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ORIGINAL ARTICLE

Health inequalities in terms of myocardial infarction and all-cause mortality: a study with German claims data covering 2006 to 2015

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Abstract

Objectives International comparisons are suggesting that mortality inequalities may have changed in the last years, although not always into the same direction. Only a few studies examined myocardial infarction (MI). In our study, long-term developments of MI and all-cause mortality were considered by analysing social gradients by income.

Methods German claims data covering 2006 to 2015 (N = 2,474,448) were used with myocardial infarction and all-cause mortality as outcomes. Socio-economic position was depicted by individual income. Health inequalities were measured by hazard ratios between and within income groups for 10 consecutive calendar years.

Results In men, income gradients of MI and all-cause mortality were decreasing. In women, no income gradients emerged for MI, and they disappeared in mortality. In men, hazard ratios of MI and mortality decreased in the intermediate and in the lowest income thirds, thus leading to a reduction of MI-related health inequalities.

Conclusions Income inequalities in terms of myocardial infarction and of mortality have narrowed in men, and those in the lowest income third were profiting most. No such changes were observed in women.

Keywords Social inequality · Health inequalities · Long-term trends · Myocardial infarction · Income · Claims data

Introduction

Social inequalities in health were reported for a multitude of disease-related outcomes (Dalstra et al. 2005) and for mortality (Mackenbach et al. 2015). Most morbidity studies were conducted with subjective health as outcome, and the designs were mostly cross-sectional (Kunst et al. 2005). Research on specific diseases is rare, and this applies also to myocardial infarction (MI) as one of the most frequently occurring diseases. Due to the shortage of longitudinal data, only a few studies on the development of social gradients over time were published. They were conducted in different countries, in different time periods and under different economic frame conditions. A study from Scotland used area-based measures of socio-economic position. Against the backdrop of decreasing MI-incidences, increasing relative inequalities were reported for the years 1990 to 1992 and 2000 to 2002 (Davies et al. 2009). For the 1970s and for the 1980s, MI-risks increased in Swedish men in intermediate and higher occupational positions, while in manual positions this development started in 1981. In women in manual positions, an unfavourable development of increasing MI-risks continued also in the subsequent years (Hallqvist et al. 1998). A Finnish study covered 1993 to 2002 as observation period. MI-incidence and mortality rates decreased over time, but social gradients persisted, whatever indicator of social position was used (Lammintausta et al. 2012). A Norwegian study examined the development of MI-rates from 2001 to 2009 and reported decreasing educational inequalities in terms of absolute numbers, while relative inequalities remained unchanged (Igland et al. 2014). For Germany, not many findings are available. MI-rates were reported to have declined over the last decades (Dégano et al. 2015;

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Freisinger et al. 2014; Herzstiftung 2018), but the available German studies on social inequalities in the occurrence of MI are cross-sectional (Geyer et al. 2006; Helmert et al. 1993) and unavailable for the recent years.

More evidence on mortality than on MI is available. A study summarizing findings from Scandinavian countries and an Italian region reported increasing relative inequalities in terms of education for 1981 to 1985 and 1991 to 1995 (Mackenbach et al. 2003). For the UK, the gap in life expectancy between the highest and the lowest status groups was widening between 1982 and 2006 (Bleich et al. 2012). A Finnish study with income as indicator of socio-economic status reported evidence for increasing mortality gradients in men and in women for the years 1988 to 2007 (Tarkiainen et al. 2013). The availability of census data covering 1991 to 2001 made it possible to examine mortalities for Belgium. Absolute mortality differentials in terms of educational level decreased in men while they were rising in women, while relative inequalities increased in women as well as in men (Renard et al. 2017). A registry-based study compared mortality inequalities by education for 11 European countries. Social inequalities increased with the exception of women from England and Wales and for males in France, although not in all cases findings were statistically significant (Mackenbach et al. 2016). Another cross-national study comparing 13 countries for the years 1990 to 2006 reported evidence for increasing social inequalities in terms of all-cause mortality except for Southern Europe. For specific causes of death, higher rates were reported in individuals with lower education. The authors concluded that social gradients may have widened, but recent developments were rather pointing towards decreasing health inequalities (Mackenbach et al. 2015). In both comparative studies, no data on the long-term development of social inequalities for Germany were presented.

Taken together, available evidence on the long-term development of social gradients is not consistent. Conclusions are hampered by the small number of studies, by their origin from different countries and by the coverage of different time periods. For Germany, corresponding evidence is rare or unavailable, and this refers both to MI-morbidity as well as to mortality.

In the following analyses, the development of social gradients in terms of income will be examined by using MI and all-cause mortality as endpoints. The analyses will be performed along the following lines:

- In the first line, income gradients between the two most remote years of observation will be examined by using individual income as indicator of socio-economic position.
- In the second line, changes of rates within different income groups over a period of ten years will be considered.

