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Trends and levels of avoidable mortality among districts: "Healthy" benchmarking in Germany

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ABSTRACT

All developed nations use indicators to monitor the health of their populations, but few nations provide a systematic monitoring of indicators for small regional units. The present study aims to contribute to the literature a single graph that provides a quick and comprehensive overview of the level of and trend in avoidable mortality in each German district as compared to the national average and development. Using mortality data from the German Federal Statistical Office, I calculated the age-standardized number of avoidable deaths, separately for men and women, in each of the 413 local districts in Germany between 2000 and 2008.

For men, the graph illustrates that the districts with the highest rates of avoidable mortality are still located in the former East German states, but that some of these districts have improved significantly between the years 2000 and 2008 and are approaching the nationwide average. The graph for women shows slightly different results. Here, many urban areas show high rates of avoidable mortality with both favorable and unfavorable trends.

Health professionals could use the graph to establish realistic benchmarks that are based on countrywide comparisons of districts to a national average and trend, which may in turn help them to identify local districts in need of primary or secondary prevention programs or a more effective provision of health care.

1. Introduction

Germany is one of the few countries in the world where equality of living conditions among regions (the German *Bundesländer*) is constitutional law [1]. Equitable access to health care and an equal chance at a healthy life for all citizens are generally understood to be part of this goal [2]. Furthermore, the idea of a right to health care and equality of living conditions is closely linked to the World Health Organisation's (WHO) view that the main goals of a health system should be to improve the health of a population, and to try to respond to the reasonable health care expectations of those populations [3]. Together these constitutional mandates and international postulations may provide the theoretical justification for the systematic monitoring of health indicators related to the availability and provision of health care.

Moreover, monitoring health at a local level may inform supply planning in both the outpatient and inpatient sectors. The responsibility for achieving equitable access to health care in Germany has been delegated to the self-administered bodies of the statutory social health insurance (SHI), which covers almost 90% of the German population [4]. In the outpatient sector, the associations of SHI physicians (*Kassenärztliche Vereinigungen*) in each *Bundesland* are legally obliged to provide an equitable level of health care to all ambulatory patients, according to their needs. They attempt to meet this objective through so-called 'needs-based planning', which regulates the number of physicians that are authorized to open a practice in

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each planning region (the 395 planning regions largely correspond to the 413 German districts) on the basis of nationally defined physician–population ratios [5]. Similarly, the inpatient sector is managed at the state level, but the planning process is often linked to the district level. Providing information on health outcomes that reflect the quality of health care provisions in the planning units may be helpful in determining how to meet the health care needs of the populations in these small regional units.

Currently, all developed nations use health indicators to monitor the health of their population at the national or large-scale regional levels, but only some nations provide a systematic monitoring of indicators for small regional units comparable to local districts in Germany. Good examples of health monitoring are the U.S. Dartmouth Atlas of Health Care, the English NHS Atlas of Care, the Austrian "Österreichischer Strukturplan Gesundheit", the Dutch "Zorgatlas des Nivel" or the newly introduced French "Agences regionales de santé". The Dartmouth Atlas for Health Care, for example, not only documents how medical resources are distributed and used in the United States, but also provides a benchmarking tool that enables the comparison of data from regions or hospitals with the national average or state average [6]. On the active policy side, the U.S. state of Oregon serves as an example of a state that has used health benchmarks as part of a long-term project to monitor health and carry out strategic planning. Since 1994 county health departments in Oregon have been required to set yearly priorities and targets in accordance with selected benchmarks [7].

Similar data-gathering initiatives do exist at the district level in Germany, but there is a lack of systematic monitoring or inclusion of the results in strategic planning or financing decisions. Moreover, most of the indicators focus only on health expectancy or mortality. These indicators are, however, influenced by both a high number of deaths in old age and systematic influences by other determinants including environmental, socioeconomic and lifestyle factors. This implies that they do not necessarily reflect the effectiveness of the health care system but primarily the influence of other non-health system determinants.

The present analysis addresses these shortcomings and presents a tool for monitoring and planning health that is based solely on data for avoidable mortality. The indicator 'avoidable mortality' incorporates the notion that deaths from certain causes would not occur given effective prevention measures, or timely and appropriate access to health care, and thus aims to provide a health outcomes measure that reflects the effectiveness of health care [8,9]. In order to account for the fact that the effectiveness of (primary and secondary) prevention and treatment of manifest illnesses substantially decreases after a particular age, only deaths before a specified age (e.g. 70), were considered avoidable.

Various lists of causes of death considered to be preventable or amenable to health care have been published, each of which are based on a different conceptualisations of avoidable mortality [9–23]. In this study, I chose to rely on the list of avoidable deaths compiled by Nolte and McKee [24], whose selection of causes of death is based on earlier work by Tobias and Jackson [25], who updated a list provided by Charlton et al. [26] and by Mackenbach [27]. Nolte and McKee selected conditions that were considered to be amenable to secondary prevention or medical treatment. In line with a later list published by Page et al. [28] who compiled a revision of the list developed by Tobias and Jackson [25], I expanded the list to include additional types of cancer that have lately been identified as being amenable to health care (cancer of the lip, oral cavity and pharynx and cancer of the liver) or as being potentially avoidable by primary prevention (cancer of the esophagus and cancer of the trachea, bronchus and lung). Also added to the list based on Page et al. [28] were traffic accidents, which are avoidable through primary prevention (i.e. road safety), and alcohol-related diseases, which are avoidable through primary prevention of alcohol misuse and are to some extent amenable to health care. Page et al. [28] provide a detailed rationale for including these conditions. Thus, most of the conditions on the list are amenable to secondary prevention or health care. A small share of indications, however, is not under the direct control of the health system but might be responsive to primary prevention programs against smoking and alcohol misuse or might be influenced through public policies.[1]

