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# Socioeconomic differences in mortality among 27 million economically active Germans: a cross-sectional analysis of the German Pension Fund data

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## ABSTRACT

**Objectives** To assess disparities in mortality by socioeconomic status in Germany.

**Design and participants** We analyse a large administrative dataset of the German Pension Fund (DRV), including 27 million person-years of exposure and 42 000 deaths in 2013. The data cover the economically active population, stratified by sex and by East and West.

**Outcome measures** Age-standardised mortality rates and Poisson regression mortality rate ratios (MRRs).

**Results** The risk of dying increases with decreasing income: the MRRs of the lowest to the highest income quintile are 4.66 (95% CI 4.48 to 4.85) among men and 3.06 (95% CI 2.90 to 3.23) among women. The impact of income attenuates after controlling for education and other explanatory variables, especially for females. In the fully controlled model for females, individual income is a weaker predictor of mortality, but there is a clear educational mortality gradient. In the fully controlled model, the MRRs of the unemployed to the employed are 2.09 (95% CI 2.03 to 2.15) among men and 2.01 (95% CI 1.92 to 2.10) among women. The risk of dying is around half as high among foreigners as among German citizens. The socioeconomic disparities are greater among East than West German men.

**Conclusions** Low socioeconomic status is a major determinant of excess adult mortality in Germany. The persisting East-West differences in male adult mortality can be explained by the higher socioeconomic status of men living in the West, rather than by contextual differences between East and West. These differences can be further monitored using DRV data.

## Strengths and limitations of this study

- ► Using a large administrative dataset of the German Pension Fund (DRV), this study provides the first population-level estimates on socioeconomic mortality differentials across the economically active population of Germany.
- ► Mortality disparities are assessed using a broad range of socioeconomic and demographic characteristics, including individual income, education, employment status, citizenship and region.
- ► The DRV data, particularly on individual income, are highly reliable because the information reported by employers serves as the basis for pension entitlements in the future.
- ► There is a relatively large share of missing values for the *education* variable, primarily because people who were unemployed or out of the labour market for other reasons had no employer to report the information on education.
- ► Our analyses do not cover individuals of working ages who are receiving pensions due to disability.

## INTRODUCTION

The reduction of mortality disparities across socioeconomic groups is an important public health priority.[1] A large body of literature shows that disparities between socioeconomic groups persist or even increase with time.[2–5] In several high-income countries, data on deaths have been linked to census or register information on socioeconomic status (SES), and mortality by SES group has been computed. Such analyses are not possible in Germany because of the country's data protection rules. Thus, despite being the EU country with the largest population and the greatest economic power, Germany is missing in many international comparisons of health disparities.[6–9]

Because of the unavailability of population-level statistics, most of the existing evidence about mortality variation by SES in Germany is based on survey estimates.[10–16] Unfortunately, surveys like the German Socio-Economic Panel (SOEP) are not designed for the assessment of mortality by SES. First, the statistical power of such data is often insufficient for estimating mortality by SES due to the small numbers of death events. Second, it is often not possible to check the vital status of individuals due to a lack of informants. Third, the surveys seldom cover individuals who live on the margins and have particularly high mortality risks. Because the existing survey-based studies differ with respect to their data and methods, definitions and analysed subpopulations, it is difficult to generalise and compare their results. In their survey-based study of differential mortality in West Germany, Luy *et al*[12] provided a thorough overview of the state of the art in Germany, and concluded that '… reliable estimates with regard to the extent of the differentials that can be assessed in an international context, and that consider different SEP dimensions, are missing for the German population'. In an attempt to address this knowledge gap, the authors (on the basis of certain assumptions) estimated life expectancy by education, household income, work status and vocational group for German citizens living in West Germany. This work relied on survey data from the early 1990s, and employed indirect methods of mortality estimation. The study found striking differences in life expectancy at age 40 across the analysed SES dimensions, particularly for men: life expectancy at age 40 among men varied by more than >5 years between the lowest and the highest household income categories, by more than >6 years between individuals with low and high levels of education, by around 10 years across the employment status categories and by almost 15 years across the vocational classes.[12]

