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ORIGINAL ARTICLE

Regional deprivation in Bavaria, Germany: linking a new deprivation score with registry data for lung and colorectal cancer

Laura Kuznetsov · Werner Maier · Matthias Hunger · Martin Meyer · Andreas Mielck

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Abstract
Objective This study aimed to examine the differences in cancer risk by regional deprivation in Bavaria, Germany.
Methods Multilevel Poisson regression analysis was used to evaluate the association between lung and colorectal cancer risk and community deprivation level based on data from the Cancer Registry of Bavaria (2003–2006). The communities ($n = 1{,}408$) were classified according to the Bavarian Index of Multiple Deprivation (BIMD), differentiated into quintiles ranging from lowest to highest deprivation.
Results Increased lung cancer risk in men and colorectal cancer risk in both genders were associated with increasing BIMD. Comparing the most deprived with the least deprived communities, the relative risk for lung cancer incidence in men was 1.39 (95% CI 1.29–1.49), for mortality risk 1.54 (95% CI 1.41–1.68). The relative risk for colorectal cancer incidence in men was 1.30 (95% CI 1.22–1.38) and in women 1.19 (95% CI 1.11–1.27); for mortality risk we found 1.57 (95% CI 1.40–1.76) in men and 1.34 (95% CI 1.19–1.51) in women.
Conclusion Area-based deprivation is significantly associated with cancer risk in Bavaria.

Keywords Social inequalities · Regional deprivation · Small-area analysis · Lung cancer · Colorectal cancer

Introduction

Lung cancer and colon cancer are among the most common cancer types in both genders in Germany. Colon cancer is the second most frequent cancer in Germany (36,300 cases in men and 32,440 in women in 2006), after prostate cancer (in men) and breast cancer (in women). Colon cancer is also the second most common cancer cause of death (Cancer in Germany 2005/2006). Lung cancer is the third most frequent cancer in both genders (32,500 cases in men and 14,600 in women in 2006) and the leading cancer cause of death among men (Cancer in Germany 2005/2006).

Analysis of regional differences in health has become increasingly popular in epidemiological and public health research (Haynes et al. 2008; Pampalon et al. 2010). A number of studies have found an association between regional deprivation and cancer incidence as well as cancer mortality (Parsons and Somerville 2000; Lancaster et al. 2006). In Germany, research regarding regional differences in health has finally gained more attention in recent years (Breckenkamp et al. 2007; Voigtländer et al. 2010). However, the relationship between regional deprivation and cancer incidence or mortality has barely been studied yet. There are a few studies from Germany showing associations at the regional level, especially for lung cancer (Kaak et al. 1996; Eberle et al. 2010). They have been conducted at an urban district level, using cancer registry data or data from death certificates. Another German study focused on the community level, showing higher risks of colorectal cancer mortality for patients from communities

L. Kuznetsov (✉) · W. Maier · M. Hunger · A. Mielck
Helmholtz Zentrum München, German Research Center for Environmental Health, Institute of Health Economics and Health Care Management, Ingolstädter Landstraße 1, 85764 Neuherberg, Germany
e-mail: laura.kuznetsov@med.uni-muenchen.de

M. Meyer
Population-based Cancer Registry of Bavaria, Östliche Stadtmauerstr. 30, 91054 Erlangen, Germany

that are socially deprived (Brenner et al. 1991). However, there is no study that includes the recent debate on regional deprivation scores.