The concept of avoidable mortality has some important limitations, chief among which is the selection of causes of death identified as potentially avoidable which – even if well informed – remains ultimately subjective [24]. Second, the rates of avoidable mortality are not a fully adequate indicator of health care availability and provision because they are irrelevant to those services that are focused primarily on relieving pain and improving quality of life [24]. Third, the frequently found high correlation with socioeconomic factors suggests that a large share of differences in these deaths is determined by socioeconomic-related differences in lifestyle among regions. While this is to a large extent true for cardiovascular diseases, most cancer types and alcohol misuse, other causes of death (for example death following measles or appendicitis) should not be affected by lifestyle. Moreover, primary and secondary prevention and medical care should contribute to reductions in potentially avoidable mortality even – or especially – in deprived areas with high risk factors and a resulting high need for health care [22].

Table 1 presents an overview of all the types of diseases considered in this study.

Several previous studies have already investigated differences in avoidable mortality within a single country [12,14,30–33]. In a 2004 study for Germany, Wiesner and Bittner [32] used the concept of avoidable mortality to explain differences in mortality rates and life expectancy

[1] Although we aimed, in accordance with the list published by Nolte and McKee [8], to include Hodgkin's disease (for the age group one to 70 years) and leukemia (for the age group one to 44 years) in our analysis as avoidable forms of cancer, mortality data on these two disease entities were incomplete, perhaps due to an error in the official coding of variables provided to us by the German Federal Statistical Office. Considering, however, that the cancer types account for a rather small proportion of overall cancer mortality in the relevant age groups [29], it seems unlikely that the absence of these data has distorted our results in a substantial way [33].

Table 1
ICD-10-GM codes for mortality considered preventable or treatable.

Avoidable mortality indication	ICD-10-GM code	Age
Intestinal infections	A00–A09	0–14
Tuberculosis	A15–19, B90	0–70
Whooping cough	A37	0–14
Other infections (diphtheria, tetanus, poliomyelitis, sepsis)	A40–A41, A36, A35, A80, M86, M869	0–70
Measles	B05	1–14
Malignant neoplasm of lip, oral cavity and pharynx	C00–C14	0–70
Malignant neoplasm of esophagus	C15	0–70
Malignant neoplasm of colon, rectosigmoid junction, rectum, and anus and anal canal	C18–C21	0–70
Malignant neoplasm of liver	C22	0–70
Malignant neoplasm of trachea, bronchus and lung	C33–C34	0–70
Malignant neoplasm of skin	C44	0–70
Malignant neoplasm of female breast	C50	0–70
Malignant neoplasm of cervix uteri	C53	0–70
Malignant neoplasm of cervix uteri and body of the uterus	C54–55	0–44
Malignant neoplasm of testis	C62	0–70
Malignant neoplasm of bladder	C67	0–70
Disease thyroid	E00–E07	0–70
Diabetes mellitus	E10–E14	0–49
Alcohol-related diseases (excluding external causes)	F10, I46.2, K70, K73–K74	0–70
Epilepsy	G40–G41	0–70
Chronic rheumatic heart disease	I05–I09	0–70
Hypertensive disease	I10–I13, I15	0–70
Ischemic heart disease	I20–I25	0–70
Cerebrovascular disease	I60–I69	0–70
All respiratory disease	J00–J09, J20–J99	1–14
Influenza	J10–J11	0–70
Pneumonia	J12–J18	0–70
Peptic ulcer	K25–K27	0–70
Appendicitis	K35–K38	0–70
Abdominal hernia	K40–K46	0–70
Cholelthiasis and cholecystitis	K80–K81	0–70
Nephritis	N00–N07, N17–N19, N25–N27	0–70
Benign prostatic hyperplasia	N40	0–70
Maternal deaths	O00–O99	All
Perinatal deaths, all causes excluding stillbirths	P00–P96, A33, A34	All
Congenital cardiovascular anomalies	Q20–Q28	0–70
Traffic accidents	V01–V99	All
Misdirected medical care	Y60–Y69, Y83–Y84	All

between former East and West Germany after German reunification in 1990. They found that the higher rates of avoidable mortality initially observed in both men and women in the former East Germany had decreased by more than half by 2001. In 2010, Sundmacher et al. conducted a spatial analysis of variation in avoidable mortality at the level of the German districts based on mean values for the years 2000 through 2004. They found that rates of premature death due to cardiovascular disease were still considerably higher in former East than in the West Germany [34]. A later study by Sundmacher and Busse [35] focused on avoidable cancer deaths and investigated the causal relationship of potentially avoidable cancer deaths to physician density using an instrumental variable regression approach. They found that higher physician density slightly reduced the number of avoidable cancer deaths.

However, no study to date has systematically compared differences in potentially avoidable mortality among local districts and over an extended time period. The present study aims to contribute to the literature a graph that illustrates relative levels and time trends in avoidable mortality among the 413 German local districts for men and women separately. The graph strives to provide a benchmark for theoretically attainable lower levels in mortality that could potentially be achieved through effective primary or secondary prevention, or timely and appropriate access to health care in local districts. Although the graph is primarily of interest to German public health professionals, it may also be relevant for neighboring European countries, which could use the concept of the graph for their own health monitoring.

