Income inequality and ischaemic heart disease in Danish men and women

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Background It has been hypothesized that areas with an unequal income distribution are less likely to invest in health and more likely to have a social environment that influences the development of ischaemic heart disease (IHD)

Methods We used pooled data from two cohort studies conducted in Copenhagen to analyse the association between area income inequality and first admission to hospital or death from IHD in women and men while controlling for individual income and other IHD risk factors. A total of 11,685 women and 10,036 men, with initial health examinations between 1964 and 1992, were followed for a median of 13.8 years. Information on median income share at parish and municipality levels was obtained from population registers.

Results During follow-up 1,700 men and 1,204 women experienced an IHD event. At parish level income share was inversely associated with an increased risk of IHD in men (hazard ratio [HR] most versus least equal quartile = 0.85 (95% CI: 0.73–0.98). Among women there was no relation between parish income inequality and IHD. Subject’s household income was inversely related to IHD, and when this variable was controlled for, the association between income inequality at parish level and IHD in men attenuated slightly. When behavioural and biological risk factors were entered into the Cox model this relation attenuated further. However, some of these risk factors might mediate rather than confound the effect of income inequality. The association between income inequality at municipality level and IHD was insignificant for men, while in women the relation had a curved shape with those living in the least equal areas having the lowest risk.

Conclusions This study provides no clear evidence for an association between income inequality measured at parish or municipality level and IHD in Danish adults. The associations were weak and varied between different strata and geographical levels.

Keywords Ischaemic heart disease, income inequality, multilevel study

Several ecological studies using different income distribution measures have shown that higher levels of inequality in income among states1–4 or counties5 in the US are associated with higher all-cause mortality. Ischaemic heart diseases (IHD) account for a large proportion of all-cause mortality in Western societies, and in their ecological study Kennedy et al.5 showed that income inequality was positively correlated with IHD mortality. Kaplan et al.4 documented associations between median income share and two IHD risk factors: smoking and sedentary lifestyle, while Lynch et al.6 did not find income inequality to be associated with IHD mortality rates in a comparison of 22 wealthy nations. The only previous multilevel study of IHD which has included both contextual and individual-level data in the analysis is the cross-sectional study from the US of Diez-Roux et al.,7 which used four IHD risk factors as outcomes. In this study including 70,534 subjects

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from the Behavioural Risk Factor Surveillance, state income inequality was associated with increased levels of body mass index (BMI), hypertension, and sedentarism, particular at low income levels (annual household incomes <US$25 000), with associations persisting after adjustment for individual-level income. These associations of inequality with the outcomes were statistically significant in women but not in men. Effects of income inequality are likely to differ by gender and be confounded by individual risk factors. However, to our knowledge no longitudinal study has examined whether area-based measures of income inequality are associated with the risk of developing IHD in women and men taking individual cardiovascular risk factors into account. Further, studies so far have been on inequality at county, state, or national level, although possible explanations include factors acting at every level from national and local policies to close neighbourhood interactions.7

The aim of the present study is thus to determine whether income inequality measured at the parish and municipality levels increases the risk of developing IHD in women and men. Individual income and standard IHD risk factors were included in the analysis as potential confounders or mediators.

Methods
Study population
The study is based on data from two longitudinal population studies conducted in Copenhagen: (1) The Copenhagen City Heart Study (CCHS)8 which comprises 14 119 randomly selected men and women aged ≥20 years from a defined area of Central Copenhagen who were included in 1976–1978. In 1981–1983 subjects were re-examined and 1560 new subjects included. The CCHS thus consisted of 15 679 subjects. (2) Between 1964 and 1992, 10 092 subjects from different birth cohorts (born in the period 1897–1957) of the population in selected Western suburbs of Copenhagen (The Glostrup Population Study)9 were examined and followed. Our combined study population consisted of 25 771 subjects, however 7846 people were invited but did not participate (participation rate 77%). In total 4050 subjects were excluded for the following reasons: died before 31 December 1980 (1080 subjects), experienced non-fatal IHD before 31 December 1980 (523 subjects), moved out of the Metropolitan area or had missing data on one or more of the covariates (2447 subjects). Thus, the present analyses are based on the 21 721 participants (11 685 women and 10 036 men) with complete data.

Subjects were followed from 1980 or date of study entry if later until 31 December 1997 for first admission to hospital or death from IHD (International Classification of Diseases, Eighth Revision [ICD-8] diagnosis codes 410–4, ICD-10 diagnosis codes I20–I25). The information was obtained from the National Board of Health’s Register of Cause of Death and the National Patient Register. Participants were followed for a median 13.8 years.

