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Original Research

Predictors of hospitalizations for diabetes in Germany: an ecological study on a small-area scale

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ABSTRACT

Objectives: Our objective was to evaluate the role of potential predictors in explaining spatial variation among diabetes hospitalization rates in Germany.
Study design: This was an ecological analysis using hospital routine data.
Methods: County-level hospitalization rates ($n = 402$) in 2015 were calculated based on the German Diagnosis Related Groups database. We used a funnel plot to identify counties with high hospitalization rates. To examine the impact of predictors such as socio-economic status or structure of primary care, we performed linear and logistic regression analyses.
Results: The crude hospitalization rate was 262 admissions per 100,000 population. In multivariable logistic models, we found the percentage of employees with academic degree (odds ratio [OR]: 0.72, 95% confidence interval [CI]: 0.56–0.91), high hospital bed rate (4th quartile vs 1st quartile; OR: 2.73, CI: 1.03–7.24), and diabetes prevalence (OR: 1.49, CI: 1.17–1.90) to be significant predictors for high hospitalization rates. In multivariable linear models, the percentage of unemployed (regression coefficient b: 4.79, CI: 0.81–8.78) and rurality (b: 0.52, CI: 0.19–0.85) explained the variation in addition to predictors from logistic regression. Primary care structure was not a significant predictor in multivariable models.
Conclusions: The non-significant impact of primary care in adjusted models casts the use of diabetes hospitalizations as indicators for access and quality of primary care into doubt. Diabetes hospitalizations may rather reflect demand for care.
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Introduction

Diabetes mellitus is one of the most prevalent non-communicable diseases, with about 451 million adults worldwide suffering from it in 2017.[1] In Germany, the disease prevalence for both type 1 and type 2 diabetes has been estimated to be 10.6% of the German adult population aged between 20 and 79 years in 2015.[2]

Uncontrolled diabetes is associated with serious complications. Approximately two-thirds of the patients suffer from diabetes-related complications which may lead to the need for inpatient care.[3] A German study estimates that the risk of hospitalizations related to type 2 diabetes is 5.5% per patient year (21,833 out of 394,828 patients during one year).[4] However, diabetes is regarded as an ambulatory care–sensitive condition.[5] Ambulatory care–sensitive hospitalizations (ACSHs) are considered potentially preventable. The idea behind ACSH is that the hospitalization risk can be lowered by effective primary care, in terms of both time and quality.[6] Population-based rates of ACSH are used to evaluate the access and quality of primary care within and between healthcare systems.[7–9] An analysis from the Organization for Economic Co-Operation and Development (OECD) showed that Germany has the sixth-highest diabetes hospitalization rate of 33 OECD countries (218 hospitalizations per 100,000 inhabitants after age and sex adjustment).[10]

ACSHs can be attributed not only to the quality of and access to primary care.[11,12] They also depend on population health status[13] and are affected by socio-economic and socio-demographic factors, even in healthcare systems with universal health coverage.[14–16] Disease prevalence may also influence hospitalization rates strongly because more prevalent cases inevitably lead to a higher number of hospitalizations under a ceteris paribus assumption.[17–20] Furthermore, diabetes prevalence is also associated with socio-economic and demographic factors and should therefore be considered as a potential confounder while analyzing the impact of those factors on diabetes hospitalizations.[21,22]

However, to the best of our knowledge, no study in Germany adjusted for disease prevalence while examining ACSHs for diabetes so far. Therefore, the aim of our study is to evaluate the impact of potential predictors on hospitalization rates for diabetes complications in Germany.

