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ORIGINAL ARTICLE

Individual- and area-level effects on mortality risk in Germany, both East and West, among male Germans aged 65+

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Abstract

Objectives This study investigates whether mortality inequalities based on individual- and area-level deprivation exist at older ages in Germany, and whether there are differences between eastern and western Germany.

Methods Data on population and death counts according to the individual-level socioeconomic status of male German pensioners aged 65+ years in Germany in 2002–2004 were obtained from the German Federal Pension Fund. Area-level characteristics for the 439 German districts were incorporated. Multilevel Poisson models were fitted.

Results Individual-level socioeconomic mortality inequalities exist among elderly men in Germany. After controlling for differential population composition in the districts, we found that district-level factors contribute to the explanation of mortality inequalities in (western) Germany. The analysis further indicated that mortality and mortality inequalities tend to be higher in more economically deprived districts, and that minor mortality differences attributable to regional conditions exist in eastern Germany.

Conclusions The results showed that regional conditions have moderate effects on health inequalities at older ages in (western) Germany, when the differential population composition in the districts is controlled for.

Keywords Mortality · Old age · Multilevel · Germany · Socioeconomic status · Inequality

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Introduction

As most deaths in Western countries now take place at old age, changes in old-age mortality generally determine increases in life expectancy (Christensen et al. 2009). It has frequently been shown that mortality and morbidity is not equally distributed across regions within countries (Valkonen 2001) and between population groups (Huisman et al. 2004; Kunst et al. 2004; Mackenbach et al. 2008; Majer et al. 2011). Reducing health inequalities at older ages between regions and population groups could lead to further declines in mortality, and could shift deaths to even older ages.

Evidence from multilevel studies has shown that both individual- and area-level factors affect mortality risk, with most of the evidence stemming from studies on working-age populations (Meijer et al. 2012; Pickett and Pearl 2001; Riva et al. 2007). Differences in mortality risks between socioeconomic groups are usually larger than between regions (Cummins et al. 2007; Pickett and Pearl 2001). Differential population structures can partly explain area-level mortality differences (Cummins et al. 2007; Diez Roux 2001; Martikainen et al. 2003; Tarkiainen et al. 2010). Systematic reviews have found that, after controlling for differential population composition according to individual-level socioeconomic status (SES), significant area effects on mortality remain present in most settings (Meijer et al. 2012; Pickett and Pearl 2001; Riva et al.

2007; Yen et al. 2009). Moreover, the area-level factors tend to have greater effects on people in more deprived and smaller areas, and among men and younger age groups (Meijer et al. 2012). Area-level mortality variation can continue to be significant later in life (Chaix et al. 2007; Martikainen et al. 2003; Yen et al. 2009).

Knowledge about the simultaneous effect of population composition and area-level factors on health outcomes is scarce for Germany, although health inequalities between population groups and regions have been documented independently (Razum et al. 2008). It has, for example, been shown that differences in remaining life expectancy at age 65 can be as much as several years between different socioeconomic groups (Kroh et al. 2012; Shkolnikov et al. 2008). Regional mortality differences are particularly interesting in Germany, as structural and health differences can still be observed between the eastern and western parts of the country. After the reunification of Germany in 1990, eastern Germany was faced with far-reaching changes in the political system, leading also to altered general economic and social conditions. Life expectancy had long been higher in the West (Nolte et al. 2000; Razum et al. 2008), and an East–West divide could also be observed at the regional level and at older ages (Kibele 2012; Luy 2006). The closing of the East–West gap after the reunification was accompanied by changes in the regional mortality pattern, mainly during the 1990s (Kibele 2012). Regional differences became increasingly important, as, for example, some western German regions were found to have mortality as high as that of deprived eastern German regions, and vice versa (Kibele 2012; Razum et al. 2008). Structural differences, such as in settlement structure and socioeconomic differences exist between eastern and western Germany. Adverse conditions are more frequently found in eastern Germany. Regional variation in socioeconomic conditions exists within eastern and within western Germany (Diehl and Schneider 2011; Queste 2007; Razum et al. 2008; Voigtländer et al. 2010a). Associations between regionally varying socioeconomic conditions and mortality indicators have been documented in Germany (Brzoska and Razum 2008; Kibele 2012; Latzitis et al. 2011; Queste 2007), and specifically in several regions of the country (e.g., Maier et al. 2012; Strohmeier et al. 2007).

