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Association of nurse understaffing and limited nursing work experience with in-hospital mortality among patients: A longitudinal register-based study

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ABSTRACT

Background: Although nurse understaffing and limited nursing work experience may affect hospital patients' risk of mortality, relatively little longitudinal patient-level evidence on these associations is available. Hospital administrative data could provide important information about the level of staffing, nurses' work experience and patient mortality over time.

Objective: To examine whether daily exposure to nurse understaffing and limited nursing work experience is associated with patient mortality, using patient-level data with different exposure time windows and accounting for several patient-related characteristics.

Methods: This longitudinal register-based study combined administrative data on patients (clinical database Auria) and employees (Titania® shift-scheduling) from one hospital district in Finland in 2013–2019, covering a total of 254,446 hospital stays in 40 units. We quantified nurse understaffing as the number of days with low nursing hours in relation to target hours (<90 % of the annual unit median), and limited work experience as the number of days with a low proportion of nurses with >3 years of in-hospital experience, and those aged over 25 (<90 % of the annual unit median). We used two survival model designs to analyze the associations between nurse understaffing and limited nursing work experience and the in-hospital mortality of the patients: we considered these exposures during the first days in hospital and as a cumulative proportion of days with suboptimal staffing during the first 30 days.

Results: In total, 1.5 % (N = 3937) of the hospital stays ended in death. A 20 % increase in the proportion of days with nurse understaffing was associated with an increased, 1.05-fold mortality risk at the patient level (95 % confidence interval, 1.01–1.10). The cumulative proportion of days with limited nursing work experience, or the combination of nurse understaffing and limited work experience were not associated with increased risk of death among all patients. However, both indicators of limited nursing work experience were associated with an increased mortality risk among patients with comorbidities (HR 1.05, 95 % CI 1.02–1.08 and HR 1.05, 95 % CI 1.00–1.10, respectively).

Conclusions: Nurse understaffing was associated with a slight, but a potentially critical increase in patient in-hospital mortality. Limited nursing work experience was associated with increased in-hospital mortality in a subgroup of patients with comorbidities. Increased use of administrative data on planned and realized working hours could be a routine tool for reducing avoidable in-hospital mortality.

What is already known

- It has been suggested that nurse understaffing may increase patient mortality risk, but relatively few studies have examined patient-level exposure assessments.

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- The results may be sensitive to the ways in which nurse understaffing was measured and what kinds of exposure time windows were used.
- The role of nurses' work experience in patients' mortality risk has seldom been explored using detailed patient-level data.

What this paper adds

- Understaffing was associated with a slight, but potentially critical increase in patients' in-hospital mortality.
- Exposure to limited nursing work experience was also associated with increased in-hospital mortality in a subgroup of patients with comorbidities.

1. Introduction

Nurse staffing levels in hospitals may have an effect on patient safety, quality of care and patient outcomes (Ball et al., 2018; Griffiths et al., 2018; Dall'Ora et al., 2022). In longitudinal patient-level analyses conducted in the US (Needleman et al., 2011; Needleman et al., 2020), Canada (Rochefort et al., 2020), the UK (Griffiths et al., 2019; Fogg et al., 2021) and Switzerland (Musy et al., 2021), for example, shortage of registered nurses has been found to be associated with higher patient mortality rates. Ward-level analyses from a Nordic country, Finland, yielded similar findings (Fagerström et al., 2018; Junttila et al., 2016). In these studies, patient mortality was higher in wards with estimated above-optimal workload among the nurses. These associations may vary depending on the characteristics of patients, with stronger associations being more likely for wards with older patients, those with more severe health problems, or for patients admitted on weekends.

The level of work experience among nurses is an additional determinant of patient outcomes. Highly experienced nurses may be better equipped to mitigate the adverse effects of low nurse staffing levels, whereas this is less likely to be the case for nurses with little work experience. To date, however, research on nurses' work experience and patient outcomes has been scarce (Stalpers et al., 2015; Audet et al., 2018). A systematic review published in 2018 found that five of seven studies reported no association between nurses' work experience and patient mortality risk (Audet et al., 2018). A patient-level longitudinal study in Canada found no association between the average work experience of nurses and patient mortality risk (Rochefort et al., 2020). In contrast, higher seniority levels were associated with lower mortality rates in a UK-based study (Zaranko et al., 2023). In Finland, limited nurses' work experience was associated with increased health-care-associated infections (Peutere et al., 2023), but mortality was not examined in that study.

