RESEARCH REPORT

Income as mediator of the effect of occupation on the risk of myocardial infarction: does the income measurement matter?

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Aim: To investigate whether the effect of occupational grade on the risk of myocardial infarction (MI) is mediated by income with different aspects of income taken into account.

Methods: Data were used from three prospective population studies conducted in Copenhagen. A total of 16 665 employees, 43% women, aged 20–75 years, with an initial examination between 1974 and 1992 were followed up until 1999 for incident (hospital admission or fatal) MI. Register based information on job categories and income was used.

Results: During follow up, 855 subjects were diagnosed with a MI: 708 men and 147 women (in total 47% fatal). The hazards by household and individual income showed a graded effect with a hazard ratio (HR) of 1.43 (95% CI 1.12 to 1.83) for the lowest household income group compared with the highest, whereas equivalent income showed an inverse ''J shape'' effect with a HR of 1.55 (95% CI 1.25 to 1.82) for the third income group compared with the highest. HR for unskilled workers as compared with executive managers was reduced from 1.55 (95% CI 1.24 to 1.93) to 1.42 (95% CI 1.12 to 1.81) after adjustment for household income.

Conclusions: Occupation and income are not mutually exclusive, but at least partly explained by or mediated through the other on the risk of MI. The mediating effect of income is independent of the choice of an income indicator. Income is not a big contributor to inequality in MI; probably because of the rather even income distribution in Denmark.

Studies on the association between social position and myocardial infarction (MI) have consistently shown social differentials independent of whether social position is measured by education, occupation, or income. None the less, the indicators are not interchangeable. Each indicator has its own merit, and probably reflects common impacts of a general social stratification in a specific society as well as different dimensions specific to each indicator.[1–5] Therefore the exact relation between health and social position may differ across societies and depend on which indicator is used. As an example the relation between income and self rated health (SRH) may differ among countries.[6 7] Danish men experience a strong positive health effect of income up to US$40 000 in equivalent household income, but no further effect occurs above that level of income, whereas men in Norway and Finland experience an improvement in SRH also at the high levels of income.[6]

The different indicators have causal and mediating relations. The health effect of education depends on which types of occupations are open to people with that type of education and the effect of occupation depends, among other things, on the income of the occupation and the person.[8] Figure 1 shows the assumed causal relation between the indicators.

One methodological question in studies on income relates to the source of income information as well as the type of income measurement used. Studies based on self reported income are at risk of misclassification compared with register based information on income.[3 9] Type of income is measurable in various ways associated with different potential mechanisms as status in the hierarchical ranking compared with consumption: gross household income (GHI) defines the total purchasing power of the household, whereas equivalent income (EI) takes household size and composition into account and thus shows the amount left after household

expenses. Individual income (II) better corresponds to individual social status represented by income. Some authors have argued that the choice of income indicators does not matter, as the conclusions about income and health would not be changed.[10] Others argue that EI should be chosen.[11–13] The three ways of measuring income overlap. Nevertheless, the potential different effects require further exploration. Only a few studies, however, discuss the implications of different income indicators. Furthermore, the income inequalities in Denmark are especially low and this gives additional reasons to study the mediating role of income.

In general, studies on social position and health select one of the three social indicators and use this one as proxy for social position neglecting or treating the others as confounders. Few studies have addressed the causal relation between the various social indicators[8] and explicitly examined the mediating effect of income on MI.[14 15] Mostly these studies are cross sectional using broad end points as SRH. The aims of this prospective study are to evaluate the role of income in mediating the effect of social position, measured as occupational class on incident MI, and to investigate whether the choice of income measurement affects the mediating effect.

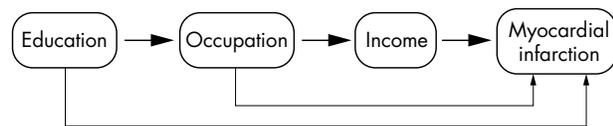...

Figure 1 Pathways between socioeconomic determinants of health.

METHODS

Study population
The study is based on data from three population based cohort studies, conducted in Copenhagen, and combined in the Copenhagen Centre for Prospective Population Studies: the Copenhagen city heart studies,[16] the Copenhagen male study,[17–19] and the Glostrup population studies.[20 21] The studies have been described previously.[22]

Eligible for this study were employees aged 20–75 years, in total 17 496 subjects. A total of 831 subjects were excluded because of missing information on the following key variables: income, tobacco, physical activity, alcohol, blood pressure, cholesterol, or body mass index (BMI). Other exclusions were caused by migration, MI, or death before start of follow up. This resulted in a study population of 16 665 subjects: 7109 women and 9556 men. The study covered a total of 213 450 person years and included 855 cases of MI.