Our study focuses on Bavaria, Southern Germany. Some evidence is available from Bavaria indicating that overall mortality is comparatively high in socially deprived regions (Kuhn et al. 2006). It has also been shown that total cancer incidence and mortality are relatively high in the north-eastern part of Bavaria, which is generally known to be more deprived in terms of the economy and tax revenues (Meyer et al. 2006; Spatial carcinoma analysis 2010). In the most recent study, Maier et al. (2011) presented a new Bavarian Index of Multiple Deprivation (BIMD), applying the method used in the UK to calculate indices of deprivation (Noble et al. 2006). At the community level, the study clearly showed that overall mortality increases with increasing regional deprivation. In order to inform health policy-makers, it is important to conduct analyses for specific chronic diseases and causes of mortality, as this might lead to more specific recommendations for interventions. The study presented here focuses on lung and colorectal cancer, as these two cancer sites are highly relevant for both men and women, testing the hypothesis that incidence and mortality increase with increasing regional deprivation of the community (as assessed by the BIMD).

Methods

Bavaria is Germany's largest state by area and its second most populous state with more than 12 million inhabitants. The system of administrative units is differentiated by hierarchically ordered regional units: governmental regions (in German 'Regierungsbezirke' $n = 7$), districts ('Landkreise' $n = 71$), independent cities ('kreisfreie Städte' $n = 25$) and communities other than independent cities ('Gemeinden' $n = 2{,}031$). In our analysis, we used the smallest regional unit available, i.e. communities plus independent cities ($n = 2{,}056$), referring to this group as 'communities'. These communities vary in population size (from the smallest with 219 people to the largest with a population of 1.3 million) with a mean population of 6,076.2 (standard deviation 2,192) and a median population of 2,770. Thus, communities are the smallest regional statistical units in Germany, but they are relatively heterogeneous in population size. Small area statistical units like the UK Super Output Areas are not available in Germany yet.

Cancer incidence and mortality data

In Germany, cancer registries are regulated at the federal state level, i.e. each state has its own legislation and its own population-based cancer registry, with compulsory registration in some but not all federal states. In Bavaria, cancer registration is implemented by non-compulsory (i.e. voluntary) notification, combined with mandatory information of patients. All physicians and local health authorities are asked to send notifications about all newly diagnosed cancer types to their respective regional Clinical Cancer Registries. Cancer registry notifications comprise patient-related data (sex, age, residence and occupation), tumour-related data (diagnosis, location, histology and staging) and treatment-related data (Radespiel-Tröger et al. 2009). Owing to strict data protection laws, it is not possible in Germany to link cancer registry data with individual data from official statistics about social indicators (Eberle et al. 2010).

Incidence and mortality data for lung cancer and colorectal cancer were obtained from the Population-based Cancer Registry of Bavaria. Following international standards, governmental regions were included only if registration met the limit of at least 90% completeness (Hofferkamp 2008). The registration completeness is estimated in Germany by the Robert Koch Institute using log-linear models based on the mortality/incidence ratio. On account of lower levels of completeness, we thus had to exclude data from two governmental regions (Swabia, with 340 communities, and Lower Franconia, with 308 communities). Cancer incidence was defined as first occurrence of cancer per person according to ICD-10 (lung cancer C33–34 and D02.1–02.2; colorectal cancer C18–21 and D01.0–01.3). Cancer mortality was defined by the underlying cause of death according to the ICD-10 (lung cancer C33–34; colorectal cancer C18–21). Information on cancer mortality is based on the death certification data and follow-up-data from the Clinical Cancer Registries in Bavaria.

In order to obtain more stable estimates, we pooled data from 2003 to 2006 (i.e. the most recent data available with sufficient completeness). The data were analyzed by the community in which the patient lived ($n = 1{,}408$ communities); this information is systematically recorded in the cancer registry. Concerning individual social status, the cancer registry includes only some information on occupation, but due to the large amount of missing data, this information should not be used in epidemiological studies.

