Recent Increase of Neighborhood Socioeconomic Effects on Ischemic Heart Disease Mortality: A Multilevel Survival Analysis of Two Large Swedish Cohorts

Basile Chaix1,2, Maria Rosvall3, and Juan Merlo1

1 Community Medicine and Public Health, Department of Clinical Sciences, Malmö University Hospital, Lund University, Malmö, Sweden.
2 Inserm, U707, UMR-S Inserm – Université Pierre et Marie Curie-Paris6, Paris, France.
3 Department of Health Sciences, Malmö University Hospital, Lund University, Malmö, Sweden.

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Studies have shown that the decrease in ischemic heart disease mortality over the past decades was paralleled by an increase in socioeconomic disparities. Using two large Swedish cohorts defined in 1986 and 1996, the authors examined whether the effect of neighborhood socioeconomic position on ischemic heart disease mortality strengthened over the period and whether the relative contribution of individual and neighborhood socioeconomic effects changed over time. Multilevel survival models adjusted for individual factors indicated that neighborhood socioeconomic effects on ischemic heart disease mortality increased markedly between the two periods (hazard ratios for residing in the most vs. least deprived neighborhoods were 1.60 (95% credible interval: 1.36, 1.89) for the 1986 cohort and 2.54 (95% credible interval: 1.99, 3.21) for the 1996 cohort). Comparing the neighborhood socioeconomic effect with the strongly predictive effect of 15-year individual income indicated that the neighborhood effect was two times weaker than the individual effect in the 1986 cohort (−48%, 95% credible interval: −22%, −68%) but of comparable magnitude in the 1996 cohort (−11%, 95% credible interval: −42%, 29%). This increase in the contribution of neighborhood factors to the socioeconomic gradient in ischemic heart disease urges investigation into the exact mechanisms between the residential context and coronary health.

cardiovascular diseases; coronary disease; follow-up studies; residence characteristics; social environment; socioeconomic factors

Abbreviation: IHD, ischemic heart disease.

Worldwide, ischemic heart disease (IHD) is the leading cause of death (1, 2). Studies conducted over the past 30 years have consistently shown an inverse association between individual socioeconomic position and IHD (3). A troublesome finding of previous literature is that the overall decrease in IHD over the past decades was paralleled by an increase in individual socioeconomic disparities (3, 4). Even if it is known that neighborhood socioeconomic position influences IHD risk independently of individual socioeconomic position (5–10), we know of no study to date that has examined whether neighborhood socioeconomic effects on IHD also increased over the recent period.

Using two large Swedish cohorts with a similar baseline age but defined in different time periods (1986 and 1996), we investigated whether the effect of neighborhood socioeconomic position on IHD mortality strengthened during a 10-year period. Second, we assessed whether the relative strength of neighborhood socioeconomic effects, as compared with individual socioeconomic effects, changed over the period. Finally, we examined whether the increase in

Correspondence to Dr. Basile Chaix, UMR-S 707 Inserm – UPMC-Paris6, Faculté de Médecine Saint-Antoine, 27 rue Chaligny, 75571 Paris cedex 12, France (e-mail: chaix@u707.jussieu.fr).
residential social segregation, defined as the concentration of poor people in certain neighborhoods (11), may have contributed to a possible strengthening of neighborhood socioeconomic effects on IHD mortality over time.

MATERIALS AND METHODS

Data sources

With the assistance of Statistics Sweden and the Swedish Center for Epidemiology, we assembled a longitudinal database including all inhabitants of Scania, Sweden (LOMAS). We used the personal identification number assigned to each person in Sweden to link the following data sources: 1) spatial coordinates of the households on January 1, 1986, and January 1, 1996; 2) yearly information on individual income from 1970 to 1995 from the Swedish Population Register; 3) education and occupation data from the 1960 and 1970 population censuses; and 4) dates and causes of death from the National Mortality Register.

We constituted two cohorts, using baseline dates of January 1, 1986, and January 1, 1996, comprising all Scanian inhabitants reaching ages 50–64 years in 1986 and 1996 (the baseline age range was similar in the two cohorts). The 1986 cohort comprised 69,815 individuals and the 1996 cohort 73,547 individuals.

Measures

We defined IHD deaths by using International Classification of Diseases, Eighth Revision and Ninth Revision codes 410–414 or Tenth Revision codes I20–I25 for the underlying or contributing causes of death.