Methodological issues may in part explain these inconsistent findings (Rochefort et al., 2020; Zaranko et al., 2023; Wang et al., 2020; Blegen et al., 2001). Many studies on nurses' work experience have been limited to cross-sectional datasets and imprecise information on the timing of exposure in relation to patient flow. Furthermore, few studies have examined the associations of nurse staffing levels and nurses' work experience within the same longitudinal study design.

Using administrative data over a 7-year period, we examined whether nurse understaffing and limited nursing work experience are associated with patient mortality. Building on designs for longitudinal analyses (Needleman et al., 2020; Rochefort et al., 2020; Griffiths et al., 2019), we measured exposure to nurse understaffing and limited nursing work experience in two ways; i) during the first one to five days in hospital and ii) during the first 30 days in hospital. To identify vulnerable groups, we examined whether older patients, patients with more severe health problems, or patients admitted on weekends were at a higher mortality risk in association with staff exposures.

2. Methods

2.1. Study context, design and setting

This is a longitudinal study based on administrative data from one public hospital district in Finland. During the study period (2013–2019), Finland had 20 hospital districts. The hospital district in the present study was responsible for the specialized health care of about 480,000 inhabitants and had about 8000 employees. Data were available from 40 of the 44 medical and surgical units treating adult inpatients, or both inpatients and outpatients. Thirty-three units belonged to the larger divisions in the central university hospital and seven units were in four smaller regional hospitals. This study did not consider psychiatric, pediatric, pregnancy and delivery units (Needleman et al., 2020; Rochefort et al., 2020).

2.2. Data sources

We used two administrative databases. The first consisted of the working-hour data retrieved from the employer's shift-scheduling software, Titania® (Härmä et al., 2015). As well as the dates and times of planned and realized work shifts and planned and realized working hours in minutes, the working-hour data also included information on employees' age, occupation codes, and work units. These data were used to obtain information on the nursing resources in the different units.

The second database was the clinical, patient-level database, Auria (Auria Clinical Informatics, 2022), including records on admission and discharge dates and times, units, type of hospital stay (inpatient or outpatient), patient sex, age, diagnoses, and dates of death. These data were used to create variables for patient characteristics.

We used unit codes and calendar days to link these two datasets providing information on nursing recourses and patients. The data sources and variables are listed in Supplementary file, Table A1.

2.3. Patients

We included inpatients aged 16 years or more, who stayed in the hospital for at least one night (i.e., stayed in the hospital for two calendar days), and who had no missing unit-level data for the first 30 days of stay in any of the 40 units included in this study (n = 254,446 patients). We combined the hospital stays of a single patient if a new stay began within the next calendar day. The data were recorded at the accuracy level of unit days; one row in the patient-level data represented one calendar day that the patient had spent in the hospital. The patients were assigned to the units they stayed in at the beginning of each calendar day. In addition to the inpatients staying in the hospital for at least two calendar days as mentioned above, we conducted some of the analyses on the basis of two subsamples. One of the subsamples contained those with hospital stays lasting more than three days (N = 131,812) and the other subsample included those with more than five-day hospital stays (N = 76,230).

2.4. Measurement of exposures and covariates

Data sources and variables are listed in Supplementary file, Table A1. After database linkages, we constructed variables indicating nursing resources (nurse understaffing and limited nursing work experience) for each unit-day, as in our prior study (Peutere et al., 2023). We accounted for only the unit-days that included information on both nurses and patients, i.e., the days for which the two databases could be linked. The exposure variables were nurse understaffing and limited nursing work experience and covariates included patient characteristics.

2.4.1. Nurse understaffing

We measured nurse understaffing from the data retrieved from the payroll-based shift-scheduling program Titania®, in which day-to-day work schedules are made and working hours are planned for each

three-week period. In Finland, health-care personnel must have a formal education. The majority of nurses who work in specialized health care are registered nurses, and the rest are licensed practical nurses. The total number of worked nursing hours per day of both the registered and licensed practical nurses was divided by the total number of targeted hours for that day. This is because working hours were planned for both occupational groups for each unit-day. Some of the units were closed on weekends and may also have been closed on specific days, such as holidays. We therefore excluded unit-days with no planned or realized working hours. We defined a unit-day as understaffed when the total working hours in relation to planned hours was <90 % of the annual unit median. This kind of categorization is in accordance with prior studies on nurse staffing levels (Needleman et al., 2020; Griffiths et al., 2019).