Method

The analyses were based on claims data of a large German statutory health insurance, the Allgemeine Ortskrankenkasse Niedersachsen (AOKN—General Local Health Insurance of Lower Saxony) covering the years 2005 to 2015 and for individuals aged at least 18 years. As pre-observation periods were allowed for, the analyses will be based on the years 2006 to 2015.

Statutory health insurances are operating under public law, and health care plans are defined by nationwide regulations. General Local Health Insurances have the highest share of the statutory health insurances in Germany (Hoffmann and Koller 2017). Health insurance coverage is compulsory for all residents, and in 2011 only 0.2% were uninsured (Bundesamt 2016). Below a certain income level, insurance with the statutory system is obligatory, in 2011 86% of all employed women and men were covered, and family members are insured free of charge.

Myocardial infarction (MI) records are based on hospital diagnoses according to ICD10. In our study, cases were classified as first myocardial infarctions if one of the diagnoses ICD-10: I21.0 to I21.9 was assigned, cases of recurrent and old myocardial infarctions (ICD-10: I22 and I25.2) were excluded. Nevertheless, some may have been misclassified as first events. Risks of MI-recurrence were reported to be highest in the year following the first event and decreasing in the subsequent years (Davidsen et al. 2001; Smolina et al. 2012). In order to reduce the likelihood of misclassifications, a pre-observation period of one year was allowed for. It was counted from the beginning of individual observation periods on, thus leading to a shortening of individual observation times of 365 days. Based on earlier evidence, it was assumed that longer pre-observation periods may not be required (Osler et al. 1999). Nevertheless, supplementary analyses with pre-observation periods of 2–4 years were performed in order to avoid erroneous conclusions on the development of MI-rates over time (see supplementary document 1). In case of misclassifications of MIs being present, a significant drop of hazard ratios should take place from the first year of observation to the next.

Mortality was depicted with date of death as it terminates insurance membership.

Income was available on the basis of individual wages as they are the basis for calculating insurance premiums. An earlier comparative study has shown that individual income

and household incomes were producing health gradients, and that none of these measures was inferior to others (Geyer 2011). The income distribution of the AOKN does not correspond to nationwide figures. In order to adjust the claims data to the German income structure, incomes were classified according to the nationwide averages as published by the German Statistical Office. Women and men were classified into the lowest group if the pre-tax annual income was lower than 40% of the average annual national income level (e.g. for 2013 this corresponds to < 12,000€). Individuals were classified into the highest group if incomes were above 80% of the national average income (e.g. corresponding to > 24,000€ in 2013), and individuals were classified into the intermediate group if their incomes were classified between these two limits (Epping et al. 2017; Tetzlaff et al. 2018).

Statistics All analyses were performed by means of Cox proportional hazards regression. It permits to take different observation times, censoring and covariates into account. In the first line of analysis, health inequalities between income groups for the first and last year of observation were considered. The second line of analysis was performed for each income category separately by using calendar year as covariate, thus permitting to estimate changes of morbidity and mortality from the year of reference to the subsequent ones. This procedure was chosen for obtaining information on whether changes were occurring gradually, whether they were proceeding regularly or irregularly over time. Our research questions were directed towards population-related changes over time, not towards intra-individual variations. Thus, incidence rates will be compared by subgroups for each year of observation. Age and type of insurance (main insured, unemployed, family insured, retired) had to be controlled for because the social structure of the insurance population may vary over time and have effects on morbidity and mortality. As analyses of relative inequalities with its emphasis on odds ratios or relative risks are leaving numeric quantities unconsidered, a second line of analysis was directed towards absolute inequalities. Event (MIs and mortality) occurrences were considered as referred to 100,000 individuals. The study population was divided into three income groups for ages under 55/55 to 70, and over 70 years. The corresponding figures are displayed as online supplement 2. The ratios between prevalent cases were used to calculate a regression line and a number that is to be interpreted as mean annual change over the observation period. Negative changes are indicating decreasing, and positive changes are indicating increasing income inequalities. All analyses were performed with Stata 14MP (Stata_Corp. 2015).

Results

The basic distributions are displayed in Table 1. Mean ages were calculated after adjustment for the sizes of age cohorts. The corresponding median age at MI-onset over the whole observation period was Md = 66.5 (Sd = 13.3; M = 66.5) years in men and Md = 75.8 (Sd = 12.2; M = 75.8) years in women. The median age at death was Md = 75.6 (Sd = 13.0; M = 73.0) years for men and Md = 83.5 (Sd = 11.8; M = 81.4) years for women. Gradients of the following analyses have to be interpreted against the backdrop of high average age at occurrence of myocardial infarction and at death, in particular in women. Comparisons of MI-rates with the whole study population over different observation periods did not yield significant hazard ratios between the reference years and the following ones. Table 1 reveals that for a substantial proportion of the insured income information was unavailable. In men, the proportions were ranging between 31.6 and 36.8% (depending on year of observation), and in women they were ranging between 35.5 and 39.8%. Differentiating the "missing-"group by type of insurance reveals that this applies to family insured, unemployed and in part to main insured individuals. The latter group was consisting of women and men with very low incomes, and of self-employed.