Besides age and gender, we considered marital status, education, occupation 25 years before baseline, and individual income averaged over the 15 years prior to baseline. Age was coded in 5-year categories. Marital status was dichotomized as married/cohabiting and living alone (i.e., single, divorced, or widowed). Education was divided into three classes (<7 years, 8–9 years, >9 years). Occupation 25 years before baseline was defined by using the 1960 and 1970 censuses for the 1986 and 1996 cohorts, respectively. We distinguished between nonmanual, manual, and other types of occupations.

Rather than household income, only individual income information was available. Averaged income over the past 15 years was defined by income in 1970, 1975, 1980, and 1985 for individuals in the 1986 cohort and by income in 1980, 1985, 1990, and 1995 for individuals in the 1996 cohort. To standardize income level across years, we converted each yearly income variable into a rank between 1 and 100. For each individual in each period, we computed the average of the four standardized income variables.

To investigate contextual effects on a local scale, we used the smallest existing geographic units. To define the neighborhood variable in neighborhoods containing a minimum number of inhabitants, we grouped parcels with fewer than 100 inhabitants aged 50–89 years with adjacent parcels. In 1996, the median number of inhabitants of all ages in the resulting 652 local neighborhoods was 1,057 (interquartile range: 720, 1,553).

We considered income of neighborhood residents aged 50–89 years 1 year prior to baseline to define neighborhood socioeconomic position. To obtain a neighborhood socioeconomic factor comparable across years, that is, independent of the year-specific income scale, we computed a standardized neighborhood income in 1985 and 1995 by converting individual income into a rank between 1 and 100 and calculating mean income rank in each neighborhood. Individual and neighborhood income factors were divided into four categories comprising an equal number of individuals.

Statistical analysis

To capture between-neighborhood variability in IHD mortality, we used multilevel Weibull survival models including a neighborhood-level random intercept (12). We followed an approach described in previous literature to facilitate assessment of the magnitude of neighborhood variations (13–15), expressing geographic heterogeneity on the hazard ratio scale with an interquartile hazard ratio (16–18). The interquartile hazard ratio expresses the difference in IHD mortality between the 25 percent of all individuals in neighborhoods with the lowest risk and the 25 percent of all individuals in neighborhoods with the highest risk.

Using Winbugs 1.4.1 to implement a Markov chain Monte Carlo approach (19), we estimated multilevel survival models separately for the 1986 and 1996 cohorts. Individuals were followed until death or until the end of a 7-year period (December 31, 1992, for the 1986 cohort and December 31, 2002, for the 1996 cohort). We first estimated empty models, then included the individual and neighborhood variables. Neighborhood socioeconomic position was first introduced into the models as a four-category variable. To estimate whether the relative strength of the neighborhood income effect, as compared with the individual income effect, changed over the period, we computed ($b_{lowNI}/b_{lowII}$), where $b_{lowNI}$ and $b_{lowII}$ are the estimated parameters on the log-hazard ratio scale for having a low neighborhood/individual income rather than a high one. A specific benefit of the Markov chain Monte Carlo approach implemented in our study is that it enabled us to derive a 95 percent credible interval for this ratio through repeated sampling.

Finally, we reestimated the models with neighborhood standardized income as a continuous variable, including both linear and quadratic effects in the models. The continuous variable was centered on its mean (for better comparability between the periods, the variables in 1985 and 1995 were centered on the mean in 1995; there was almost no difference in the mean between the two periods: 51.0 and 50.7, respectively).

RESULTS

In our sample of individuals aged 50–64 years, 2.33 percent died from IHD in the 7-year follow-up of the 1986 cohort versus 1.30 percent in the 1996 cohort. Thus, IHD mortality decreased substantially between the periods.
Empty multilevel survival models indicated significant between-neighborhood variations in IHD mortality in both the 1986 cohort and the 1996 cohort. However, spatial variability in IHD mortality increased markedly over the period: the between-neighborhood variance increased from 0.16 (95 percent credible interval: 0.10, 0.22) in the 1986 cohort to 0.32 (95 percent credible interval: 0.22, 0.44) in the 1996 cohort (with nonoverlapping 95 percent credible intervals). The interquartile hazard ratios were 2.48 and 3.67 in the 1986 and 1996 cohorts, respectively.