2. Methods

2.1. Data

Mortality data at the level of German districts have been maintained by the German Federal Statistical Office since 1991 but were not made available to the public until 1998. At the individual level, data are gathered in each local district and include information on age and region, as well as the complete ICD code (as reported on death certificates) for all persons one year of age or older. Infant mortality (deaths of children under the age of one year) is not reported in the mortality statistics. In the present study, I used the German modification (GM) of the 10th revision of the International Classification of Diseases (ICD-10) to identify deaths that can be considered avoidable and which took place between 2000 and 2008. Then, in concordance with the great body of literature on avoidable mortality, I set an upper age limit beyond which deaths could no longer be considered preventable or amenable to health care. In doing so I chose, in line with the German Robert Koch Institute, the conservative upper value of 70 years for most indications [33,36] (the age limit is lower for some indications).

Finally, for each year in the dataset, I calculated the age-standardized number of avoidable deaths separately for men and for women in each of the 413 districts that existed in Germany between 2000 and 2008 (i.e., prior to an administrative reform that slightly reduced the number of districts). The districts in Germany correspond to level 3 of the Nomenclature of Statistical Territorial Units system developed and used by the European Union for statistical and other purposes[2] [37].

2.2. Graphic visualization

In this study I sought to visualize both levels and time trends in avoidable mortality in German districts over nine years in one graph. To do so, I constructed a coordinate system that situates the level of avoidable mortality on the vertical axis and time trends in avoidable mortality on the horizontal axis. The vertical axis reflects the nationwide average in avoidable mortality for men and for women. Positive values on the vertical axis (which fall in the northern quadrants) reflect levels of avoidable mortality that are higher than the nationwide average, while negative values (which fall in the southern quadrants) reflect levels lower than the national average. A value of 20 implies, for example, that there are 20 more avoidable deaths per 100 000 inhabitants in the district than there are per 100 000 inhabitants on average in the nation as a whole.

The point of origin on the horizontal axis reflects the average nationwide trend in avoidable mortality for the years 2000 through 2008. Positive values reflect a slower rate of decrease in avoidable mortality or even an increase (above a certain value) in relation to the average decrease in avoidable mortality over the nine years. The negative values reflect a rate of decrease that is faster than the national trend between 2000 and 2008.

To obtain these values for each district, I considered two models: one restricted and one unrestricted linear regression model. The restricted model regressed the average of avoidable mortality in the 413 districts on a continuous variable that was increasing in the years 2000–2008. The results of this regression showed a highly significant negative linear trend in avoidable mortality throughout Germany. The unrestricted model included two additional parameters: the differential intercept and the differential time slope for one of the 413 districts. The differential time slopes gave the values for the vertical axis. In total, I estimated 413 models for each of the German local districts and plotted the differential slope onto the coordinate system. The estimation approach is visualized in Fig. 1 and explained in Appendix A.

Fig. 1 shows that the graph breaks the data down into four quadrants. The northeast quadrant contains red data points for local districts with relatively higher rates of avoidable mortality, which are decreasing more slowly or even increasing as compared to the nationwide trend. The threshold for the change from absolutely decreasing to increasing rates in avoidable mortality is indicated by the red dotted line in the east quadrants. The northwest quadrant contains yellow data points for the districts where the level of avoidable mortality is higher but decreasing more quickly as compared to the nationwide trend. The southeast quadrant contains light green-colored districts with lower levels of avoidable mortality. In these districts, rates are decreasing more slowly or are even increasing in comparison to the national trend. The threshold for the change from decreasing to increasing rates in avoidable mortality is again indicated by the red dotted line in the east quadrants. The southwest quadrant shows dark green-colored districts with a lower level of avoidable mortality that is also decreasing more quickly than the nationwide trend.

Before plotting the graph, I tested whether the unrestricted model was nested in the restricted model for each local district using a simple F test. If the hypothesis of a nested model was rejected at the 10% level or lower, I had moderate evidence that the trend and level of avoidable mortality in that local district was statistically different from the nationwide trend and level. If there was no evidence for statistical difference, the data points were colored in blue. Although the data on avoidable mortality is based on the total population data, and significance tests are usually used to indicate whether or not the variation across units is due to chance or function sampling, I opted to conduct the tests because the population size varies greatly between local districts. The test therefore allowed for both a very high level of variation in avoidable mortality in districts with smaller populations over time and more stable trends in districts with a greater population size. In this way, I viewed avoidable mortality in districts as the result of a probability process that unfolds over time.

3. Results

Figs. 2 and 3 illustrate trends and levels of avoidable mortality for men and women across Germany from 2000 to 2008. Avoidable mortality decreased from about 134 deaths in men per 100 000 population in 2000 to about 110 deaths in men per 100 000 population in 2008, reflecting a linear reduction of about 2.78 deaths per 100 000 each year. On average there were about 122 avoidable deaths in men per 100 000 population each year between 2000 and 2008. The level of avoidable mortality in women in Germany was about 60 per 100 000 population in 2000, with a linear reduction of about 0.53 avoidable deaths each year through 2008. On average, there were roughly 58 avoidable deaths

[2] The NUTS-regions are based on the existing national administrative subdivisions. In countries where only one or two regional subdivisions exist, or where the size of existing subdivisions is too small, a second and/or third level is created. This may be on the first level (ex. France, Italy, Greece, and Spain), on the second (ex. Germany) and/or third level (ex. Belgium). In smaller countries, where the entire country would be placed on the NUTS 2 or even NUTS 3 level (ex. Luxembourg, Cyprus, Ireland), levels 1, 2 and/or 3 are identical to the level above and/or to the entire country.