Data on social position
In this study, social position was assessed by occupation. Only people employed at the time when occupation was registered were included. Employees were divided into five positions according to occupation and position at work. The positions are closely related to level of education required for each position.

Information on occupation was obtained via a linkage between the individual civil registration number and the employment classification module (ECM). ECM includes all citizens above 16 years with taxable income.[23] All occupations are coded according to the ISIC (international standard classification of all economic activity), version 1968. We obtained the ISIC coding for each subject for every year from 1980 to 1996. For subjects examined from 1974 to 1984, we used codes from 1980. For subjects examined from 1985 to 1989 and 1990 to 1992, we used the codes from 1985 and 1990, respectively.

Data on income
The study population was linked via the person identification number to registers on Socioeconomic Information in Statistics Denmark. Information on income and family type were obtained for study participants and the cohabiting adult for the years 1980, 1985, and 1990. We used information on income from the same year as information on occupation.

Information on annual gross household income (GHI) was obtained from the Register of Income Statistics for each study participant and their cohabitant. GHI comprises all income types subject to taxation (wages and salaries, all types of benefits and pensions, net surplus or deficit, interest and share dividends).

We calculated GHI as the sum of the person's and cohabitant's gross income. We also wanted to investigate the effect of the gross individual income (II), and hence used the income of the study participant. Income was corrected for inflation since 1980 using the appropriate adjustments from Statistic Denmark's price index. Income was expressed in 1995 prices. In 1995, 10 DKK were considered equal to £1.[24] By contrast with the GHI, which shows the consumer power of the household, the goal of using equivalent income (EI) is to adjust for the number of family members that are dependent on the income. The EI is calculated on the basis of GHI by dividing GHI with a scale (e). The scale (e) used in this study is based on the Danish Ministry of Finance and is as follows[12]:

$$(e) = [nA]^{0.8} + 0.5 \times [nC]^{0.8}$$

nA refers to number of adults and nC to number of children younger than 19 years in the family. A family is defined as consisting only of two adults.

Based on initial analyses of the effect of income in deciles on MI, the income measurements GHI, II, and EI were categorised into four groups (deciles 1–2, 3–5, 6–8, and 9–10) which were used in the final models.

Confounding/mediating exposures
In the cohorts, a broad range of well known contributing causes of MI were assessed for each participant at each examination using self administered questionnaires, clinical examinations, and blood samples. Although the phrasing of questions differed slightly in various sub-cohorts, it was possible to achieve sufficient consistency among the covariates used for this investigation.

- *Smoking* behaviour was determined using questions that categorise smokers according to their present tobacco consumption. Current smoking status was categorised into five groups according to the rate of tobacco consumption: never, former, 1–14, 15–24, $\geqslant$25 g/day.

- *Alcohol consumption* was categorised into four groups: none, 1–2, 3–5, >5 drinks/day.

- *Physical activity in leisure time* (PALT) was divided into three groups, measured in hours per week: none/little, moderate 2–4 hours, moderate >4 hours/hard work 2–4 hours/competition, hard work >4 hours.

The participants underwent a health examination with anthropometrical measurements and various laboratory tests.

- *Body mass index* (BMI), based on data collected by trained nurses, was calculated as weight in kilograms divided by height in metres squared and categorised into five groups: <22, 22–24, 25–27, 28–32, >32.

- *Systolic blood pressure* (SBP) and blood lipids measured as *total cholesterol*, were divided into quintiles within cohorts, to avoid systematic errors in measurement among the cohorts.

Information on risk factors was collected at baseline and control for changes in risk factors during follow up was not undertaken in the main analysis. Information on cohabitation was obtained from registers. People were defined as cohabiting if they were married or lived with another adult person.

Follow up
Subjects were examined during 1974–1992, and were followed up for MI incidence until 31 December 1999. The first linkage between the study population and the register data was in 1980. Consequently, the follow up started in 1981 or at study entry, whichever was latest. It seems as if the increased risk of developing MI does not develop rapidly, such as after reporting loss of job control, but increases gradually over time.[25] As we were concerned with the mediating effect of income between occupation and MI, subjects were censored five years after retirement, which occurred at age 67. The subjects who continued to work after 67 were censored at age 75 years.