Data
The study population was linked to Registers with socioeconomic information in Statistics Denmark10 using the personal identification number as a key. Information on housing, income, occupation, and education were obtained for study participants and for their cohabiting partners (married or non-married) for the years 1980, 1985, and 1990. The present study used data from the year nearest and prior to the baseline examination. Area-based information was obtained by aggregating individual information for each year for the whole population (around 1.1 million) at two geographical levels: parish and municipality/inner city. The municipality level is thought to reflect local political authorities and associated institutions, while the parish level represents no specific policy, but is assumed to mirror the social environment close to the individual. The 153 parishes had a mean population of 7500 (range 600–17 400), while the 19 municipalities and 15 inner city districts had on average 48 000 (range 8300–85 600) inhabitants, in 1990. The number of participants in the areas ranged from 2 to 1985 for the parishes, and from 14 to 4998 for the municipalities.

Measures of income inequality in area of residence
We used the median share of income in each parish or municipality estimated as the proportion of total household gross income earned by the poorer 50% of the households in the area,5 calculated on the basis of information on all adult inhabitants in the study area. The mean median share of income across parishes was 22.3% (median 22.7%; range: 7.5–33.3%), and for municipalities 20.9% (median 22.3%; range: 16.4–31.8%).

Measures of individual income
All Danish inhabitants above age 15 years are classified annually according to income and wealth in the Register of Income Statistics. For each participant and cohabiting partner we obtained information on gross income and calculated household income as the sum of the individual and his or her cohabitant’s gross income. The gross income comprises all income types subject to income taxation (wages and salaries, all types of benefits and pensions, net surplus or deficit, interest received and share dividends).11 Income was corrected for inflation since 1980 using the appropriate components from Statistic Denmark’s price index. They are expressed in 1995 prices and 10 Danish kroner was considered equal to £1. Our previous analyses of the relation between individual income and incidence of coronary heart disease12 showed that the effect of income on coronary heart disease risk was almost the same for people with annual incomes between £15 000 and £40 000. Therefore, individuals were divided into four groups on basis of their income (<£7500; 7500–14 999; 15 000–39 999; 40 000) in the present study.

Other covariates
Information on type of household at the individual level (four categories: one or two adult cohabiting partners with or without children under age 18 years) and area level (the proportion of cohabiting partners in an area with children under age 18 years and mean household income) was derived from registers in Statistics Denmark.

Standard risk factors were assessed for each participant at baseline by a self-administered questionnaire, and health examination. Body mass index (weight [kg]/height [m]²), was based on data collected by trained nurses. Systolic blood pressure and total cholesterol were divided into quintiles within cohorts in

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order to avoid systematic errors in measurement between the cohorts being investigated. Self-reported diabetes was categorized yes/no. Smoking behaviour was elucidated using questions to categorize smokers according to present tobacco consumption. Subjects were divided into five groups according to current smoking status (never, ex, 1–14, 15–24, 25 g tobacco/day). Alcohol consumption was classified according to total weekly intake: <1, 1–6, 7–13, 14–27, 28–41, >41 drinks; one drink contained 9–13 g alcohol. Moderate alcohol use (a weekly intake of 1–6 drinks) was used to evaluate reduced IHD risk. Physical activity in leisure time was classified into three categories as sedentary; moderately active <4 hours per week; and moderate activity >4 hours per week.

**Statistical methods**

Associations between risk factors and incident IHD were analysed using Cox’s proportional hazards regression models with age as the underlying time scale. Follow-up time was calculated from 1 January 1980 for subjects examined before that date or at study entry. The proportional hazards assumption was evaluated for all variables by comparing estimated -ln(-ln) survivor curves over the different categories of the variables being investigated versus ln{(analysis time)}(log log plots) and by tests based on the generalization of Grambsch and Therneau. The continuous variables were evaluated for linearity by visual inspection of graphs of estimated coefficients versus midpoints of groups or centiles and by fractional polynomial analysis. This exercise showed that dividing income inequality into quartiles would capture the variation in the relation to IHD. Because the number of participants in each area varied and those belonging to the same area are more likely to be alike, data were analysed using a robust estimator of variance. Test for interaction between income inequality and income of individuals was made using the likelihood ratio test. Statistical analyses were performed using STATA for Unix version 7. The initial regression analyses were performed using the steps recommended by Hosmer & Lemeshow.

**Results**

The population living in parishes with the most equal income distribution had higher income levels, and included higher proportions of cohabiting partners with children, moderate alcohol users, and people with sedentary leisure time, whereas the proportion of smokers, and mean blood pressure levels were lower compared with those living in parishes with a more unequal income distribution. Mean levels of cholesterol were highest in the most equal areas in men, but lowest in women when compared with the least equal areas (Table 1). A similar distribution of the covariates was seen within quartiles of income inequality measured at the municipality level (data not shown).