Recently, Germany has implemented policies that provide researchers with access to administrative microdata. von Gaudecker and Scholz,[17] Shkolnikov *et al*,[18] Kibele *et al*[19] and Wenau *et al*[20] took advantage of data from the German Pension Insurance Union (Deutsche Rentenversicherung Bund; hereafter DRV) to analyse mortality differentials among Germans aged 65+. While we also use DRV data, unlike previous studies we examine mortality disparities in Germany's working-age population; and we assess these mortality differentials using a broader range of SES characteristics, including income, education and employment status. Although the association of these characteristics with mortality is well-documented,[1–7] it has been shown that different SES indicators are not fully interchangeable, as each has its own specific effect on mortality.[21 22] We also carry out a comparative analysis of differences between East and West Germany in mortality by SES, and of the role of SES in the persisting East-West gap in midlife male mortality.[23]

## METHODS

### DRV data

The legal issues, principles and concepts related to the administration and maintenance of the DRV databases have been described in detail elsewhere.[24–26] Here, we distinguish between two DRV datasets. The first dataset consists of records on all pensions paid by the DRV. The pension recipients are former employees who left work due to disability (*Erwerbsminderungsrenten*; hereafter EMR). The second database contains records on contributions paid by the economically active insured population (*Aktiv Versicherte*; hereafter AKV). Participation in the statutory pension insurance scheme is mandatory in Germany for all working individuals except the self-employed and civil servants. Both the EMR and AKV datasets provide information on the demographic and socioeconomic characteristics of the population, as well as on the number of death events. However, because the characteristics covered in the two data sets are not comparable, a detailed analysis of the combined (AKV+EMR) dataset is not possible. Notably, the inactive population covered by the EMR dataset cannot be properly classified by education and employment status. Moreover, the income variable in the EMR dataset is not comparable to that in the AKV dataset. The former is based on the pension points accumulated over a lifetime, while the latter refers to current income.

Consequently, our main analyses are based on the AKV data for the year 2013, which we obtained through the FDZ-DRV (*Forschungsdatenzentrum*-DRV Research Data Centre) in Berlin.[26] The centre was created in 2006 to facilitate scientific data use.[27 28]

The DRV data collection system functions as a population register that (unlike the Nordic population registers) focuses exclusively on people's employment and educational careers, and on other factors that influence people's rights to retire and collect a pension. DRV follows up everyone who contributes to the German economy. This study looks at the reporting year from 31 December 2012 to 31 December 2013. To estimate mortality in 2013, we relied on three datasets: 1) individual records on living individuals at the end of 2012, 2) similar records at the end of 2013 and 3) records on deaths that occurred during 2013. We linked records on living individuals with corresponding death records and assigned to each individual his/her exposure time and vital (alive/deceased) status at the end of 2013. On completing our work at the FDZ, we received the data in the form of a frequency table in which the deaths and the corresponding exposures were classified according to all possible combinations of the sociodemographic variables.

Our analysis includes the population aged 30–59 years. The lower age limit was chosen based on the assumption that educational status changes little after age 30. Although the AKV data include information up to age 65, people aged 60–64 years were excluded from the analysis, as many would have left the AKV to retire early (possible after age 63) or collect a disability pension. As the early retirement is correlated with poor health, the remaining AKV population aged 60–64 years is substantially smaller, more selective and experiences implausibly low death rates compared with the population aged 55–59 years.

The final AKV dataset used in the analysis contains data on 42 200 deaths and 27.1 million person-years of observation; or 50% of all deaths that occurred in 2013 and 80% of the total German population for those aged 30–59 years.[29] The EMR dataset for the same ages includes 25 500 deaths and 1.2 million person-years (30% and 3.5%, respectively). Figure 1 indicates that mortality is 9 times higher among men and is 14 times higher among women in the EMR than in the AKV population.