Until now, the question of whether the area-level relationship between deprivation and mortality is due to differential regional population composition or to area-level influences had not yet been explored (an earlier version of this study was published in Kibele 2012). A few studies investigating area-level health inequalities in Germany found evidence of independent area effects on several health outcomes, after controlling for differential regional population composition (Breckenkamp et al. 2007; Diehl and Schneider 2011; Dragano et al. 2007; Kemptner et al. 2008; Kreft and Doblhammer 2012; Voigtländer et al. 2010b).

As mortality inequalities between population groups and between regions are significant in Germany, as they are in other Western countries, special attention should be paid to the influence and interplay of these factors (Razum et al. 2008). This study seeks to fill previous research gaps by investigating the impact of individual- and area-level determinants on mortality inequalities at old age in Germany. We study whether regional mortality variation exists after we control for differential population composition, and at whether the remaining variation in regional mortality could be explained by area-level conditions. In recognition of the previous division of Germany and the structural differences that resulted from this separation, regional mortality differences are assessed for the whole of Germany, as well as for the country's eastern and western parts. By making this distinction, we study whether individual- and area-level mortality determinants are equally important in eastern and western Germany.

Methods

The German Federal Pension Fund provided highly reliable data on population and death counts for all male pensioners aged 65+ in Germany, who received an old-age pension in the years 2002–2004 (FDZ-RV 2012; Shkolnikov et al. 2008). The sample size consisted of 12,692,434 person years (71 % of the male population aged 65+ residing in Germany in the study period, 66 % of western Germans and 87 % of eastern Germans) and 638,491 deaths. The data used are count data with death counts and population exposures for all possible combinations of the variable values (FDZ-RV 2012). Table 1 shows the relative distribution of population exposures and death counts according to the variable values.

The area division was based on the NUTS 3 regions (Nomenclature of territorial units for statistics) in Germany in the study period, which is the most detailed area division available from the pension fund data. There were 439 urban and rural districts (in German *kreisfreie Städte and Kreise*), with 326 districts in western Germany and 113 districts in eastern Germany (including Berlin). The sample sizes across the districts ranged from 5,004 exposure years and 242 deaths (in Landau in der Pfalz) to 450,452 exposure years and 22,872 deaths (in Berlin).

Individual variables

The dataset contained age, type of earlier employment, type of health insurance, lifetime earnings, and retirement age as individual-level characteristics. Age was broken

Table 1 Age-adjusted mortality rate ratios (MRRs) by individual-level mortality determinants; Mortality rate ratios with 95 % confidence intervals; Germany, western Germany, and eastern Germany 2002–2004

Ind.-level variables	Germany			Germany with dummy eastern Germany	Western Germany			Eastern Germany		
	% P	*% D*	MRR	MRR	*% P*	*% D*	MRR	*% P*	*% D*	MRR
Lifetime earnings										
60 + (ref.)	24.2	20.6	1	1	23.3	19.6	1	26.8	23.6	1
50–59	30.8	29.5	1.13 (1.12−1.13)	1.13 (1.12−1.13)	30.8	28.9	1.12 (1.11−1.13)	30.8	31.4	1.17 (1.15−1.18)
40–49	30.3	31.9	1.29 (1.28−1.30)	1.29 (1.28−1.30)	29.9	32.0	1.28 (1.26−1.29)	31.5	31.5	1.35 (1.33−1.37)
30–39	14.7	18.0	1.44 (1.43−1.46)	1.44 (1.43−1.46)	16.1	19.5	1.43 (1.42−1.44)	10.8	13.4	1.54 (1.51−1.57)
Occupation										
White-collar (ref.)	41.7	36.5	1	1	41.1	35.7	1	43.7	39.0	1
Blue-collar	51.1	55.5	1.16 (1.15−1.16)	1.16 (1.15−1.16)	51.8	56.2	1.14 (1.13−1.15)	49.3	53.2	1.19 (1.17−1.20)
Miner	7.1	8.0	1.03 (1.02−1.04)	1.03 (1.02−1.04)	7.2	8.1	1.00 (0.99−1.01)	7.0	7.8	1.11 (1.09−1.14)
Health insurance										
Private (ref.)	7.2	3.5	1	1	8.2	4.2	1	4.1	1.3	1
CHI	92.8	96.5	1.62 (1.60−1.65)	1.62 (1.60−1.64)	91.8	95.8	1.55 (1.52−1.57)	95.9	98.7	2.24 (2.14−2.34)
Retirement age										
65 + (ref.)	17.7	22.2	1	1	11.7	13.3	1	35.4	49.4	1
60–64	68.2	59.1	1.23 (1.22−1.24)	1.24 (1.23−1.25)	72.1	65.5	1.28 (1.27−1.29)	56.7	39.7	1.21 (1.19−1.22)
<60	14.1	18.7	1.94 (1.92−1.95)	1.95 (1.93−1.97)	16.2	21.3	2.02 (1.99−2.07)	7.8	10.8	1.92 (1.89−1.96)
Country part										
Western Germany (ref.)	74.8	75.3		1						
Eastern Germany	25.2	24.7		1.23 (1.21−1.25)						
LL			−197,084	−196.894			−151,543			−44.878
Constant			−4.9009	−4.9552			−4.9010			−5.1793
ARD			1.75	1.17			1.29			0.71