Deprivation index

We applied the BIMD, which has been developed recently (Maier et al. 2011). The BIMD is based on the Index of Multiple Deprivation (IMD), i.e. a method well established in the UK (Noble et al. 2006). Regional deprivation indices are commonly used in epidemiological and public health research (Noble et al. 2006; Morris and Carstairs 1991), and the IMD represents the most up-to-date method. The BIMD was calculated using official statistical data (mostly for 2006). It comprises seven deprivation domains (i.e. income, education, employment, environment, municipal revenue, social capital and social security). In the study by Maier et al. (2011), after calculating the BIMD score for each Bavarian community, the communities were divided into quintiles from the most deprived to the least deprived. These quintiles were used in the present study as well, indicating the level of the community deprivation in which the patient lived. The deprivation quintiles have not been weighted by the number of people. In Germany, the smallest statistical units covering the whole of the country are municipalities ("Gemeinden"). Lacking relatively homogenous spatial units such as the Super Output Areas in the United Kingdom, we started our analyses based on this administrative small area scale. We are aware of the problem that, like the wards formerly used in the UK, municipalities are heterogeneous units varying in population size.

Statistical analysis

For both cancer sites, standardized incidence ratios (SIR) and standardized mortality ratios (SMR) were calculated as the ratio of the observed to the expected number of cases. This information was used to show maps of the geographic distribution. Poisson regression analysis was used to examine the association between the risks of incidence and mortality on the one hand, and regional deprivation on the other. Multilevel regression was applied to account for the hierarchical data structure in which age and gender groups (level 1) are nested within communities (level 2). The dependent variable was represented by the number of cases, and the logarithm of the corresponding population size was used as an offset term. The following covariates were included in the regression models: age (5 strata) and gender as group-level covariates, and deprivation index (quintiles) as a community-level covariate. To investigate gender-specific effects, a cross-level interaction between gender and deprivation index was also included. To account for potential overdispersion, the scale parameter of the Poisson distribution was estimated rather than fixed at 1. Age- and gender-adjusted relative risks (RR) concerning regional deprivation are reported together with their 95% confidence intervals (95% CI), with the lowest level of deprivation used as the reference group. A p value < 0.05 was considered to indicate statistical significance. All statistical analyses were performed using SAS 9.2 (SAS Institute Inc.).

Results

For lung cancer, the dataset comprised 15,605 incident cases (70.32% men) and 10,450 mortality cases (71.65% men). The corresponding numbers for colorectal cancer were 29,575 incident cases (54.61% men) and 8,190 mortality cases (51.16% men). The geographic variations in SIR and SMR for lung and colorectal cancer by gender are illustrated in Figs. 1, 2 respectively. Visually comparing the regional distribution of SIR and SMR, suggests that cancer incidence and mortality could be especially high in north-east Bavaria, i.e. a region with high deprivation.

Looking at the relative risks and their association with the BIMD, a clear gradient can be seen for both cancer sites, and for incidence as well as for mortality. The relative risk increases gradually with increasing deprivation, resulting in significant relative risks between 1.25 and 1.46 in the communities with the highest deprivation (Table 1). Significant unexplained variation in incidence and mortality was observed across communities as indicated by the random variance estimates in Table 1. Compared to a multilevel Poisson model without community-level covariates (estimates not shown), the BIMD variable reduced the unexplained across-community variance by between 24 and 53%, i.e. between one quarter and half of the variation between communities can be attributed to deprivation (37%/53% for lung cancer incidence/mortality, and 24%/37% for colorectal cancer incidence/mortality). The relative risk for both cancer sites also increases with increasing age and is higher in men than in women (results not shown).

The gender-specific analyses are presented in Table 2. Interestingly, significant associations concerning incidence and mortality between BIMD and lung cancer can be seen for men, but not for women. Thus, the significant associations between lung cancer and regional deprivation presented in Table 1 have to be attributed solely to men. A different picture emerges for colorectal cancer. For men as well as women, incidence and mortality risks increase with increasing deprivation. The relative risks are somewhat larger for men than for women but, in the communities with high deprivation scores, they are significant for both.