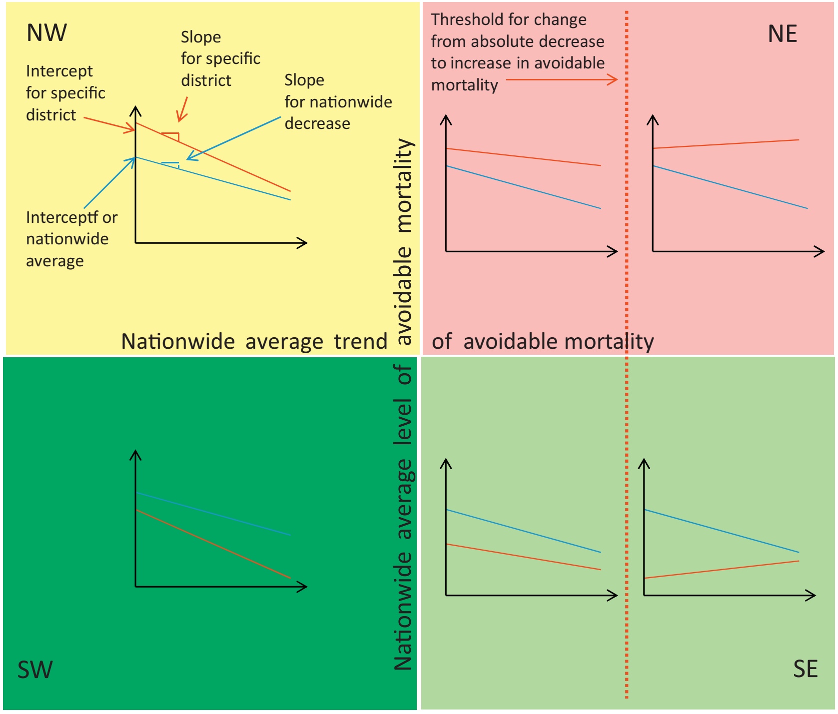

Fig. 1. Estimation and visualization approach for monitoring health outcomes.

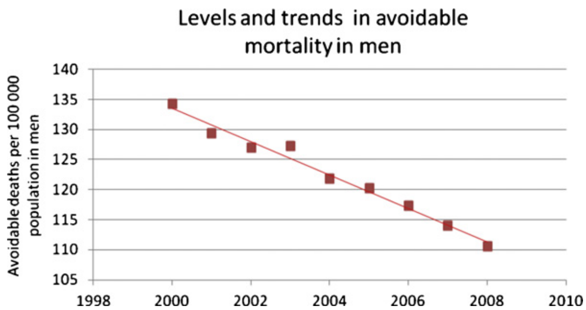

Fig. 2. Levels and trend in avoidable mortality in men.

in women per 100 000 population each year between 2000 and 2008.

A slope equal to or higher than 2.78 for men and 0.53 for women indicates absolutely increasing avoidable mortality over the observed time period.

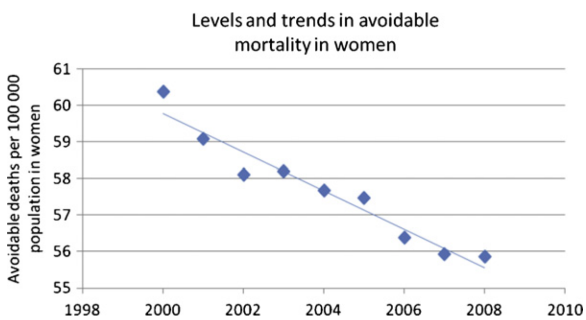

Fig. 3. Levels and trends in avoidable mortality in women.

Fig. 4 shows the distribution of levels and trends in avoidable mortality for men in the 413 German local districts for the years 2000–2008. The blue data points indicate that the model for each district is nested in the model for all of Germany while the other colors show moderate evidence that the model for each district is statistically different from the national model. A closer look at the data points reveals a round-shaped data cloud centered on the origin, with less variation in the south quadrants than in the north quadrants. Positive deviations from the nationwide average level of avoidable mortality are therefore far higher (with up to 90 additional deaths per 100 000 per year) than negative deviations (with only up to 50 fewer avoidable deaths). In addition, the wide distribution of data points in the northwest quadrant indicates a high degree of variation where the districts with higher but more quickly decreasing avoidable mortality rates compared to the nationwide trend are shown. What stands out here is that districts in this quadrant are located primarily in the former East Germany, especially in Mecklenburg-Western Pomerania and Brandenburg. Rural areas are also disproportionately represented. The districts with higher levels and an unfavorable trend are located not only in former East Germany, but also in the western parts of Germany. Most flourishing cities and regions in the south of Germany (Tübingen, Freiburg and Landkreis Starnberg), on the other hand, are found in the southern quadrants, and hence have rates of avoidable mortality that are lower than the national average.

