 (-2.62, 9.52)	3.67 (-2.42, 9.75)
0 to 4 years		0.94 (-0.59, 2.48)		0.18 (-1.39, 1.75)
5 to 9 years			4.39 (2.57, 6.21)	4.33 (2.48, 6.20)
GNI per capita	0.01 (-0.02, 0.03)	0.01 (-0.02, 0.03)	0.01 (-0.02, 0.03)	0.01 (-0.02, 0.03)
Variances				
Country				
Time	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)
Constant	1.39 (0.82, 2.38)	1.43 (0.84, 2.43)	1.35 (0.79, 2.32)	1.40 (0.82, 2.39)
*Country year**				
Constant	0.24 (0.18, 0.33)	0.24 (0.18, 0.32)	0.24 (0.18, 0.33)	0.24 (0.18, 0.32)
Residual	37.09 (36.98, 37.20)	37.11 (37.00,37.22)	37.09 (36.98, 37.20)	37.11 (37.00, 37.21)
Goodness-of-fi				
AIC	5,734,914	5,730,930	5,712,698	5,712,677
BIC	5,735,055	5,731,082	5,712,850	5,712,841
n (countries)	40	40	40	40
n (country* years)	180	179	180	179
n (students)	888,841	885,335	888,220	885,335

CI = confidence interval, GNI = gross national income, AIC = Akaike's information criterion, BIC = Bayesian information criterion.

associations between income inequality and life satisfaction, nor between per capita income and life satisfaction. Life satisfaction was lower in females than in males and in older age groups. Life satisfaction was also higher in higher affluence groups. As was found in reported health symptoms, income inequality from birth to age 4 had no association with adolescent health symptoms (Model 2), and a significant lagged (and negative) association was found between average income inequality from age 5 to age 9 and life satisfaction (b = -3.62, 95% CI = -4.88, -2.37; Model 3). The contemporaneous association with income inequality was still not significant when the early exposure variable was entered. Finally, the results of Model 4, which had all three income inequality variables entered, confirmed that exposure to inequality at age 5 to 9 was the dominant determinant of later life satisfaction in adolescence (b = -3.61, 95% CI = -4.90, -2.32).

Table 3 - ***Regression analysis of life satisfaction in 11- to 15-year-olds in 40 countries (2002 to 2014)***

Variable	Model 1 b (95% CI)	Model 2 b (95% CI)	Model 3 b (95% CI)	Model 4 b (95% CI)
Constant	6.13 (5.14, 7.12)	6.20 (5.21, 7.19)	6.28 (5.29, 7.27)	6.29 (5.29, 7.28)
Gender (female)	-0.21 (-0.23, -0.20	-0.21 (-0.23, -0.20)	-0.21 (-0.23, -0.20)	-0.21 (-0.23, -0.20)
Age group				
11 years	ref.	ref.	ref.	ref.
13 years	-0.82 (-0.84, -0.81)	-0.82 (-0.84, -0.81)	-0.83 (-0.84, -0.81)	-0.83 (-0.84, -0.81)
15 years	-1.36 (-1.37, -1.34)	-1.36 (-1.378 -1.34)	-1.37 (-1.39, -1.35)	-1.37 (-1.39, -1.35)
Family affluence	1.30 (1.28, 1.32)	1.30 (1.28, 1.33)	1.30 (1.28, 1.32)	1.30 (1.28, 1.32)
Time (years)	0.02 (0.00, 0.03)	0.02 (0.00, 0.03)	0.02 (0.00, 0.03)	0.02 (0.00, 0.03)
Income inequality				
Current	-2.22 (-5.27, 0.82)	-1.97 (-5.01, 1.06)	0.89 (-2.31, 4.08)	0.90 (-2.30, 4.09)
0 to 4 years		-0.51 (-1.26, 0.24)		-0.04 (-0.81, 0.73)
5 to 9 years			-3.62 (-4.88, -2.37)	-3.61 (-4.90, -2.32)
GNI per capita	-0.01 (-0.02, 0.00)	-0.01 (-0.02, 0.00)	-0.01 (-0.02, 0.00)	-0.01 (-0.02, 0.00)
Variances				
Country				
Time	0.00 (0.00, 0.01)	0.00 (0.00, 0.01)	0.00 (0.00, 0.05)	0.00 (0.00, 0.05)
Constant	0.25 (0.14, 0.44)	0.25 (0.14, 0.43)	0.25 (0.14, 0.43)	0.25 (0.14, 0.43)
*Country year**				
Constant	0.06 (0.04, 0.10)	0.06 (0.04, 0.09)	0.07 (0.05, 0.10)	0.07 (0.05, 0.10)
Residual	7.42 (7.39, 7.44)	7.42 (7.39, 7.44)	7.42 (7.39, 7.44)	7.42 (7.39, 7.44)
Goodness-of-fi				
AIC	3,283,684	3,283,684	3,283,653	3,283,655
BIC	3,283,821	3,283,833	3,283,802	3,283,815
n (countries)	40	40	40	40
n (country* years)	137	137	137	137
n (students)	678,031	678,031	678,031	678,031

