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Research Article

Staffing and the incidence of pressure ulcers in German hospitals: A multicenter cross-sectional study

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Abstract In this study, we investigated the association between nurse and physician staffing and the incidence of hospital-acquired pressure ulcers in acute care hospitals in Germany. The study population, derived from the Quality Reports of German Hospitals and the Hospital Directory, consisted of 710 hospitals covering 716,281 cases in the first quarter of 2010, and 672 hospitals covering 757,665 cases in the first quarter of 2012. The relationship between staffing variables and the standardized incidence ratios of pressure ulcers was examined using bivariate and multivariable linear regression models. Estimates were controlled for several patient and hospital characteristics. The total number of nurses and physicians per 100 beds did not show significant associations with outcome variables. However, the proportion of nurses with at least 3 years of training to total nursing staff was inversely associated with the incidence of pressure ulcers at hospital level, indicating a higher efficacy of pressure ulcer-prevention measures.

Key words hospital, nurse staffing, physician staffing, pressure ulcer, quality of care, skill mix.

INTRODUCTION

Evidence from numerous studies shows a clear relationship between nurse staffing and the quality of patient care. A higher nurse-to-patient ratio (nurse staffing level) and a higher proportion of registered nurses to total nursing staff (nursing skill mix) are associated with fewer adverse events and generally more favorable outcomes in hospital patients (Lang *et al.*, 2004; Lankshear *et al.*, 2005; Kravitz *et al.*, 2002; Kane *et al.*, 2007; Stalpers *et al.*, 2015). In addition, staffing levels have also been linked to nurse outcomes, including burnout and job dissatisfaction (Aiken *et al.*, 2012; Nantsupawat *et al.*, 2015).

An indicator to measure the quality of care in relation to nurse staffing is the incidence of hospital-acquired pressure ulcers (HAPU). Pressure ulcers are localized injuries to the skin and/or underlying tissue, caused by pressure, shear, and/or friction. They are frequent adverse events in hospitals, with significant impact on the patient, length of hospital stay, mortality, and healthcare costs (Avital *et al.*, 2014). Pressure ulcers are graded using a four-point classification system denoting severity, in accordance with the International Classification of Diseases-10, ranging from non-blanchable erythema of intact skin to full-thickness tissue loss (Avital *et al.*, 2014). Nurses are believed to play an essential role in the process of HAPU prevention, by identifying patients at risk and performing counter measures. Understaffing of the nursing workforce, however has been linked to unfinished or missed nursing care (Ausserhofer *et al.*, 2014; Zander *et al.*, 2014), which in turn could lead to higher incidence rates. Therefore, the incidence rates of pressure ulcers are considered sensitive to nurse staffing levels by many experts (Van den Heede *et al.*, 2007) and have been used widely in previous studies, not only in hospitals (Lake & Cheung, 2006; Stalpers *et al.*, 2015) but also in nursing homes (Bowblis, 2011; Spilsbury *et al.*, 2011).

However, there is still no clear evidence on the relationship between nurse staffing levels and HAPU incidence. Previous studies reveal huge methodological variations, and in some instances, even show conflicting results, which impede drawing definitive conclusions (Lake & Cheung, 2006; Brennan *et al.*, 2013; Stalpers *et al.*, 2015).

In addition, current research seems to be focused on nurse staffing, while the contribution of other healthcare professionals is mostly overlooked. Only few studies have investigated the effect of physician staffing on patient outcomes in a general hospital setting (Jarman *et al.*, 1999; Yasunaga *et al.*, 2012). However, in practice, the responsibility of patient care is shared between nurses and physicians. Taylor *et al.* (2012) demonstrated that nurses' perception of nurse–physician collaboration is negatively associated with HAPU incidence rates, and it might well be the case that physicians also contribute directly to HAPU prevention by supporting patient assessment or leading hospital quality initiatives, for example. For the purpose of improving patient care, it seems reasonable to extend the scope of research, focusing on the entire caregiver team.

Furthermore, despite the progress that has been achieved in the past few years (Aiken *et al.*, 2014), the majority of studies in this field still originate from only a few countries, and

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predominantly the USA. This means that the applicability of results to other healthcare systems might be limited because of differences in organizational structure in general, and the range of skills and education levels of staff in particular.