Table 1 Baseline characteristics, subjects by occupational groups in the Copenhagen Centre for Prospective Population studies

		Executive managers/academic n = 2275	Leading managers n = 2742	Salaried employee n = 5312	Skilled workers n = 2107	Unskilled workers n = 4229
Women	%	15.0	35.6	65.0	5.1	52.8
Myocardial infarction	number	130	151	209	142	223
Gross household income <225000 DKK	%	5.1	11.5	24.7	15.0	31.9
Individual gross income <150000 DKK	%	2.3	7.7	23.8	4.5	34.7
Equivalent income <150000 DKK	%	7.7	14.3	22.1	22.5	32.9
Mean age	years	52.3	50.0	48.3	49.9	49.0
Heavy smokers: >15 g/day	%	32.6	32.2	33.9	42.1	40.8
Alcohol: >5 drinks/day	%	4.0	3.2	2.1	7.7	5.5
Physical activity: none/little	%	14.6	16.8	19.7	16.1	24.9
BMI kg/m^2 ≥ 32	%	2.4	3.7	3.9	4.7	7.1
SBP (mean)	mm Hg	128	126	125	129	129
Cholesterol (mean)	mmol/l	6.0	6.0	6.0	6.1	6.0
Education (<8 years)	%	9.4	24.6	32.3	49.6	63.0
Living alone	%	20.9	27.1	32.3	20.5	29.1

End point

The end point was defined as the first incidence of fatal or non-fatal MI. The cause of death was obtained from the National Death Register and cases of inpatient care for acute MI were obtained from the National Hospital Discharge Register. MI was defined according to the International Classification of Diseases: 8th revision code 410, and 10th revision codes I21–I22. Validity studies of the data in The National Hospital Discharge Register on MI have shown that they are sufficiently reliable.[26]

Statistical methods

The association between risk factors and incidence of MI was analysed using Cox's proportional hazards regression with age as the underlying time scale. A basic Cox model was developed that included GHI, II, and EI, respectively divided in four groups, with adjustment for cohort of investigation and marital status. A second model was developed that included occupational groups with adjustment for cohort of investigation, and marital status. In a third model, we tested the effect of including occupation into the income model and reverse. Lastly, the covariates tobacco, alcohol, PALT, SBP, cholesterol, and BMI were each entered separately as categorical covariates, as described above. The proportional hazards assumption was evaluated for all variables by comparing the estimated log-log survivor curves over the different categories of variables being investigated, and by tests based on the generalisation of Grambsch and Therneau.[27] All covariates were tested for an interaction with social position and income by means of the likelihood ratio test. We found no interaction defined as departure from multiplicativity. The mediated proportion is calculated by

$$100 \times \frac{HR_{Unadj} - HR_{Adj}}{HR_{Unadj} - 1} \%$$

Initial survival analyses were carried out separately for women and men. As the associations were similar, and the power for analysing women separately too small, all analyses were founded on pooled data, in a model permitting different baseline hazards for women and men. Statistical analysis was performed using Stata for Windows version 8 (StataCorp, College Station, TX).

RESULTS

During follow up, 855 subjects experienced an MI: 708 men, 147 women, and 402 events (47%) were fatal. Table 1 gives the baseline data of the study population by socioeconomic position. The data do not show a clear social gradient for all covariates, mainly because of the skilled workers. In this group, a smaller proportion belongs to the lowest GHI and II groups compared with salaried employees. A larger

Table 2 Income and risk of myocardial infarction. Hazard ratios (95% confidence intervals) of myocardial infarction by gross household, gross individual, and equivalent income based on 9556 men and 7109 women from the Copenhagen Centre for Prospective Population study

DKK 1000	Cases	Gross household *	Gross household †	Gross household ‡
>465	144	1	1	1
350–465	238	1.06 (0.86 to 1.30)	0.98 (0.79 to 1.22)	0.90 (0.73 to 1.12)
225–350	323	1.32 (1.07 to 1.61)	1.19 (0.96 to 1.48)	1.09 (0.88 to 1.35)
<225	150	1.43 (1.12 to 1.83)	1.26 (0.96 to 1.64)	1.11 (0.85 to 1.44)
		Gross individual *	**Gross individual †**	**Gross individual ‡**
>300	187	1	1	1
300–225	287	1.07 (0.89 to 1.29)	0.97 (0.79 to 1.19)	0.91 (0.74 to 1.11)
225–150	294	1.35 (1.12 to 1.64)	1.18 (0.94 to 1.47)	1.05 (0.84 to 1.31)
<150	87	1.48 (1.10 to 1.98)	1.26 (0.92 to 1.73)	1.17 (0.85 to 1.61)
		Equivalent income*	**Equivalent income†**	**Equivalent income ‡**
>250	175	1	1	1
200–250	223	1.21 (0.99 to 1.47)	1.14 (0.93 to 1.40)	1.06 (0.86 to 1.30)
150–199	298	1.51 (1.25 to 1.82)	1.40 (1.15 to 1.71)	1.32 (1.08 to 1.61)
<150	159	1.27 (1.02 to 1.58)	1.16 (0.92 to 1.46)	1.10 (0.88 to 1.39)

*Adjusted for cohort of investigation, age, cohabitation, and sex. †Adjusted for occupation, cohort of investigation, age, cohabitation, and sex. ‡Adjusted for cohort of investigation, age, cohabitation, occupation, tobacco, alcohol, physical activity, body mass index, systolic blood pressure, cholesterol, and sex, as described in the text.