CI = confidence interval, GNI = gross national income, AIC = Akaike's information criterion, BIC = Bayesian information criterion.

A final set of analyses aimed to specify the period of early childhood development that was most sensitive to the effects of income inequality. We tested the fit of all possible iterations of Model 2 (shown in Tables 2 and 3), each time with a different income inequality exposure from birth through to age 10. We could not test lagged effects after age 10 because the outcomes were measured in 11-to 15-year-olds. As before, the regression analyses controlled differences in contemporaneous income inequality and per capita income and individual differences owing to cohort differences, historical period, age, gender, and family affluence. Table 4 shows the adjusted lagged effects of early childhood income inequality on adolescent health symptoms and life satisfaction. Figure 2 displays these effects as standardised beta coefficients (β) that represent standard deviation differences in health symptoms and life satisfaction scores that correspond to exposures to income inequality from birth to age 10. Lagged effects of early income inequality on later

Table 4 - ***Associations between early life income inequality, from birth to age 10, and health symptoms and life satisfaction in adolescence***

Age of exposure (years)	Health symptoms b (95% CI)	t	Life satisfaction b (95% CI)	t
0	-0.25 (-1.56, 1.06)	-0.38	-0.55 (-1.17, 0.08)	-1.72
1	-0.18 (-1.50, 1.14)	-0.27	-0.53 (-1.17, 0.10)	-1.64
2	0.62 (-0.68, 1.93)	0.93	-0.30 (-0.92, 0.33)	-0.93
3	1.56 (0.22, 2.90)	2.28*	-0.25 (-0.92, 0.41)	-0.75
4	2.36 (0.95, 3.77)	3.28**	-0.27 (-1.00, 0.45)	-0.74
5	2.95 (1.47, 4.44)	3.90***	-0.48 (-1.32, 0.36)	-1.11
6	3.68 (2.14, 5.22)	4.68***	-1.93 (-2.96, -0.92)	-3.75***
7	3.65 (2.04, 5.26)	4.45***	-3.19 (-4.31, -2.07)	-5.58***
8	3.22 (1.57, 4.86)	3.83***	-4.23 (-5.39, -3.07)	-7.16***
9	3.24 (1.59, 4.89)	3.84***	-4.74 (-5.95, -3.52)	-7.63***
10	3.58 (1.92, 5.23)	4.23***	-4.05 (-5.31, -2.78)	-6.28***

Note: Shown are regression coefficients (b) and 95% confidence intervals (CI) of the lagged effects, analogous to Model 2 shown in Tables 2 and 3. The t-score represents deviation from the null. The coefficients are adjusted for concurrent income inequality and country wealth, historical period (survey year), and individual differences in gender, age, and family affluence, and birth year (cohort). *p<0.05. **p<0.01. ***p<0.001.