At present, comprehensive restructuring of healthcare systems is underway in many industrialized nations, leading to considerable effects on the levels of hospital staffing (Buchan *et al*., 2013; Clemens *et al*., 2014). In Germany, hospitals have come under increasing economic pressure after the gradual implementation of case-based payments (diagnosis-related groups) in 2003 (Zander *et al*., 2013). Between 2001 and 2011, the number of nurses employed in hospitals fell by approximately 3%, whereas the number of cases to be treated rose by approximately 6% (Federal Statistical Office, 2003, 2011). By international standards, Germany now has a poor nurse-to-patient ratio. A study conducted by Aiken *et al*. (2012) comparing staffing levels of 12 European countries and the USA assigns Germany the worst score with an average of 10.5 patients per nurse. This number is confirmed by a German study by Isfort *et al*. (2013). The professional group of physicians also underwent significant changes. Between 2001 and 2011, their number increased by more than 26% (Federal Statistical Office, 2003, 2011). However, the biggest share of this increase was due to the implementation of a European working time directive, restricting the number of hours per week to 48, a number which also factors in the number of hours on call. In fact, Germany faces a shortage of physicians, according to a survey by the German Hospital Institute. Smaller hospitals in rural areas have particular difficulties in filling their vacancies (Blum & Löffert, 2010).

Already in 2006, a systematic review by the German Institute for Quality and Efficiency in Health Care (2006) concluded that the current evidence does not allow for predicting the implications of the changing hospital workforce on the quality and safety of patient care in Germany. To the best of our knowledge, German studies regarding the effects of staffing on quality of care are scarce (Zander *et al*., 2014), and studies investigating the effects of staffing on patient outcomes in German hospitals are still lacking.

In this study, we aimed to make a first start at closing this research gap and enhancing the evidence base measuring the impact of hospital staffing on patient outcomes in acute care hospitals in Germany. In particular, this study investigates the association of three hospital staffing variables with the standardized incidence ratios of HAPU stages I–IV and II–IV. Aside from nurse staffing levels and the nursing skill mix, physician staffing levels are introduced as an explanatory factor. We assumed that high staffing levels and a rich skill mix were associated with lower HAPU rates, indicating a higher quality of HAPU prevention.

METHODS

Study design

We conducted a cross-sectional study using aggregated secondary data from 2010 and 2012 accessed from two large national databases to achieve the proposed objective of the study. Associations between staffing variables and outcome measures were assessed, while controlling for several patient and hospital characteristics. Analysis was performed at the hospital level.

Data sources

This study is based on secondary data from the structured quality reports of hospitals (SQR) (AQUA Institute GmbH, 2014) from 2010 and 2012, supplemented with data from the German Hospital Directory (GHD). All German hospitals are legally required to submit an SQR, which provides information on several quality indicators. These include standardized HAPU incidence ratios, nurse and physician staffing, and other hospital characteristics. SQR are made publicly available by the AQUA Institute on behalf of the Federal Joint Committee. The data are aggregated at the hospital level. Information on individual patients is not included. The SQR were originally designed to assess the quality of care in hospitals and identify areas for improvement. The data obtained were augmented with information of hospital beds per department from the GHD, which is compiled by the Federal Statistical Office (2014).

Setting and participants

SQR contain aggregated information on all acute care hospitals in Germany. The patient population being studied for HAPU quality indicators, as defined by the AQUA Institute, comprised all patients older than 74 years, admitted without any pressure ulcers to a hospital in the first quarter and discharged before 30 April in the subsequent year. In 2010 1871 hospitals produced SQR, totaling 1,208,701 cases eligible for HAPU quality indicators. The figures for 2012 were 2171 hospitals and 1,180,396 cases, respectively.

Several hospitals were excluded from this study in order to reduce bias. Hospitals excluded from the analysis were those that submitted their SQR in the form of a network report only, with the consequence that it was not possible to attribute data to individual hospitals (2010: $n = 249$, 2012: $n = 599$) and those not included in the GHD (2010: $n = 92$, 2012: $n = 128$).

Hospitals which had 50% or more psychiatric beds were excluded from the analysis (2010: $n = 156$, 2012: $n = 155$), as patient and staffing characteristics of those facilities differ significantly from other acute care hospitals. In addition, hospitals were only included in the study when standardized incidence ratios of HAPU stages I–IV and II–V were provided (without pertinent data, 2010: $n = 18$, 2012: $n = 144$).