Income gradients

In men, income gradients were calculated for 2006 and for 2015 (Table 2). In both cases, income inequalities were decreasing over the observation period, i.e. for 2006 the hazard ratios (HR) of the lowest as compared to the highest income group was HR = 1.53 and HR = 1.33 for 2015. A similar pattern emerged for mortality, where the respective hazard ratio was HR = 1.90 for 2006 and 1.78 for 2015. In women, for myocardial infarction income gradients were absent for both calendar years. For mortality, the hazard ratio (HR = 1.26) was statistically significant for 2006. For 2015, the income differences were decreasing to a low level (HR = 1.08), although still being statistically significant. The analyses of hazard ratios without differentiating by income revealed that different pre-observation periods did not lead to marked declines of hazard ratios between the years of reference and the following ones (supplementary online document 1).

MI-rates over time by income category

In men of the upper income third, MI-rates were decreasing over time (Table 3), but these changes were inconsistent, and confidence intervals were large, suggesting that MI-

Table 1 Basic distributions of income levels, deaths and myocardial infarctions for the years 2006 to 2015, German data

		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Men	Income level										
	Highest	226,913	225,729	222,345	222,144	222,032	230,506	236,539	236,181	236,355	252,072
		(26.4%)	(26.3%)	(26.3%)	(26.3%)	(26.1%)	(26.6%)	(27.0%)	(26.8%)	(26.8%)	(28.3%)
	Intermediate	235,796	237,676	239,771	234,175	236,159	246,030	249,706	248,771	249,429	250,988
		(27.4%)	(27.7%)	(28.3%)	(27.8%)	(27.8%)	(28.4%)	(28.5%)	(28.2%)	(28.3%)	(28.2%)
	Lowest	82,271	86,946	92,100 (10.9%)	89,982 (10.7%)	93,457	100,692	106,589	109,979	112,201	106,573
		(9.6%)	(10.1%)			(11.0%)	(11.6%)	(12.2%)	(12.5%)	(12.7%)	(12.0%)
	Unclassified	316,333	308,093	292,614	297,395	299,244	288,522	282,816	286,489	284,764	282,120
		(36.7%)	(35.9%)	(34.6%)	(35.3%)	(35.2%)	(33.3%)	(32.3%)	(32.5%)	(32.3%)	(31.6%)
	N	861,313	858,444	836,830	843,696	850,892	865,750	875,650	881,420	882,764	891,753
	Deaths, *N* (%)	14,552	14,159	14,428	14,516	14,347	14.332	14,531	15,120	14,720	15,186
		(1.65%)	(1.65%)	(1.70%)	(1.72%)	(1.69%)	(1.66%)	(1.66%)	(1.72%)	(1.67%)	(1.70)
	Myocardial inf.; *N*/%	3492	3610	3621	3507	3487	3524	3615	3565	3511	3413
		(0.41%)	(0.42%)	(0.43%)	(0.42%)	(0.41%)	(0.41%)	(0.41%)	(0.40%)	(0.40%)	(0.38%)
	Age at death	73.3/13.4	73.1/13.5	73.5/13.2	73.7/13.3	73.9/13.1	74.1/13.2	74.5/12.9	74.8/12.9	74.8/13.0	75.0/13.1
	Age at MI	67.3/12.9	67.1/12.8	67.3/12.9	67.4/13.3	67.1/13.0	67.6/13.2	67.5/13.3	67.3/13.2	67.1/13.4	66.6/13.2
Women	Income level										
	Highest	70,638	68,259	68,285	73,776	75,243	77,460	79,844	80,470	83,615	94,266
		(7.1%)	(6,9%)	(7.4%)	(7.7%)	(7.8%)	(8.0%)	(8.2%)	(8.3%)	(8.6%)	(9.7%)
	Intermediate	242,255	238,446	235,366	238,679	239,631	243,592	246,079	246,330	250,573	266.835
		(24.3%)	(24.2%)	(24.3%)	(24.9%)	(24.9%)	(25.1%)	(25.2%)	(25.3%)	(25.8%)	(27.4%)
	Lowest	288,164	287,336	289,409	278,823	279,465	287,530	291,876	292,225	283,415	267,681
		(28,9%)	(29.2%)	(29.9%)	(29.0%)	(29.1%)	(29.6%)	(29.9%)	(30.0%)	(29.2%)	(27.5%)
	Unclassified	395,498	392,788	376,497	368,798	366,771	362,555	358,257	356,025	353,484	345,286
		(39.7%)	(39.8%)	(38.8%)	(38.4%)	(38.2%)	(37.3%)	(36.7%)	(36.5%)	(36.4%)	(35.5%)
	N	996,555	987,329	969,557	960,076	961.110	971,137	976,096	975,050	971,087	974,068
	Deaths, *N* (%)	18.553	18,346	18,622	18,473	18,401	17.582	17,932	18,848	17,384	18,437
		(1.86%)	(1.86%)	(1.92%)	(1.92%)	(1.91%)	(1.81%)	(1.84%)	(1.89%)	(1.79%)	(1.89%)
	Myocardial inf.; *N*/%	2635	2618	2542	2459	2405	2486	2513	2324	2250	2167
		(0.26%)	(0.27%)	(0.26%)	(0.26%)	(0.25%)	(0.26%)	(0.26%)	(0.24%)	(0.23%)	(0.22%)
	Age at death	82.1/11.7	82.2/11.9	82.4/11.8	82.3/11.8	82.4/11.8	82.3/11.7	82.5/11.6	82.5/11.8	82.4/11.8	82.9/11.5
	Age at MI	76.1/11,8	76.4/11.8	76.4/11.5	76.8/12.2	76.4/12.3	75.9/12.5	75.7/12.5	76.3/12.3	75.6/12.5	76.0/12.4
Men and women, *N*		1,857,868	1,845,773	1,806,387	1.803,772	1,812,002	1,836,887	1,851,746	1,856,470	1,853,507	1,865,821