Methods

Study design

Our study was an ecological analysis, using hospitalization data obtained in 2015. All 402 German counties and cities with county rights served as observation units. Adult population across counties varied substantially from 30,000 to about three million. We calculated hospital admission rates for diabetes by using the national Diagnosis Related Groups (DRG) database hosted by the German Federal Statistical Office. This database includes the hospital discharge data from all 1619 German hospitals with DRG reimbursement and covers about 18.20 million hospital discharges in 2015.[23]

Dependent variable

The calculation algorithm of diabetes hospital admission rates was adopted from the OECD Health Care Quality Indicators Project. The OECD uses population-based rates of avoidable hospital admissions of various conditions to evaluate the quality of primary care across OECD member countries.[24] For application in Germany, we adapted the indicator definition[25] to the German Modification of the International Statistical Classification of Diseases and Related Health Problems 10th revision (ICD-10-GM). According to the indicator definition, we included all specified cases aged 15 years and older with a principal diagnosis of diabetes in 2015 in the numerator. We calculated county-level crude hospitalization rates with population data provided by the German Federal Statistical Office. The denominator is the number of the population aged 15 years and older on county level in 2015.

To identify counties with remarkably high crude hospitalization rates, we constructed a funnel plot. Funnel plots are an application of statistical process control and provide two forms of variation: variation due to chance (common cause variation) and variation related to extrinsic factors (special cause variation).[26] Based on an a priori specified probability distribution, a funnel plot contains so-called control limits, which are plotted around a target outcome and show the limits of common cause variation. Finally, counties with higher or lower hospitalization rates than the specific probability distribution can be identified.[27] Those counties are subject to special cause variation. In our study, hospitalizations rates of counties lying above the control limits are defined as remarkably high.

We also constructed a second funnel plot using hospitalization rates adjusted for age, sex, and diabetes prevalence to show how special cause variation changes after controlling for these variables. We performed indirect age-sex standardization using the German population from 2015 as standard population. For prevalence adjustment, we used a method based on linear regression models which has been used for disease prevalence adjustment of hospitalization rates before.[20]

Funnel plots use sample size as a measure of precision, which leads to narrower limits for counties with higher population. Our control limits corresponded to 95% confidence intervals (CIs). We defined our target outcomes as the average hospitalization rate on county level and used an inverse binomial distribution to calculate the control limits.[27] To counteract the problem of multiple statistical comparisons, we performed Bonferroni corrections. We used SAS 9.4 (SAS Institute Inc., Cary, NC, USA) for calculation and graphical preparation of the funnel plots.

Predictor variables

Potential independent variables were selected from literature on predictors of ACSHs. We included variables depending on data availability and classified them according to the Andersen Behavioral Model of Health Services Use.[28] Andersen stated that healthcare utilization can be described as a function of three groups of factors: (a) predisposing factors to use medical care, (b) enabling characteristics that allow people to use medical services, and (c) the need for care.[28] As our study follows an ecological approach, we have not included individual factors. All variables are on county level. Included predisposing variables were population average age in years, unemployment rate (proportion of civilian labor force in %), proportion of women (in %), proportion of employees with an academic degree (in %), and average household income (in Euros).[29–31] We assessed household income as a predisposing factor, but not as an enabling characteristic, because health insurance is mandatory and covers all essential care in Germany. Enabling characteristics were rate of general practitioners (per 100,000 population) and rate of all medical specialists (per 100,000 population) as measures of access to primary care, as well as rate of hospital beds (per 10,000 population) and rurality (% of population in communities with population density < 150 population/km^2).[29,30,32–34] Need variables were disease prevalence and average life expectancy (in years) as an overall measure of disease burden.[29]

For disease prevalence, the Central Research Institute of Ambulatory Health Care in Germany (Zi) provided small-area estimates based on nationwide ambulatory diagnosis data from 2014. This database covered treatment information on statutorily health-insured persons. About 90% of the German population is statutorily insured. The Zi calculated the number of patients with ambulatory visits for diabetes (numerator) in relation to all patients with ambulatory visits (denominator). To ensure that cases with chronic conditions were included, the Zi counted only those patients in the numerator who had ambulatory diabetes treatment in at least two quarters of the evaluation period. For the other independent variables, we used the indicators, maps, and graphics on spatial and urban monitoring (INKAR database) maintained by the Federal Institute for Research on Building, Urban Affairs and Spatial Development. Definitions and measurement methods for these variables can be found elsewhere.[35] We used the latest available data from 2014.