Given the relatively low risk of pressure ulcers, they rarely occur in hospitals with low-case volumes. In fact, many smaller hospitals did not record any HAPU, and therefore, their ratio of observed-to-expected HAPU was zero. In these cases, however, positive results did not necessarily imply high quality of care. In order to minimize this bias, hospitals with fewer than 500 cases eligible for HAPU quality indicators were excluded from the study (2010: $n = 646$, 2012: $n = 473$).

After the application of exclusion criteria, 710 hospitals (37.9%) with a total of 716,281 patient cases (69.6%) were analyzed in 2010. For 2012, the official database did not contain data on hospitals in the federal state of Rhineland Palatinate,

and it was more problematic to link the datasets available with the individual hospitals under consideration. As a consequence, the analysis only covered a total of 672 hospitals (31%) and 757,665 cases (64.2%).

Dependent variables

Standardized incidence ratios of HAPU were used as dependent variables. These described the ratio of the observed rate to expected rate of HAPU stages II–IV (observed/expected HAPU II–IV) and I-IV (observed/expected HAPU I–IV) at the hospital level. The observed/expected ratios for each hospital were calculated by the AQUA Institute. They were adjusted for age (75–84/>85), intensive care treatment (<24 h/>24 h), diabetes mellitus, micro-movements, and interaction terms. A detailed description and the exact formula can be found in the respective AQUA Institute reports (2010, 2012).

Staffing measures

As explanatory variables, we used three different measurements of hospital staffing: nurse staffing levels, nursing skill mix, and physician staffing levels. Staffing was calculated per hospital using full-time equivalents.

Nurse staffing levels describe the number of nurses who care for 100 patient beds. All nursing personnel reported in the SQR were considered: general nurses (3 years of training, roughly comparable to registered nurses), pediatric nurses (3 years of training), geriatric nurses (3 years of training), and nursing assistants and nursing aides (1–2 years of training).

The nursing skill mix describes the percentage of nurses with at least 3 years of training to total nursing staff (general nurses, pediatric nurses, and geriatric nurses). The training and responsibilities of nurses vary between countries (see Robinson and Griffiths 2007 for a short comparative overview of nursing education in Germany). In spite of recent efforts to strengthen academic nursing training, nurses rarely have university degrees in Germany (Aiken *et al.*, 2013). For the few that do, the SQR did not provide accurate information on the number of employees in full-time equivalents. Therefore, academically-trained nurses could not be taken into account.

As described earlier, we also considered physician staffing levels as an explanatory factor for the incidence rates of HAPU. This was calculated as the number of in-house and affiliated physicians per 100 beds.

Hospital characteristics

The following hospital characteristics were available to control their potential confounding effects: type of ownership (public, independent/non-profit, for profit), region (north, south, east, west), teaching status (teaching, non-teaching), number of hospital beds, case volume, patient turnover, existence of specific specialist wards (neurology, geriatrics, orthopedics), and the state of technology (normal, high technology). These characteristics were operationalized in the following manner.

Hospitals were grouped into four regions, according to the Federal State Index: north (Bremen, Hamburg, Lower Saxony, Schleswig-Holstein), south (Baden–Württemberg, Bavaria), east (Berlin, Brandenburg, Mecklenburg–Vorpommern, Saxony, Saxony–Anhalt, Thuringia), and west (Hesse, North Rhine–Westphalia, Rhineland–Palatinate, Saarland). The case volume was the number of cases eligible for HAPU quality indicators (all patients aged >75 years admitted and discharged during the first quarter of the year) obtained from the denominators of the quality indicators. This number, however, had to be estimated for some hospitals (2010: $n = 54$, 2012: $n = 21$) with few HAPU (2010: 1–5 cases, 2012: 1–3 cases), as rare occurrences are not reported in absolute numbers in the SQR for data-protection reasons. Where necessary, estimations were derived by working back from 95% confidence intervals for quality indicator values. The patient turnover was calculated by dividing the number of in-patient cases by the number of hospital beds. A hospital was assumed to have a specialist department if it had one or more respective beds. Finally, high-technology status was accorded when a hospital had a department for neurosurgery or cardiovascular surgery.