Note: models controlled for age and all individual-level variables

% P percentage of population, *% D* percentage of deaths (per variable), *Ref* reference group, *LL* log likelihood, *ARD* average relative deviation

down into 5-year age groups from 65–69 to 95+ years. Lifetime earnings were expressed in earning points accumulated over the individual's working life, with employees gaining one earning point per year if they earned the annual average income. Income above and below the average was credited proportionally. Periods other than employment, such as unemployment or long-term sick leave, were partially credited. We distinguished between four income groups of 30–39, 40–49, 50–59, and 60 or more earning points. The paid-off pensions were the sum of the earning points multiplied by a pension factor (approximately 26 euros in western Germany and just under 23 euros in eastern Germany in the study period). Because additional income sources were not reflected here, the group with the lowest pension income (0–29 earning points) was excluded. This group contained people with extremely low pension income, but also previously self-employed people with private pensions and extra wealth. Mortality risk in this group was approximately average (Shkolnikov et al. 2008). The type of former employment was the type of employment before retirement: blue-collar worker, white-collar worker, or miner. People who had been employed in the mining industry at some point during their working lives were assigned to the "miner" category by the pension fund. Up until 2004, different pension fund branches existed for the three employment groups. Because the branches were merged in 2005, this information on employment type was no longer available. The year 2004 was, therefore, chosen as the last year of study. The type of health insurance referred to whether people had compulsory vis-a-vis a private or voluntary health insurance. The small group of people with another type of health insurance—i.e., foreign health insurance or unknown—were excluded. Retirement age was divided into those who retired at age 65 or later, those who retired between the ages 60 and 64, and those who retired before they reached age 60. Workers cannot draw an old-age pension before turning 60, though they may collect a disability pension prior to this age. Early retirement was hence an indicator of severe disability.

The representation of SES was insufficient if the pensioners did not have full employment histories in dependent employment. As this affected mainly women, non-Germans, pensioners with very low pensions, and pensioners whose health insurance type was unknown (Shkolnikov et al. 2008), these population groups were not included in this study. Retired civil servants, having a lower mortality risk than pensioners in the German Federal Pension Fund (Himmelreicher et al. 2008), have their own pension system and therefore cannot be represented in this study.

Contextual variables

Area-level conditions were represented by different characteristics of the districts in different dimensions. The settlement structure in the districts (i.e., urban vs. rural, population density, net migration) and economic and social conditions (i.e., unemployment rate, mean disposable income, voter turnout) were considered (Regionaldatenbank Deutschland 2012).

Statistical analyses

A two-level Poisson regression model, with mortality as the outcome, person years as an offset, and individuals nested in the 439 districts, was applied. A random intercept for the districts was assumed in all of the models (Rabe-Hesketh and Skrondal 2008). The log-likelihood indicated the goodness of fit. Mortality risk was presented as the mortality rate ratio (MRR), with the reference group having an MRR of 1. Values above and below reflected proportional mortality risks. For example, an MRR of 1.2 indicated that the mortality risk was elevated by 20 % as compared to the reference group. The percentage of average mortality deviation across the districts was reflected by the population-weighted measure of average relative deviation (ARD) (Martikainen et al. 2003; Tarkiainen et al. 2010).