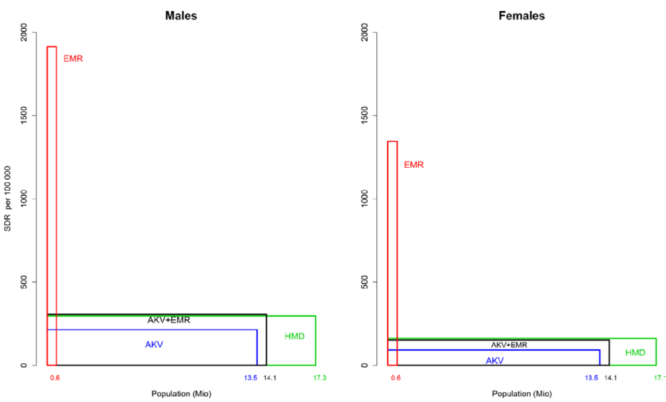


**Figure 1** Standardised mortality rate (SDR) (per 100 000) and corresponding population size (million) by data source, ages 30–59 years, 2013. EMR (*Erwerbsminderungsrenten*)—population receiving disability pensions (SDR (m)=1912, SDR (f)=1345, population (m)=0.603, population (f)=0598); AKV (*Aktiv Versicherte*)—economically active insured population (SDR (m)=215, SDR (f)=93, population (m)=13 543, population (f)=13 513); AKV+EMR—combined AKV and ERM population (SDR (m)=306, SDR (f)=151, population (m)=14 146, population (f)=14 111); HMD—Human Mortality Database (SDR (m)=297, SDR (f)=161, population (m)=17 317, population (f)=17 107).

Therefore, the exclusion of the EMR population from the analysis explains why the AKV-based mortality rates are lower than the mortality rates for the total national population presented in the Human Mortality Database (HMD).[29] The age-standardised mortality rates (SDRs) calculated from the combined (AKV+EMR) data are nearly identical to the respective rates for the entire German population (HMD). This suggests that the German pension data are highly reliable.

The following characteristics are considered in the analysis: age, sex, region (East, West), citizenship (foreign, German), employment (employed, unemployed), income (quintile of the current pension income) and education.

In DRV data, *foreigners* are individuals who have current citizenship of other countries (holders of foreign passports). Individuals who were unemployed and were searching for job for at least 1 day in the year of reporting or the previous year are defined by the DRV data as *unemployed*. The information on education was extracted from the nine-digit *occupation key* (*Tätigkeitsschlüssel*) based on the German Classification of Professions (*KldB 2010*). We use four educational categories: i) *lower*, which includes *no diploma* (ohne Schulabschluss) and *lower secondary education* (Haupt/Volkschulabschluss); ii) *secondary* (Mittlere Reife oder gleichwertiger Abschluss); iii) *higher*, which includes *tertiary education* (Abitur/Fachabitur) and iv) *unknown* (fehlender Wert, Abschluss unbekannt).[30] Unfortunately, around 40% of the *education* variable values turned out to be *unknown*, primarily because people who were unemployed or out of the labour market for other reasons had no employer to report the educational information. Additional tabulation (not shown here) indicates that roughly 60% of the males with *unknown* education were either unemployed or belonged to the lowest income quintile. This observation is consistent with the literature suggesting that individuals with unknown education tend to be the least educated.[31 32] We, therefore, decided to treat the *unknown* category separately, rather than to redistribute it proportionally among the other educational categories.

## Statistical analyses

To evaluate mortality differentials, we used both empirical and model-based mortality measures. For each socioeconomic category, we computed age-specific mortality rates and SDRs using the European population standard.[33] The model-based mortality rate ratios (MRRs) resulted from the Poisson model, with a log link and a logarithm of person-years being used as an offset (function *glm* in R).

We assessed mortality disparities using the measure of *combined relative mortality risk* (combined MRR). Here, we used the mutually adjusted MRRs for all combinations of the values of two SES variables: *education and income*. These two-dimensional risk estimates were based on the assumption that the explanatory variables with no interaction presented additive risks. An example of the calculation of a combined MRR is given in the 'Results' section.