First computing the crude percentage of IHD deaths in each neighborhood socioeconomic category (table 1), we observed that IHD mortality increased regularly with neighborhood socioeconomic deprivation. In multilevel survival models including individual variables and the neighborhood socioeconomic factor coded in four categories (table 2), we found that IHD mortality was higher for males, older people, noncohabiting individuals, people with low levels of education, and individuals with a low averaged income over the past 15 years.

After adjustment for individual characteristics, IHD mortality regularly increased with neighborhood socioeconomic deprivation (bottom of table 2). There was a striking difference in the neighborhood effect between the 1986 and 1996 cohorts, with a much stronger impact of socioeconomic context on IHD mortality in the recent period. This increase in neighborhood socioeconomic effects over time was also reflected in the distribution of IHD deaths across neighborhoods (table 1): 36 percent of IHD deaths occurred in the most deprived neighborhoods in the 1986 cohort versus 45 percent in the 1996 cohort.

In the 1986 cohort, the neighborhood socioeconomic effect on IHD mortality was two times weaker than the effect of 15-year averaged individual income (−48 percent, 95 percent credible interval: −22 percent, −68 percent). This was no longer the case in the 1996 cohort (−11 percent, 95 percent credible interval: −42 percent, 9 percent); the individual and neighborhood income effects were of comparable magnitude (the 95 percent credible interval included 0). In multilevel models including the individual and neighborhood variables, between-neighborhood variance was 97 percent and 99 percent lower than in the empty models in the 1986 and 1996 cohorts, respectively.

To explain the increase in neighborhood socioeconomic effects, we examined whether social segregation strengthened over the period. We found that 33 percent of individuals in the most deprived neighborhoods had a low income in 1985 compared with 39 percent in 1995. Using the F statistic to test for equality of variance, we found a larger variance in neighborhood-standardized income in 1995 than in 1985 (two-sided p = 0.007 for the 652 neighborhoods).

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**TABLE 1. Number of IHD deaths, IHD mortality rate, and distribution of IHD deaths by neighborhood socioeconomic position in the three main cities of Scania, Sweden, 1986 and 1996 cohorts**

<table>
<thead>
<tr>
<th>Neighborhood socioeconomic position</th>
<th>No. of cases/p</th>
<th>Rate (%)</th>
<th>Distribution of IHD deaths (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>587/17,497</td>
<td>3.3</td>
<td>36</td>
</tr>
<tr>
<td>Mid-low</td>
<td>461/17,392</td>
<td>2.7</td>
<td>28</td>
</tr>
<tr>
<td>Mid-high</td>
<td>356/17,509</td>
<td>2.0</td>
<td>22</td>
</tr>
<tr>
<td>High</td>
<td>224/17,417</td>
<td>1.3</td>
<td>14</td>
</tr>
<tr>
<td>1996 cohort</td>
<td>432/18,394</td>
<td>2.3</td>
<td>45</td>
</tr>
<tr>
<td>Low</td>
<td>253/18,393</td>
<td>1.4</td>
<td>26</td>
</tr>
<tr>
<td>Mid-low</td>
<td>174/18,361</td>
<td>0.9</td>
<td>18</td>
</tr>
<tr>
<td>High</td>
<td>96/18,399</td>
<td>0.5</td>
<td>10</td>
</tr>
</tbody>
</table>

* IHD, ischemic heart disease.
† Percentage of all IHD deaths that occurred in each neighborhood socioeconomic category (total = 100%).

**TABLE 2. Individual-level effects and neighborhood socioeconomic effect on ischemic heart disease mortality, as estimated from multilevel survival models, in the three main cities of Scania, Sweden, 1986 and 1996 cohorts**