Fig. 5 shows the distribution of levels and trends in avoidable mortality for women in the 413 German districts for the years 2000–2008. The shape of the data cloud

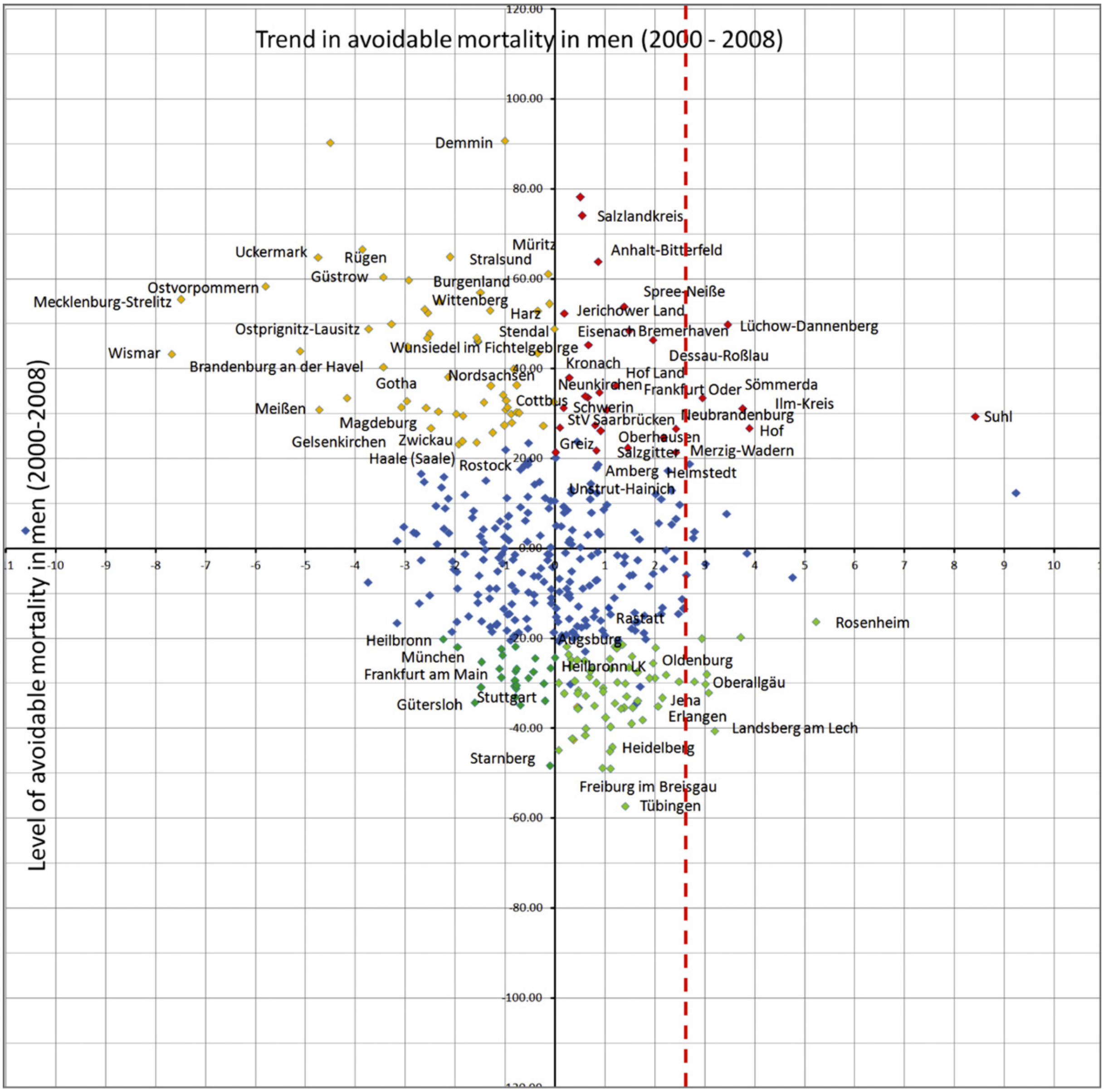

Fig. 4. Trend and levels of avoidable mortality in men in one graph.

is similar to the figure for men, but the amplitude of the level of avoidable mortality is more equal in both directions. An exception is the outlier Tübingen, which has the lowest avoidable mortality rate. In contrast to the figure for men, the districts falling in the northeast quadrant show the highest degree of variation. Especially interesting here is that these districts are not primarily located in former East Germany but also in districts in the West, like Lüchow-Dannenberg, Aachen Land, Duisburg and Essen. The districts with higher than average but declining rates of avoidable mortality, are as well located in eastern (e.g. Stralsund and Rostock) and western (e.g. Remscheid, Bremen and Bochum) Germany. Interestingly, many of the districts with high levels of avoidable mortality are urban (e.g. Essen, Duisburg, Düsseldorf and Frankfurt-Oder) and not rural areas, as was the case in the graph for men. The districts in the south quadrants can again be found in the south and west of Germany with one noticeable exception: Jena, the district with the second lowest rate, is in former East Germany.