Statistical analysis

SQR datasets were imported from an XML format, linked to the GHD, and analyzed using SPSS 22 (IBM Corp., Armonk, NY, USA). Linkage was performed based on the hospitals' street address, and manually reviewed. The unit of analysis was the hospital. Descriptive statistics were used to illustrate the median and interquartile ranges (IQR) or the frequency and percentage distribution of the study variables. We conducted bivariate and multivariable linear regression using observed/expected HAPU II–IV and I–IV as dependent variables and staffing variables, and other hospital characteristics as explanatory variables. For each year and dependent variable, separate models were created. Comparisons between the years 2010 and 2012 were not attempted, as samples of hospitals differed and tracking of individual hospitals over time was difficult because of the particular data structure of SQR (Kraska *et al.*, 2015). Initially, bivariate analyses were performed to identify independent variables associated with observed/expected HAPU II–IV and I–IV. Two different approaches were then used for the creation of multivariable models. One model including all variables, the other including variables that were significantly correlated with the dependent variables in a bivariate model at the 10% level of significance. As the purpose of this study was to investigate the effect of hospital staffing on the observed/expected ratios of HAPU, all three staffing variables were included in these models, irrespective of their association in bivariate models. Beta-coefficients, 95% confidence intervals, and *P*-values are reported for each predictor. With regard to the explorative character of the study, $P < 0.05$ was interpreted as significant, with no adjustment for multiple comparisons. R^2 values are provided for multivariable linear regression models.

Ethical considerations

Both data sources, SQR and GHD, are publicly available. Only aggregated, anonymous data were used. Information on individual patients was not included. Therefore, ethical approval was not required for this study.

Table 1. Staffing and hospital characteristics

Variable	2010	2012
Nurse staffing level – median (IQR)	65.84 (18.90)	68.29 (20.20)
Nursing skill mix – median (IQR)	95.68 (5.43)	95.69 (5.89)
Physician staffing level – median (IQR)	25.77 (8.85)	28.02 (9.14)
No. beds – median (IQR)	346.5 (266.5)	341.5 (271)
Case volume – median (IQR)	883.0 (549.75)	985 (643.25)
Patient turnover – median (IQR)	40.29 (8,75)	42.40 (9,45)
Teaching hospital – N (%)	427 (60.1%)	432 (64.3%)
Ownership		
Public – N (%)	302 (42.5%)	305 (45.4%)
Non-profit – N (%)	303 (42.7%)	260 (38.7%)
For profit – N (%)	105 (14.8%)	107 (15.9%)
Region		
North – N (%)	117 (16.5%)	130 (19.3%)
South – N (%)	155 (21.8%)	164 (24.4%)
East – N (%)	135 (19.0%)	148 (22.0%)
West – N (%)	303 (42.7%)	230 (34.2%)
Departments		
Geriatrics – N (%)	134 (18.9%)	142 (21.1%)
Neurology – N (%)	228 (32.1%)	209 (31.1%)
Orthopedics – N (%)	198 (27.9%)	175 (26.0%)
High technology– N (%)	138 (19.4%)	134 (19.9%)
Hospitals – N	710	672

Case volume, cases eligible for pressure ulcer quality indicators; Nurse staffing level, nurses per 100 beds; nursing skill mix, percentage of nurses with at least 3 years of training to total nursing staff; physician staffing level, physicians/100 beds.

RESULTS

Descriptive results

In 2010, the median observed/expected ratio for the 710 hospitals included was 0.90 (IQR: 0.90) for HAPU stages II–IV and 0.90 (IQR: 0.80) for HAPU stages I–IV. For the 672 hospitals included in 2012, these figures were 0.85 (IQR: 0.91) for HAPU stages II–IV and 0.90 (IQR: 0.82) for HAPU stages I–IV, respectively. The descriptive statistics for staffing and hospital variables are illustrated in Table 1.

Associations between staffing and the incidence of HAPU

The statistical models for the associations between explanatory variables, including staffing variables and observed/expected HAPU II–IV and I–IV are shown in Tables 2 and 3. The first column in both tables shows the results for the bivariate regression. The second column shows the results of the multivariable regression, including variables that were associated with the outcome at the 10% level of significance and staffing variables. Column three shows the results for the multivariable regression using all variables. As these figures illustrate, nurse and physician staffing levels did not have a statistically-significant impact on the observed/expected ratios in any of these models. However, the proportion of nurses with at least 3 years of training to total nursing staff was inversely associated with observed/expected HAPU II–IV and I–IV in 2010 and observed/expected HAPU I–IV in 2012 at a statistically-significant level in both the bivariate and multivariable models.

Associations between other hospital characteristics and the incidence of HAPU

The region where a hospital was located turned out to be a significant predicator of HAPU observed/expected ratios. Most other hospital characteristics did not have significant or consistent associations with dependent variables. The number of beds, case volume, geriatric department, neurology department, and teaching hospital status did not show any association with the standardized HAPU incidence ratios. Orthopedic department, state of technology, and type of ownership were only significantly associated with observed/expected HAPU II–IV in 2010.