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>HR 95% CI</td>
<td>HR 95% CI</td>
<td>HR 95% CI</td>
<td>HR 95% CI</td>
<td>HR 95% CI</td>
</tr>
<tr>
<td>Male vs. female gender</td>
<td>5.28 4.60, 6.00</td>
<td>3.94 3.35, 4.67</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age at baseline</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First 5-year group</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Second 5-year group</td>
<td>1.85 1.59, 2.15</td>
<td>1.94 1.62, 2.34</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Third 5-year group</td>
<td>3.07 2.65, 3.53</td>
<td>3.19 2.70, 3.75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Living alone vs. married/cohabiting</td>
<td>1.69 1.52, 1.88</td>
<td>1.87 1.64, 2.14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Educational attainment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>1.13 0.96, 1.32</td>
<td>1.15 0.96, 1.39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>1.14 1.00, 1.31</td>
<td>1.33 1.10, 1.60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occupation 25 years before baseline</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonmanual</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manual</td>
<td>1.18 1.03, 1.34</td>
<td>1.07 0.90, 1.26</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15-year averaged income</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mid-high</td>
<td>1.29 1.11, 1.49</td>
<td>1.62 1.28, 2.02</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mid-low</td>
<td>1.90 1.61, 2.22</td>
<td>2.04 1.62, 2.62</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>2.45 2.07, 2.90</td>
<td>2.84 2.24, 3.73</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neighborhood socioeconomic position</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mid-high</td>
<td>1.29 1.10, 1.53</td>
<td>1.47 1.14, 1.91</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mid-low</td>
<td>1.49 1.27, 1.76</td>
<td>1.81 1.40, 2.31</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>1.60 1.36, 1.89</td>
<td>2.54 1.99, 3.21</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Individual and neighborhood effects were adjusted for each other.
† HR, hazard ratio; CI, credible interval.
Those results indicate that social segregation increased over the period.

Neighborhood standardized income was then introduced into the models as a continuous variable with both linear and quadratic terms. As shown in figure 1, there was no evidence of a quadratic effect in the 1986 cohort (only a linear effect). Conversely, there was a quadratic effect of neighborhood income in the 1996 cohort, indicating that residing in an affluent neighborhood was particularly protective for the 1996 cohort (evidenced by the curved form of the dotted line). On the other hand, neighborhood standardized income in deprived neighborhoods was lower in 1995 than in 1985 (refer to the gap on the x-axis between the filled squares on the left of the figure).

**DISCUSSION**

Our study expands upon previous literature in showing that the effect of neighborhood socioeconomic position on IHD mortality, after adjustment for individual socioeconomic characteristics, markedly increased over the recent period.

There were limitations to our study. Most importantly, we had no information on behavioral and biomedical risk factors and health care utilization. However, we do not conceptualize those variables as confounders but as possible mediators of the neighborhood effects investigated (5, 6). Indeed, the lack of infrastructure and the built environment (20), as well as the knowledge, norms, and attitudes (21), in deprived neighborhoods may encourage health-damaging behavior and reduce health care utilization. Therefore, in contrast to the usual approach in cardiovascular disease epidemiology of identifying a new risk factor that predicts IHD beyond the effects of other known risk factors, neighborhood social characteristics, as upstream determinants of disease, may be viewed not as competing with risk factor explanations but as forces that shape the distribution of risk factors (20).

Before researchers investigate the exact mediating mechanisms, it is of importance to properly describe effects of neighborhood social characteristics, a task to which our study contributes in placing contextual influences in a temporal perspective (22). Over a 10-year period, we observed a strong increase in neighborhood socioeconomic effects on IHD mortality. Strikingly, in the second period, neighborhood income effects became as strong as the impact of 15-year individual income. The relative contribution of neighborhood factors, as compared with individual factors, to the socioeconomic gradient in IHD strengthened over the period. At least in our setting, contextual epidemiology must therefore play a decisive role in understanding social disparities in IHD.

Additional analyses indicated that the increase in neighborhood socioeconomic effects over the period was due to both 1) a higher concentration of poverty in deprived neighborhoods and 2) the particularly protective effect of affluent neighborhoods in the second period. On one hand, the concentration of material poverty in deprived neighborhoods may create conditions detrimental to developing health preservation values and attitudes, leading to initiation and permanence of unhealthy behavior (21). On the other hand, residents of affluent neighborhoods may have more resources to receive prevention messages and integrate the corresponding recommendations into their daily life behavior (21). Moreover, health knowledge in affluent neighborhoods may help residents obtain the most appropriate and newest medical treatments.

Implications of our study include the need 1) to monitor carefully the evolution of neighborhood effects on IHD (do they also increase in other industrialized countries?); 2) to investigate how the physical environment (infrastructures and services, built environment, air pollution, and noise, etc.) and social environment (social interaction patterns) contribute to neighborhood effects on IHD; and 3) to contextualize intervention strategies, that is, adapt them to the specificities of the neighborhood context.

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