Three modeling steps were undertaken. The first model type included age and all of the other individual-level variables (all as categorical variables). This model was enhanced by one area-level factor at a time, whereas the area factors were divided into quartiles based on the number of districts. Finally, it was assessed whether district characteristics modified the mortality impact of SES. This was exemplified using the lifetime earnings as a SES measure and unemployment as district-level context (which yields the greatest improvement of the model, as compared to the model that controlled for only individual-level variables for Germany). Random intercepts, upon which the calculation of the ARD was based, were obtained through post-estimation (Rabe-Hesketh and Skrondal 2008). All of the analyses were done using the "xtmepoisson" command in Stata 10 (StataCorp 2007) via long-distance computation at the research data center of the German Federal Pension Fund.

All of the analyses were done for the entire sample of Germany, and separately for the eastern and western parts. The mortality differences between eastern and western Germany were found to be small within the total population, with the remaining life expectancy at age 65 amounting to 16.3 years in western and 15.8 years in eastern Germany (Human Mortality Database 2012). This difference in remaining life expectancy at age 65 was shown to be even smaller in our sample, at 16.1 years in western Germany and 15.9 years in eastern Germany. This is probably attributable to the exclusion of the pensioners in the lowest lifetime earnings group, which was smaller in eastern Germany. Some differences in the population composition between eastern and western Germany exist (Table 1). In the comparison of eastern and western Germany, we checked whether the structural differences between these regions could be reflected in mortality inequalities.

Results

Mortality risks among male pensioners aged 65+ years varied significantly between population groups (Table 1). Mortality gradually increased for pensioners with lower lifetime earnings. Those in the lowest lifetime earnings group had a mortality risk that was 44 % higher than that of pensioners in the highest lifetime earnings group. Former blue-collar workers had a 16 % higher mortality risk than that of former white-collar workers, while the mortality risk of former miners was close to that of the former white-collar workers. The mortality risk of pensioners holding compulsory health insurance was 62 % higher than that of pensioners with private health insurance. Mortality risk was lowest for those who retired at age 65 or older. Retiring between ages 60 and 64 yielded a 23 % higher mortality risk, and retiring before the age of 60 yielded a mortality risk that was almost twice as high as that of workers, who retired at ages 65 and above.

There were relatively few differences between western and eastern Germany in the mortality effects of the individual-level characteristics. The mortality gradient according to lifetime earnings, type of former occupation, and type of health insurance was steeper in eastern Germany. Miners had a higher mortality risk than white-collar workers in eastern Germany, but there was no difference in western Germany. Mortality in eastern Germany according to the model controlling for all individual-level variables was 23 % higher than in western Germany; age-standardized mortality, however, was only elevated by 5 % (95 % confidence interval MRR 1.03–1.07). Additional models including age, another individual-level variable and the dummy variable for eastern Germany showed modest excess mortality in eastern Germany; only the model including retirement age as an explanatory variable revealed eastern German excess mortality as high as in the full model (results not shown). Higher eastern German excess mortality in the full model as compared to the age-standardized model is related to different population composition in eastern and western Germany, especially with respect to retirement age. Controlling for differential population composition across Germany's districts did not explain all of the regional mortality variation at age 65 and above. The average relative deviation of mortality was 1.75 across all German districts and decreased to 1.17 when the dummy variable for eastern Germany was included. It was 1.29 across the western German districts and 0.71 across the eastern German districts (Table 1, lower part).

Classifying the districts into quartiles by contextual characteristics showed that mortality tended to be higher in the districts with higher unemployment rates and lower voter turnout, even if all of the individual-level mortality determinants were controlled for (Table 2). In interpreting the area-level effects across all German districts, it should be noted that western German districts made up three quarters of the German districts, and that the economically most deprived districts were primarily in eastern Germany.

In Germany, after controlling for differential population composition, male old-age mortality was lower in rural than in urban districts, and in districts with higher net migration, higher income, and higher voter turnout. Mortality was higher in districts of higher unemployment. Population density had no significant effect on mortality. The inclusion of unemployment yielded the greatest improvement in the model fit. The models for western Germany pointed in roughly the same directions as those for the whole of Germany. However, mortality was higher in districts with higher population densities. There was no significant effect of district-level income. For eastern Germany, most district-level characteristics did not yield a significant mortality effect. In eastern Germany, significant mortality effects were only seen in the quarter of the districts with the highest unemployment rates (elevated mortality), and in the quarter of the districts with the highest voter turnout (lower mortality). Area-level mortality effects for Germany as a whole exceed the corresponding effect sizes for western and eastern Germany.