2.4.2. Limited nursing work experience

We measured limited nursing work experience with two indicators for each unit-day. The first indicator was based on the proportion of nurses with more than three years of work experience. This measure accounted for calendar years when the employees had any realized working hours as a registered nurse or a registered practical nurse in the same hospital district since 2008, i.e., the earliest year in which the data were available. As we had no data on the total work history, it was unreasonable to calculate the mean years of experience. Instead, we calculated the proportion of those with at least a certain amount of experience in each work unit for each day. Due to the limitations related to this measure, we also approximated limited nursing work experience by calculating the proportion of employees in the unit who were aged over 25. In Finland, it is possible to start vocational education after completing primary school at the age of 15 and to become a licensed practical nurse in two to three years. After completing the licensed practical nurse degree, or alternatively, three years of upper secondary school (at the age of 19), it is possible to obtain the degree of registered nurse in a university of applied sciences in 3.5 years. We created categorical variables using the same logic as we used for the measure of nurse understaffing. Unit-days on which the proportion was <90 % of the annual unit median were defined as being staffed by nurses with limited work experience; measured as either a low proportion of nurses with >3 years of in-hospital experience or a low proportion of nurses aged >25.

2.4.3. Patient characteristics

The covariates included age, sex and comorbidities. The comorbidity information was based on the diagnoses recorded for each hospital stay, classified according to the Charlson Comorbidity Index (Charlson et al., 1987; Quan et al., 2011). We also included a dummy variable indicating whether the patient was admitted on a weekend or not, as the organization of staffing and other resources may also differ on weekends and weekdays. Moreover, in some cases, weekend admission may indicate more urgent problems (Tolvi et al., 2020). Staffing resources may be more limited on weekends due to higher wage costs and patients with less urgent problems may be more likely scheduled to weekdays. A cumulative proportion of days in which the patient had visited the intensive care unit since admission before the current day was also included, as in a prior study (Rochefort et al., 2020).

2.5. Ascertainment of patient mortality

The outcome of this study was patient death in hospital within 30 days, that is, the follow-up period lasted either until the day of death, day of discharge, or the 30th day in hospital, whichever occurred first. All deaths occurring during the hospital stay (e.g., on the last day of the stay) were considered in-hospital mortality.

2.6. Statistical analysis

We first give descriptive information on the patients in the data and nursing resources in the hospital district. We used mixed-effects survival models to analyze the associations between nurse understaffing and limited nursing work experience and patient mortality risk. We analyzed the associations with exposures i) on the first day, the first three days and the first five days of the hospital stay and ii) during the first 30 days. When analyzing exposure to one, three and five days, we had to bear in mind that those with more health problems probably have longer hospital stays and are at a greater mortality risk. To take this into account, we formed three subcohorts and predicted mortality using a fixed number of days for which the patient was exposed during their first day, first three days and first five days in hospital and restricted the analyses to patients with inpatient stays lasting more than one, three and five days, respectively. This ensured that the patients with different lengths of stay were comparable and that the association between exposure and outcome was not biased by the greater health problems and mortality risk related to longer hospital stays. In these analyses, we assumed that the association between exposure to nurse understaffing and limited nursing work experience during the first day, the first three days or the first five days remained the same until the end of the follow-up, which was 30 days maximum. We tested this proportional hazard assumption using the test based on Schoenfeld residuals in Stata (Stata manuals).

When examining exposure to nurse understaffing and limited nursing work experience during the first 30 days of hospital stay, we utilized the approach of a prior study (Rochefort et al., 2020). This approach treats each patient's exposure as a time-varying cumulative proportion, i.e., the proportion of days on which the patient was exposed to nurse understaffing or limited nursing work experience measured before the current day.

As a sensitivity analysis, we replicated these main analyses using lower and higher cut-points (<85 % and <95 %) when identifying days with exposure to nurse understaffing and limited nursing work experience, i.e., when categorizing nursing hours in relation to planned hours, proportion of nurses with >3 years of experience and proportion of nurses aged 25 or over in relation to the annual unit median. We also conducted additional analyses by excluding patients who had stayed in the intensive care unit, because although nurse understaffing or limited nursing work experience was not common, mortality risk was higher in that unit than in others.

To examine whether nurse understaffing is particularly harmful in combination with limited nursing work experience, we created combination variables indicating the cumulative proportion of days on which the patient was exposed to both nurse understaffing and limited experience during the first 30 days. In these analyses, we also adjusted for exposure to the main variables, i.e., cumulative proportion of exposure to days with nurse understaffing and limited nursing work experience. Furthermore, to examine whether older patients, patients with more severe health problems, or patients admitted on weekends were at a higher risk of mortality, we calculated the interactions among the main exposure variables and age groups, groups based on the comorbidity index score and weekend admissions.