Statistical analysis

We conducted descriptive analyses, including funnel plots, to describe the distribution of diabetes hospitalizations. We calculated global Moran's I for all variables to determine the amount of spatial autocorrelation. To explain the variation of diabetes hospitalizations, we performed linear regression analyses. The dependent variable was the crude hospitalization rate on county level. Independent variables were all included as categorical data based on quartiles first, but, to improve statistical power, we changed some of them to continuous representation when we found linear trends in bivariate models. After regression diagnostics, we found no major violation of underlying Gauss-Markov assumptions. Evaluation of the variance inflation factor (VIF) showed no signs of multicollinearity (VIF > 10).

We also calculated logistic regression models to analyze the impact of potential predictors on the probability that diabetes hospitalization rates were remarkably high. The dependent dichotomous variable was a hospitalization rate above the upper control limit of the previously estimated funnel plot for crude rates. The reference group was 'hospitalization rates inside or below Bonferroni-corrected control limits.'

In both approaches, the impact of potential predictor variables on hospitalization rates was calculated in crude, partly adjusted for diabetes prevalence (inclusion of prevalence as continuous variable in %) and fully adjusted models. All statistical examinations were conducted in SPSS 23 (version 23.0; IBM SPSS Statistics for Windows, IBM Corp., NY).

Results

Descriptive analysis

In 2015, the total number of diabetes hospitalizations (principal diagnosis) in Germany was 186,710 and the crude rate on federal level was 261.88 admissions per 100,000 population. Table 1 shows descriptive statistics for both hospitalization rate and potential predictor variables on county level. The median for hospitalization rate was 250.67 admissions per 100,000 population (range: 105–775 admissions per 100,000 population). Rates varied substantially across counties; the

Table 1 – Descriptive statistics of crude diabetes hospitalization rates and potential predictors on county level ($n = 402$) in Germany.

Variable	Mean (SD)	Median (min–max)	Moran's I
Diabetes hospital admissions (admissions per 100,000 population in 2015)	276 (97.5)	251 (105–775)	0.59*
Predisposing characteristics (2014)			
Population average age (years)	44.4 (1.87)	44.2 (39.9–49.6)	0.61*
Unemployed (%)	6.3 (2.88)	5.8 (1.4–15.4)	0.67*
Women (%)	50.9 (0.66)	50.8 (48.8–52.9)	0.29*
Employees with academic degree (%)	6.7 (3.06)	5.7 (2.8–20.7)	0.30*
Average household income (€)	1749 (216)	1744 (1345–3451)	0.48*
Enabling characteristics (2014)			
General practitioners (number per 100,000 population)	61.2 (7.74)	61.0 (46.4–90.2)	0.20*
Specialists (number per 100,000 population)	109.5 (57.56)	86.0 (22.8–340.0)	0.06*
Hospital beds (number per 10,000 population)	64.5 (38.28)	55.8 (0–215.7)	0.03
Rurality (% of population in communities with population density < 150/km^2)	30.1 (30.32)	22.8 (0–100)	0.45*
Need characteristics (2014)			
Diabetes prevalence (%)	10.2 (2.5)	9.5 (5.8–18.8)	0.84*
Life expectancy at birth (years)	80.3 (1.17)	80.3 (75.8–83.0)	0.47*

SD, standard deviation.
* significant ($P < 0.05$).

ratio between the highest and the lowest rate was about 7.4. Primary care resources also showed a high variation in terms of the rate of specialists. The minimum of hospital beds was zero because one German county had no hospitals. Diabetes prevalence varied more than threefold from 5.8% to 18.8% per county. For all variables except hospital beds, we found a significant positive measure of spatial autocorrelation.

Funnel plots

Fig. 1 shows the funnel plot of the crude diabetes hospitalization rate according to county population. For better illustration, we excluded three counties with more than 1 million inhabitants from the figure (Berlin, Hamburg, and Munich). Under consideration by the Bonferroni correction, the rates of 170 counties were between control limits, indicating common cause variation. The data of 116 counties were above and below the control limits. They were subject to special cause variation.