In our sensitivity analysis we used the Multivariate Imputation by Chained Equations (MICE) algorithm implemented in R package *mice*.[34] The method assumes the imputation of unknown values for the variable of interest on the basis of relationships between known *education* values and other variables (predictors).

## Patient and public involvement

Patients or public were not involved.

# RESULTS

## Mortality differentials by socioeconomic characteristics

The results of the analysis on the AKV data are summarised in table 1. Because of the large sample sizes, we do not report (very narrow) confidence limits for the SDRs. Along with the SDRs, we show the two types of model-based MRRs: i) age-adjusted with the variable of interest and age included (model 1) and ii) fully adjusted MRRs with age and all explanatory variables included simultaneously (model 2).

Of the variables used in the analysis, the differentials are particularly large for *employment*, *income* and *education*. The SDR values show how the absolute level of mortality varies across sociodemographic groups. This variation is greater among males than among females.

The outcomes of the mutually adjusted model 2 differ considerably from those of model 1. In particular, the advantage of West German males relative to their East German counterparts found in model 1 disappears after controlling for other variables. The effects of male

Table 1 Standardised death rate (SDR) and model-based mortality rate ratio (MRR) by sociodemographic categories (2013, ages 30–59 years)

| Males | Person-years of exposure | Deaths | SDR, per 100 000 | Model-based MRR Model 1 | Model-based MRR Model 2 |
|---|---|---|---|---|---|
| **Region** | | | | | |
| Eastern Germany | 2 402 169 | 6447 | 251.5 | **1.00 (ref)** | **1.00 (ref)** |
| Western Germany | 11 019 226 | 22 349 | 200.4 | 0.79*** (0.77–0.82) | 1.04*** (1.01–1.07) |
| Unknown | 121 583 | 556 | 455.4 | 1.82*** (1.67–1.98) | 2.56*** (2.34–2.79) |
| **Nationality** | | | | | |
| Foreign | 1 598 249 | 2123 | 154.8 | **1.00 (ref)** | **1.00 (ref)** |
| Germany | 11 944 729 | 27 229 | 217.8 | 1.41*** (1.35–1.47) | 2.03*** (1.94–2.12) |
| **Employment** | | | | | |
| Employed | 10 850 485 | 16 735 | 149.2 | **1.00 (ref)** | **1.00 (ref)** |
| Unemployed | 2 692 493 | 12 617 | 478.1 | 3.22*** (3.15–3.30) | 2.09*** (2.03–2.15) |
| **Education** | | | | | |
| Higher | 2 616 949 | 2665 | 113.8 | **1.00 (ref)** | **1.00 (ref)** |
| Secondary | 2 832 094 | 4299 | 152.9 | 1.36*** (1.30–1.43) | 1.12*** (1.07–1.18) |
| Lower | 3 232 296 | 6465 | 187.8 | 1.67*** (1.60–1.75) | 1.29*** (1.23–1.35) |
| Unknown | 4 861 639 | 15 923 | 305.4 | 2.72*** (2.61–2.84) | 1.57*** (1.50–1.64) |
| *Test for linear trend* | | | | *P=0.046* | *P=0.018* |
| **Income quintile** | | | | | |
| 1 | 2 329 163 | 11 243 | 469.4 | 4.66*** (4.48–4.85) | 2.49*** (2.37–2.61) |
| 2 | 2 736 943 | 6062 | 233.5 | 2.33*** (2.24–2.43) | 1.66*** (1.59–1.75) |
| 3 | 2 817 235 | 4823 | 171.3 | 1.71*** (1.63–1.79) | 1.46*** (1.39–1.53) |
| 4 | 2 826 523 | 4107 | 139.5 | 1.39*** (1.33–1.46) | 1.28*** (1.22–1.34) |
| 5 | 2 833 114 | 3117 | 100.4 | **1.00 (ref)** | **1.00 (ref)** |
| *Test for linear trend* | | | | *P=0.037* | *P=0.017* |
| **Females** | **Person-years of exposure** | **Deaths** | **SDR, per 100 000** | **Model-based MRR Model 1** | **Model-based MRR Model 2** |
| **Region** | | | | | |
| Eastern Germany | 2 402 613 | 2176 | 83.8 | **1.00 (ref)** | **1.00 (ref)** |
| Western Germany | 11 030 615 | 10 373 | 92.8 | 1.12*** (1.07–1.17) | 1.25*** (1.19–1.31) |
| Unknown | 79 682 | 270 | 343.8 | 4.12*** (3.63–4.68) | 4.80** (4.22–5.46) |
| **Nationality** | | | | | |
| Foreign | 1 417 246 | 867 | 72.7 | **1.00 (ref)** | **1.00 (ref)** |
| Germany | 12 095 664 | 11 952 | 94.2 | 1.29*** (1.21–1.39) | 1.96*** (1.83–2.11) |
| **Employment** | | | | | |
| Employed | 11 007 692 | 8332 | 72.4 | **1.00 (ref)** | **1.00 (ref)** |
| Unemployed | 2 505 218 | 4487 | 188.9 | 2.62*** (2.52–2.71) | 2.01*** (1.92–2.10) |
| **Education** | | | | | |
| Higher | 2 367 803 | 1221 | 59.2 | **1.00 (ref)** | **1.00 (ref)** |
| Secondary | 3 780 230 | 2528 | 65.1 | 1.09** (1.02–1.17) | 1.08** (1.01–1.16) |
| Lower | 2 211 302 | 2181 | 85.4 | 1.45*** (1.35–1.55) | 1.30*** (1.21–1.40) |
| Unknown | 5 153 574 | 6889 | 127.9 | 2.15*** (2.02–2.29) | 1.60*** (1.50–1.71) |
| *Test for linear trend* | | | | *P=0.059* | *P=0.029* |
| **Income quintile** | | | | | |
| 1 | 2 328 066 | 4029 | 202.3 | 3.06*** (2.90–3.23) | 1.75*** (1.64–1.86) |