Discussion

Using data from the Population-based Cancer Registry of Bavaria, the results of this ecological study showed that the incidence of and mortality from lung cancer (in men only) and colorectal cancer (in men and women) increase with increasing deprivation in the community. Most of these relative risks are statistically significant. The incidence in the most deprived communities is up to 1.39 times higher

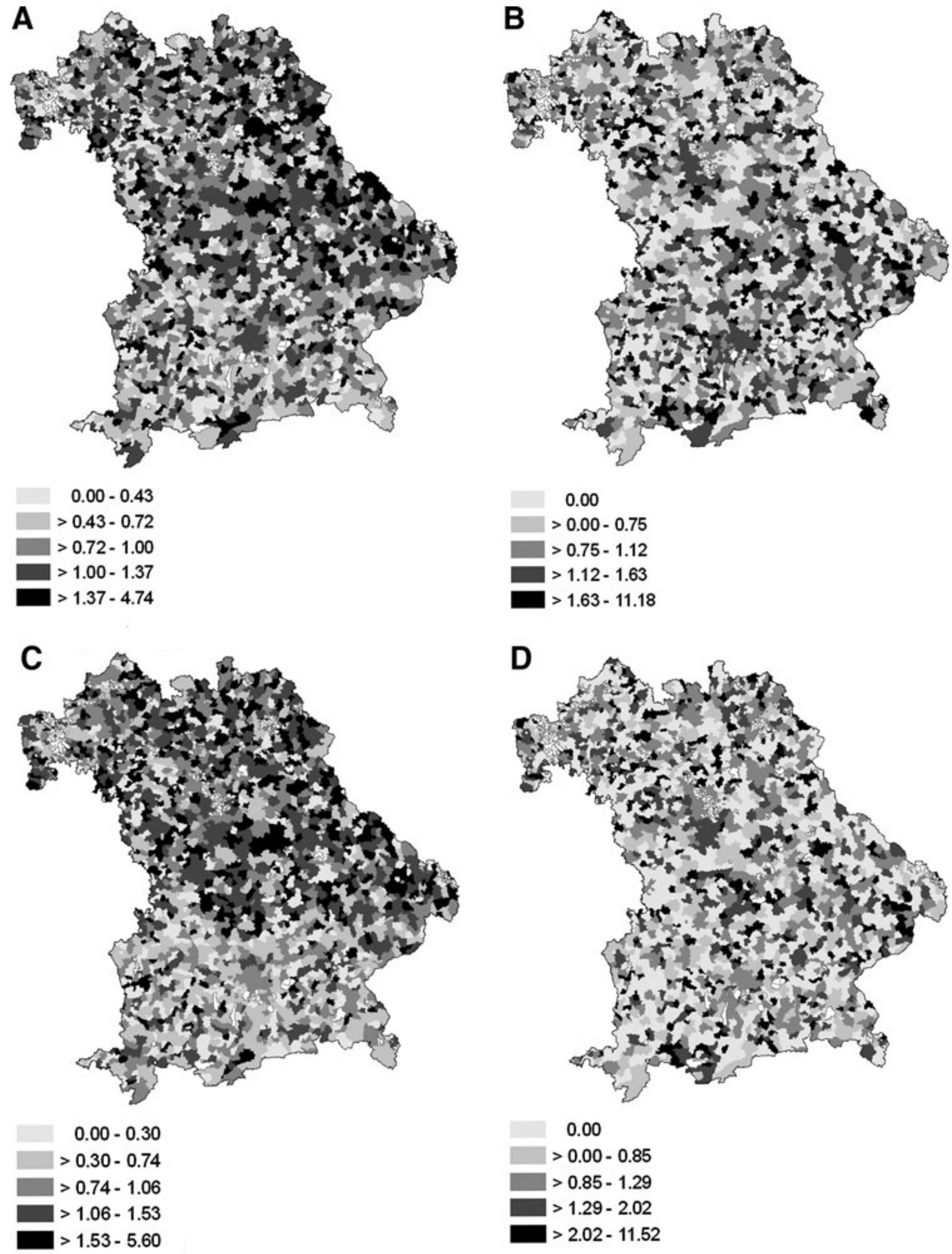

Fig. 1 Geographic distribution of lung cancer incidence (standardized incidence ratios) in males (**a**) and females (**b**), and mortality (standardized mortality ratios) in males (**c**) and females (**d**) in Bavarian communities, Germany, 2003–2006