Regional mortality variation usually decreased when area-level characteristics were included (Table 2), especially among those models with the best model fit. Although the ARD was 1.75 across all German districts, the ARD decreased to 1.00 if the level of unemployment in districts was included as a district-level variable. Mortality variation not explained by population composition was greater across the western German districts than across the eastern German districts (Table 1). In western Germany, a larger part of the remaining regional mortality variation was related to area-level conditions (Table 2).

Additional analyses, including a dummy variable for eastern Germany in the model for Germany as a whole showed significant mortality effects for the dummy variable for eastern Germany ($p < 0.001$) and for all area-level variable categories except for income ($p < 0.05$); for population density and voter turnout, the mortality effects were significantly different from the reference category in the third and fourth quartile. The mortality effects were weaker as compared to the models presented in Table 2; for population density, mortality effects were stronger. The ARD decreased especially for district type and population density, but hardly for unemployment (results not shown).

Using a cross-level interaction (controlling for all individual characteristics), we checked whether the mortality risk by individual-level SES (lifetime earnings) was modified by the district-level context (unemployment rate). Figure 1 shows the mortality differences by lifetime earnings according to area characterization. SES mortality gradients were smaller in districts of lower unemployment. This effect occurred in Germany, as well as in western Germany. In eastern Germany, this effect was not pronounced. The ARD in Germany and western Germany was reduced by the inclusion of the cross-level interaction. Additional analyses testing cross-level interactions with other district-level characteristics pointed in the same direction. Including a dummy variable for eastern Germany in the model for Germany as a whole showed attenuated, although consistently significant ($p < 0.05$), area-level mortality effects in the cross-level interaction (results not shown).

Discussion

The objective of this study was to investigate the impact of both individual- and district-level mortality determinants on mortality among male German pensioners aged 65+ in 2002–2004 in Germany as a whole, and in the eastern and western parts of the country. Considering old-age mortality inequalities in Germany from a broader perspective by studying individual- and area-level determinants simultaneously, it adds to previous studies based only on individual-level factors or in ecological settings.

In line with the previous research, this study found a social mortality gradient among male elderly in Germany (Kroh et al. 2012; Luy 2006; Shkolnikov et al. 2008) of

Table 2 Age-adjusted mortality rate ratios (MRRs) by area-level mortality determinants; mortality rate ratios with 95 % confidence intervals; Germany, western Germany, and eastern Germany 2002–2004