4. Discussion

The main contribution of this paper is to provide, through a single graph, a quick and comprehensive overview of how the level and trend in avoidable mortality in each German local district compares to the national average and development. Health professionals could use the graph to establish realistic benchmarks that are based on countrywide comparisons of districts to a national

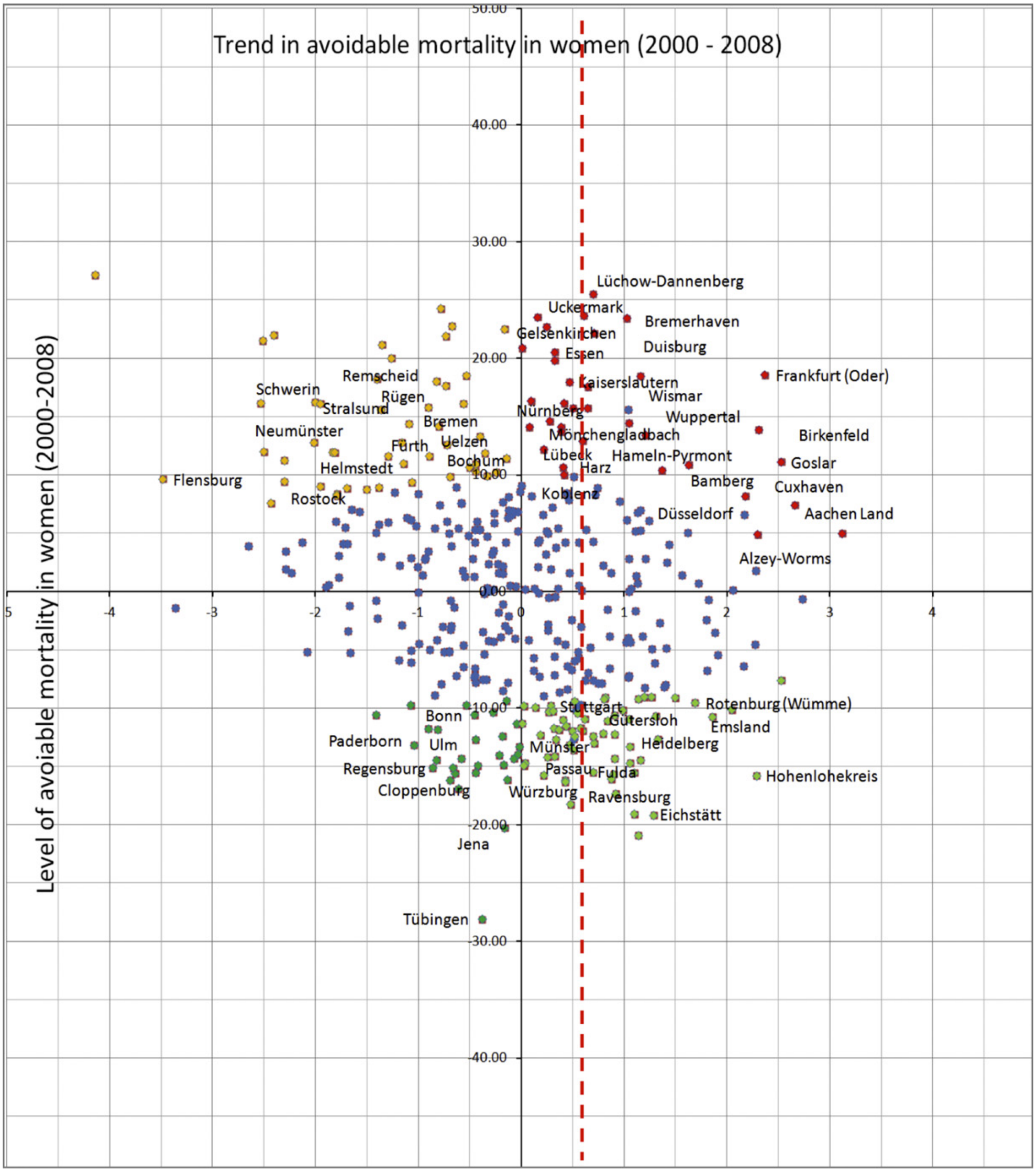

Fig. 5. Trend and levels of avoidable mortality in women in one graph.

average and trend, which may in turn help them to identify local districts in need of primary or secondary prevention programs or a more effective provision of health care.

For men, the graph illustrates that the districts with the highest rates of avoidable mortality are still located in the former East German states, but that some of these districts have improved significantly between the years 2000 and 2008 and are approaching the nationwide average. The districts with higher levels and an unfavorable trend are located not only in economically deprived areas in the East, but also in western Germany. Interestingly, Hof, Helmstedt, and Bremerhaven are all western German districts that have witnessed a significant population loss over the past several years. The graph for men thus shows that economically deprived and so-called shrinking districts are experiencing the most worrying trends in avoidable mortality. From earlier studies, it is known that cardiovascular diseases and cancer of the trachea, bronchus and lung make up the largest share of avoidable mortality in men in Germany and some newer figures suggest that those diseases are responsible for most potentially avoidable deaths in economically deprived areas [38].

The graph for women shows slightly different results. Here, many urban areas show high rates of avoidable mortality with both favorable and unfavorable trends. It is interesting that many districts with an unfavorable development are located in urban areas, especially in the western parts of Germany (e.g. Bremerhaven, Duisburg, Essen and Mönchengladbach). This could be explained by the fact that for some deaths, in particular deaths potentially avoidable through primary prevention such as those from lung cancer or alcohol-related diseases, there is an increasing trend for women in urban areas which is thought to be related to the increased number of female smokers and higher alcohol consumption among some women [33,34,38]. It should, however, be noted that while the presented graph helps to identify the better or worse performing districts, it does not reveal the causes of death that influence the trend. This would necessitate further disaggregation of the avoidable death figures into the individual components.