During follow-up 1204 women and 1700 men experienced an IHD event. At parish level income share was inversely associated with IHD risk in men (Table 2), while there was no relation between income inequality and IHD in women (Table 3). Individual’s household income was inversely related with IHD, and when this variable was included in the model, the association between income inequality and IHD in men attenuated slightly. This relation further attenuated when all other risk factors were controlled for. There were no significant multiplicative or additive interactions between income inequality and individual’s household income indicating that the relative effect of income inequality on IHD was the same in the four income groups. At municipality level the inverse association between income inequality and IHD in men was insignificant.

**Table 1** The distribution of risk factors in relation to level of income inequality at parish level in men and women

<table>
<thead>
<tr>
<th>Area income inequality (%)</th>
<th>First quartile</th>
<th>Second quartile</th>
<th>Third quartile</th>
<th>Fourth quartile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean systolic Bp&lt;sup&gt;d&lt;/sup&gt; (SD)</td>
<td>149 (20)</td>
<td>138 (21)</td>
<td>133 (20)</td>
<td>128 (17)</td>
</tr>
<tr>
<td>% with diabetes</td>
<td>2.0</td>
<td>2.3</td>
<td>2.4</td>
<td>1.8</td>
</tr>
<tr>
<td>Mean cholesterol&lt;sup&gt;c&lt;/sup&gt; (SD)</td>
<td>5.89 (1.13)</td>
<td>5.99 (1.20)</td>
<td>6.01 (1.24)</td>
<td>6.11 (1.27)</td>
</tr>
<tr>
<td>Mean BMI&lt;sup&gt;b&lt;/sup&gt; (SD)</td>
<td>25.6 (3.8)</td>
<td>25.7 (3.6)</td>
<td>25.5 (3.6)</td>
<td>25.4 (3.6)</td>
</tr>
<tr>
<td>Mean IHD&lt;sup&gt;a&lt;/sup&gt; events</td>
<td>2657</td>
<td>3337</td>
<td>1682</td>
<td>2660</td>
</tr>
<tr>
<td>% of participants</td>
<td>21 000</td>
<td>26 320</td>
<td>26 260</td>
<td>31 690</td>
</tr>
<tr>
<td>% cohabitant partners with children</td>
<td>21.7</td>
<td>22.5</td>
<td>31.9</td>
<td>47.4</td>
</tr>
<tr>
<td>% moderate drinkers</td>
<td>21.0</td>
<td>22.2</td>
<td>27.7</td>
<td>30.6</td>
</tr>
<tr>
<td>% smokers</td>
<td>68.1</td>
<td>68.2</td>
<td>64.6</td>
<td>61.0</td>
</tr>
<tr>
<td>% income &lt;US$7500</td>
<td>8.4</td>
<td>7.3</td>
<td>5.3</td>
<td>2.5</td>
</tr>
<tr>
<td>% moderate leisure</td>
<td>18.7</td>
<td>20.1</td>
<td>19.5</td>
<td>24.5</td>
</tr>
<tr>
<td>% income share (%) (least equal) (most equal) (least equal) (most equal)</td>
<td>7.5–21.6</td>
<td>21.7–22.3</td>
<td>22.4–23.6</td>
<td>23.7–33.3</td>
</tr>
</tbody>
</table>

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<sup>a</sup> Ischaemic heart disease.
<sup>b</sup> Body mass index (kg/m²).
<sup>c</sup> Cholesterol in mmol/l.
<sup>d</sup> Blood pressure in mmHg.
In women, income share was related to IHD in an upward curved manner, and those in the least equal areas had the lowest risk. This relation persisted after adjustment for other covariates.