compared with those who are least deprived (see lung cancer incidence for men), and mortality is up to 1.57 times higher (see colorectal mortality for men). Deprivation at the community level has been assessed by the BIMD, a new index developed recently. As far as we know, this is the first study to apply a community-based regional deprivation score to cancer incidence and mortality data in Germany.

Our findings regarding lung cancer are in agreement with other studies. A previous German study focused on the city of Bremen; it used incidence and mortality data for different cancer sites and compared them with the 'Bremen Discrimination Index' (a social index developed specifically for small areas within the city of Bremen). The results showed increasing risks of lung cancer incidence and mortality with decreasing social status of the town district (Eberle et al. 2010). Another German study focused on the city of Hamburg and analyzed the relationship between lung cancer mortality, social status and urban concentration. It indicated that lung cancer mortality risks are especially high in those areas of Hamburg that are characterized by low social status (Kaak et al. 1996). Compared with this rather limited scope for discussion in Germany, research is far more advanced in some other countries. These studies have repeatedly shown that lung cancer incidence and mortality increase with increasing

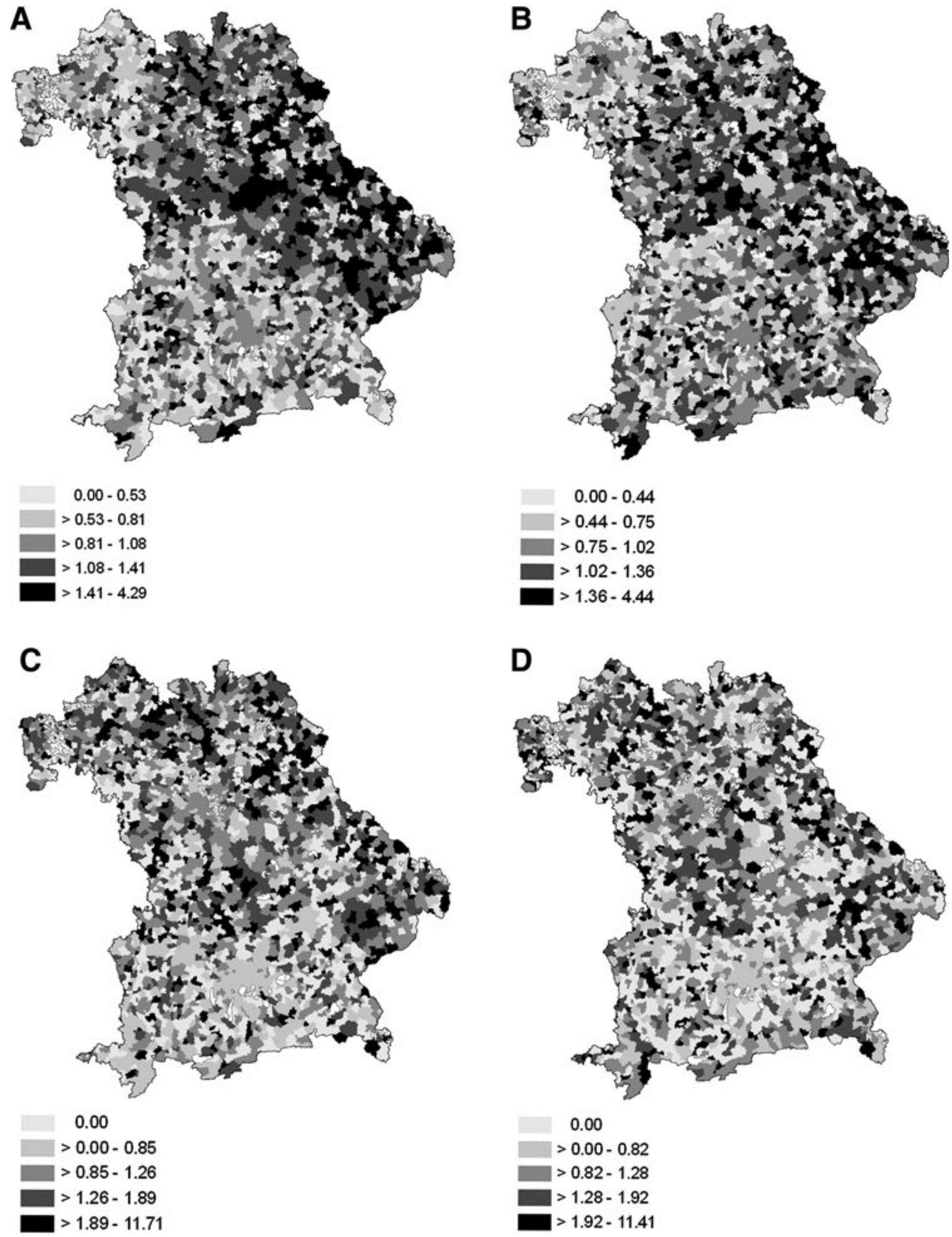

Fig. 2 Geographic distribution of colorectal cancer incidence (standardized incidence ratios) in males (**a**) and females (**b**), and mortality (standardized mortality ratios) in males (**c**) and females (**d**) in Bavarian communities, Germany, 2003–2006

regional deprivation (often with significant increases for men, but not for women), for example in the UK (Parsons and Somerville 2000; Lancaster et al. 2006), in Spain (Barceló et al. 2009), New Zealand (Haynes et al. 2008), Canada and in the USA (Mackillop et al. 2000). Concerning incidence as well as mortality, our study has shown significant associations