Table 3 Occupational group and the mediating effect of three measures of income divided into four groups. Hazard ratios (95% confidence intervals) of myocardial infarction by occupational group based on 9556 men and 7109 women from the Copenhagen Centre for Prospective Population studies

	Basic model *	Basic model+GHI	Basic model + II	Basic model + EI	Basic model+ risk factors †
Executive managers	1	1	1	1	1
Leading managers	1.23 (0.97 to1.55)	1.18 (0.93 to1.50)	1.21 (0.94 to1.54)	1.16 (0.91 to1.47)	1.18 (0.94 to1.50)
Salaried employees	1.34 (1.07 to1.68)	1.25 (0.98 to1.59)	1.26 (0.97 to1.63)	1.23 (0.97 to1.56)	1.23 (0.98 to1.54)
Skilled workers	1.21 (0.95 to1.53)	1.13 (0.88 to1.45)	1.16 (0.89 to1.51)	1.11 (0.86 to1.42)	1.13 (0.89 to1.44)
Unskilled workers	1.55 (1.24 to1.93)	1.42 (1.12 to1.81)	1.42 (1.10 to1.84)	1.40 (1.11 to1.78)	1.32 (1.05 to1.66)

*Adjusted for cohort of investigation, age, cohabitation, and sex, as described in the text. †Adjusted for cohort of investigation, age, cohabitation, tobacco, alcohol, physical activity, body mass index, systolic blood pressure, cholesterol, and sex, as described in the text.

proportion of skilled workers are heavy smokers and drinkers compared with the unskilled workers.

Initial analyses of the association between GHI, II, and EI and risk of MI (table 2) show a clear income gradient in the risk of MI. The gradient is slightly steeper for II compared with GHI. EI showed a ''reversed J shape'' effect with highest HR for the third income group compared with the highest. When occupational group is included in the simple model, the estimates are attenuated, but significance remains only for the third EI group. Occupational groups explain 40% of the increased risk among GHI low income groups. After adjustment for all risk factors, the income gradient almost disappears. However, it remained significant for the third EI group.

Initial analyses of the association between occupational groups and risk of MI, adjusted for sociodemographic confounders (table 3) show a social gradient in the risk of MI. When income is included in the model, the estimates remain significant only for unskilled workers. The mediating effect of income is independent of the method of measuring income, and is similar in strength for all three measures of income. Adjusting for GHI reduced the HR of unskilled workers to 1.42 (95% CI 1.12 to1.81). Therefore in this group, adjustment mediated 24% of the increased risk. The explained fraction when cardiovascular risk factors, but not income, were included in the model was 42%. When cardiovascular risk factors and GHI were simultaneously included in the model, the HR for unskilled workers compared with executive managers was reduced to 1.28 (95% CI 1.00 to1.63 (results not shown).

DISCUSSION
This study shows that there is an effect of income on incident MI. The gradient in the risk of MI differs for EI compared with gross incomes. The effect is much weaker after adjustment for occupational grade. A small part of occupational differences in the risk of MI is mediated by income. Furthermore, the study shows that the mediating effect of income is independent of the choice of an income indicator in a Danish context.

Key points

- The production of social inequality in MI depends on interrelations among various socioeconomic indicators.
- There is no single ''best'' socioeconomic indicator.
- Parts of the effects of each socioeconomic indicator can either be explained by or mediated through other socioeconomic indicators.
- The mediating effect of income is independent of the choice of income indicator.

Policy implications

Low income inequalities seem to diminish the effect of income on the risk of MI.