MI myocardial infarction, *Incomes* "Lowest income level": Individual pre-tax incomes lower than 40% of the average national income level; "Intermediate income level": Individual pre-tax incomes between 40 and 80% of the average national income level; "Highest income level": Individual pre-tax incomes higher than 80% of the average national income level; "unclassified": Income information unavailable

Table 2 Myocardial infarctions in women and in men by income level after controlling for type of insurance and age as estimated by Cox proportional hazards regression, (2006–2015; German data)

		Myocardial infarction			Mortality		
		HR	95% CI	*p*	HR	95% CI	*p*
Men							
2006	Income levels						
	Highest	Ref.	–	–	Ref.	–	–
	Intermediate	1.32	1.17–1.49	< 0.001	1.43	1.34–1.52	< 0.001
	Lowest	1.53	1.33–1.75	< 0.001	1.90	1.77–2.04	< 0.001
	Unclassified	1.11	0.94–1.31	0.22	0.60	0.52–0.71	< 0.001
2015	Income levels						
	Highest	Ref.			Ref.	–	–
	Intermediate	1.28	1.13–1.44	< 0.001	1.31	1.22–1.40	< 0.001
	Lowest	1.33	1.16–1.52	< 0.001	1.78	1.65–1.91	< 0.001
	Unclassified	1.26	1.08–1.48	0.003	0.24	0.19–0.30	< 0.001
Women							
2006	Income levels						
	Highest	Ref.	–	–	Ref.	–	–
	Intermediate	1.20	0.98–1.47	0.08	1.21	1.12–1.31	< 0.001
	Lowest	1.11	0.90–1.36	0.33	1.26	1.16–1.36	< 0.001
	Unclassified	1.11	0.78–1.59	0.57	2.87	0.88–1.26	0.58
2015	Income levels						
	Highest	Ref.	–	–	Ref.	–	–
	Intermediate	1.11	0.90–1.36	0.33	1.09	1.02–1.17	0.01
	Lowest	1.01	0.82–1.23	0.95	1.08	1.01–1.16	0.03
	Unclassified	1.12	0.79–1.57	0.53	0.25	0.19–0.33	< 0.001

Incomes "Lowest income level": Individual pre-tax incomes lower than 40% of the average national income level; "Intermediate income level": Individual pre-tax incomes between 40 and 80% of the average national income level; "Highest income level": Individual pre-tax incomes higher than 80% of the average national income level; "unclassified": Income information unavailable

rates remained rather constant over time. The same holds for mortality that remained unchanged over 10 years. In the intermediate third, the decreases of rates were continuous, more consistent and statistically significant from 2011 on, reaching HR = 0.58 in 2015. In comparison, changes of age-adjusted mortalities were smaller (HR = 0.79) and statistically significant only for 2014 and 2015. For the lowest third of the income distribution, rates were also decreasing, reaching HR = 0.57 in 2015. For the last year of observation, the hazard ratio was HR = 0.42. Mortality rates also were moving downwardly, reaching HR = 1.29 for 2015. For unclassified men, rates remained unchanged over the observation period, while mortalities were decreasing down to HR = 0.71 for the last year of observation. In women, MI-rates remained unchanged at all income levels including the group of unclassified individuals (Table 4). Mortality rates were not varying in the upper third of the income distribution. At the intermediate income level, age-adjusted mortality rates were increasing, and changes were consistently moving into the same direction reaching HR = 1.29 for 2015. In the lowest income third, no changes occurred over time, and in the unclassified mortality rates decreased, reaching HR = 0.52 for 2015. It has to be noted that the mean age at death and at the end of the observation period in this group was lower than in the women with classified incomes.