The German districts with low levels of avoidable mortality for both sexes can mostly be found in the economically flourishing south of Germany. Southern Germany not only has better economic indicators, it also displays the highest physician–population ratios in Germany. Tübingen, Freiburg, Stuttgart and Heidelberg are all university cities showing low levels of avoidable mortality across gender and are also known to have one of the highest physician–population ratios in Germany. It is difficult to establish a causal relationship between physician density and population health because it is not clear whether their high number actually improves the quality of health care provision in those regions, or whether they chose to practise in areas with already low levels of mortality caused by other determinants [35]. It is, however, evident that the highest physician–population ratios can be found in areas with low levels of avoidable mortality while many districts with high levels of avoidable mortality and worrying socioeconomic indicators have problems attracting physicians to their areas.

For some time, the Associations of SHI Physicians, or *Kassenärztliche Vereinigungen* (KVen), has been criticized for not fulfilling their legal mandate of providing an equitable level of health care to all ambulatory patients according to their needs, especially in rural areas. The main criticism is that the scheme bases the optimal physician–population ratio on a historic distribution of physicians instead of on a scientifically proven need-based measure [5]. In this context, the graph may for example be used to inform the need-based planning scheme by serving as a warning system or by providing important information on the health needs of regions, if necessary broken down by levels and developments of different indications. The graph could of course also be used for similar planning purposes in the hospital sector or may help public health professionals to monitor the development of health outcomes in their local district in relation to a national benchmark and other regions.

The graph presented here thus reveals useful and interesting data, but it has also some important limitations. First, the benchmarks correspond to national averages, not optimal levels and trends. An analysis of the data for the quintile of districts with the lowest level of avoidable mortality would certainly allow us to set more ambitious and inspiring benchmarks. But taking as a starting point the goal of equality among regions inscribed in the German constitution, I chose to base the benchmark on Germany's average national level and rate of decrease. Second, the analysis is based on mortality data which relies on the validity of death certificates. However, some differences in avoidable mortality may be in parts due to systematic differences in coding between the districts of *Bundesländer* depending on medical practice habits or views [24]. Further research that develops techniques to identify and quantify regional coding differences would be desirable.

Third, the German districts vary greatly in size and population and range from about 35 000 to over 3 million inhabitants, calling the comparability between these administrative areas into question. I applied significance tests to identify variations in avoidable mortality that may result from small sample size, which acknowledges but does not solve the problem of a lack of comparability.

Finally, as an outcome measure, avoidable mortality has some important limitations that are thoroughly discussed in the introduction of the paper. It is however important to reiterate that the concept of avoidable mortality should not be mistaken for definitive evidence of differences in the effectiveness of health care. As Nolte and McKee have stated: "It should [only] be interpreted as an indicator of potential weaknesses in health care that may require further investigation" [24].

Appendix A. Regression approach

I considered two models: one restricted and one unrestricted.

The restricted model regressed the average of avoidable mortality in the 413 districts on a continuous variable that was increasing in the years 2000–2008:

$$AMR_{ct} = \alpha_1 + \beta_1 Y_t + \varepsilon \quad (1)$$

where *AMR* is the age-standardized avoidable mortality rate in district c in year t. Y is the continuous variable that is increasing in the years 2000–2008. α_1 and β_1 are the coefficients to be estimated. ε is the error term.

The unrestricted model included two additional parameters: the differential intercept α_2 and the differential time slope β_2 for one of the 413 districts. D is a vector of dummy variables that take a value of one for each of the 413 local districts c.

$$AMR_{ct} = \alpha_1 + \alpha_2 D_c + \beta_1 Y_t + \beta_2 Y_t D_c + \varepsilon \quad (2)$$

In total, I estimated 413 models for each of the German local districts.

References

[1] Bundesministerium der Justiz. Artikel 72, Abs. 2 GG; 2012. http://www.gesetze-im-internet.de/gg/art_72.html [accessed 27.11.11].

[2] Weinbrenner S, Wörz M, Busse R. Gesundheitsförderung im europäischen Vergleich. Bonn/Frankfurt a.M.: KomPart Verlagsgesellschaft; 2007.

