Family income inequalities and trajectories through childhood and self-harm and violence in young adults: a population-based, nested case-control study

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Summary

Background Childhood poverty is associated with elevated later risks for self-directed and externalised violence, but how risks are modified by parental socioeconomic mobility remains unclear. We investigated parental income trajectories during childhood and subsequent risks of self-harm and violent criminality in young adulthood.

Methods Using Danish national registers, we delineated a nested case-control study of Danish citizens born from Jan 1, 1982, to Dec 31, 2000, with first hospital-treated self-harm episodes and first violent crime convictions at ages 15–33 years. Each case was matched on age and gender to 25 randomly selected controls. Parental income was assessed in birth-year and at ages 5 years, 10 years, and 15 years. We considered parental age, the child's number of siblings, parental mental health, and parental education to be covariates. We estimated incidence rate ratios (IRRs) by conditional logistic regression inherently adjusted for age, gender, and calendar year; we then made additional adjustments for the covariates considered.

Findings We identified 21 267 first episodes of hospital-treated self-harm, to which we matched 531 675 controls, and 23 724 first violent crime convictions, to which we matched 593 100 controls. We observed inverse relationships between parental income and risks for the two outcomes for each of the ages parental income was measured. The longer a child lived in poorer circumstances, the higher their subsequent risks for self-harm and violent criminality, and vice versa for time spent living in affluent conditions. Associations were stronger for violent criminality than for self-harm. Compared with individuals who were born and remained in the most affluent families, all other income trajectories were associated with elevated risks for both outcomes. Those who remained in the least affluent quintile showed the highest risks for self-harm (IRR 7·2, 95% CI 6·6–7·9; 1174 [6%] cases) and for violent criminality (IRR 13·0; 95% CI 11·9–14·1; 1640 [7%] cases). The risk patterns were attenuated, but essentially persisted, after covariate adjustment. For any parental income level at birth, being upwardly mobile was associated with lower risk compared with downward mobility.

Interpretation Parental income represents a multitude of unmeasured familial sociodemographic indices. Tackling the causes of inequality and associated psychosocial and sociocultural challenges to enable upwards socioeconomic mobility could potentially reduce risks for self-directed and externalised violence.

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Introduction

Childhood socioeconomic disadvantage predicts numerous adversities over the life-course, from poorer birth outcomes and child development,[1] behavioural problems,[2,3] and physical and mental health deterioration[4,5] to premature death.[6] Socioeconomic disparities have also been reported in relation to self-directed and externalised violence risks.[7–9] These two forms of violence pose serious public health challenges. After accidents, intentional self-harm and assault are the next two most common causes of death among people aged 20–24 years globally,[10] with many more affected individuals consequently experiencing non-fatal injuries and emotional trauma. Although internally and externally directed aggression might seem incongruent behaviours,

they share common individual and familial risk factors, including emotional dysregulation, lack of impulse control, mental illness, and parental psychopathology,[11–13] prompting calls for more integrated approaches to research and prevention.[14]

Of the three key socioeconomic indices—income, education, and occupation—income represents the most direct measure of affluence versus deprivation, and is the variable that can be tracked most sensitively over time. However, in addition to material resources, income also strongly indicates a person's psychosocial and socio-cultural environment.[15] Elevated risks for delinquency and internally and externally directed violence have been linked with experiencing persistent poverty during childhood.[2,9,16] However, it remains unclear how the associations vary

Research in context

Evidence before this study

We reviewed the published literature on this topic by searching for article titles in MEDLINE, PsycINFO, and Embase, published from Jan 1, 1990, to April 3, 2018, that included the following terms: (income* OR socio-economic* OR socioeconomic* OR poverty OR poor* OR inequalit* OR social class OR employ* OR unemploy* OR labour OR labor OR work OR occupation* OR educat*) AND (maternal OR paternal OR famil* OR parent* OR mother* OR father* OR childhood* OR generation* OR household*) AND (self-harm* OR self harm* OR suicid* OR self-poison* OR self poison* OR self-inj* OR self inj* OR poison* OR parasuicid* OR intent* inj* OR overdos* OR violen* OR offend* OR crime* OR crimin* OR forensic* OR offense* OR offence* OR prison* OR imprison* OR incarcer* OR homicid* OR kill* OR murder*). Although it has been widely reported that experiencing poverty and socioeconomic disadvantages during childhood is associated with elevated risks for delinquency and criminality, many of the published studies have been cross-sectional, with a focus on low-income or disadvantaged families or only considering average family income over time. How risks vary by fluctuating familial socioeconomic circumstances remains unclear. Similarly, although studies have reported differences in risk for suicides and self-harm according to varying socioeconomic circumstances, the evidence base for the associations between parental income—especially changes in income—and subsequent risk of self-harm in offspring is small. Therefore, important research questions, including whether and how risks for self-harm and violent criminality are modified by socioeconomic mobility during childhood, remain to be answered. Additionally, although it is increasingly recognised that internalised and interpersonal violence are correlated behaviours sharing many common determinants, it is unknown how risks for these outcomes vary by familial socioeconomic circumstances.

Added value of this study

We did a large population-based study on risks for self-harm and violent criminality in young adulthood (ages 15–33 years)

in relation to parental income trajectories experienced during childhood. Parental income was categorised in quintiles, measured in the year of the child's birth, and at ages 5 years, 10 years, and 15 years. Unlike many previous studies that have focused on low-income families, we tracked income across time encompassing the whole parental income spectrum, examining whether and how risks for the two adverse outcomes could be influenced by upwards and downwards socioeconomic mobility during childhood. We found a strong graded risk pattern showing that the longer a child lived in poorer circumstances, the higher the subsequent risks for self-harm and violent offending, and vice versa for time spent growing up in affluent conditions. The strengths of association were sensitive to changing parental income levels across the entire income spectrum from birth to age 15 years. Associations were also stronger for violent offending than for self-harm. Compared with individuals who were born and remained in families with the highest parental income at age 15 years, all other parental income trajectories were associated with elevated risks for the two adverse outcomes. Most importantly, however, for any parental income level at birth, being upwardly mobile economically was associated with lower risk compared with being downwardly mobile.