DISCUSSION

This study provides some support for an inverse association between the nursing skill mix and the incidence rate of HAPU in German hospitals. Estimated coefficients suggest that a 10% increase in the proportion of nurses with at least 3 years of training to total nursing staff was associated with a decrease in HAPU observed/expected ratios of 0.12–0.15 points, depending on the outcome variable and the year. Surprisingly, the nursing skill mix did not have a significant impact on observed/expected HAPU II–IV in 2012.

Contrary to expectations, the staffing levels of both nurses and physicians did not reveal any significant association with dependent variables. We investigated a number of different approaches, which are not reported here, in order to validate the results. Excluding outliers and influential cases, binning staffing variables, as reported in previous publications (van den Heede *et al.*, 2009b), dividing hospitals into two categories based on their observed/expected ratios, and using logistic regression did not substantially alter the results. We also tried to study the effects of change in staffing on change in observed/expected ratios of HAPU between 2010 and 2012. Overall change of staffing was small (median change in 2010–2012: physicians/100 beds = +1.6; nurses/100 beds = +1.8; nursing skill mix = 0.0) and did not explain changes in observed/expected ratios.

Most other hospital characteristics also showed no significant or consistent association with dependent variables. Discussion of these effects goes beyond the scope of this study. Future research should further explore these associations, especially the regional variation of observed/expected ratios.

One possible explanation of our findings in relation to the association between the nursing skill mix and the incidence of HAPU might be that in hospitals with a lower percentage of nurses with 3 years of training to total nursing staffing, the quality of HAPU prevention, determined by adherence to the recommended process of care, is worse than in hospitals with a greater proportion of qualified nurses. Evidence-based guidelines for pressure ulcer prevention, including recommendations on risk assessment, pressure-relieving surfaces, repositioning, and other nursing interventions, are available (Avital *et al.*, 2014). Implementation of these guidelines, however, requires advanced knowledge and a certain set of skills.

Table 2. Association between hospital staffing and standardized incidence ratios of hospital-acquired pressure ulcers in 2010