Fig. 2 shows the funnel plot of rates adjusted for age, sex, and prevalence. Adjustment decreased the number of counties with special cause variation. Sixty-nine counties were above and 90 counties were below the control limits.

Regression analysis

Table 2 presents the results of linear regression analyses. In crude analyses, we did not find any statistically significant association between the percentage of women and diabetes hospitalizations. The rate of general practitioners and specialists showed significant regression coefficients only for the highest quartile (vs the lowest quartile). Although the coefficient in the highest quartile for general practitioners was positive (regression coefficient b = 31.06, 95% CI = 3.94–58.17), we found a negative association in the highest quartile of specialists (b = −41.18, 95% CI = −68.01–14.34). Diabetes prevalence showed the highest coefficient of determination (R^2 = 0.48, b = 26.84, 95% CI = 24.06–29.61). Adjusting for disease prevalence led to lower coefficients for some variables. In the fully adjusted model, all variables were included. We found statistically significant associations among the percentage of unemployed (b = 4.79, 95% CI = 0.81–8.78), percentage of employees with an academic degree (b = −4.25, 95% CI = −7.99 to −0.50), hospital beds (third quartile; b = 22.78, 95% CI = 3.66–41.09), rurality (b = 0.52, 95% CI = 0.19–0.85), and diabetes prevalence (b = 16.98, 95% CI = 11.66–22.31). The fully adjusted model explained more than half of the variation of diabetes hospitalizations (R^2 = 0.57).

Table 3 shows the results of logistic regression analyses, which investigated the impact of predictors on the probability for a county to show a crude rate above control limits. Crude regression coefficients revealed associations similar to those in linear models. One exception was the rate of general practitioners, which had no statistically significant effect. After adjusting for disease prevalence, the percentage of unemployed, rate of specialists, and life expectancy no longer showed a significant impact. In the fully adjusted model, we found significant positive associations between diabetes prevalence (odds ratio [OR] = 1.49, 95% CI = 1.17–1.90) and the rate of hospital beds in the highest quartile (vs lowest quartile, OR = 2.73, 95% CI = 1.03–7.24) and a significantly negative association for the percentage of employees with an academic degree (OR = 0.72, 95% CI = 0.56–0.91).

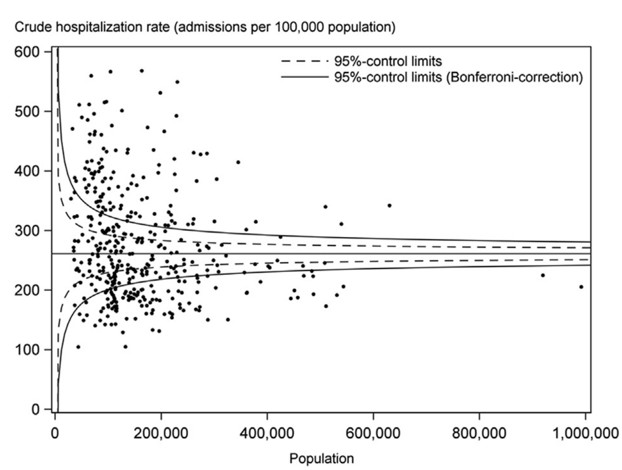

Fig. 1 – Funnel plot for crude diabetes hospitalization rates on county level (*n* = 402) in Germany 2015. Note: 3 counties with populations >1 million were excluded from the figure.