Continued

**Table 1** Continued

| Females | Person-years of exposure | Deaths | SDR, per 100 000 | Model-based MRR | |
|---|---|---|---|---|---|
| | | | | Model 1 | Model 2 |
| 2 | 2 715 934 | 2457 | 88.1 | 1.35*** (1.27–1.43) | 1.05 (0.99–1.11) |
| 3 | 2 806 998 | 2133 | 72.4 | 1.11*** (1.04–1.17) | 0.92*** (0.86–0.98) |
| 4 | 2 826 513 | 2170 | 73.0 | 1.11*** (1.05–1.18) | 1.01 (0.95–1.08) |
| 5 | 2 835 399 | 2030 | 65.6 | **1.00 (ref)** | **1.00 (ref)** |
| *Test for linear trend* | | | | *P=0.108* | *P=0.179* |

P<0.01***; 0.01<P<0.05**
Model 1—adjusted for age; model 2—adjusted for age and all other variables.
Confidence intervals are presented in the parentheses.

unemployment as well as the education and income gradients are substantially attenuated in the fully adjusted model 2.

In model 2, living in West Germany is associated with a higher mortality risk among females. Like for males, the risk of dying for females is twice as high among citizens than among non-citizens, and among the unemployed than among the employed. The educational mortality gradient among females is very consistent. Although mortality risk is clearly elevated in the lowest income quintile, across other quintiles female mortality declines only weakly in model 1, and does not change in a regular manner in model 2.

More information on the distribution of the population at risk, death counts by ages and age-specific mortality rates by SES are given in the online supplementary appendix 1.

## Combined mortality risks

To estimate the combined MRRs, we first run additional regression models separately for East and West Germany (see the results in the online supplementary appendix 2). The mutually adjusted MRRs for *education (four categories) and income (five categories)* were then used to calculate the combined MRRs across 20 (4×5) combinations of the categories of the two variables. For example, the combined MRR for East German males with secondary education and in income quintile 3 is estimated as follows:

MRR=exp(ln(1.12)+ln(1.55))=1.74, where 1.12 and 1.55 are the point estimates of the HRs for the secondary education and the third income quintile, respectively (see online supplementary appendix 2).