Changes of rates over time

Changes of rates by income for myocardial infarction and mortality are displayed in detail in supplementary online document 2. These findings are presented in order to clarify the numeric background of the main results. A summary of changes of income inequalities is displayed in Table 5.

For the case of myocardial infarction, income inequalities in men were narrowing over the observation period. This was mainly due to changes within the age group 55–69 years where absolute inequality decreased by 4% per year. Apart from the change between the highest and the lowest third of the income distribution, the differences between the intermediate and the highest income third were narrowing thus leading to increasing differences between

Table 3 Myocardial infarctions and mortality in men by income levels after controlling for type of insurance and age (2006–2015; German data)

Income			Myocardial infarction			Mortality		
			HR	95% CI	*p*	HR	95% CI	*p*
Highest	Year	2006	Ref.	–	–	Ref.	–	–
		2007	0.98	0.66–1.45	0.91	1.05	0.77–1.44	0.76
		2008	1.14	0.77–1.68	0.52	0.89	0.68–1.21	0.46
		2009	1.07	0.73–1.58	0.72	1.00	0.73–1.38	0.73
		2010	0.96	0.65–1.40	0.82	0.97	0.71–1.32	0.86
		2011	0.98	0.68–1.41	0.92	1.16	0.87–1.56	0.31
		2012	0.90	0.62–1.30	0.58	0.96	0.71–1.29	0.77
		2013	0.87	0.60–1.26	0.47	0.68	0.49–0.93	0.02
		2014	0.97	0.67–1.40	0.87	0.81	0.59–1.11	0.19
		2015	0.78	0.53–1.14	0.20	0.95	0.71–1.28	0.74
Intermediate	Year	2006	Ref.	–	–	Ref.	–	–
		2007	1.14	0.85–1.54	0.37	0.93	0.79–1.10	0.40
		2008	0.82	0.62–1.10	0.19	0.87	0.75–1.02	0.10
		2009	0.79	0.59–1.06	0.12	0.94	0.80–1.11	0.47
		2010	0.78	0.58–1.05	0.08	0.90	0.76–1.06	0.20
		2011	0.77	0.58–1.03	0.01	0.92	0.79–1.08	0.32
		2012	0.68	0.51–0.89	< 0.001	0.83	0.71–0.97	0.02
		2013	0.52	0.38–0.69	< 0.001	0.90	0.77–1.05	0.19
		2014	0.54	0.41–0.72	< 0.001	0.80	0.68–0.94	0.01
		2015	0.58	0.44–0.78	< 0.001	0.79	0.67–0.93	0.01
Lowest	Year	2006	Ref.	–	–	Ref.	–	–
		2007	0.75	0.52–1.09	0.13	0.92	0.78–1.10	0.38
		2008	0.68	0.48–0.98	0.04	0.80	0.68–0.95	0.01
		2009	0.46	0.32–0.66	< 0.001	0.81	0.69–0.97	0.02
		2010	0.53	0.37–0.77	< 0.001	0.79	0.66–0.94	0.01
		2011	0.54	0.37–0.77	< 0.001	0.75	0.63–0.89	0.001
		2012	0.54	0.37–0.77	< 0.001	0.64	0.54–0.76	< 0.001
		2013	0.59	0.42–0.85	< 0.001	0.62	0.52–0.74	< 0.001
		2014	0.43	0.30–0.62	< 0.001	0.60	0.51–0.72	< 0.001
		2015	0.42	0.28–0.61	< 0.001	0.57	0.48–0.69	< 0.001
Unclassified	Year	2006	Ref.	–	–	Ref.	–	–
		2007	1.15	0.94–1.42	0.18	0.86	0.74–1.00	0.06
		2008	1.21	0.98–1.50	0.08	0.77	0.66–0.90	0.001
		2009	1.10	0.89–1.36	0.37	0.82	0.70–0.96	0.01
		2010	1.08	0.88–1.34	0.47	0.81	0.69–0.95	0.01
		2011	1.05	0.84–1.30	0.65	0.75	0.64–0.88	< 0.001
		2012	0.96	0.77–1.19	0.71	0.69	0.59–0.81	< 0.001
		2013	1.05	0.85–1.30	0.62	0.80	0.68–0.93	< 0.001
		2014	0.88	0.71–1.10	0.26	0.64	0.55–0.75	< 0.001
		2015	0.90	0.72–1.13	0.37	0.71	0.61–0.83	< 0.001

Incomes "Lowest income level": Individual pre-tax incomes lower than 40% of the average national income level; "Intermediate income level": Individual pre-tax incomes between 40 and 80% of the average national income level; "Highest income level": Individual pre-tax incomes higher than 80% of the average national income level; "unclassified": Income information unavailable

the lowest and the intermediate third. For women, the situation is unclear as small case numbers did not permit substantive interpretations. Only a small increase of 2% per year emerged in the age group of 70 years of age and older.