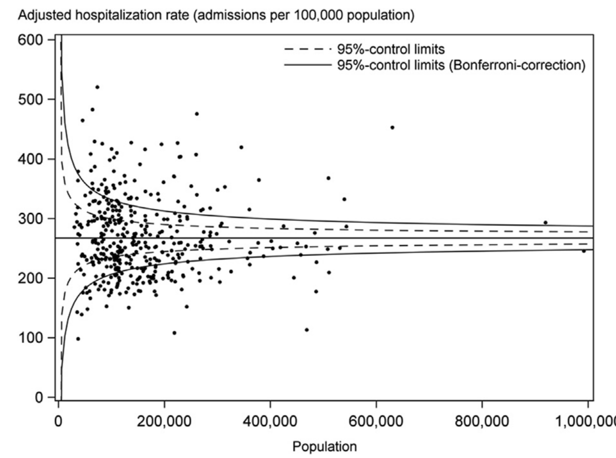

Fig. 2 – Funnel plot for diabetes hospitalization rates on county level (*n* = 402) in Germany 2015, adjusted for age, sex, and prevalence. Note: 3 counties with populations >1 million were excluded from the figure.

Discussion

We investigated the impact of several variables on potentially preventable hospitalizations for diabetes mellitus on a small-area scale in Germany. By applying multivariable models, the rate of hospital beds and diabetes prevalence had a positively significant impact, whereas the percentage of employees with an academic degree had a negatively significant impact on explaining the remarkably high hospitalization rates. Notably, the percentage of unemployed and rurality were positively significant predictors, explaining variation in hospitalizations in both linear and logistic regression models. The structure of primary care, such as the rate of general

Table 2 – Linear regression analysis predicting hospitalization rates with diabetes, on county level (n = 402).

Predictors	Crude		Partly adjusted for disease prevalence		Fully adjusted	
	b (95% CI)[a]	R^2	b (95% CI)[a]	R^2	b (95% CI)[a]	R^2
Predisposing characteristics						
Population average age (years)	32.62 (28.61; 36.62)	0.391	11.33 (5.40; 17.27)	0.493	2.17 (−5.45; 9.79)	0.568
Unemployed (%)	14.59 (11.60; 17.59)	0.186	2.43 (−0.46; 5.32)	0.478	4.79 (0.81; 8.78)	
Women (%)						
1st quartile (48.8–50.4)	Reference	0.015	Reference	0.479	Reference	
2nd quartile (50.4–50.8)	5.42 (−18.10; 28.93)		−7.38 (−24.56; 9.80)		−3.93 (−20.40; 12.54)	
3rd quartile (50.8–51.2)	14.61 (−7.09; −36.31)		3.99 (−11.85; 19.83)		0.83 (−15.80; 17.46)	
4th quartile (51.2–52.9)	−17.63 (−41.51; 6.26)		−14.36 (−31.76; 3.03)		−1.77 (−22.55; 19.01)	
Employees with academic degree (%)	−14.01 (−16.82; −11.21)	0.194	−7.61 (−9.90; −5.33)	0.526	−4.25 (−7.99; −0.50)	
Average household income (€)	−0.21 (−0.25; −0.17)	0.215	−0.06 (−0.10; −0.02)	0.486	−0.015 (−0.06; 0.03)	
Enabling characteristics						
General practitioners (number per 100,000 population)						
1st quartile (46.4–55.7)	Reference	0.017	Reference	0.478	Reference	
2nd quartile (55.7–60.95)	−0.14 (−27.06; 26.78)		−9.59 (−29.26; 10.08)		−3.53 (−22.39; 15.33)	
3rd quartile (60.95–64.75)	14.49 (−12.56; 41.53)		−4.31 (−24.15; 15.52)		−0.54 (−20.89; 19.80)	
4th quartile (64.75–90.2)	31.06 (3.95; 58.17)		5.59 (−14.38; 25.55)		13.89 (−8.25; 36.03)	
Specialists (number per 100,000 population)						
1st quartile (22.8–73.0)	Reference	0.032	Reference	0.494	Reference	
2nd quartile (73.0–85.95)	1.62 (−25.09; 28.33)		6.78 (−12.56; 26.13)		7.55 (−12.54; 27.64)	
3rd quartile (85.95–128.18)	−5.20 (−31.97; 21.57)		6.94 (−12.49; 26.36)		1.29 (−22.09; 24.67)	
4th quartile (128.18–340.0)	−41.18 (−68.01; −14.34)		−25.94 (−45.43; −6.44)		−16.28 (−53.54; 20.98)	
Hospital beds (number per 10,000 population)						
1st quartile (0–37.1)	Reference	0.042	Reference	0.483	Reference	
2nd quartile (37.1–55.8)	28.67 (2.11; 55.24)		4.25 (−15.47; 23.96)		27.67 (0.95; 54.39)	
3rd quartile (55.8–84.38)	50.61 (24.05; 77.18)		23.42 (3.66; 43.17)		22.78 (3.66; 41.90)	
4th quartile (84.38–215.7)	46.67 (20.18; 73.17)		13.23 (−6.59; 33.05)		19.65 (−1.98; 41.27)	
Rurality (% of population in communities with population density < 150/km^2)	1.19 (0.90; 1.48)	0.137	0.63 (0.40; 0.86)	0.510	0.52 (0.19; 0.85)	
Need characteristics						
Life expectancy at birth (years)	−40.23 (−47.37; −33.08)	0.234	−13.60 (−20.47; −6.73)	0.494	−0.97 (−10.58; 8.64)	
Diabetes prevalence (%)	26.84 (24.06; 29.61)	0.480			16.98 (11.66; 22.31)	