Figure 2 summarises the obtained two-dimensional MRR estimates and provides an overview of mortality disparities in Germany by means of the population risk profile.

The first segment of the black line in the left-hand panel of figure 2 shows an MRR of 8.1. This reflects the finding that in East Germany, the most disadvantaged male population group (income quintile 1, unknown education; 14.2% of the total population) has a mortality risk that is 8 times higher than that of the vanguard group (income quintile 5, higher education; 4.7% of the total population). The highest risk group in West Germany makes up 11% of the population and has an MRR of 5.5. Among females in East Germany, the group with the highest MRR (income quintile 1, unknown education; 11.4%) has a mortality risk that is 5 times higher than that of the vanguard group. The corresponding MRR for females residing in West Germany is 3.8.

## Sensitivity analyses

We carried out sensitivity analyses of possible influences on the results: 1) of the non-inclusion of the EMR population and 2) of the large share of unknown (missing) values for the education variable.

### Non-inclusion of EMR population

Disabled pensioners of working ages (as reflected by EMR data) are not included in the analysis, which may result in somewhat biassed estimates of SES-related mortality differences. To address this issue, we performed an experiment by distributing the EMR population and deaths across socioeconomic categories of the active population

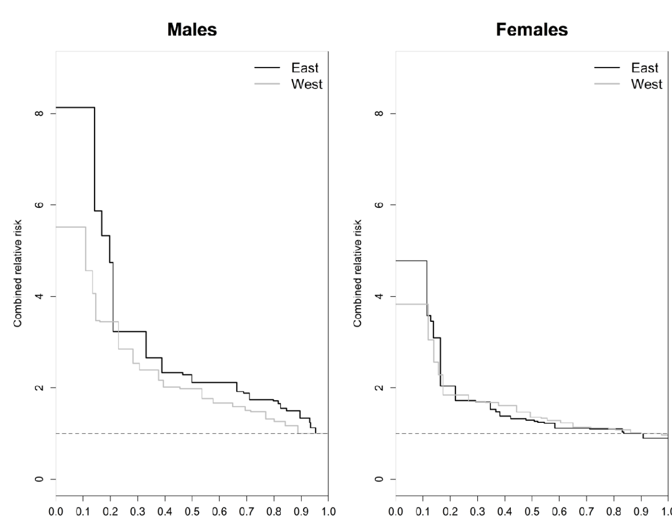


**Figure 2** Combined relative risk and corresponding population shares by sex; East and West Germany, ages 30–59 years, 2013. Based on all 20 possible combinations of categories of education (4) and income quintile (5).

Table 2 Age-adjusted mortality rate ratios for education before and after the redistribution of the unknown educational category, ages 30–59 years, 2013

| | Males | | Females | |
|---|---|---|---|---|
| **Education** | **Initial** | **After imputation** | **Initial** | **After imputation** |
| Higher | **1.00 (ref)** | **1.00 (ref)** | **1.00 (ref)** | **1.00 (ref)** |
| Secondary | 1.36*** (1.30–1.43) | 1.35*** (1.31–1.40) | 1.09** (1.02–1.17) | 1.23*** (1.16–1.29) |
| Lower | 1.67*** (1.60–1.75) | 1.69*** (1.64–1.75) | 1.45*** (1.35–1.55) | 1.65*** (1.57–1.74) |
| Unknown | 2.72*** (2.61–2.84) | – | 2.15*** (2.02–2.29) | – |

P<0.01***; 0.01<P<0.05**

Confidence intervals are presented in the parentheses.