Inequalities in terms of deaths of men were decreasing between the highest and the lowest third of the income distribution for the under 55-year-olds (− 9% per year) and − 7% per year for the 55- to 69-year-olds. In the same age

Table 4 Myocardial infarctions and mortality in *women* by income levels after controlling for type of insurance and age (2006–2015; German data)

Income			Myocardial infarction			Mortality		
			HR	95% CI	*p*	HR	95% CI	*p*
Highest	Year	2006	Ref.	–	–	Ref.	–	–
		2007	1.39	0.44–4.39	0.57	0.76	0.46–1.26	0.28
		2008	0.92	0.30–2.81	0.88	0.76	0.45–1.27	0.29
		2009	2.12	0.70–6.39	1.18	0.68	0.40–1.13	0.13
		2010	0.96	0.29–3.20	0.95	0.99	0.59–1.69	0.89
		2011	1.01	0.33–3.06	0.98	0.88	0.52–1.48	0.63
		2012	0.70	0.23–2.19	0.54	0.88	0.54–1.44	0.62
		2013	0.47	0.13–1.62	0.23	0.65	0.39–1.09	0.10
		2014	0.29	0.08–1.14	0.08	0.78	0.47–1.31	0.35
		2015	0.53	0.12–1.47	0.18	0.79	0.48–1.31	0.37
Intermediate	Year	2006	Ref.	–	–	Ref.	–	–
		2007	1.05	0.68–1.61	0.81	1.09	0.93–1.28	0.27
		2008	0.95	0.62–1.44	0.80	1.06	0.90–1.23	0.50
		2009	1.05	0.68–1.61	0.82	1.17	0.99–1.37	0.06
		2010	1.02	0.65–1.58	0.94	1.39	1.18–1.64	< 0.001
		2011	0.93	0.61–1.43	0.75	1.07	0.91–1.26	0.42
		2012	1.04	0.69–1.55	0.87	1.11	0.96–1.31	0.16
		2013	0.73	0.48–1.13	0.16	1.33	1.13–1.54	< 0.001
		2014	0.78	0.50–1.22	0.28	1.32	1.13–1.64	0.001
		2015	0.92	0.60–1.40	0.70	1.29	1.10–1.52	0.002
Lowest	Year	2006	Ref.	–	–	Ref.	–	–
		2007	0.91	0.60–1.37	0.65	0.99	0.84–1.15	0.87
		2008	0.80	0.54–1.20	0.28	1.04	0.89–1.22	0.63
		2009	0.78	0.51–1.15	0.21	1.25	1.07–1.48	0.01
		2010	0.73	0.49–1.11	0.14	1.22	1.04–1.44	0.01
		2011	0.74	0.49–1.11	0.14	0.98	0.84–1.15	0.81
		2012	0.74	0.51–1.10	0.14	0.97	0.83–1.13	0.72
		2013	0.57	0.38–0.85	0.01	1.08	0.93–1.26	0.32
		2014	0.84	0.57–1.24	0.38	1.03	0.88–1.21	0.69
		2015	0.88	0.59–1.30	0.52	1.07	0.91–1.26	0.40
Unclassified	Year	2006	Ref.	–	–	Ref.	–	–
		2007	1.05	0.71–1.54	0.81	0.71	0.57–0.89	0.003
		2008	0.92	0.62–1.35	0.66	0.67	0.54–0.84	< 0.001
		2009	1.03	0.69–1.52	0.90	0.68	0.54–0.85	0.001
		2010	0.92	0.62–1.35	0.66	0.62	0.49–0.77	< 0.001
		2011	0.92	0.62–1.35	0.67	0.57	0.46–0.72	< 0.001
		2012	0.89	0.61–1.32	0.57	0.52	0.42–0.66	< 0.001
		2013	0.90	0.61–1.32	0.58	0.53	0.42–0.65	< 0.001
		2014	0.86	0.58–1.27	0.45	0.59	0.47–0.74	< 0.001
		2015	0.58	0.38–0.89	0.01	0.52	0.41–0.65	< 0.001

Incomes "Lowest income level": Individual pre-tax incomes lower than 40% of the average national income level; "Intermediate income level": Individual pre-tax incomes between 40 and 80% of the average national income level; "Highest income level": Individual pre-tax incomes higher than 80% of the average national income level; "unclassified": Income information unavailable

groups, marked changes occurred between the intermediate and the highest income third, thus leading to narrowing inequalities and to increasing inequalities between the intermediate and the lowest incomes. In women, the numbers at the extreme ends of the income distribution were inconsistent, while changes between the intermediate