O/E ratio pressure ulcers stage II-IV 2010						
	Bivariate model		Multivariate		Multivariate all	
	Coefficient B (95%CI)	p	Coefficient B (95%CI)	p	Coefficient B (95%CI)	p
Nurse staffing lvl.	-0.002 (-0.005;0.001)	0.198	-0.002 (-0.005;0.002)	0.401	-0.001 (-0.005;0.003)	0.600
Nursing skill mix	-0.016 (-0.027;-0.006)	0.002	-0.015(-0.025;-0.004)	0.007	-0.015 (-0.025;-0.004)	0.008
Physician staffing lvl.	-0.003 (-0.008;0.003)	0.335	0.003 (-0.004;0.010)	0.438	0.003 (-0.006;0.011)	0.514
Number of beds	0.000 (0.000;0.000)	0.487			0.000 (0.000;0.001)	0.523
Case volume	0.000 (0.000;0.000)	0.793			0.000 (0.000;0.000)	0.961
Patient turnover	-0.007 (-0.013;0.000)	0.040	-0.005 (-0.011;0.002)	0.177	-0.005 (-0.013;0.003)	0.248
Geriatric Dep.	0.087 (-0.038;0.212)	0.172			-0.001 (-0.137;0.135)	0.988
Neurology Dep.	-0.018 (-0.123;0.087)	0.732			-0.063 (-0.197;0.071)	0.357
Orthopaedic Dep	0.017 (-0.093;0.126)	0.764			-0.015 (-0.129;0.099)	0.793
High-Tech	-0.065 (-0.189;0.059)	0.301			-0.099 (-0.267;0.070)	0.250
Teaching hospital	0.050 (-0.050;0.151)	0.323			0.048 (-0.064;0.160)	0.399
Type of Ownership						
public	Ref.				Ref.	
non profit	0.069 (-0.037;0.175)	0.202			0.025 (-0.096;0.145)	0.688
for profit	0.014 (-0.134;0.161)	0.858			-0.047 (-0.201;0.108)	0.552
Region						
West	Ref.		Ref.		Ref.	
North	-0.072 (-0.214;0.069)	0.315	-0.040 (-0.186;0.106)	0.591	-0.030 (-0.185;0.126)	0.707
East	0.082 (-0.052;0.217)	0.230	0.106 (-0.029;0.240)	0.124	0.125 (-0.020;0.269)	0.090
South	-0.162 (-0.290;-0.034)	0.013	-0.120 (-0.252;0.013)	0.076	-0.106 (-0.255;0.042)	0.159
Constant			2.595 (1.588;3.602)	0.000	2.497 (1.444;3.550)	0.000
Adjusted R^2			0.020		0.036	
O/E ratio pressure ulcers stage I-IV 2010						
	Bivariate model		Multivariate		Multivariate all	
	Coefficient B (95%CI)	p	Coefficient B (95%CI)	p	Coefficient B (95%CI)	p
Nurse staffing lvl.	-0.001 (-0.003;0.002)	0.526	-0.001 (-0.005;0.002)	0.480	-0.001 (-0.004;0.003)	0.700
Nursing skill mix	-0.013 (-0.023;-0.004)	0.007	-0.014(-0.023;-0.004)	0.007	-0.014 (-0.024;-0.004)	0.006
Physician staffing lvl.	-0.001 (-0.006;0.004)	0.737	0.003 (-0.003;0.009)	0.369	0.003 (-0.005;0.011)	0.524
Number of beds	0.000 (0.000;0.000)	0.178			0.000 (0.000;0.001)	0.220
Case volume	0.000 (0.000;0.000)	0.472			0.000 (0.000;0.000)	0.674
Patient turnover	-0.005 (-0.011;0.001)	0.107			-0.004 (-0.011;0.004)	0.340
Geriatric Department	0.046 (-0.071;0.163)	0.442			-0.022 (-0.147;0.104)	0.736
Neurology Department	-0.016 (-0.114;0.082)	0.751			-0.080 (-0.204;0.045)	0.209
Orthopaedic Dep	0.027 (-0.075; 0.128)	0.609			-0.018 (-0.124;0.087)	0.733
High-Tech	-0.018 (-0.134;0.097)	0.757			-0.082 (-0.238;0.075)	0.306
Teaching hospital	0.034 (-0.059;0.128)	0.469			0.018 (-0.086;0.123)	0.727
Type of Ownership						
for profit	Ref.				Ref.	
public	0.000 (-0.099;0.099)	0.996			-0.007 (-0.119;0.105)	0.897
non profit	0.000 (-0.138;0.139)	0.995			-0.068 (-0.211;0.075)	0.353
Region						
West	Ref.		Ref.		Ref.	
North	-0.037 (-0.168;0.094)	0.582	-0.030 (-0.164;0.104)	0.659	0.004 (-0.140;0.148)	0.958
East	0.219 (0.095;0.344)	0.001	0.231 (0.107;0.356)	0.000	0.253 (0.119;0.387)	0.000
South	-0.079 (-0.198;0.040)	0.192	-0.060 (-0.181;0.060)	0.326	-0.043 (-0.180;0.094)	0.539
Constant			2.233 (1.316;3.150)	0.000	2.353 (1.377;3.329)	0.000
Adjusted R^2			0.030		0.025	

Physician staffing level = Physicians per 100 beds, Nurse staffing level = Nurses per 100 beds, Nursing skill mix = Percentage of nurses with at least 3 years of training to total nursing staff, Case volume=Cases eligible for pressure ulcer quality indicators

Table 3. Association between hospital staffing and standardized incidence ratios of hospital-acquired pressure ulcers in 2012