Implications of all the available evidence

Income inequality during childhood, and not only low income, is associated with subsequent risks for self-directed and interpersonal violence. Tackling the causes of inequality and associated psychosocial challenges to enable upwards socioeconomic mobility, at any stage during a child's development, could potentially reduce risks for these correlated harmful behaviours in the longer term. Because risk elevations were observed across the entire income distribution, effective interventions should be implemented population-wide, with additional specific initiatives focused on the most disadvantaged families.

with changing socioeconomic position across the developmental period because parental income trajectories are rarely considered. Previous studies have tended to be cross-sectional or with short-term follow-up,[2,9,16] with income averaged throughout childhood or welfare benefit receipt applied as measures of familial economic circumstances.[7,8] How risks for self-directed and external-ised violence compare across the entire socioeconomic spectrum, and whether and how risks for later adverse outcome could be modified by socioeconomic mobility during childhood, thus remain unknown.

Using national registry data, we investigated the associations between parental income inequalities and trajectories during childhood and subsequent risks for self-harm and violent criminality. Parental income was conceptualised as a marker for a multitude of material, psychosocial, and sociocultural familial environmental

circumstances. We examined the associations by parental income during childhood, measured at ages 0 years (birth-year), 5 years (early childhood), 10 years (middle childhood), and 15 years (adolescence); time spent growing up in financially disadvantaged versus affluent conditions; and parental income trajectories between birth and age 15 years.

Methods

Study design and population

We did a nested case-control study of Danish citizens who had first hospital-treated self-harm episodes and first violent crime convictions at age 15–33 years. In Denmark, all residents are registered with the Civil Registration System, which captures information on date and place of birth, gender, parents' identities, and continuously updated records of residential address and

vital status.[17] The study cohort was delineated using this resource, with its unique personal identification number enabling accurate inter-register linkage. Parental links were based on legal relationships. The study cohort consisted of all people born in Denmark from Jan 1, 1982, to Dec 31, 2000, with two Danish-born parents and both parents still residing in Denmark on cohort members' 15th birthdays. Restricting the study cohort in this way eliminated potential for confounding linked with immigration.[18] The Danish Data Protection Agency approved the study, with data access agreed by the Danish Health Data Authority and Statistics Denmark. Because it was based exclusively on registry data, according to the Danish Act on Processing of Personal Data, Section 10, informed consent from cohort members was not required.

Cases and controls
We defined cases by identifying individuals with first episodes of hospital-treated self-harm or first violent crime convictions during 1997–2015 at ages 15–33 years, with both outcomes ascertained from the individual's 15th birthday. Individuals with hospital-treated self-harm episodes before this age were excluded. First hospital-treated self-harm episodes were identified from the National Patient Register[19] and the Psychiatric Central Research Register[20] and classified using a previously developed algorithm[21] (see appendix p 4 for details). All convictions for interpersonal violence, comprising homicide, assault, robbery, aggravated burglary or arson, possessing a weapon in a public place, threats, extortion, human trafficking, abduction, kidnapping, rioting or other public order offences, terrorism, and sexual offences, were extracted from the National Crime Register. We considered the first violent crime conviction after each individual's 15th birthday—the age for adult criminal responsibility in Denmark. We used the same lower bound of 15 years for self-harm to ensure comparability between the outcomes; the upper bound of 33 years is a result of the study design. Each person who had self-harmed or had been convicted for violent criminality was matched to 25 randomly selected controls of the same gender and age (ie, date of birth) and who had not experienced the outcome of interest at the index date for each matched case.

Exposures
Parental income was the exposure of interest. Maternal and paternal income information was obtained from the Income Statistics Register, including information such as salaries, entrepreneurial income, capital income, public transfer payments, and pensions.[22] These data were measured in the child's birth-year (ie, at age 0 years), and at ages 5 years, 10 years, and 15 years, irrespective of whether the parents were still living together or were separated. Maternal and paternal income measured at each of these four ages was summed and categorised into

quintiles derived from the national income distribution of all parents in that calendar year, with quintile 1 representing the lowest income (ie, least affluent) and quintile 5 the highest (most affluent). Further details are available in the appendix (p 5).

We constructed a cumulative parental income scale by summing the parental income quintiles measured at each of the four ages. The scale ranges from 4 to 20, with a value of 4 indicating parental income in the lowest quintile across all four measurement points (ie, $1+1+1+1$) and 20 representing the highest income quintile at each of these ages (ie, $5+5+5+5$). If parental income was in quintile 3 at three measurement points and quintile 1 at the other, the scale would be 10, (ie, $3+3+3+1$). Thus, the scale quantifies both relative parental income levels and their duration between birth and 15th birthday.

Covariates
We considered the following to be covariates: parental age, the child's number of siblings, parental mental illness, and parental education. Maternal and paternal ages at cohort members' births and number of full and half siblings born before their 15th birthdays were obtained from the Civil Registration System.[17] Information on any secondary care-treated maternal and paternal mental illness was obtained from the Psychiatric Central Research Register.[20] Information on the highest maternal and paternal educational levels attained was extracted from the Integrated Database for Labour Market Research for the year of cohort members' 15th birthdays.

Statistical analysis
Our use of incidence density sampling enabled estimation of incidence rate ratios (IRRs) from conditional logistic regression models inherently adjusted for age, gender, and calendar year (hereafter referred to as inherent adjustment). We made additional adjustments for history of maternal and paternal mental illnesses, parental education, parental age, and number of full and half siblings. All covariates were fitted as categorical variables. Analyses were done using Stata version 15.1.