with regional deprivation for men, but not for women, which might be explained by higher smoking prevalence in Germany among men (41.6% in 1984–1986 and 38.9% in 1990–1992) as compared to women (26.7 and 28.7%, respectively; Federal Statistical Office 2006). Similar gender-specific differences have been found in some other European countries comparing individual social status and lung cancer mortality (Mackenbach et al. 2004).

Our results concerning colorectal cancer are supported by similar studies from Germany. A recent regional comparison of colon cancer incidence in Bavaria has found the highest incidence in the north-eastern part of Bavaria (Spatial carcinoma analysis 2010). For the German state of Saarland, the study by Brenner et al. (1991) showed that survival rates for patients with colorectal cancer were particularly low in those communities that were characterized by a high percentage of people with a low educational level. In the study from the city of Bremen already mentioned above, no consistent associations were

Table 1 Parameter estimates for the community-level (level 2) effects for incidence of and mortality from lung and colorectal cancer in Bavarian communities, Germany, 2003–2006

	Incidence				Mortality			
	Lung cancer		Colorectal cancer		Lung cancer		Colorectal cancer	
	n = 15,605		n = 29,575		n = 10,450		n = 8,190	
	RR (95% CI)	p value	RR (95% CI)	p value	RR (95% CI)	p value	RR (95% CI)	p value
Fixed								
Deprivation quintile								
1 (least deprived)[a]	1		1		1		1	
2	1.05 (0.97–1.12)	0.2202	1.06 (1.00–1.12)	0.0518	1.05 (0.96–1.15)	0.2514	1.03 (0.93–1.14)	0.6132
3	1.07 (1.00–1.15)	0.0518	**1.09 (1.03–1.16)**	0.0018	**1.11 (1.02–1.20)**	0.0210	**1.14 (1.03–1.26)**	0.0126
4	**1.21 (1.13–1.30)**	<0.0001	**1.22 (1.15–1.29)**	<0.0001	**1.32 (1.21–1.43)**	<0.0001	**1.42 (1.29–1.57)**	<0.0001
5 (most deprived)	**1.25 (1.17–1.33)**	<0.0001	**1.25 (1.19–1.31)**	<0.0001	**1.39 (1.29–1.50)**	<0.0001	**1.46 (1.33–1.60)**	<0.0001
Random*								
Variance (SE)	0.014 (0.0035)		0.022 (0.0031)		0.020 (0.0057)		0.049 (0.0098)	