Area-level variables	Germany		Western Germany		Eastern Germany	
		MRR		MRR		MRR
Settlement structure						
District type	Urban	1	Urban	1	Urban	1
	Rural	0.96 (0.94−0.98)	Rural	0.93 (0.92−0.95)	Rural	1.00 (0.98−1.03)
LL		−197,080		−151,540		−44,878
ARD		1.65		1.14		0.70
Population density (population per km^2)	<118.3	1	<131.4	1	<85.5	1
	118.3–199.9	0.97 (0.94−1.00)	131.4−231.8	1.01 (0.99−1.03)	85.5–142.3	1.01 (0.98−1.04)
	199.9–654.6	0.97 (0.94−1.00)	231.8−777.4	1.06 (1.04−1.09)	142.3−343.1	0.98 (0.95−1.02)
	>654.6	1.01 (0.98−1.05)	>777.4	1.11 (1.08−1.13)	>343.1	0.99 (0.96−1.02)
LL		−197,078		−151,496		−44,877
ARD		1.64		1.30		0.67
Net migration (per 10,000 population)	<−15.2	1	<11.2	1	<-82.3	1
	−15.2–21.8	0.84 (0.82−0.86)	11.2–30.0	0.97 (0.95−0.99)	−82.3–56.5	1.00 (0.97−1.04)
	21.8–41.6	0.84 (0.82−0.86)	30.0–45.3	0.97 (0.95−0.99)	−56.5–31.2	0.99 (0.96−1.02)
	>41.6	0.84 (0.82−0.86)	>45.3	0.97 (0.94−0.99)	>−31.2	0.98 (0.95−1.02)
LL		−196,960		−151,538		−44,877
ARD		1.41		1.27		0.67
Economic conditions						
Unemployment rate	<6.8	1	<6.2	1	<16.7	1
	6.8–8.8	1.05 (1.03−1.07)	6.2–7.7	1.06 (1.04−1.08)	16.7–18.5	1.02 (0.99−1.05)
	8.8–14.4	1.12 (1.09−1.14)	7.7–9.4	1.08 (1.05−1.10)	18.5–21.7	1.03 (1.00−1.07)
	>14.4	1.28 (1.25−1.30)	>9.4	1.12 (1.09−1.14)	>21.7	1.04 (1.01−1.07)
LL		−196,874		−151,498		−44,875
ARD		1.00		1.01		0.67
Income (in Euro)	<14,714	1	<16,204	1	<13,683	1
	14,714–16,456	0.85 (0.83−0.87)	16,204–17,110	0.97 (0.95−0.99)	13,683–14,028	0.99 (0.96−1.02)
	16,456–17,808	0.82 (0.80−0.84)	17,110–18,304	0.99 (0.97−1.02)	14,028–14,512	0.99 (0.96−1.02)
	>17,808	0.83 (0.81−0.85)	>18,304	0.99 (0.97−1.02)	>14,512	0.98 (0.95−1.02)
LL		−196,948		−151,540		−44,878
ARD		1.31		1.28		0.69
Social conditions						
Voter turnout	<75.1	1	<79.0	1	<70.1	1
	75.1–79.6	0.86 (0.84−0.88)	79.0–80.7	0.96 (0.94−0.98)	70.1–72.8	0.98 (0.95−1.01)
	79.6–81.8	0.82 (0.81−0.84)	80.7–82.3	0.96 (0.94−0.98)	72.8–74.4	0.99 (0.96−1.02)
	>81.8	0.81 (0.79−0.82)	>82.3	0.93 (0.91−0.95)	>74.4	0.96 (0.93−0.98)
LL		−196,919		−151,527		−44,874
ARD		1.22		1.19		0.61
Cross-level interaction: lifetime earnings * unemployment rate						
LL		−196,782		−151,436		−44,869
ARD		0.99		1.09		0.73