Table 5 Annual changes of absolute inequalities of myocardial infarction and mortality by income levels for women and men (2006–2015; German data)

	Men			Women		
	< 55 years	55–69 years	≥ 70 years	< 55 years	55–69 years	≥ 70 years
Myocardial infarction						
Low–high	− 0.01	− 0.04	+ 0.01	*	*	+ 0.02
Interm.–high	− 0.03	− 0.05	± 0.0	*	*	+ 0.02
Low–interm.	+ 0.01	+ 0.01	+ 0.01	*	± 0.00	± 0.00
Death						
Low–high	− 0.09	− 0.07	+ 0.01	*	+ 0.09	− 0.02
Interm.–high	− 0.16	− 0.20	+ 0.02	− 0.08	− 0.06	− 0.01
Low–interm.	+ 0.21	+ 0.07	+ 0.02	− 0.04	+ 0.08	− 0.02

Incomes "Lowest income level": Individual pre-tax incomes lower than 40% of the average national income level; "Intermediate income level": Individual pre-tax incomes between 40 and 80% of the average national income level; "Highest income level": Individual pre-tax incomes higher than 80% of the average national income level. "unclassified": Income information unavailable

*Categories where results should not be interpreted. The developments of events over time are unsteady due to small absolute case numbers in the exposed population as well as in terms of MI and death events

and the upper and lower income categories were pointing towards decreasing differences in the age groups below 55 years. Inconsistent changes emerged in 55- to 69-year-old women, and changes in females aged 70 years and older were pointing towards lowering income inequalities.

Discussion

In males, income gradients emerged over the whole observation period. Against the backdrop of persisting gradients, the hazard ratios of MI-rates by income turned out as heterogeneous: While in the highest income group no changes were found, in the intermediate and in the lowest third of the income distribution hazard rates were decreasing, although not always being statistically significant. In unclassified men, no such changes occurred. These findings are pointing towards a narrowing of income gradients in MI, and this was fuelled by changes in the intermediate and in the lowest income groups. Research has shown that health-related lifestyle patterns may be held responsible for variations of MI. In order to explain our findings, changes of health behaviours should have taken place in the same way as found in our data. As in other high-income countries, the rate of smokers in Germany has decreased over the years (Huxley and Woodward 2011; Kuntz and Lampert 2014), and social gradients were reported in all available studies (Pötschke-Langer et al. 2015). Unfortunately, the available evidence on social gradients of smoking behaviour in Germany was derived from cross-sectional studies. Thus, it has to be discussed whether the pace of changes of health-related behaviour differs by socio-economic position, or whether in the highest third of the income distribution a ceiling effect had occurred. In the same way, no longitudinal survey data on exercise and on nutrition are available.

In women, MI-associated income inequalities were absent, and the rate ratios did not change over the observation period. This has to be interpreted against the backdrop of lower incidence rates than in men and a higher mean onset age (M = 9.3 years) in women. It will have to be considered whether further decreases of rates may be possible and whether competing risks (e.g. stroke) may be present.

Our findings on relative changes are differing from those of other European countries (Davies et al. 2009; Hallqvist et al. 1998; Igland et al. 2014; Lammintausta et al. 2012), but it has to be kept in mind that these findings are based on data collected in the 1990s or earlier, and in the first years after the millennium. This may make figures hardly comparable, apart from the challenges of international comparisons that also have to take national peculiarities of behaviour and economic crises into account.

In men, the patterns of mortality changes were largely following those of MI, but at a lower level. While no changes were found in the highest income group, changes in the intermediate and in the lowest incomes were nearly continuous and statistically significant. In the intermediate group, this applies to the last two years of the observation period, while the most pronounced changes occurred in the lowest income group. Direct comparisons of our findings with earlier studies are hampered by differences of study designs as some of them depicted socio-economic position in terms of education (Mackenbach et al. 2003, 2015; Renard et al. 2017; Silventoinen and Lahelma 2002), others used education and occupational class, (Mackenbach et al.

2016) or education and a poverty measure (Ki et al. 2017). A recent registry-based study reported rising relative inequalities by education for Scandinavian countries, while no changes were found for England/Wales, and for France. In some countries, standardized mortality rates had decreased, in particular in the lowest educational groups (Mackenbach et al. 2016), but the patterns of social gradients were far from coherent. Changes have rather occurred regionally and may be dependent on social and economic developments.

Our analyses were performed separately for women and for men. There is evidence that they are differing with respect to presentation and quality of MI-symptoms. In women, this may lead to misdiagnoses (Bucholz et al. 2014; Ladwig and Waller 2014), but the consequences for the interpretation of our findings are difficult to assess. The presentation of ambiguous symptoms may lead to delay in confirming a correct diagnosis, to an underestimation of MI-rates and higher risks of death, but effects on results may be more relevant if disease courses are studied.