All models adjusted for level 1 covariates gender and age (estimates not shown). Statistically significant relative risks are marked in bold

RR relative risks with their 95% CI, *SE* standard error

[a] Reference group

* Estimates are not relative risks, but variances with standard errors

found between the social status of the town district and colon/rectum cancer incidence, but colon/rectum cancer mortality increased significantly with decreasing social status (Eberle et al. 2010). Studies in other countries, like Northern Ireland (Kee et al. 1996), New Zealand (Haynes et al. 2008), Canada and the USA (Mackillop et al. 2000) generally support the finding that the risk of colorectal cancer is increased in deprived regions.

It is well known that the risk for lung cancer depends on various factors such as lifestyle (smoking including second-hand smoking, poor diet, lack of physical activity) and exposure to occupational and environmental carcinogens (CDC 2011a; Emaus and Thune 2010; Büchner et al. 2010). Tobacco smoking is the major risk factor for lung cancer. About 90% of all lung cancer deaths in men and almost 80% of lung cancer deaths in women can be attributed to smoking (CDC 2011b). The inverse association between socioeconomic status and smoking is well known (Flint and Novotny 1997). It has also been shown repeatedly that other risk factors differ by social status as well (i.e. they are often particularly common in low status groups), thus potentially contributing to the explanation for the regional differences reported above (Huisman et al. 2005; Stringhini et al. 2010). Exposure to occupational carcinogens affecting certain cancer sites such as the lung is usually more frequent in lower than in higher social classes (Boffetta et al. 1997). Also, a number of studies have shown that people with low income often live in regions with poor environmental quality, with increased exposure to ambient particulate, gaseous pollutants and traffic (Finkelstein et al. 2005; Kruize et al. 2007). Next to cigarette smoking, radon is the second main cause of lung cancer in the general population not affected by occupational exposure (Schmid et al. 2010). However, we are not aware of a study that has analyzed the potential contribution of radon to social status differences in lung cancer.

All the risk factors listed above could help to explain why lung cancer incidence and mortality increase with increasing regional deprivation. To date, there seems to be no study comparing the contribution of different risk factors.

Looking at colorectal cancer, apart from inflammatory bowel diseases and genetic syndromes, lifestyle characteristics (i.e. alcohol consumption, smoking, lack of physical activity, diet, and overweight) are again important risk factors (CDC 2011c). The association between alcohol consumption and socioeconomic status is still a matter of debate. For a number of countries (including Germany) a large study on alcohol consumption in Europe found, for example, that women from upper and men from lower status groups were most at risk (Bloomfield et al. 2006). Lifestyle risk factors for colorectal cancer other than alcohol and smoking are well known to be more prevalent in low status groups (see above). Colonoscopy screening has been offered by the German Statutory Sickness Funds since 2002 and it is available free of charge for all insured persons aged 55 years and older. The study from Bavaria mentioned above has found that utilization of preventive colonoscopy is especially high in regions characterized by a high level of income and urbanization, low unemployment and high turnout of voters; and that it is especially low in regions with high colon cancer incidence (Spatial carcinoma analysis 2010). Another study analyzing

Table 2 Relative risks for incidence of and mortality from lung and colorectal cancer according to quintiles of regional deprivation in Bavarian communities, by gender, Germany, 2003–2006