[3] World Health Organization. The world health report 2000. Health systems: improving performance. Geneva: WHO; 2000.
[4] Busse R, Riesberg A. Gesundheitssysteme im Wandel: Deutschland. Kopenhagen: WHO Regionalbüro für Europa im Auftrag des Europäischen Observatoriums für Gesundheitssysteme und Gesundheitspolitik; 2005.
[5] Ozegowski S, Sundmacher L. Ensuring access to health care – Germany reforms supply structures to tackle inequalities. Health Policy 2012, http://dx.doi.org/10.1016/j.healthpol.2012.04.002.
[6] The Dartmouth Atlas of Health Care; 2012. http://www.dartmouthatlas.org/ [accessed 27.11.11].
[7] Leichter H, Tyrens J. Achieving better health outcomes: the Oregon benchmark experience. New York, Milbank: Memorial Fund; 2002.
[8] Nolte E, McKee M. Does health care save lives? Avoidable mortality revisited. London: The Nuffield Trust; 2004.
[9] Nolte E, McKee M. Measuring the health of nations: analysis of mortality amenable to health care. British Medical Journal 2003;327:1129.
[10] Rutstein DD, Berenberg W, Chalmers TC, Child CG, Fishman AP, Perrin EB. Measuring the quality of medical care. A clinical method. New England Journal of Medicine 1976;294:582–8.
[11] Charlton JR, Hartley RM, Silver R, Holland WW. Geographical variation in mortality from conditions amenable to medical intervention in England and Wales. Lancet 1983;1:691–6.
[12] Poikolainen K, Eskola J. The effect of health services on mortality: decline in death rates from amenable and non-amenable causes in Finland, 1969–81. Lancet 1986;1:199–202.
[13] Holland WW. European community atlas of avoidable death: Vol. 1 (CEC Health Services Research). Oxford: University Press; 1997.
[14] Mackenbach JP, Kunst AE, Looman CW, Habbema JD, van der Maas PJ. Regional differences in mortality from conditions amenable to medical intervention in the Netherlands: a comparison of four time periods. Journal of Epidemiology and Community Health 1998;42:325–32.
[15] Treurniet HF, Boshuizen HC, Harteloh PPM. Avoidable mortality in Europe (1980–1997): a comparison of trends. Journal of Epidemiology and Community Health 2004;58:290–5.
[16] Sanchez JA, Sanchis Noguera B, Prado Del Baño MJ, Sabater Pons A, Sanchez CS. Testing a new health indicator: Using avoidable causes of death and life expectancy for Spain between 1975–1986. European Journal of Epidemiology 1993;9:33–9.
[17] Song YM, Byeon JJ. Excess mortality from avoidable and non-avoidable causes in men of low socioeconomic status: a prospective study in Korea. Journal of Epidemiology and Community Health 2000;54:166–72.
[18] Tobias M, Jackson G. Avoidable mortality in New Zealand, 1981–97. Australian and New Zealand Journal of Public Health 2001;25:12–20.
[19] Levi F, Lucchini F, Negri E, Zatonski W, Boyle P, la Vecchia C. Trends in cancer mortality in the European Union and accession countries, 1980–2000. Annals of Oncology 2004;15:1425–31.
[20] James PD, Manuel DG, Mao Y. Avoidable mortality across Canada from 1975 to 1999. BMC Public Health 2006;23:137.
[21] Ward J, Girgis S, Adily A. Attributable fractions for premature mortality avoidable through public health action: updated estimates by Australian public health physicians. Australian and New Zealand Journal of Public Health 2006;30:407–12.
[22] Korda RJ, Butler JRG, Clements MS, Kunitz SJ. Differential impacts of health care in Australia: trend analysis of socioeconomic inequalities in avoidable mortality. International Journal of Epidemiology 2007;36:157–65.
[23] Chung JI, Song YM, Choi JS, Kim BM. Trends in avoidable death over 20 years in Korea. Journal of Korean Medical Science 2008;23:975–81.
[24] Nolte E, McKee M. Does health care save lives? Avoidable mortality revisited. The Nuffield Trust; 2004.
[25] Tobias M, Jackson G. Avoidable mortality in New Zealand, 1981–97. Australian and New Zealand Journal of Public Health 2001;25:12–20.
[26] Charlton JRH, Hartley RM, Silver R, Holland WW. Geographical variation in mortality from conditions amenable to medical intervention in England and Wales. Lancet 1983;i:691–6.
[27] Mackenbach J. How important have medical advances been? In: Sussex J, editor. Improving population health in industrialised countries. London: Office of Health Economics; 2000. p. 53–69.
[28] Australia New Zealand Atlas of avoidable mortality; 2006. http://www.publichealth.gov.au/publications/australian-and-new-zealand-patlas-of-avoidable-mortality.html [accessed 27.11.11].
[29] Deutsches Krebsforschungszentrum. Die 20 häufigsten Krebstodesursachen in Deutschland im Jahr 2008; 2009. http://www.dkfz.de/de/krebsatlas/gesamt/organ.html [accessed 26.05.11].
[30] Humblet PC, Lagasse R, Leveque A. Trends in Belgian premature avoidable deaths over a 20 year period. Journal of Epidemiology and Community Health 2000;54:687–91.
[31] Andreev EM, Nolte E, Shkolnikov VM, VaraviKova E, McKee M. The evolving pattern of avoidable mortality in Russia. International Journal of Epidemiology 2003;32:437–46.
[32] Wiesner G, Bittner EK. Life expectancy, potential years of life lost (PYLL), and avoidable mortality in an East/West comparison. Bundesgesundheitsblatt 2004;47:266–78.
[33] Sundmacher L, Gaskins M, Hoffman K, Busse R. Spatial distribution of avoidable cancer mortality. Journal of Public Health 2011, http://dx.doi.org/10.1007/s10389-011-0441-443.
[34] Sundmacher L, Kimmerle J, Latzitis N, Busse R. Vermeidbare Sterbefälle in Deutschland: Räumliche Verteilung und regionale Konzentrationen. Das Gesundheitswesen 2011;73(4):229–37.
[35] Sundmacher L, Busse R. The impact of physician supply on avoidable cancer mortality in Germany. Health Policy 2011;103:53–62.
[36] Gaber E. Sterblichkeit, Todesursachen und regionale Unterschiede. In: Gesundheitsberichterstattung – Themenheft. 2011.
[37] European Commission NUTS – Nomenclature of territorial units for statistics: National structures (EU); 2011. Available from: http://epp.eurostat.ec.europa.eu/portal/page/portal/nuts_nomenclature/correspondence_tables/national_structures_eu [accessed 27.11.11].
[38] Technische Universität Berlin – Management im Gesundheitswesen. Vermeidbare Mortalität in Kreisen und kreisfreien Städten (2000–2008); 2012. http://www.mig.tu-berlin.de/menue/research/aktuelle_projekte/avoidablemortality/sterbefaelle/ [accessed 02.05.12].