CI, confidence interval.
[a] Regression coefficient.

practitioners and rate of medical specialists, had no impact in multivariable models.

The calculated number of hospitalizations on county level was comparable with a previous national study. Freund et al.[36] reported 172,303 hospitalizations for diabetes in 2010, whereas we found 186,710 hospitalizations in 2015 by using a slightly different indicator definition.

Burgdorf and Sundmacher[29] investigated predictors of ACSHs for four chronic conditions on county level and adjusted for age and life expectancy as proxy variables for overall disease burden. They found a positive association between increasing age and diabetes hospitalizations, whereas life expectancy showed a significantly negative association with hospitalization rate. This is consistent with our results because type 2 diabetes prevalence is strongly correlated with age. However, as our study shows, there was no additional effect of age on diabetes hospitalizations after consideration of diabetes prevalence and other factors. Ansari et al.[37] found a significant association between ACSH and disease prevalence in crude analysis, but not in multivariable models. In their study, ACSH and disease prevalence were a general measure combining several conditions and not restricted to diabetes mellitus. In consideration of our results, this may imply that disease prevalence is a significant predictor of some ambulatory care–sensitive conditions such as diabetes, but not of all ACSHs. Laditka et al.[38] support this assumption using death rates as a proxy variable for prevalence and disease severity in an analysis of predictors of ACSHs in 642 urban US counties. Applying a combined measure of ACSHs, they found significant associations between ACSHs and death rates from diabetes in the population aged 18–39 years. The death rate related to chronic obstructive lung disease had no impact.

Access to primary care, measured as rates of general practitioners and specialists, was positively associated with diabetes hospitalizations in the crude models of our study.

However, in multivariable models, we did not find any impact of access to primary care. Many other authors, but not all, reported a negative relationship between physician supply and ambulatory care–sensitive conditions, in general[39] as well as in particular, for diabetes in Germany.[29] Our results are probably not entirely comparable because we adjusted for diabetes prevalence and other potential predictors. Our analyses suggest that diabetes hospitalizations do not properly reflect access to ambulatory diabetes care in Germany.

It has to be taken into account that access to care is related not only to the structure of care but also to physical accessibility, acceptability, and affordability of care.[40] A study by van Loenen et al.[41] on ACSHs for diabetes in 23 countries found a positive association between patient-perceived access and hospitalizations. Even though access to care in Germany is formally universal and free through full cost coverage, possible barriers may be of a predisposing nature. In our data, a smaller percentage of employees with an academic degree and a higher percentage of unemployed persons are associated with more diabetes-related hospitalizations (Table 2). More employees with an academic degree also lowered the probability that a county was subject to special cause variation. This suggests that socio-economic factors are related to diabetes hospitalizations. Our finding supports the relevance of health literacy in diabetes care.[42]

Regarding enabling factors, rurality is positively associated with the diabetes hospitalization rate, which implies an influence of infrastructure when ambulatory care is necessary. In addition, more hospital beds per population may lead to more hospitalizations for diabetes, indicating a supply-induced demand for inpatient care.