Deprivation quintile	Incidence				Mortality			
	Lung cancer		Colorectal cancer		Lung cancer		Colorectal cancer	
	RR (95% CI)	*p* value	RR (95% CI)	*p* value	RR (95% CI)	*p* value	RR (95% CI)	*p* value
Men	*n* = 10,973		*n* = 16,151		*n* = 7,487		*n* = 4,190	
1 (least deprived)[a]	1		1		1		1	
2	**1.11 (1.03–1.21)**	0.0117	**1.08 (1.01–1.16)**	0.0309	**1.12 (1.01–1.24)**	0.0268	1.03 (0.90–1.18)	0.6846
3	1.06 (0.98–1.15)	0.1200	**1.09 (1.02–1.16)**	0.0137	**1.11 (1.01–1.22)**	0.0352	1.14 (1.00–1.30)	0.0466
4	**1.32 (1.22–1.43)**	<0.0001	**1.25 (1.17–1.34)**	<0.0001	**1.44 (1.31–1.58)**	<0.0001	**1.49 (1.31–1.68)**	<0.0001
5 (most deprived)	**1.39 (1.29–1.49)**	<0.0001	**1.30 (1.22–1.38)**	<0.0001	**1.54 (1.41–1.68)**	<0.0001	**1.57 (1.40–1.76)**	<0.0001
Women	*n* = 4,632		*n* = 13,424		*n* = 2,963		*n* = 4,000	
1 (least deprived)[a]	1		1		1		1	
2	0.90 (0.80–1.02)	0.1004	1.03 (0.95–1.11)	0.4605	0.90 (0.77–1.05)	0.1725	1.02 (0.89–1.18)	0.7355
3	1.08 (0.97–1.20)	0.1639	**1.10 (1.02–1.18)**	0.0096	1.09 (0.95–1.24)	0.2115	1.14 (1.00–1.30)	0.0544
4	0.97 (0.87–1.09)	0.6343	**1.18 (1.09–1.27)**	<0.0001	1.05 (0.91–1.21)	0.4975	**1.35 (1.19–1.54)**	<0.0001
5 (most deprived)	0.96 (0.87–1.07)	0.4692	**1.19 (1.11–1.27)**	<0.0001	1.07 (0.94–1.21)	0.3033	**1.34 (1.19–1.51)**	<0.0001

All models adjusted for age (data not shown). Statistically significant relative risks are marked in bold

RR relative risks with their 95% CI

[a] Reference group

educational inequalities in utilization of preventive services, including colon cancer screening among elderly in different European countries has observed for most countries (including Germany) that people with lower education were consistently less likely to undergo colon cancer screening (Stirbu et al. 2007).

Some limitations of our study have to be taken into account. One relates to the ecological design and another to the lack of individual-level information on social status and risk factors. We are only able to show associations. We still do not know why regional social characteristics might influence cancer incidence and mortality. Perhaps the effect results from differences in individual social status, as deprived communities will include a high percentage of people with low individual social status. The effect could also be due to regional characteristics beyond these individual differences, such as air pollution or the provision of medical care (Diez-Roux 1998; Gomez et al. 2007). Also, we had to exclude data from two districts in Bavaria (Swabia and Lower Franconia) because cancer registration did not meet the level of 90% completeness. Another important issue is the potential bias in the estimates introduced by the heterogeneity of communities. Although communities are the smallest regional statistical units in Bavaria, they also comprise a few big cities which are socially more heterogeneous compared to smaller communities. However, evidence suggests that measures from smaller geographic units may produce results for aggregate socioeconomic measures that are less biased (Soobader et al. 2001).

Conclusion

We believe that this study could be an important contribution to research concerning the association between regional deprivation and risks for lung and colorectal cancer. It shows that lung cancer risk for men and colorectal cancer risk for both genders increase with increasing regional deprivation in Bavaria. It points also to the importance of including individual-level information on social status and cancer risks in the cancer registries. The results indicate that interventions aimed at reducing the risks of lung and colorectal cancer should primarily focus on socially deprived communities.

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