Note: models controlled for age and all individual-level variables

Districts classified into quartiles according to district-level characteristics

LL log likelihood, *ARD* average relative deviation

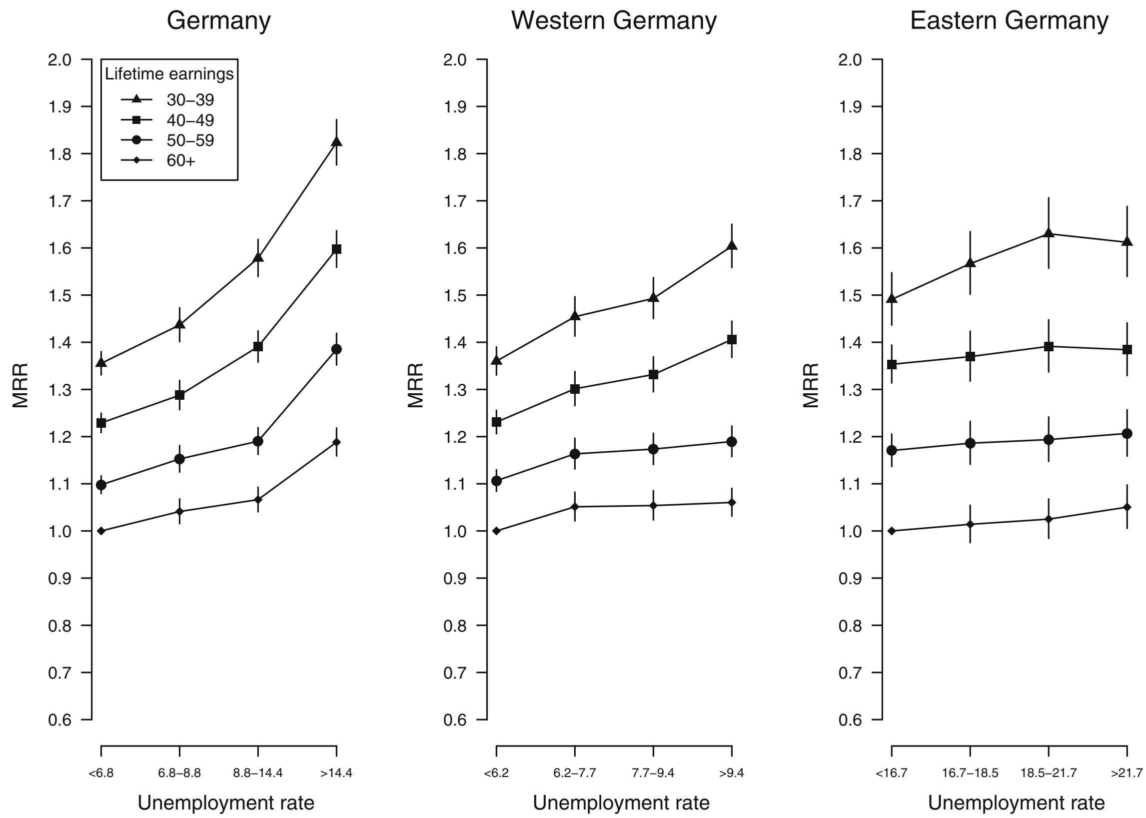

Fig. 1 Mortality rate ratios by lifetime earnings * unemployment rate, with 95 % confidence intervals; Germany, western Germany, and eastern Germany 2002–2004. Note: models controlled for age and all individual-level variables, districts classified into quartiles according to district-level characteristics, *MRR* mortality rate ratio

similar extent as in other European countries (Huisman et al. 2004; Kunst et al. 2004; Majer et al. 2011). In addition, this analysis showed that the mortality differences based on the individual-level characteristics were similar in eastern and western Germany, although the population compositions differed to some extent.

Most international research has found evidence of area-level mortality effects after adjustment for individual-level socioeconomic conditions, with a few studies finding no significant area effects (Meijer et al. 2012; Pickett and Pearl 2001; Riva et al. 2007; Yen et al. 2009). Although regional health effects tended to be strongest at younger ages and in smaller regions, like neighborhoods (Meijer et al. 2012), this study found significant effects from district-level conditions on male old-age mortality in (western) Germany. The area-level mortality effects were found to be smaller than individual SES mortality differences. The study also showed that mortality was higher in areas with higher unemployment rates and lower voter turnout, independent of population composition. In line with the previous findings in other countries, a larger social mortality gradient among the worse-off was found in the districts with higher unemployment rates of (western) Germany (Martikainen et al. 2003; Riva et al. 2007).

Specific area-level factors affect mortality to differing degrees. In Germany, strong area-level effects were found for the unemployment rate, an indicator of general economic prosperity; and for voter turnout, a potential indicator of area-based social capital and civic engagement (Lantz and Pritchard 2010). The mortality effect of the mean disposable income, also an indicator of general regional prosperity, but after taxes and transfers, was less pronounced. As eastern German districts tended to cluster in a single area quartile, the strength of the area-level mortality effects was partly related to East–West mortality differences.

Regional mortality variation was lower in eastern than in western Germany when controlled for differential population composition, and also when additionally controlled for area-level characteristics. In western Germany, population density, unemployment, and voter turnout had the strongest district-level mortality effects. The district-level mortality effects in eastern Germany were negligible even though the extent of variation in the area-level conditions was substantial. The effects of the various area-level factors in western Germany suggest that several area dimensions should be considered when studying the impact of area-level characteristics on health outcomes (Diez Roux 2001; Riva et al. 2007).

Earlier research has shown that higher population density and the degree of urbanization are related to higher mortality in western Germany, with the opposite being the case in eastern Germany (Kibele 2012; Queste 2007). The current study confirmed these results, especially for western Germany. Area-level characteristics can have different meanings in their relation to health in the different settings of eastern and western Germany. Different meanings of area-level characteristics may also help to explain the marginal area mortality effects in the East.

Strengths and limitations

A particular strength of this study is the large dataset, which allowed us to study mortality as an established health outcome, while providing reliable information about individual-level mortality determinants. The data allowed for the simultaneous estimation of mortality inequalities between individuals, as well as between districts.