In summary, our study shows high treatment equality regarding diabetes care in Germany. When comparing coefficients of determination and c-statistics in our models, we can see that diabetes prevalence is the most important factor explaining variation of diabetes hospitalizations. In addition, adjustment for age, sex, and prevalence reduced special cause variation. This shows that ACSHs for diabetes do not necessarily reflect supply (structure of care) but demand for care. Access barriers to care may result from rural infrastructure and socio-economic disadvantage, but those factors play a minor role in the prediction of diabetes hospitalizations. Although some of the analyzed factors may have an impact on disease prevalence, they do not influence diabetes hospitalizations in addition to prevalence. Swart et al.[43] stated that disease prevalence mostly has little effect on hospitalizations in general, whereas, for example, the structure of ambulatory care and accessibility of inpatient care are more important factors. Our results contradict this hypothesis with regard to hospitalizations for diabetes.

Limitations

Some limitations should be considered. First, given the ecological character of our study, we cannot draw conclusions at an individual level. Second, data on diabetes prevalence for 2014, which we obtained from the Central Research Institute of Ambulatory Health Care in Germany (Zi), show higher rates than did previously published data from the German Health Interview and Examination Survey for Adults (DEGS1) for 2008–2011 (10.2% v 7.2% on county level).[44] However, data

Table 3 – Logistic regression analysis predicting rates above control limits in funnel plot ($n = 402$).

Predictors	Crude		Partly adjusted for disease prevalence		Fully adjusted	
	Odds ratio (95% CI)	C-statistics	Odds ratio (95% CI)	C-statistics	Odds ratio (95% CI)	C-statistics
Predisposing characteristics						
Population average age (years)	2.12 (1.80–2.51)	0.802	1.30 (1.03–1.65)	0.820	1.06 (0.76–1.48)	0.873
Unemployed (%)	1.35 (1.24–1.47)	0.735	1.09 (0.98–1.21)	0.828	1.18 (0.97–1.43)	
Women (%)						
1st quartile (48.8–50.4)	Reference	0.560	Reference	0.816	Reference	
2nd quartile (50.4–50.8)	1.08 (0.64–1.82)		0.85 (0.44–1.64)		0.78 (0.38–1.62)	
3rd quartile (50.8–51.2)	1.37 (0.84–2.21)		1.26 (0.69–2.29)		1.04 (0.51–2.14)	
4th quartile (51.2–52.9)	0.75 (0.43–1.30)		0.76 (0.39–1.48)		0.93 (0.38–2.31)	
Employees with academic degree (%)	0.68 (0.59–0.77)	0.724	0.76 (0.66–0.88)	0.846	0.72 (0.56–0.91)	
Average household income (€)	0.99 (0.99–0.99)	0.782	0.99 (0.99–0.99)	0.836	1.00 (1.00–1.00)	
Enabling characteristics						
General practitioners (number per 100,000 population)						
1st quartile (46.4–55.7)	Reference	0.569	Reference	0.821	Reference	
2nd quartile (55.7–60.95)	0.94 (0.49–1.79)		0.69 (0.31–1.52)		0.82 (0.34–1.96)	
3rd quartile (60.95–64.75)	1.43 (0.77–2.67)		1.05 (0.50–2.22)		1.23 (0.50–3.00)	
4th quartile (64.75–90.2)	1.73 (0.94–3.21)		1.06 (0.50–2.26)		1.64 (0.61–4.41)	
Specialists (number per 100,000 population)						
1st quartile (22,8–73,0)	Reference	0.566	Reference	0.817	Reference	
2nd quartile (73,0–85,95)	1.10 (0.61–1.98)		1.31 (0.61–2.80)		0.99 (0.41–2.38)	
3rd quartile (85,95–128,18)	1.02 (0.56–1.85)		1.43 (0.69–2.96)		0.87 (0.31–2.42)	
4th quartile (128,18–340,0)	0.51 (0.27–0.99)		0.57 (0.25–1.25)		0.67 (0.14–3.23)	
Hospital beds (number per 10,000 population)						
1st quartile (0–37.1)	Reference	0.621	Reference	0.829	Reference	
2nd quartile (37.1–55.8)	2.42 (1.18–4.93)		1.49 (0.65–3.42)		2.51 (0.79–7.98)	
3rd quartile (55.8–84.38)	3.50 (1.74–7.02)		2.52 (1.12–5.70)		2.41 (0.99–5.85)	
4th quartile (84.38–215.7)	3.75 (1.87–7.50)		2.32 (1.03–5.25)		2.73 (1.03–7.24)	
Rurality (% of population in communities with population density < 150/km^2)	1.01 (1.01–1.02)	0.653	1.01 (1.00–1.01)	0.816	1.00 (0.99–1.01)	
Need characteristics						
Life expectancy at birth (years)	0.49 (0.40–0.61)	0.738	0.82 (0.63–1.07)	0.826	1.43 (0.92–2.20)	
Diabetes prevalence (%)	1.82 (1.61–2.06)	0.818			1.49 (1.17–1.90)	