In each analysis, we adjusted the models for the patient's sex, age, comorbidity index score, whether they were admitted on a weekend or not, the cumulative proportion of days they had spent in the intensive care unit, current year, and current hospital division. Age, sex, comorbidities and weekend admissions were treated as time-invariant variables. When one or more hospital stays of the same patient were combined into a single period, we used the values of the first period in the analyses. The patient-level analyses consisted of only inpatient admissions, although most of the hospital units also treated outpatients and the same patient could have both inpatient visits and polyclinical outpatient visits and operations. However, the unit-level measures of nurse understaffing and limited nursing work experience (described above) covered both patient groups, as it was not possible to separate the exposures in the units that treated both types of patients.

We analyzed the data using Stata version 17 and conducted the survival analyses using the mestreg command. We included the current unit as the random effect in the analyses and applied a Weibull distribution for the baseline hazard function. When evaluating the proportional hazard assumption mentioned above, we used Cox proportional hazard models with hospital unit as a shared frailty. We report our results as hazard ratios with 95 % confidence intervals.

2.7. Ethical consideration

This study was approved by the hospital district. Auria Clinical Informatics retrieved and gave access to the data, in which personal identification numbers were replaced with pseudonyms. According to Finland's legislation and recommendations, ethical approval and consent to participate were not required, as the study was fully based on administrative register data.

3. Results

3.1. Descriptive information on patients and nursing resources

In total, 254,446 hospital stays lasting more than one day were included in the study (see patient selection in Fig. 1), and the number of patients with more than three days and five days in hospital were 131,812 and 76,230, respectively. The mean lengths of stay before censoring the follow-up to 30 days in these three groups were 5.4, 8.2 and 11 days, respectively. Table 1 presents descriptive information on the patient observations according to the minimum length of stay. In comparison to the patients with >1-day stays, the patients with >3- and >5-day stays belonged to the older age groups, had higher Charlson Comorbidity Index scores, were more often admitted on weekends, had been treated in the intensive care unit, and had died in hospital. In total, 1.5 % (n = 3937) of the hospital stays that lasted more than one