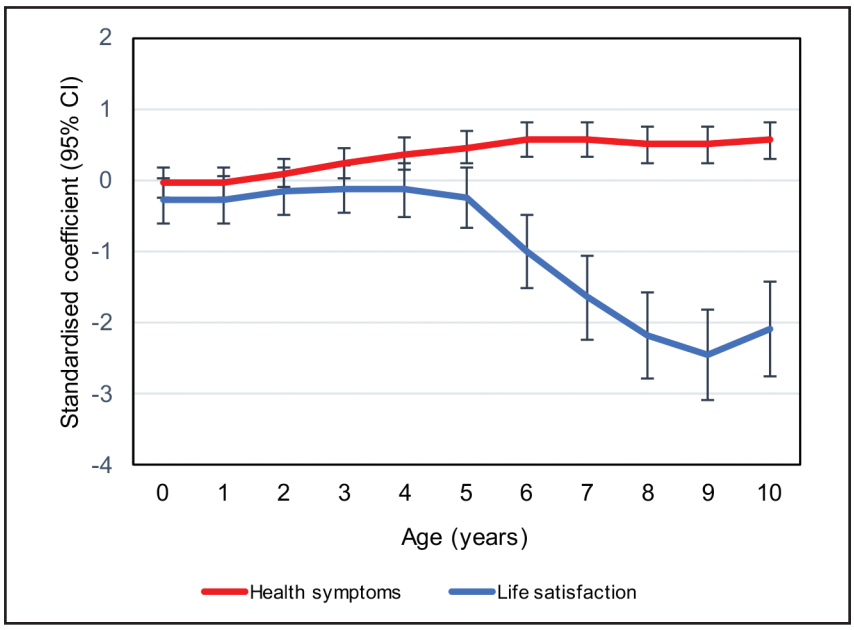

Figure 2 - ***Association between early life exposure to income inequality each year from birth to age 10, and later health symptoms and life satisfaction in adolescence (11 to 15 years).***

Shown are standardised beta coefficients (β) and 95% confidence intervals of the lagged effects, adjusted for concurrent income inequality and country wealth, historical period (survey year), and individual differences in gender, age, and family affluence, and birth year (cohort). The data correspond to the results shown in Table 4.

*p<0.05. **p<0.01. ***p<0.001.

health symptoms first emerged at age 3 (b =1.56, 95% CI = 0.22, 2.90), peaked at age 6 (b = 3.64, 95% CI = 2.14, 5.21), and remained statistically greater than zero through to age 10. Income inequality exposures at birth, age 1, and age 2 had no association to health symptoms. The lagged effects of early income inequality on life satisfaction first emerged at age 6 (b = 1.93, 95% CI = -2.94, -0.92), peeked at age 9 (b = -4.74, 95% CI = -5.95, -3.52), and remained statistically greater than zero from ages 6 to 10.

4. DISCUSSION

This is the most comprehensive study to date on the consequences of early life income inequality for adolescent health and well-being. It exceeds previous analyses of early life income inequality and subsequent health outcomes. By pooling data from multiple survey cycles of the HBSC study in multiple countries and linking them to country level data on current and earlier income inequality, we found robust evidence of lagged effects of income inequality in early childhood on self-reported psychosomatic symptoms and life satisfaction in adolescence.

These results make three key contributions to the literature. First, they help to establish antecedent-consequence conditions in the association between income inequality and health. Questions about their temporal order have remained unanswered in causal interpretations of the association.[20] Although we could not track individual changes in health and well-being in relation to income inequality, the quasi-longitudinal design allowed us to separate early-life exposures and later health outcomes by up to 10 years. Therefore, the results address a fundamental criterion of causal inference and questions about the direction of influence between income inequality and individual health and well-being.[20,24]

Second, the study addresses the scarcity of developmental studies on the structural determinants of child health and well-being.[18] We found that growing up in European and North American countries that have historically been more equal, with relatively lower income inequality, was related to fewer physical and mental health symptoms and greater life satisfaction in adolescents. The developmental consequences of income inequality were evidently independent of country wealth (per capita income) as well as differences in gender, age, and family affluence. We also identified periods of child development when exposure to income inequality had the greatest effects on adolescent health: between ages 3 and 10 for health symptoms (peaking at age 6) and between ages 6 and 10 for life satisfaction (peaking at age 9). We had expected to find that the effects of income inequality would be greatest during the first few years of life, when children's brain development and physiological stress pathways are known to be highly sensitive to deprivation and stress.[26,27,29,31] One explanation for these results could be that the health impact of early stress caused by inequality wanes as more time elapses between the exposure and outcome. Further analysis using similarly structured international panel surveys of adult data would be needed to confirm this, however to our knowledge no such data source exists.