This study is the first to add evidence for Germany to international research on individual- and area-level mortality variation. The usual restriction to studying either mortality determinants between population groups (Kroh et al. 2012; Shkolnikov et al. 2008) or regional mortality determinants in ecological analyses (Brzoska and Razum 2008; Latzitis et al. 2011; Maier et al. 2012; Queste 2007) was overcome. By combining both the individual and the regional dimensions, we were able to further develop our understanding of the relationship between health and SES.

The limitations of this study include the population coverage, the limitations in individual-level mortality determinants, and problems related to the administrative area classification into relatively large and heterogeneous districts.

The current study covered almost three-quarters of the male population residing in Germany at age 65 or above in the years 2002–2004. The mortality level in the study population was very close to overall mortality levels in Germany. However, those with very little money were excluded, and those with very high income were, presumably, not adequately captured (Himmelreicher et al. 2008; Shkolnikov et al. 2008). This mainly affected western Germans. Consequently, and particularly in western Germany, the extent of the social mortality gradient was probably underestimated, also by the cross-level interaction.

A drawback of using highly reliable mortality data from an administrative source with much greater population coverage than survey data is that the variables for study are limited. Apart from retirement age as a crude indicator of severe disability, it would have been desirable to have had information on marital status, individual lifestyle, social relations and health behavior. Such factors are known to possibly mediate the relationship between SES and health (Klein et al. 2012; Kroh et al. 2012; Mohnen et al. 2012). Not including these factors might lead to an overestimation of the individual SES mortality differences (Mohnen et al. 2012). In multilevel settings in general, having a limited number of individual-level variables might lead to an overestimation of the regional variation in the outcome and the strength of area-level mortality effects (Pickett and Pearl 2001; Turrell et al. 2007).

Like most related studies, this study draws on an administrative area division (Cummins et al. 2007; Diez Roux 2001; Meijer et al. 2012; Pickett and Pearl 2001; Riva et al. 2007). The area classification into the German NUTS 3 level districts is the smallest geographical resolution that the German Federal Pension Fund can provide. This resolution has been chosen in several other multilevel studies on the relationship between individual- and area-level health characteristics in Germany (Diehl and Schneider 2011; Kemptner et al. 2008; Kreft and Doblhammer 2012; Voigtländer et al. 2010b) but the disadvantage of using this resolution is that it compares heterogeneous districts with small and large entities (Diehl and Schneider 2011). The eastern German districts are especially large in terms of area size, which might not adequately capture individuals' health-relevant contexts (Diez Roux 2001; Merlo 2011; Riva et al. 2007). This issue could partly explain the marginal area effect found for eastern Germany.

Comparisons with other studies must be done with care. International studies on the common influence of individual- and area-level characteristics often make use of smaller area units than the German districts, such as neighborhoods, and therefore show greater area-level mortality variation and stronger area effects (Meijer et al. 2012; Pickett and Pearl 2001). Comparisons of the size of these effects are further complicated when the studies deal with different age groups (Tarkiainen et al. 2010; Yen et al. 2009), and with different measures of area-level variation (Chaix et al. 2007; Tarkiainen et al. 2010).

Future research and implications

Future research into the interplay of individual- and area-level mortality inequalities should, ideally, differentiate between a greater number of area levels, as this would generate more precise information about the health-relevant contexts people live in (Diez Roux 2001). Including a time perspective (Cummins et al. 2007; Diez Roux 2001; Merlo 2011; Voigtländer et al. 2010b) could provide us with a better understanding of the relationship between inequalities and health outcomes, and could eventually enable us to formulate more precise health policy interventions at multiple levels.

In addition, in the German setting, mortality determinants more directly related to health outcomes, such as lifestyle factors, social relations and health behavior, should, ideally, be considered as well. Further research should investigate why area effects are significant in western, but not in eastern Germany. The above-mentioned approaches might contribute to this research.

Health conditions are not comparable across Germany, and it appears that regional inequality contributes to individual-level inequality. Districts seem to contribute to the health-relevant context in which people live. Although healthy lifestyles as more proximate health determinants should, of course, be promoted among the whole population (Kroh et al. 2012; Mackenbach et al. 2008), focusing on the socioeconomically most deprived elderly, and especially those living in the more districts with higher unemployment rates, could help to shift deaths to ever higher ages. At the same time, more research is needed on to identify the most appropriate health-relevant area context for the elderly (Cummins et al. 2007; Diez Roux 2001; Merlo 2011; Yen et al. 2009).

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