Choice of income indicator
Mixed results regarding the strength and shape of the association between income and health are usually attributed to studies being incomparable because of the use of different income indicators as well as broad end points such as SRH.[6 11 13 28] Our study shows that the association between income and MI is similar in direction and strength, independent of the income indicator used except for the lowest quartile of EI. Compared with those in the third quartile of EI, those in the fourth have a lower risk of MI. This result is similar to findings in other studies.[6 13 28] There are, however, potential biases that may generate this result. One explanation could be if these people have a higher income than reported in the registers. This result is potentially sensitive to how EI is calculated. One assumption of calculating EI is that children cost less than that of adults and this remains similar throughout childhood and adolescence. A second possibility is that the benefits of a large household are underestimated. To account for this we attempted to give each person in the household the same value (1). This lowered the income and attenuated the results, but the shape of the relation remained the same (results not shown). A third assumption is that the equivalent factor is similar for all levels of income, which is unlikely and difficult to account for.[12] This discussion questions the advantage of using EI rather than GHI and emphasises that theoretical considerations should guide the selection of an indicator.[10] The fact that income, independent of the measurement used, mediates only part of the occupational difference does not support that purchasing power is more important than hierarchical ranking or vice versa. Rather it emphasises the necessity of exploring processes between occupational grade, income, and MI that are not related to basic consumption. These include neomaterial conditions such as negative exposures and lack of individual ressources, psychosocial processes, social participation, relative deprivation besides those related to hierarchical ranking in the social structure.[29 30]

Small income inequalities
The effect of income depends both on the exposure contrast generated by the income inequality and on the role of potential effect modifiers protecting against the effects of income. These include welfare policies aimed at reducing the duration of poverty, adverse housing conditions, poor nutrition, etc, linked to low income. A study comparing

income related SRH in nine industrialised countries found a fairly clear correlation ($r = -0.87$) between the ill health concentration index and the Gini coefficient.[7] Figures from The OECD show, that Denmark, with a Gini coefficient around 22 in the 1990s was the country with the smallest income inequality. In our study, income mediates only a small part of the occupational difference. This may be because of a low Gini coefficient, but it is also dependent on the cut off point used to define income groups.[31]

Confounders/mediators

Information on occupation and income was collected at the same point in time, which makes it possible to show in table 2, that if including occupation in the model, at least part of the effect of income is confounded by occupation. As illustrated in figure 1, we assume that income is on the causal pathway from occupation to MI. Table 3 shows the proportion of the effect mediated by income is similar for all three measures of income. However, the mediated proportion is smaller than in other studies,[8 15] which may be explained by the small wage range in Denmark and the moderating effect of its welfare state. For most of the cohorts, information on cardiovascular risk factors, which seems to be related to social position and also to be a cause of MI, was collected earlier in time than information on occupation and income, and may therefore primarily be seen as confounders. However, these covariates tend to track over the life course and thus may also work as mediators. If cardiovascular risk factors are treated as causal intermediates between income and MI adjusted for occupation, then table 2 shows that a large part of the income difference disappears except for EI group 3. The explained fraction when cardiovascular risk factors, but not occupation, were included in the model was similar to the proportion explained by occupation (data not shown).

Income measured only once

A potential limitation of our study design is that income was measured only at one point in time. To fully understand the impact of income, it may be important to account for income dynamics.[32] Long term poverty may have a different impact on health than short term poverty. A British cross sectional study found that long term income is more important for health than current income, and that income levels are more important than income change.[33] Lifetime salaries are more equal than salaries for a single year,[33] which means that we may underestimate the effects attributable to non-differential misclassification. About 3.6% of the Danish population remains in poverty (defined as being below 70% of the median income) as assessed by life incomes.[34] Additionally, income inequality may differ during follow up. However, recent data show that the relative difference between occupational social groups was stable during the study period.[35]

Only employees

The study includes employees, excluding those without employment, self employed, and employers. This may reduce the range of contrast in the study. However, it needs to be considered that income information from the excluded groups may be less reliable. Strengths of this study is that we used valid register based information and a well defined end point.

Conclusion

This study, using register based information on income as well as valid MI incidence, shows that both occupation and different income measures have an effect on the risk of MI. The effect of occupation is at least partly mediated by income.

The study confirms other results that have shown that income is not a big contributor to inequality in health in Denmark. This is probably attributable to the rather even distribution of income in Denmark.

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THE *JECH* GALLERY ....

The words of the prophets

Public health professionals are increasingly engaged in evaluating knowledge and attitudes about health among populations and a variety of validated qualitative and quantitative methods are in use.

Graffiti—whether on subway walls, tenement halls, or on a bus shelter in Glasgow, UK (picture)—may also provide useful insights into public health concerns. ''DON'T WORRY ABOUT FAT. ADDITAVES (sic) ARE THE REAL ENEMY'' reflects how fears about new food technologies may be of greater concern than conventional public health nutritional priorities.

(The empty sand-timer is an advertisement that social benefits books are being withdrawn).

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