Role of the funding source
The funder had no role in the study design; collection, analysis, and interpretation of data; writing of the report; or the decision to submit the report for publication. The corresponding author (RTW) had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Results
We identified 21267 first episodes of hospital-treated self-harm (of which 8399 [39·5%] occurred in men), to whom we matched 531675 controls, and 23724 first violent crime convictions (of which 20709 [87·3%] occurred in men), to whom we matched 593100 controls, that occurred during 1997–2015 at ages 15–33 years (appendix).
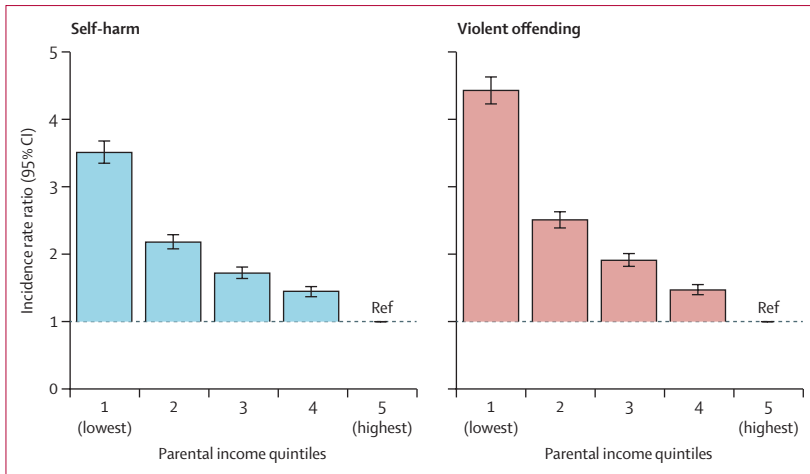
Figure 1: Incidence rate ratios for self-harm and violent offending by parental income quintiles measured at age 15 years
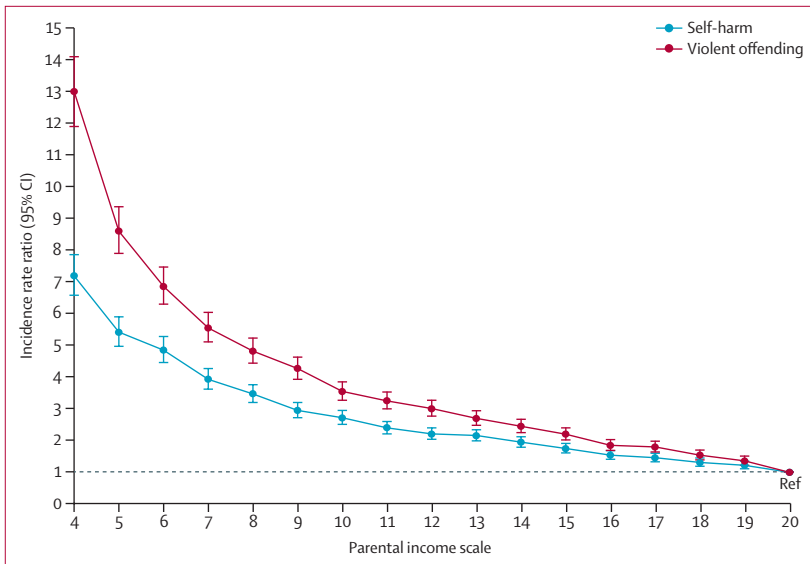Ref=reference group (incidence rate ratio = 1).

Figure 2: Incidence rate ratios for self-harm and violent offending by cumulative parental income scale during childhood
The cumulative parental income scale was derived by summing the parental income quintiles measured in the year of birth and at ages 5 years, 10 years, and 15 years. A value of 4 indicates the lowest income quintile at each of the four measurement ages whereas 20 (reference category) represents the highest income quintiles at all four ages. Ref=reference group (incidence rate ratio = 1).

Basic demographic information on people who self-harmed and committed violent crimes (ie, cases) is presented in the appendix (p 6), alongside information on covariates for both cases and controls and the associated numbers of cases and controls by parental income quintile and scale (appendix pp 7–10). We observed inverse relationships between parental income at age 15 years and risks for the two outcomes (figure 1). These associations were non-linear, with cohort members in the lowest parental income quintile showing disproportionately higher risks (IRR 3·51 [95% CI 3·35–3·68] for self-harm and 4·43 [4·23–4·63] for violent offending). Similar risk

patterns were observed for parental income measured at birth-year and at ages 5 years and 10 years (appendix p 11). The associations were stronger for violent offending than for self-harm, especially so for the lowest income quintile (figure 1). Relative risks of self-harm were similar for male and female individuals, whereas those for violent offending were notably greater for female individuals than for male individuals (appendix pp 12–13). However, the relative risk patterns in relation to parental income were essentially the same for both genders—ie, we observed non-linear, inverse relationships between parental income and risks for the two outcomes, with cohort members in the lowest parental income quintile showing disproportionately higher risks (appendix pp 12–13).

When considering risk by duration of parental income circumstances through childhood, as shown by the cumulative parental income scale, we observed a steep, non-linear gradient showing increased risk for lower values (ie, lower parental income through childhood; figure 2). The associations were also stronger for violent offending than for self-harm. Compared with individuals from families in the highest income quintile across the four ages (ie, with a parent income scale score of 20), being brought up in a less affluent family was associated with higher risks for both adverse outcomes (figure 2). Those who remained in the lowest quintile throughout their childhood (ie, score of 4)—1174 (6%) of cohort members who had a self-harm episode and 1640 (7%) of those who were convicted of a violent offence—showed the highest risks (IRR 7·2 [95% CI 6·6–7·9] for self-harm and 13·0 [11·9–14·1] for violent criminality). Overall, the strengths of association were sensitive to changing parental income levels from birth to age 15 across the entire income spectrum (figure 2).