(AKV) assuming that disabled individuals are more prevalent at lower SES levels. We used three scenarios in which we assumed that the share of the EMR population increases as SES decreases. For *scenario 1*, we assumed that the share of EMR individuals in the highest SES group (higher education and the fifth income quintile) is 50% lower than that in the AKV population. Because the EMR population is small (about 4% of the total population), its redistribution did not result in notable changes in the composition of the total population; instead, it just somewhat increased mortality levels in all education-income groups. Altering the initial EMR/AKV distribution ratio parameter for the vanguard group from 50% to 25% (*scenario 2*), or even to 10% (*scenario 3*), also did not result in dramatic changes in the mortality distribution across the combined groups. More details are provided in the online supplementary appendix 3.

### Missing values for the education variable

To find out what would happen to the mortality rate ratios of education categories after a reasonable redistribution of the unknown values, we performed a sensitivity analysis. For the reasons discussed in details in online supplementary appendix 4, we did not rely on simple approaches such as complete-case analysis, the proportional redistribution of unknowns and assigning unknowns to the lowest educational category. Instead, the missing observations were imputed using the MICE imputation algorithm.[34] Table 2 shows the age-adjusted effects of education on mortality obtained on the basis of the two datasets: 1) initial (with the *unknown* category) and 2) after imputation (without the *unknown* category).

The redistribution of the unknown educational category did not have a notable influence on the results for males. For females, the relative risk increased slightly in both the *secondary* and *higher* categories that is, the redistribution strengthened rather than weakened the educational mortality gradient.

## DISCUSSION

### Main findings

The mortality disparities among the German working-aged population are strongly associated with inter-individual differences in income. Although the income-related mortality gradient is more consistent among males, the death hazard in the lowest income quintile is greatly elevated for both sexes—nearly fivefold for males and threefold for females in the unadjusted models. In the fully adjusted model, the income gradient persists among men and is inconsistent among women. This finding, which merits further study, may be influenced by the insufficiency of the individual income variable for many women whose wealth depends on other household members. Thus, when studying females, it may be more appropriate to use household-based income measures.[35] We also found that the income-related mortality gradient is more pronounced at midlife than at older ages.[18]

The unadjusted risk of dying was shown to be 3 times higher among unemployed males and females than among their employed counterparts. After controlling for income, education and other covariates, the relative risk was reduced to a factor of 2. These results are compatible with those reported by a meta-analysis of the relationship between unemployment and all-cause mortality, but only for males.[36] Our estimates for females, however, are higher than those of Roelfs *et al*.[36] Moreover, unlike other studies, we found that excess relative risk due to unemployment is nearly identical for German males and females.

This is the first study to investigate the population-level mortality impacts of education in Germany. In the unadjusted models, the pronounced educational effects on mortality are in the expected direction. Our finding that the educational gradient among males weakens in the fully adjusted model suggests that the relationship between income and male mortality is substantially mediated by education.

Our results support the existence of a 'healthy migrant effect'.[37] After adjusting for socioeconomic and other variables, we found that non-citizens of working age were half as likely to die as German citizens. The increased (relatively to model 1) advantage of non-citizens is explained by the fact that in spite of having lower SES foreigners experience lower mortality compared with Germans. The additional tabulation based on the AKV data (not shown here) indicates a substantial disadvantage of foreigners in terms of current income: for both males and females about 40% of the foreign population falls into the first income quintile and only less than one-tenth to the fifth income quintile. The corresponding figures for the German citizens constitute 17% and 22%.

The fully adjusted models indicate that although some mortality effects attenuate after mutual adjustment, most remain large. This implies that each of the SES variables provides information on 'general well-being' and on more specific health risks solely related to the particular variable.[22] Therefore, using an aggregate risk measure combining income and education is justifiable. We found that individuals in the lowest income group and with the unknown and lower education face the highest mortality risks. By contrast, the vanguard group was shown to consist of individuals who are highly educated and belong to the fifth income quintile. The results also indicated that mortality disparities are more pronounced among males than among females, and are particularly large among East German males.

The analysis of unadjusted mortality risks revealed that East German females have a slight advantage that increases once all variables are controlled for. Some studies have attributed this advantage to higher rates of female smoking in the West than in the East.[38] Notably, the disadvantage found among East German males disappears after controlling for individual SES characteristics. This finding suggests the East-West mortality difference in adult mortality is driven by the higher SES of men living in the West.