O/E ratio pressure ulcers stage II-IV 2012						
	Bivariate		Multivariable		Multivariable all	
	Coefficient B (95%CI)	p	Coefficient B (95%CI)	p	Coefficient B (95%CI)	p
Nurse staffing lvl.	0.000 (-0.002;0.003)	0.780	0.000 (-0.004;0.004)	0.922	0.001 (-0.005;0.003)	0.671
Nursing skill mix	-0.008 (-0.018;0.002)	0.126	-0.007 (-0.018;0.003)	0.160	-0.008 (-0.025;-0.004)	0.150
Physician staffing lvl.	0.001 (-0.004;0.006)	0.663	0.002 (-0.006;0.009)	0.676	0.007 (-0.006;0.011)	0.148
Number of beds	0.000 (0.000;0.000)	0.738			0.000 (0.000;0.001)	0.320
Case volume	0.000 (0.000;0.000)	0.655			0.000 (0.000;0.000)	0.561
Patient turnover	-0.003 (-0.009;0.002)	0.214			-0.007 (-0.013;0.003)	0.049
Geriatric Dep.	-0.040 (-0.162;0.082)	0.519			-0.066 (-0.137;0.135)	0.315
Neurology Dep.	0.043 (-0.064;0.151)	0.430			0.098 (-0.197;0.071)	0.169
Orthopaedic Dep	0.171 (0.058;0.283)	0.003	0.138 (0.022;0.255)	0.020	0.140 (-0.129;0.099)	0.019
High-Tech	-0.084 (-0.209;0.040)	0.185			-0.172 (-0.267;0.070)	0.049
Teaching hospital	0.010 (-0.094;0.114)	0.849			-0.003 (-0.064;0.160)	0.966
Type of Ownership						
public	Ref.		Ref.		Ref.	
non profit	0.119 (0.010;0.228)	0.032	0.149 (0.032;0.267)	0.013	0.130 (-0.096;0.145)	0.036
for profit	0.126 (-0.018;0.271)	0.087	0.060 (-0.088;0.209)	0.425	0.047 (-0.201;0.108)	0.537
Region						
West	Ref.		Ref.		Ref.	
North	0.038 (-0.103;0.180)	0.597	0.066 (-0.080;0.212)	0.375	0.061 (-0.185;0.126)	0.419
East	0.270 (0.133;0.407)	0.000	0.300 (0.156;0.443)	0.000	0.304 (-0.020;0.269)	0.000
South	-0.046 (-0.177;0.085)	0.494	0.012 (-0.128;0.152)	0.862	0.006 (-0.255;0.042)	0.939
Constant			1.409 (0.414;2.403)	0.006	1.589 (1.444;3.550)	0.003
Adjusted R^2			0.041		0.046	
O/E ratio pressure ulcers stage I-IV 2012						
	Bivariate		Multivariable		Multivariable all	
	Coefficient B (95%CI)	p	Coefficient B (95%CI)	p	Coefficient B (95%CI)	p
Nurse staffing lvl.	0.000 (-0.002;0.003)	0.734	0.000 (-0.004;0.004)	0.923	0.001 (-0.005;0.003)	0.709
Nursing skill mix	-0.013 (-0.023;-0.003)	0.010	-0.012(-0.022;-0.003)	0.014	-0.012 (-0.025;-0.004)	0.019
Physician staffing lvl.	0.002 (-0.003;0.007)	0.497	0.005 (-0.002;0.012)	0.179	0.007 (-0.006;0.011)	0.116
Number of beds	0.000 (0.000;0.000)	0.224			0.000 (0.000;0.001)	0.912
Case volume	0.000 (0.000;0.000)	0.644			0.000 (0.000;0.000)	0.847
Patient turnover	-0.006 (-0.011;-0.001)	0.031	-0.004 (-0.010;0.001)	0.146	-0.004 (-0.013;0.003)	0.201
Geriatric Dep.	0.071 (-0.047;0.188)	0.237			0.011 (-0.137;0.135)	0.858
Neurology Dep.	0.083 (-0.021;0.186)	0.117			0.071 (-0.197;0.071)	0.297
Orthopaedic Dep.	0.101 (-0.008;0.210)	0.070	0.050 (-0.061;0.161)	0.374	0.053 (-0.129;0.099)	0.349
High-Tech	-0.021 (-0.141;0.099)	0.733			-0.153 (-0.267;0.070)	0.066
Teaching hospital	0.078 (-0.022;0.178)	0.124			0.059 (-0.064;0.160)	0.302
Type of Ownership						
for profit	Ref.		Ref.		Ref.	
public	0.089 (-0.016;0.193)	0.097	0.067 (-0.044;0.179)	0.237	0.053 (-0.096;0.145)	0.371
non profit	0.133 (-0.006;0.273)	0.061	0.071 (-0.071;0.213)	0.324	0.064 (-0.201;0.108)	0.384
Region						
West	Ref.		Ref.		Ref.	
North	-0.142 (-0.277;-0.008)	0.038	-0.133 (-0.273;0.008)	0.065	-0.153 (-0.185;0.126)	0.035
East	0.172 (0.042;0.303)	0.010	0.186 (0.049;0.323)	0.008	0.185 (-0.020;0.269)	0.008
South	-0.222 (-0.346;-0.097)	0.001	-0.182(-0.317;-0.048)	0.008	-0.183 (-0.255;0.042)	0.010
Constant			2.153 (1.192;3.113)	0.000	2.026 (1.444;3.550)	0.000
Adjusted R^2			0.056		0.056	