We considered the risks for self-harm and violent offending in relation to changes in parental income quintiles from birth to age 15 years. The number of people with adverse outcomes by income trajectories between these two ages are reported in table 1 and table 2. The reference category for both outcomes was parental income quintile 5—ie, the highest income level—at birth-year and at age 15 years. Compared with this generic reference, all other trajectories had higher risks for both adverse outcomes, irrespective of whether their parental income moved from a higher to a lower quintile (downwardly mobile), from a lower to a higher quintile (upwardly mobile), or remained unchanged between the two ages (figure 3). For any parental income quintile at birth, the higher the income at age 15 years, the lower the risk for both outcomes, and for any parental income at age 15 years, the lower the parental income at birth, the higher the risk. In particular, those whose parental income belonged to the lowest quintile at birth and remained so at age 15 years showed the highest risks: IRR 6·0 (95% CI 5·6–6·5) for self-harm and 9·9 (9·2–10·6) for violent offending. Although risks were still elevated compared with the reference group, for those individuals whose

	First parental income quintile at age 15 years (lowest)	Second parental income quintile at age 15 years	Third parental income quintile at age 15 years	Fourth parental income quintile at age 15 years	Fifth parental income quintile at age 15 years (highest)
Cases (n=21 267)					
Parental income quintile at birth					
1 (lowest)	1666 (7·8%)	627 (2·9%)	326 (1·5%)	250 (1·2%)	129 (0·6%)
2	1989 (9·4%)	1197 (5·6%)	735 (3·5%)	450 (2·1%)	201 (0·9%)
3	1679 (7·9%)	1315 (6·2%)	1107 (5·2%)	744 (3·5%)	331 (1·6%)
4	941 (4·4%)	1035 (4·9%)	1185 (5·6%)	1117 (5·3%)	539 (2·5%)
5 (highest)	415 (2·0%)	396 (1·9%)	559 (2·6%)	960 (4·5%)	1374 (6·5%)
Controls (n=531 660)					
Parental income quintile at birth					
1 (lowest)	16 191 (3·0%)	9568 (1·8%)	6787 (1·3%)	5655 (1·1%)	4615 (0·9%)
2	23 815 (4·5%)	21 334 (4·0%)	17 218 (3·2%)	12 441 (2·3%)	7622 (1·4%)
3	24 097 (4·5%)	30 174 (5·7%)	28 953 (5·4%)	22 360 (4·2%)	12 705 (2·4%)
4	16 889 (3·2%)	26 699 (5·0%)	35 447 (6·7%)	37 708 (7·1%)	24 815 (4·7%)
5 (highest)	9122 (1·7%)	10 909 (2·1%)	18 805 (3·5%)	36 395 (6·8%)	71 336 (13·4%)

15 controls had missing parental income information either at birth or at age 15 years. Because controls were matched to the cases by age and gender, no inference should be made to the parental income distribution of the general population.

Table 1: Self-harm cases and controls by parental income trajectories between birth and age 15 years

	First parental income quintile at age 15 years (lowest)	Second parental income quintile at age 15 years	Third parental income quintile at age 15 years	Fourth parental income quintile at age 15 years	Fifth parental income quintile at age 15 years (highest)
Cases (n=23 724)					
Parental income quintile at birth					
1 (lowest)	2237 (9·4%)	697 (2·9%)	316 (1·3%)	205 (0·9%)	100 (0·4%)
2	2400 (10·1%)	1271 (5·4%)	759 (3·2%)	465 (2·0%)	230 (1·0%)
3	2023 (8·5%)	1502 (6·3%)	1201 (5·1%)	758 (3·2%)	342 (1·4%)
4	1170 (4·9%)	1235 (5·2%)	1307 (5·5%)	1156 (4·9%)	586 (2·5%)
5 (highest)	467 (2·0%)	443 (1·9%)	662 (2·8%)	920 (3·9%)	1272 (5·4%)
Controls (n=593 077)					
Parental income quintile at birth					
1 (lowest)	17 012 (2·9%)	9512 (1·6%)	6688 (1·1%)	5603 (0·9%)	4595 (0·8%)
2	26 236 (4·4%)	22 719 (3·8%)	17 959 (3·0%)	12 906 (2·2%)	8067 (1·4%)
3	27 904 (4·7%)	34 652 (5·8%)	32 059 (5·4%)	24 048 (4·1%)	13 712 (2·3%)
4	19 432 (3·3%)	30 732 (5·2%)	40 753 (6·9%)	42 884 (7·2%)	27 173 (4·6%)
5 (highest)	10 189 (1·7%)	12 614 (2·1%)	21 580 (3·6%)	42 144 (7·1%)	81 904 (13·8%)

23 controls had missing parental income information either at birth or at age 15. Because controls were matched to the cases on age and gender, no inference should be made to the parental income distribution of the general population.

Table 2: Violent offending cases and controls by parental income trajectories between birth and age 15 years

parental income progressed from quintile 1 (lowest income) to quintile 5 (highest income) between the two ages—ie, the most upwardly mobile group—the magnitude of the risk elevations were much reduced (IRR 1·6 [95% CI 1·4–2·0] for self-harm and 1·6 [1·3–2·0] for violent offending). Moreover, the risk elevations for both outcomes linked with this most upwardly mobile group were notably smaller than those associated with the most downwardly mobile group—ie, those whose parental income dropped from the highest to the lowest income quintile (2·3 [2·1–2·6] for self-harm and 2·9 [2·6–3·2] for

violent offending). In general, for any parental income stratum at birth, being upwardly mobile was associated with lower risk for the two adverse outcomes compared with being downwardly mobile (figure 3).