Other interpretations of these lagged effects come from the proposed pathways through which income inequality relates to health. Wilkinson's psychosocial hypothesis focuses on the divisive effects of inequality at a broad social level and not in the home environment where infants and toddlers spend nearly all their time.[10,17] Children are not fully exposed to the psychosocial consequences of income inequality until they are old enough to form social relationships outside the home, such as play groups, day care centres, and primary schools. According to Arsenio and Gold's developmental hypothesis, inequality affects children's moral development while they are developing the cognitive schemas of distributive justice and fairness,[21] an ability that emerges between the ages of 3 and 8.[50] This developmental milestone coincides with the age range we found most sensitive to

income inequality exposure. Finally, there are material explanations focussing on cash transfers to families and quality of public services and infrastructure,[22] which are more likely to affect children's health and well-being once they begin primary schooling. Families with infant children may be buffered from the stressors of inequality by social security services, income supports, parental leave benefits, health visiting, home nurses, and preschool play groups. The beginning of formal schooling at age 4 or 5 marks a transition to fewer supports, new financial stressors, and greater reliance on good quality public schools and health services. These financial pressures can compromise parental health and the quality of parenting.[51] There is also recent evidence that indicates that income inequality relates to the maltreatment of children by parents.[16] However, our data do not allow this proposed mechanism to be investigated or substantiated.

The third main contribution of the study is the demonstration of societal growth curve modelling to extract a high level of statistical power in the multilevel analysis of complex survey data.[38] Cross-national studies of macro determinants of health and well-being are often constrained by the number of countries that can be included in any one study. The study showed how to manage this power limitation by pooling data from repeated survey cycles and then statistically controlling group differences and autocorrelation in the time series. A similar approach, pooled time-series analysis (or fixed effects modelling), requires the data to be 'flattened' to an aggregated country-level variable like an average health score, prevalence, or mortality rate (e.g., see Elgar et al.[6,13]). Fairbrother's societal growth curve model preserves the multilevel structure of the data, which is crucial for separating the compositional effects of the sample and clustering from the contextual effects of the country-level construct.[38]

Limitations of these analyses should also be noted. First, the study assumed zero migration in the sample from birth to age 15 because adolescents' nationality in the HBSC study determined the country of income inequality exposure and we did not have information about their country of birth nor age of migration. This uncontrolled variable may have introduced some noise to our results but we do not expect that different results would have emerged had we controlled for differences in migration. Another recent analysis of data from the Health and Retirement Study in the United States found long-term lagged relationships between inequality and mortality after age 50 after taking migration into account.[52]

Second, we analysed only two indicators of health and well-being, psychosomatic symptoms and life satisfaction. Whilst these provided a general assessment of adolescent health and well-being using well-validated self-report tools, we cannot extrapolate our results to other domains of health nor to older age groups. Replications of these findings on data that were collected in successive international surveys of adult health would be useful. Third, we could not include schools as a fourth level of variation in the multilevel models due to computational limitations. Seven to 8% of the variation in health and well-being was attributed to school-level clustering, which is near recommended thresholds for using multilevel analysis.[53] Fourth, although exact response rates in the HSBC study could not be established, fieldworker reports from several countries showed that 5 to 10% of pupils were absent from the surveys, which inevitably poses the possibility of non-response bias due to illness and school truancy. Finally, although we can speculate on

the causal mechanisms involved in these associations, we have not fully explored the health impacts of family contexts (such as family structure and quality of family relationships) during the early years. These family processes in early life and their links to income inequality and later health outcomes in adolescence require further investigation.

5. CONCLUSIONS

Over the past two decades, theorists have begun to argue more forcefully that understanding and enhancing health requires greater attention on upstream determinants on health early in life. The literature has expanded its focus from individual risk or protective factors to the social patterns and structures that shape children's chances to be healthy.[7] In 2008, the WHO Commission on Social Determinants of Health (SDH) emphasised the importance of a life-course approach to action on SDH.[54] However, life-course approaches thus far have focused on early childhood predictors of adult health and have paid limited attention to adolescence.[5,55] This is surprising because social inequalities have been reported at every stage of the life course, and because health and health behaviours track strongly from early adolescence through to old age.[54]

The present study addresses a significant knowledge gap in the literature by showing a relation between early childhood exposure to income inequality and adolescent health and well-being. The results not only show negative health consequences of income inequality early in life, but they also suggest that inequality alters formative developmental pathways to adult health and well-being during this understudied stage of the life course. Current global trends in rising income inequality pose major social and ethical challenges to governments. Some of the health and social problems associated with income inequality can be seen as products of cumulative risk through the life course, beginning at a very early age. The good news is that these results also point to policy options for governments that could mitigate these effects by reducing inequality and supporting child health and well-being.

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