Physician staffing level = Physicians per 100 beds, Nurse staffing level = Nurses per 100 beds, Nursing skill mix = Percentage of nurses with at least 3 years of training to total nursing staff, Case volume=Cases eligible for pressure ulcer quality indicators

Replacing nurses with at least 3 years of training with nursing aides could have a negative impact on the quality of HAPU prevention because of a reduction in nursing expertise, leading to higher incidence rates. However, the cross-sectional study design does not provide sufficient evidence to infer causality from correlation.

Consistent with our findings, several reviews have shown that the current evidence does not support a consistent relationship between nurse staffing or nursing skill mix and the incidence of HAPU (Lang *et al*., 2004; Lankshear *et al*., 2005; Lake & Cheung, 2006; Kane *et al*., 2007; Stalpers *et al*., 2015). Although most studies observed a significant inverse relationship between nurse staffing levels or nursing skill mix and the incidence of HAPU (Aydin *et al*., 2015), some studies also reported contradictory results, ranging from mixed and non-significant findings to counterintuitive findings. To give an example, Burnes Bolton *et al.* (2007) estimated that after the introduction of minimum nurse staffing ratios in California, each additional hour of nursing care per patient day led to an increase in the rate of HAPU by 1% in step-down units. Inconsistent findings are at least partly attributed to the eclectic use of methods in this field, including unit of observation, risk adjustment, adjustment for potential confounding factors, measures of staffing variables, and calculation of effect sizes (Brennan *et al*., 2013). However, as long as researchers have to rely on secondary administrative data, differences in approaches are unavoidable.

Many authors have already called for further and more sophisticated investigations and have made specific conceptual recommendations for pertinent studies (e.g. Brennan *et al*., 2013). Although physician staffing did not show any significant association with HAPU incidence, future studies should take into account all healthcare professionals involved in patient care. This study appears to confirm the need for more granular data.

Limitations

The study suffers from several limitations. The SQR used for the analysis also serve as an instrument of competition. The relatively low decubitus ulcer rates in the SQR, as reported by the hospitals themselves, might call the reliability of data into question (Lahmann *et al*., 2012).

The risk adjustment of observed/expected HAPU II–IV and I–IV does not cover all risk factors considered relevant for the development of bedsores (Coleman *et al*., 2013), nor does it include younger patients at risk.

In addition, staffing levels and skill mix were calculated at the hospital level using the number of staff (or rather, the full-time equivalent thereof) and the number of hospital beds. Patient turnover was used as a proxy for workload. This can only be considered to be an approximation of the actual situation in which a hospital patient at risk for HAPU is treated. Data aggregated in this manner might obscure associations between staffing and quality of care (Van den Heede *et al*., 2009a,2009b). Unfortunately, it was not possible to obtain staffing levels at ward level or details about nursing workload. However, nurse staffing levels and skill mix at the hospital level might reflect the general staffing policies of individual hospitals. Hospital staffing is just one aspect of HAPU prevention. The statistical models explained only a marginal amount of variance found in observed/expected ratios of HAPU, as indicated by R^2 values between 0.020 and 0.056. Organizational culture, availability of appropriate equipment, and other relevant factors, which might explain a major amount of variance, could not be considered in this study.

By excluding hospitals with fewer than 500 cases eligible for HAPU quality indicators, small and privately-owned hospitals are underrepresented in this study when compared to the national average.

Conclusion and implications

Using large national databases, this study demonstrates that, in Germany, the proportion of qualified nurses is positively related to success in preventing the development of pressure ulcers in hospitals.

Our findings, however, should be treated with caution due to the limitations discussed above. The absence of an association between hospital staffing levels and the incidence of HAPU should not be interpreted to imply that nurse-to-patient or physician-to-patient ratios do not affect quality of care. Hospital managers should review the composition of their staff critically. The level of qualification of nurses and their knowledge of HAPU-prevention strategies should be appropriate to the patients' needs to ensure safe patient treatment, effective HAPU care, and low HAPU incidence. Until evidence-based recommendations are available, the evaluation of hospital staffing has to be considered on an individual basis. Further investigations across different countries and based on more comprehensive and detailed data are required to determine unequivocally-safe staffing levels and skill mix in order to guide policy makers in enhancing the quality of patient care.

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