When adjusting for parental education, parental age, history of parental mental illnesses, and number of full and half siblings, in addition to inherent adjustment for age, gender, and calendar year, we found that all IRRs were attenuated but the risk gradients across income quintiles essentially persisted (figure 4). Estimates adjusted for each domain separately, as well as for all
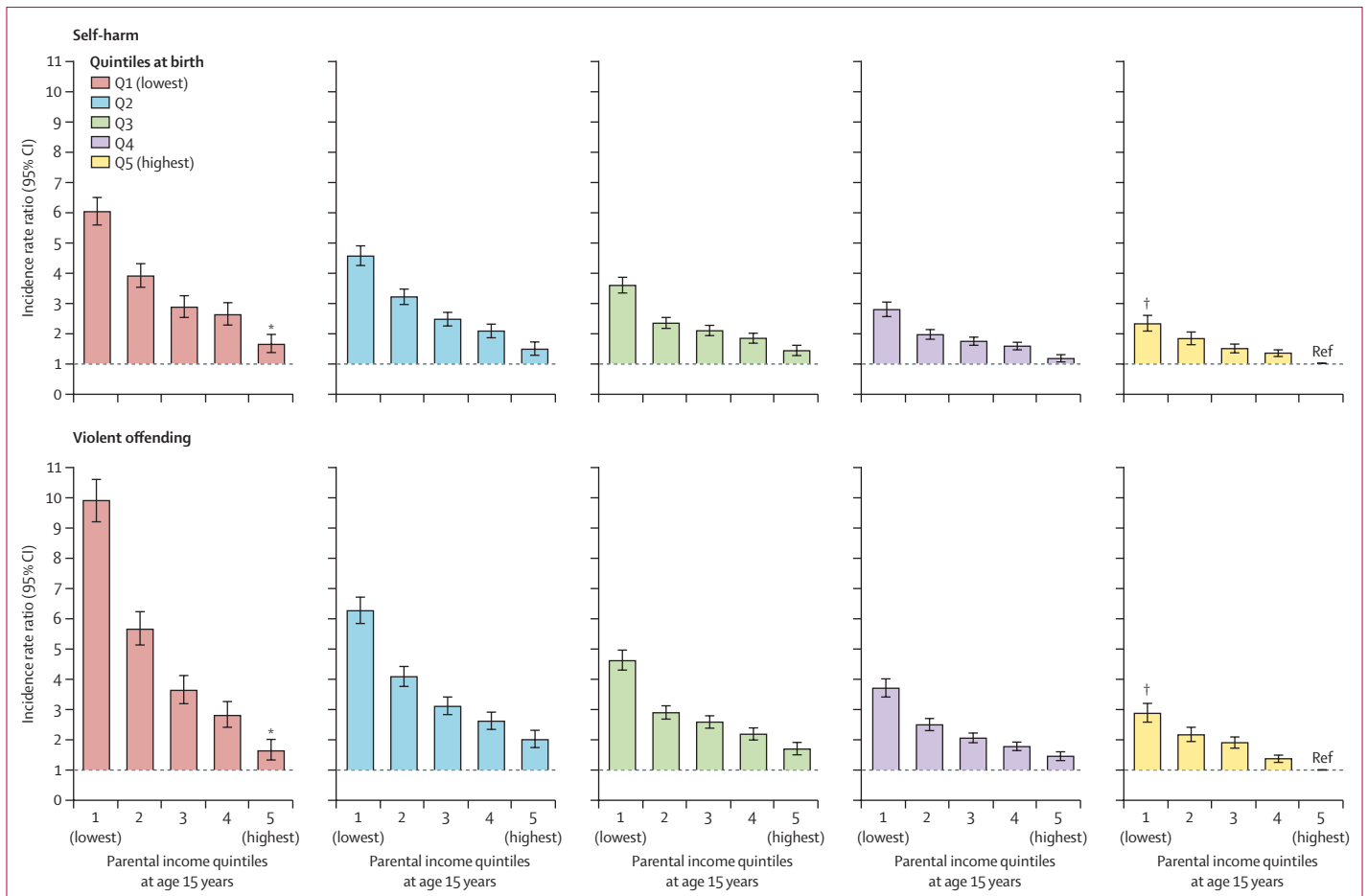
***Figure 3*:** Incidence rate ratios for self-harm and violent offending in relation to trajectories in parental income levels between birth and age 15 years
For each outcome, the same reference category (parental income quintile 5 at birth-year and age 15 years) was used for incidence rate ratio estimation across all quintiles at birth. Ref=reference group (incidence rate ratio = 1). *Most upwardly mobile group (ie, lowest quintile at birth and highest quintile at age 15 years). †Most downwardly mobile group (ie, highest quintile at birth and lowest quintile at age 15 years).

covariates, are presented in the appendix (pp 14–39). When considering IRRs across all ages of income measurement, parental education explained 31–54% of the elevated risks for self-harm and 52–65% for violent offending—a considerably greater influence than that observed for the other sociodemographic covariates assessed separately. Comparing these fully adjusted estimates with the inherently adjusted IRRs showed that around 42–80% of the elevated risks for self-harm and 66–83% for violent offending were accounted for by these covariates. Inherently and fully adjusted risk estimates by cumulative parental income scale and by parental income trajectories between birth-year and age 15 years are shown in the appendix (pp 40–47). Again, although all IRRs were attenuated after adjustment for the covariates, the patterns of risk remained.

Discussion
An inverse, non-linear relationship was observed between childhood family income and subsequent risks for self-harm and violent offending, with those from families in the lowest income quintile showing disproportionately higher risks. These risk patterns were attenuated, but essentially persisted, after covariate adjustment. The associations were stronger for violent offending than for self-harm, especially so for the lowest income quintile. The longer a child lived in poorer circumstances, the higher the risks, and conversely, the longer the time spent growing up in more affluent conditions, the lower the risks. Compared with parental income being in the highest income quintile at birth-year and also at age 15, all other parental income trajectories were associated with higher risks for both adverse outcomes. In general, however, for any parental income level at birth, being upwardly mobile was associated with lower risk versus downward mobility.