CI, confidence interval.

published from the DEGS1 cover the population aged 18–79 years, whereas we calculated data for a population older than 15 years. Another analysis based on routine data found a higher prevalence of diabetes (types 1 and 2) in 2010 (9.9%) when including all age groups.[45] In addition, the prevalence data in our study were not based on the entire population but was calculated as a proportion of the statutorily health-insured population that received ambulatory treatment for any reason in 2014. This may lead to a systematic over-estimation of diabetes prevalence and to distortions on county level; persons with no visit to an ambulatory care physician were not included in the denominator. Because the utilization of ambulatory care is very high in Germany, we believe that the bias is low. In 2012, about 87% of the German adult population received ambulatory medical treatment.[46]

Third, although outcome variables were from 2015, data on independent variables were from 2014. This may lead to distortions when independent variables change much over time. However, we compared INKAR variables from 2013 with data from 2014 and found very high correlations ($r > 0.95$) for all variables, indicating that changes over time are low.

Fourth, although median household income would be a more accurate and robust measure for income than average household income, this measure was not available in the INKAR data set.

Fifth, even after adjustment for age, sex, and prevalence, 69 counties were identified with remarkably high hospitalization rates. This shows that there are possibly additional unknown factors, e.g. different coding practices, treatment preferences, or organization of care, with impact on hospitalizations. Data for those factors were not available in the INKAR data set.

Sixth, global Moran's I showed a significant amount of spatial autocorrelation for most variables, especially for diabetes prevalence. This was to be expected to some degree as reasons for high prevalence or socio-economic conditions are probably not linked to administrative boundaries. However, spatial autocorrelation may affect coefficients and significance tests in regression models.[47] Future studies should take this spatial autocorrelation into account, for example by using spatial lag or spatial error models.

Finally, the German DRG database, which was our data source for hospitalizations, did not allow linkage of hospitalizations on patient level for privacy policy reasons. Subsequently, there might have been readmissions, which we could not consider in our study.

Conclusions

Variation of diabetes hospitalizations in Germany can be explained by disease prevalence, education, rurality, and socio-economic disadvantage in terms of unemployment, even when controlling for several other potential confounders. The findings of our study indicate that spatial distribution of diabetes hospitalizations is not attributable to variation in physician supply on county level but to regional differences in demand for diabetes care. These results suggest that diabetes hospitalizations should not be used for monitoring access and quality of ambulatory care in Germany regardless of information on diabetes prevalence.

Author statements

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Ethical approval

Ethical approval was not required for this study because it is a routine data analysis.

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Competing interests

None declared.

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