In women, hazard ratios of mortality did not change within the three income groups with the unclassified group being an exception. Against the backdrop of the ongoing discussion on the maximum biological life expectancy in demography (Burger et al. 2012; Dong et al. 2016) and the high mean age at death, for the case of women it may be debatable whether there is space for a further decrease of standardized mortality rates in women. Decreasing hazard ratios of the unclassified group are not a contradiction, but rather an argument in favour of this hypothesis. Their mean age at death or upon censorization was much lower than in the three income groups. This information was available for pensioners, but not for family members, students, or for unemployed individuals.

In contrast to MI, some international studies on long-term developments of social inequalities in terms of all-cause mortality are available. The most recent one (Mackenbach et al. 2016) covered the years 1990 to 2009. Their findings were not consistent over the 11 countries considered, and the authors acknowledged substantial improvements of health and health-related behaviours. This is pointing into the same direction as our findings, although the overlap of observation periods with our study is small.

Our study examined the 10-year development of income inequality in terms of myocardial infarction and all-cause mortality. It was performed with a large dataset from Germany as a country that had seldom been included in international comparisons. It turned out that for a proportion of the insurance population income information was unavailable, and it has to be discussed in which way this may have affected our results. The subgroup with low income can be assumed to have higher morbidity than the whole insurance population, thus leading to an underestimation of the health gradient. In turn, for the self-employed the opposite is true, but the net effect of weighing one group against the other cannot be estimated. Family members or family insured were shown to have slightly higher morbidity levels than main insured women and men, but this applies to all levels of socio-economic position (Muschik et al. 2015). Thus, the morbidity level of the individuals with income information may be underestimated, but the size of the income gradient will remain unaffected. For unemployed as compared to employed individuals, higher morbidity and mortality rates were reported (Geyer and Peter 2003; Lundin et al. 2014; Roelfs et al. 2011). Omitting unemployed may lead to an underestimation of the income gradient and of total morbidity levels.

Our study has several strengths. Our claims data were covering a complete population instead of a sample. In contrast to survey studies, this included also individuals living in institutions or who are not able or willing to respond to survey questions. There is also evidence that the likelihood to participate in surveys is decreasing with decreasing health (Thefeld et al. 1999). Claims data are also unaffected by panel attrition that occurs in longitudinal survey studies (Lugtig et al. 2014; Schnell and Trappmann 2006). Finally, the diagnoses can be considered as complete, and it was shown that MI-diagnoses recorded in routine data can claim a high degree of validity (Madsen et al. 2003). These advantages have to be weighed against some limitations. The socio-economic characteristics of the insurance population correspond to the population of Lower Saxony and of Germany in terms of age and gender. This was not the case for the socio-economic composition as the insurance population was shown to include a higher proportion of individuals with lower occupational qualifications than in Germany as a whole (Jaunzeme et al. 2013). Two more studies on the social structure of health insurance populations reported that the morbidity level of Local Statutory Health Insurances (Allgemeine Ortskrankenkassen—AOK) was higher than of other statutory health insurances. This may primarily be due to different social structural compositions (Hoffmann and Icks 2011; Hoffmann and Koller 2017). Another shortcoming of our data is due to legal regulations. The upper decile of the income distribution is not represented, but it is an open question whether this may have created a source of bias. If present, it may be due to the lowest end of the income distribution with the increment of disease risks becoming smaller as incomes are increasing. From some point of the income distribution on a plateau will be reached where higher incomes are no longer associated with improvements of health (Blakely et al. 2004; Mortensen et al. 2016). It is also unlikely that changes of health inequality were underestimated as morbidity and mortality changes

were absent in the highest third of the income distribution of our insurance population.

In studies on health inequalities, socio-economic position is usually depicted by income, education and occupation, and each indicator has independent effects on outcome measures (Geyer et al. 2006; Tjepkema et al. 2013). In our study, only income was available, because the other two indicators were only recorded for employed women and men. More differentiated findings had been possible if the other two indicators had also been available. The use of household income is more common, but social gradients were emerging with individual as well as with different types of income (Geyer 2011).

As a conclusion, income gradients in terms of myocardial infarction and all-cause mortality have narrowed in men. In women, MI-related income gradients were absent, but for mortality and in a younger subgroup they had declined.

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Compliance with ethical standards

Conflict of interest S. Geyer has received several project fundings from the Allgemeine Ortskrankenkasse Niedersachsen—AOKN (Local Statutory Health Insurance of Lower Saxony, Germany (no funding number assigned), and from the Stiftung Kinderherzen. For the present paper, he received also funding from the Deutsche Forschungsgemeinschaft (DFG) under project number GE1167/15-1. J. Tetzlaff is partly employed in the project this paper is based on; thus, she is indirectly receiving a salary from the AOKN. S. Sperlich No conflict of interest declared. J. Epping No conflict of interest declared. S. Eberhard She is employed by the AOKN.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent Not applicable as the study was conducted with routine data.

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