To our knowledge, this study provides the first examination of the links between childhood family income trajectories and subsequent risks for self-directed and externalised violence in the same study cohort. Although research using Norwegian[8] and Swedish[23] registry data has reported an inverse relationship between
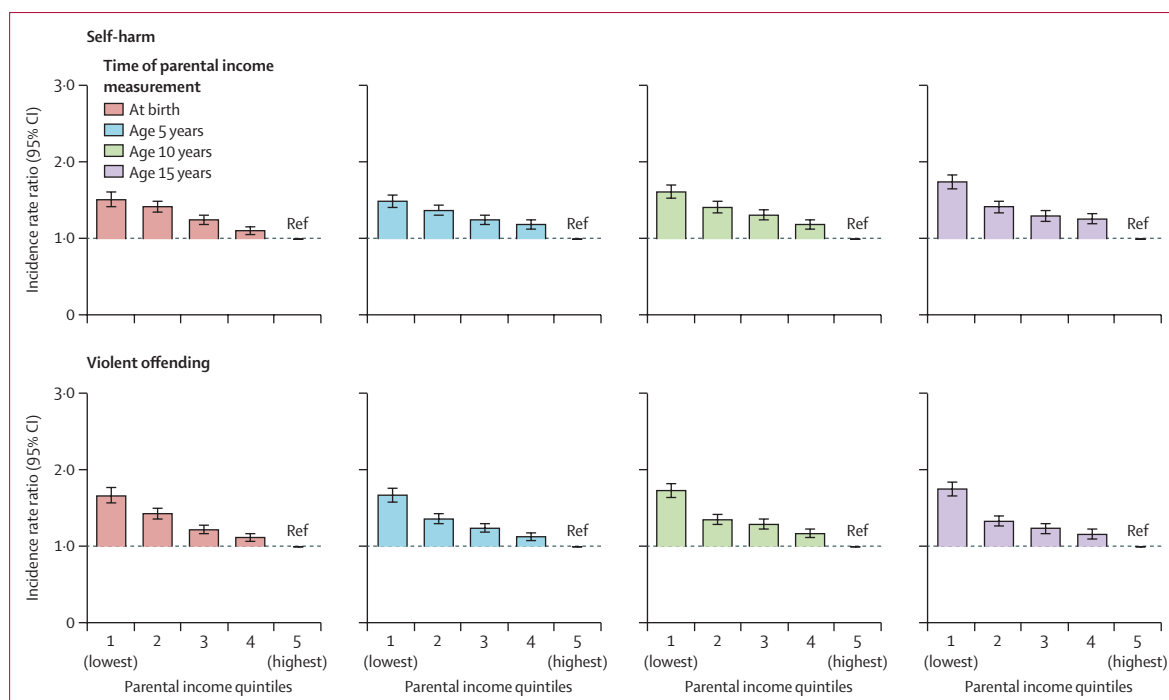
Figure 4: **Fully adjusted incidence rate ratios for self-harm and violent offending by parental income quintiles measured during birth-year and at ages 5 years, 10 years, and 15 years**

In additional to inherent adjustment for age, gender, and calendar year, we also adjusted for number of full and half-siblings, parental age at cohort member's birth, history of any parental mental illness, and highest levels of maternal and paternal educational attainment. Ref=reference group (incidence rate ratio = 1).

family income distribution and later violent criminality risk, and findings from a birth-cohort study[9] in England showed that low household income at 33 months and at 134 months was associated with increased self-harm risk at age 16–18 years, income trajectories were not investigated in these studies. Furthermore, although repeated experience of poverty during childhood has been shown to be more detrimental than transient poverty on risks of self-harm and delinquency,[2,9,16] the strong risk gradients we observed have not been reported before. Our findings, however, concur with the risk patterns reported for other health outcomes. For example, research in Sweden[24] has shown that downward income trajectories during childhood were linked with elevated risks for psychiatric disorders in late adolescence and early adulthood versus individuals from the highest familial income trajectory. Even children from families with slightly lower but increasing levels of income showed higher risk compared with this most affluent group. The highest risk, however, was observed amongst those whose familial income remained consistently low.[24] In the UK, transition into income poverty during early childhood has been linked with raised risk for socioemotional behavioural problems in middle childhood.[3] Research from the USA[25] has also found that a large fall in familial income during infancy was associated with behavioural problems in later childhood.

Although income indicates a family's material resource levels, it also captures a multitude of other influences on child development, such as access to services, housing, neighbourhood, social status, participation, and exclusion.[1,6,26] Exposure to poverty during birth-year might also have adverse implications for in-utero, prenatal, and postnatal environments, negatively affecting early child neurocognitive development with possible consequences for subsequent behavioural outcomes.[1] Economic pressure raises risks for parental psychopathology, parental conflict and separation, negative parenting behaviours, and child neglect, leading to harmful impact on children's psychosocial development and wellbeing.[3,26,27] Familial adversities are also interrelated; children from poorer households are more likely than those from more affluent backgrounds to be exposed to multiple hardships, with deprived families having less material resources to buffer the consequences of these experiences.[26,27] Parental income is thus a marker for a range of familial physical and psychosocial environments. In fact, it is unlikely that the graded relationships observed in this study could solely be explained by the differential access to financial and material resources. Exposure to multiple childhood adversities has also been shown to have the greatest effect on subsequent internalised and externalised violence risks compared with other health outcomes.[28] Therefore, rather than striving to discern the independent effect of parental income per se, we interpreted income as a marker for an array of measured and unmeasured correlated familial circumstances. Adjusting for additional covariates would attenuate the IRRs further but residual confounding

would remain. It would never be possible to control for or even identify all confounders and therefore truly isolate the independent effect of income per se. In addition, parental education—another indicator for parental socioeconomic status—is likely to be one of the key determinants of parental income level, and parental age and number of half and full siblings might have some influence too. Similarly, onset of parental mental illness could affect parental income, and could also lie on the causal pathway between parental income and offspring adverse outcomes. Therefore, in our approach, parental education, parental age, parental mental illness, and number of siblings should not be considered as being confounders of the link between parental income and later risks of adverse outcomes in their children. Because of these interpretational issues, including potential for marked under-adjustment and over-adjustment, we have presented the estimates that were inherently adjusted for age, gender, and calendar year as our primary results.

Our findings could also partly be explained by intergenerational transmission of parental characteristics such as emotional dysregulation and antisocial traits, which are linked to both parental socioeconomic outcomes and offspring propensity for violence, and evidence for both social causation and social selection has been reported.[9,23,26,29] Suicidal and violent behaviours also cluster within families.[29,30] Although we could not elucidate these complex mechanisms, most importantly our study has shown that upwards mobility could, to some extent, mitigate the risks for both adverse outcomes associated with low socioeconomic position at birth.