Our findings are consistent with the study of all Swedish employees in the age range 35–59 years.[22] Likewise, we have reported more pronounced mortality disparities among men, clear net associations between education and mortality for both sexes and the strong net association between individual income from work in men but not in women. Our results are also consistent with previous research on mortality differentials by SES in Germany,[39] even though these analyses differed from our study in terms of the methods and data used and the populations analysed. In line with the results of the study by Luy *et al*,[12] we found a strong association between SES and mortality that is more pronounced among males than among females. We also identified clear mortality gradients for both income and education, as the findings indicate that the risk of dying increases with decreasing income and level of educational attainment.

## Strengths and limitations

To our knowledge, this analysis provides the first population-level evidence on socioeconomic mortality differentials among Germany's working-age population. Using large administrative data of the German pension insurance system, we assessed the mortality disparities using a broad range of socioeconomic and demographic characteristics, including individual income, education, employment status, citizenship and region for the year 2013. As no notable changes in adult mortality in Germany have occurred since 2013, analysing more recent data would not be expected to affect our main conclusions. The data used in our analysis, particularly on individual income, are highly reliable because the information reported by employers serves as the basis for pension entitlements in the future.

Several study limitations must be taken into account while interpreting the results. The most important of them are attributable to the limitations of the administrative data used in the analysis, over which we have no influence. First of all, our analyses do not cover individuals of working ages who are receiving pensions due to disability (EMR population). This implies that our results might not be directly comparable with many other studies on health inequalities. Nevertheless, the performed sensitivity analysis suggests that the hypothetical inclusion of this population would not affect our conclusions. Second, a large proportion of the data for the education variable was missing. The sensitivity analysis has shown that a plausible redistribution of this high-risk category among the three well-defined categories does not substantially change the relative risks of the lower and secondary educational categories. Third, our analysis refers to one calendar year so that there is no time lag between the exposure to risk factors and the event (death) implying that the numerical regression outputs should be seen as cross-sectional associations. Fourth, the individual income variable used in this study might be insufficient for assessing mortality differentials among women; household-based income measures could be more appropriate. Fifth, the definition of unemployment in the DRV data is too sensitive so that the pronounced mortality effects of unemployment found in our study should be seen as conservative estimates.

Several other caveats should be also mentioned. The two-dimensional (combined) disparity profile (figure 2) was based on the assumption that the mortality impacts of education and income are independent. Some studies have, however, found interactions between the health effects of education and income.[40 41] While our previous study[18] and our own additional analysis (not shown here) has confirmed the statistical significance of some education-income interactions in Germany, these interactions produce only minor effects at the population level. The model-based 'inequality stairs' in figure 2 are in line with the empirical (non-parametric) estimates of the risk across education-income groups (analysis not shown here). Because the distinction between East and West is based on the current residence, some selection effects due to migration of healthier people from East to West are possible. Finally, analysing the effects on mortality of occupation, which is an important SES dimension, was beyond the scope of this paper. Because of both the complex structure of the KldB2010 classification of professions and the large gaps in the coverage of the *Tätigkeitsschlüssel,* this dimension could not be included in this study. However, examining mortality differentials by occupational class is an important direction for future research, as international studies[42] and research on mortality differentials in Germany[12] have shown.

## Conclusions

Low SES is a major determinant of excess adult mortality in Germany. The results of this study are relevant for identifying components of the remaining East-West mortality differences within Germany. These differences are large for males only, and can be explained by the higher SES of men living in the West, rather than by contextual differences between the two parts of the country. However, as long as a male life expectancy gap between the two parts of Germany persists, it merits the attention of policy-makers. The further monitoring and analysis of these differences, which can be performed using DRV data, should be prioritised.

**Contributors** PG, RS and VS designed the study. RS arranged the work with individual-level data at the FDZ, and supplied the data in the form of a frequency table. PG performed the statistical analysis and drafted the manuscript which was revised by RS and VS. All authors read and approved the final version of the manuscript.

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