Discussion

The present study showed a weak association between parish income inequality and experience of an IHD event during follow-up in men, while there was no such relation when inequality was measured at the municipality level. In women, there was a curved association between income inequality and IHD at municipality level, but no significant relation at the parish level. No other studies have examined the association between income inequality and IHD in a longitudinal design, but the cross-sectional study of Diez-Roux showed a positive association between State income inequality and four IHD risk factors.
factors (BMI, history of hypertension, sedentarism, and smoking) in women, but not in men. We also found unadjusted associations between area inequality and two of these risk factors (blood pressure and smoking) measured at baseline in both men and women. All other studies on the effect of income inequality on individuals’ health have had all-cause mortality or self-rated health as outcomes. Based on the results from these and some ecological studies, it has been suggested that an effect of income inequality appears at larger levels of geographical aggregation, i.e. states or regions. At lower levels of aggregation (metropolitan area, county, and census tracts) the relationship of income inequality with health is less evident. Thus, one of the key issues in the analysis of effects on health of income inequality is the area unit of analysis. Do individuals feel deprived because they feel that they have fewer opportunities compared with others in their nearest neighbourhood or does income inequality associate with underinvestment in public resources, which reflects political decisions and usually operates on larger geographical scales? Close neighbourhood environments may be related to IHD through a variety of mechanisms such as differences in the availability of healthy foods, in the distribution of recreational spaces, in patterns of social interactions and stressors, which theory has linked to income inequality. In the present study, inequality at parish level was used as a measure of the social environment close to the individual, and it did not represent specific political units. Indeed, focus on old church districts is a potential limitation because of the somewhat artificial nature of boundaries and because people compare themselves with others within a smaller or another area. However, our data were derived from public registers and the level of aggregation had to be based on existing political or administrative units. The municipality level represented a local political authority and associated institutions and policies, which might reflect another of the possible mediating mechanisms related to universally accessible services, but it should be noted that the inner city districts only represented social administrative units in the large municipality of Copenhagen. Further, we did not monitor changes in area of residence during follow-up, and some subjects might have moved out of an area years before they develop IHD. This might dilute a potential effect of the area of residence. On the other hand, we avoid the bias of cross-sectional studies investigating contextual effects of neighbourhood, that people may be selected into neighbourhoods based on values of the outcome studied.

Wilkinson has suggested that differences in mortality in areas with small populations are closely related to average income, but only weakly to inequality within the area. According to him, inequality is only important in areas with a large enough population to contain social heterogeneity, but in areas with small populations, such as residential neighbourhoods, income differences matter less because the social comparisons between social strata are lost. Following this view, one should expect to observe lower income inequality in areas with successively smaller populations. However, from a statistical point of view, income share in small areas will be more influenced by a few subjects with extreme incomes, and consequently one would expect greater statistical variation in smaller areas than in larger ones. In agreement with the latter view, we found a larger dispersion of the inequality measure when data were aggregated at the lower parish level. Social inequality is a product of the complex interplay of political, economic, social, and other conditions which vary from country to country, and the areas with the highest rates of inequality in the present study were not comparable to the very unequal, low poverty areas found in the US. This might be due to the fact that Danish housing policy ensures that even those relying on social welfare payments have access to housing in well-off areas. A rise in housing prices in Denmark has left elderly people with relatively low annual expenses living side by side with high-income households that can afford the increasing housing costs. This contributes to greater economic variation in areas that have relatively high average incomes. Thus, in the present study some, but not all, of the least equal areas were the more affluent suburban areas with fewer families with children, and features common in high-income areas such as access to open space, and low crime rates. Consequently, it is debatable whether measures of income inequality are adequate under such circumstances. Access to services, perceived economic strain, and the possibility of living up to expectations and norms may be more relevant indicators, but they are not available from registers. On this basis, one might question why we expected income inequality to matter in an egalitarian society as the Danish one. However, several studies both at municipality and individual level have shown relatively large and increasing inequalities in Denmark, and given this background we found it relevant to study the effect of contextual factors related to mortality and IHD in a Danish setting.

Another criticism of multilevel studies investigating contextual effects of neighbourhood environments involves residual confounding by other contextual and individual-level variables. In our study, we adjusted for individual income as well as behavioural and biological IHD risk factors. This attenuated the estimates markedly. Another view is that at least some of the behavioural and biological factors are a part of a causal pathway, and should not be controlled for. Many characteristics of neighbourhoods are correlated, and this was also the case in the present study. We found that income share was associated with household composition and income level. When these measures were included in the statistical model the effect of income inequality changed, and this suggests that income share is only one of different characteristics of social conditions in an area which might influence IHD risk among its residents.

In conclusion, the present study provides no clear evidence for an association between income inequality measured at parish or municipality level and IHD in Danish adults. Associations were weak and varied unsystematically between the different strata and geographical levels. This might be due to residual confounding by unmeasured contextual and individual variables and reflect that the measure of inequality was not adequate in the present Danish setting.

Acknowledgement

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KEY MESSAGES

- This study provided no clear evidence for an association between income inequality measured at parish or municipality level and IHD in Danish adults, since the associations were weak and varied between the different strata and geographical levels.
- We found a larger dispersion of income inequality at the parish than at the municipality level.
- It is debatable whether measures of income inequality are adequate in an egalitarian society such as the Danish one.

References