Stronger associations were observed for violent offending than for self-harm, especially in the lowest income quintile. This result suggests that any environmental, psychosocial, or sociocultural influences linked with low family income were likely to have a bigger impact on offspring's externalised than internalised aggressive behaviours. Studies examining other exposures such as parental psychopathology[11] and frequent residential mobility during adolescence[31] have also reported stronger links for violent offending than for self-harm.

Risk and protective factors for health and wellbeing accumulate over the life-course, and they transmit across generations.[5,32] Our findings suggest that, irrespective of familial circumstances at birth, tackling socioeconomic inequalities during a child's upbringing could potentially mitigate some of the disadvantages—both monetary and non-monetary—linked with low family income. We believe that this implication is likely to apply to other high-income countries. Ill health and a multitude of social problems have been reported to be more prevalent in unequal societies.[33] Income inequality in Denmark is amongst the lowest globally,[34] and the country has a comprehensive welfare system, including free mental and physical health care, for the entire population. It is thus most likely that the graded risk patterns that we observed would be more pronounced in countries with higher income inequalities, greater and more widespread levels of poverty, and lower redistribution of resources, such as the UK. A US study[35] reported that implementation of the Earned Income Tax Credit to alleviate poverty was associated with enhanced child development. Secondary analysis of the Great Smoky Mountains Study has also revealed that children of families receiving income supplement from a gambling casino subsequently showed lower risks for psychopathology and minor offences than those who did not participate in the intervention.[36,37] Improved parental wellbeing, parenting quality, and familial interactions were some of the factors linked with improved offspring outcomes in these studies, suggesting that the benefits of additional income went beyond improved material resources alone.

In addition to poverty alleviation, national initiatives are needed to support upwards social mobility, such as wider access to better educational, training, and employment opportunities; reduction of neighbourhood violence; tackling of gang culture; promotion of community cohesion; stable housing; and positive parenting skills. Integrated actions from educational, social, and mental health services are also needed to help families to tackle the multiple adversities linked with poverty, and to prevent social exclusion of those who are economically disadvantaged. Our results indicate that much of the risks of self-harm and interpersonal violence in young people could be attributed to parental educational attainment level, suggesting that enhancing education might be key to reducing intergenerational transmission of these risks. Elevated risks for self-harm and violent criminality were not only found among individuals in the lowest income stratum—they were observed across the entire income distribution. One-size-fits-all public health interventions might benefit the most affluent recipients more than those from more disadvantaged backgrounds, resulting in an inadvertent widening of inequalities;[38] therefore, to maximise public health impact, effective interventions must be implemented population-wide, with additional specific initiatives focused on the most disadvantaged families.

A key strength of our study was use of Danish national registry data, which provided routine longitudinal recording of parental income for the entire population, and statistical power and precision. Risks were assessed in association with the whole income distribution, not only low versus high income, and in relation to income mobility during childhood. By implementing a nested case-control study, complex time-dependent influences and cohort effects linked with parental income levels (eg, inflation) were accounted for intrinsically by design. Investigation of both self-directed and externalised violence in the same cohort also enabled associations with parental income to be compared without differential intercohort biases.

Our study has some limitations. We included only secondary care-treated self-harm cases and violent crime

convictions. Thus, less serious, unregistered self-harm and interpersonal violence episodes were not examined. We were unable to adjust for parental violent criminality[29] because national crime records were only available from 1981. However, a history of parental violent offending is likely to be a marker for a multitude of household dysfunctionalities, and controlling for it would thus grossly overadjust the relative risk estimates. Finally, although the cumulative parental income scale is an indicator of relative parental income levels and their duration during childhood, it does not distinguish the timing of exposure.

In conclusion, childhood family income is associated with later suicidality and violent criminality, with individuals growing up in the lowest income families having disproportionately elevated risks. The longer a child lives in poorer circumstances, the higher their risks for internalised and externalised violence and vice versa for time spent growing up in affluent conditions. Tackling the underlying causes of inequality to enable upwards socioeconomic mobility, at any stage during a child's development, could potentially ameliorate risks for these destructive behaviours in the longer term. Future research could investigate crucial and sensitive periods of exposure to inform on the most effective timing for intervention. The promotion and enablement of upwards socioeconomic mobility for large sections of the population could also ultimately reduce the likelihood of intergenerational transmission of inequality, producing substantive societal gains.

References
1   Jensen SKG, Berens AE, Nelson 3rd CA. Effects of poverty on interacting biological systems underlying child development. *Lancet Child Adolesc Health* 2017; **1:** 225–39.
2   Najman JM, Clavarino A, McGee TR, Bor W, Williams GM, Hayatbakhsh MR. Timing and chronicity of family poverty and development of unhealthy behaviors in children: a longitudinal study. *J Adolesc Health* 2010; **46:** 538–44.
3   Wickham S, Whitehead M, Taylor-Robinson D, Barr B. The effect of a transition into poverty on child and maternal mental health: a longitudinal analysis of the UK Millennium Cohort Study. *Lancet Public Health* 2017; **2:** e141–48.
4   McLaughlin KA, Breslau J, Green JG, et al. Childhood socio-economic status and the onset, persistence, and severity of DSM-IV mental disorders in a US national sample. *Soc Sci Med* 2011; **73:** 1088–96.
5   Poulton R, Caspi A, Milne BJ, et al. Association between children's experience of socioeconomic disadvantage and adult health: a life-course study. *Lancet* 2002; **360:** 1640–45.
6   Galobardes B, Lynch JW, Smith GD. Is the association between childhood socioeconomic circumstances and cause-specific mortality established? Update of a systematic review. *J Epidemiol Community Health* 2008; **62:** 387–90.
7   Engström K, Diderichsen F, Laflamme L. Parental social determinants of risk for intentional injury: a cross-sectional study of Swedish adolescents. *Am J Public Health* 2004; **94:** 640–45.
8   Galloway TA, Skardhamar T. Does parental income matter for onset of offending? *Eur J Criminol* 2010; **7:** 424–41.
9   Page A, Lewis G, Kidger J, et al. Parental socio-economic position during childhood as a determinant of self-harm in adolescence. *Soc Psychiatry Psychiatr Epidemiol* 2014; **49:** 193–203.
10 Mokdad AH, Forouzanfar MH, Daoud F, et al. Global burden of diseases, injuries, and risk factors for young people's health during 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet* 2016; **387:** 2383–401.
11 Mok PLH, Pedersen CB, Springate D, et al. Parental psychiatric disease and risks of attempted suicide and violent criminal offending in offspring: a population-based cohort study. *JAMA Psychiatry* 2016; **73:** 1015–22.
12 O'Donnell O, House A, Waterman M. The co-occurrence of aggression and self-harm: systematic literature review. *J Affect Disord* 2015; **175:** 325–50.
13 Sahlin H, Kuja-Halkola R, Bjureberg J, et al. Association between deliberate self-harm and violent criminality. *JAMA Psychiatry* 2017; **74:** 615–21.
14 Brent DA, Melhem NM, Wilcox HC. Violent offending and suicidal behavior have common familial risk factors: a rejoinder to Tolstoy. *JAMA Psychiatry* 2016; **73:** 1005–07.
15 Galobardes B, Shaw M, Lawlor DA, Lynch JW, Davey Smith G. Indicators of socioeconomic position (part 1). *J Epidemiol Community Health* 2006; **60:** 7–12.
16 Jarjoura GR, Triplett RA, Brinker GP. Growing up poor: examining the link between persistent childhood poverty and delinquency. *J Quant Criminol* 2002; **18:** 159–87.
17 Pedersen CB. The Danish Civil Registration System. *Scand J Public Health* 2011; **39:** 22–25.
18 Webb RT, Antonsen S, Mok PLH, Agerbo E, Pedersen CB. National cohort study of suicidality and violent criminality among Danish immigrants. *PLoS One* 2015; **10:** e0131915.
19 Lynge E, Sandegaard JL, Rebolj M. The Danish National Patient Register. *Scand J Public Health* 2011; **39:** 30–33.
20 Mors O, Perto GP, Mortensen PB. The Danish Psychiatric Central Research Register. *Scand J Public Health* 2011; **39:** 54–57.
21 Nordentoft M, Mortensen PB, Pedersen CB. Absolute risk of suicide after first hospital contact in mental disorder. *Arch Gen Psychiatry* 2011; **68:** 1058–64.
22 Baadsgaard M, Quitzau J. Danish registers on personal income and transfer payments. *Scand J Public Health* 2011; **39:** 103–05.
23 Sariaslan A, Larsson H, D'Onofrio B, Långström N, Lichtenstein P. Childhood family income, adolescent violent criminality and substance misuse: quasi-experimental total population study. *Br J Psychiatry* 2014; **205:** 286–90.
24 Björkenstam E, Cheng S, Burström B, Pebley AR, Björkenstam C, Kosidou K. Association between income trajectories in childhood and psychiatric disorder: a Swedish population-based study. *J Epidemiol Community Health* 2017; **71:** 648–54.
25 Ramanathan S, Balasubramanian N, Faraone SV. Familial transient financial difficulties during infancy and long-term developmental concerns. *Psychol Med* 2017; **47:** 2197–204.
26 Conger RD, Conger KJ, Martin MJ. Socioeconomic status, family processes, and individual development. *J Marriage Fam* 2010; **72:** 685–704.
27 Green JG, McLaughlin KA, Berglund PA, et al. Childhood adversities and adult psychiatric disorders in the national comorbidity survey replication I: associations with first onset of DSM-IV disorders. *Arch Gen Psychiatry* 2010; **67:** 113–23.

28 Hughes K, Bellis MA, Hardcastle KA, et al. The effect of multiple adverse childhood experiences on health: a systematic review and meta-analysis. *Lancet Public Health* 2017; **2:** e356–66.

29 Frisell T, Lichtenstein P, Långström N. Violent crime runs in families: a total population study of 12.5 million individuals. *Psychol Med* 2011; **41:** 97–105.

30 Tidemalm D, Runeson B, Waern M, et al. Familial clustering of suicide risk: a total population study of 11.4 million individuals. *Psychol Med* 2011; **41:** 2527–34.

31 Webb RT, Pedersen CB, Mok PLH. Adverse outcomes to early middle age linked with childhood residential mobility. *Am J Prev Med* 2016; **51:** 291–300.

32 Marmot M, Goldblatt P, Allen J, et al. Fair society, healthy lives: the Marmot review. Strategic review of health inequalities in England post-2010. London: The Marmot Review, 2010.

33 Wilkinson RG, Pickett KE. The problems of relative deprivation: why some societies do better than others. *Soc Sci Med* 2007; **65:** 1965–78.

34 Keeley B. Income inequality: the gap between rich and poor. Paris: OECD Publishing, 2015.

35 Hamad R, Rehkopf DH. Poverty and child development: a longitudinal study of the impact of the Earned Income Tax Credit. *Am J Epidemiol* 2016; **183:** 775–84.

36 Akee RKQ, Copeland WE, Keeler G, Angold A, Costello EJ. Parents' incomes and children's outcomes: a quasi-experiment. *Am Econ J Appl Econ* 2010; **2:** 86–115.

37 Costello EJ, Erkanli A, Copeland W, Angold A. Association of family income supplements in adolescence with development of psychiatric and substance use disorders in adulthood among an American Indian population. *JAMA* 2010; **303:** 1954–60.

38 M White, J Adams, P Heywood. How and why do interventions that increase health overall widen inequalities within populations? In: Babones S, ed. Social inequality and public health. Bristol: Policy Press, 2009: 65–82.