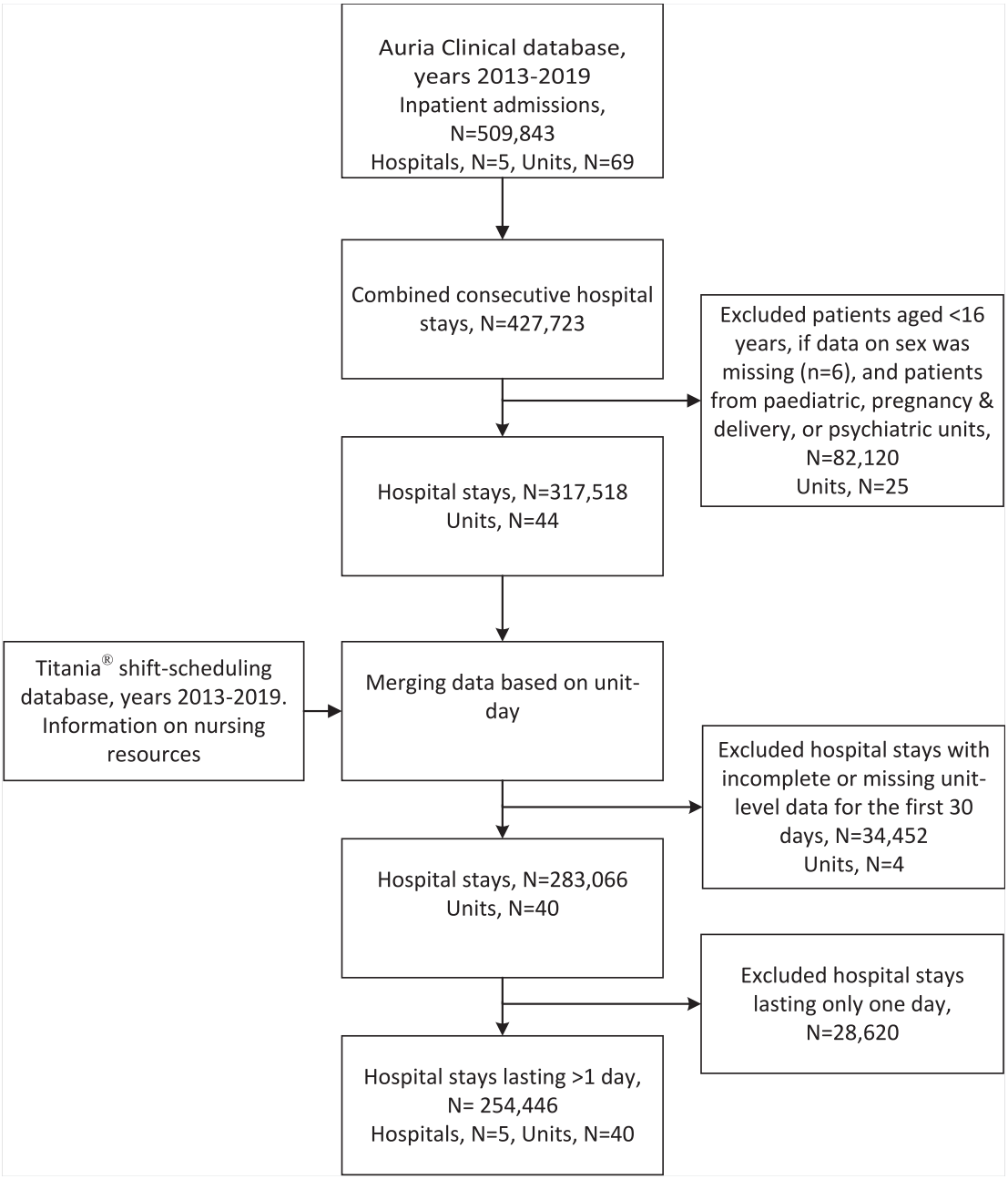

Fig. 1. Flowchart of sample selection.

Table 1
Descriptive information on hospital stays in different patient samples based on minimum length of stay.

	>1-day stay		>3-day stay		>5-day stay	
	N = 254,446		N = 131,812		N = 76,230	
	%	N	%	N	%	N
Sex						
Women	50.1	127,474	49.9	65,782	48.9	37,303
Men	49.9	126,972	50.1	66,030	51.1	38,927
Age groups						
16–30	6.6	16,897	4.7	6209	4.0	3074
31–50	15.0	38,205	12.1	16,012	11.0	8400
51–70	38.8	98,820	38.8	51,189	38.5	29,363
71–90	37.3	94,970	41.7	54,939	43.7	33,294
>90	2.2	5554	2.6	3463	2.8	2099
Charlson Comorbidity Index score						
0	73.8	187,732	70.1	92,436	66.6	50,784
1	5.4	13,660	5.6	7343	5.9	4496
2	17.1	43,605	19.5	25,707	21.7	16,508
3 or more	3.7	9449	4.8	6326	5.8	4442
Weekend admission						
No	85.0	216,363	81.8	107,773	82.7	63,063
Yes	15.0	38,083	18.2	24,039	17.3	13,167
Treated in intensive care unit						
No	95.9	244,081	92.7	122,160	88.7	67,639
Yes	4.1	10,365	7.3	9652	11.3	8591
Died within 30 days of admission						
No	98.5	250,509	97.9	129,097	97.3	74,203
Yes	1.5	3937	2.1	2715	2.7	2027

day ended in death, the respective proportions in the subsamples being 2.1 % (n = 2715) and 2.7 % (n = 2027).

The inpatients were treated in a total of 44 medical and surgical units for adult patients, of which 40 units could be linked to the staffing data for the study years 2013–2019. In total, 91 % of the unit-days with data on patients, staffing or both, included data from both sources. Tables A2 and A3 in Supplementary file 1 show the distribution of the three exposure variables according to hospital divisions within unit-days, and the proportions of days defined as understaffed or having limited nursing work experience per each unit. On average, the proportion of nursing hours relative to planned hours was 97 % (median), and the proportion of unit-days with a low proportion of actualized nursing hours relative to planned hours was 11 %.

The median proportion of nurses with >3 years of in-hospital experience was 82 %, and the median proportion of nurses aged over 25 was 93 % (Supplementary file 1, Table A2). According to these two indicators, the percentages of unit-days with exposure to limited nursing work experience were 20 % and 11 % of unit-days, respectively (Supplementary file 1, Table A3). There was a positive correlation between the proportion of nurses with >3 years of experience and the proportion of nurses aged >25 (r = 0.46). In total, both indicators were low on 8 % of the unit-days, whereas neither was low for 77 % of the days.

3.2. Exposure to nurse understaffing or limited nursing work experience during the first one to five days in hospital

Table 2 shows the results of the survival analyses stratified by the minimum length of hospital stay. Compared to the patients with no exposure, the hazard ratios (HRs) for exposure to nurse understaffing and limited nursing work experience during the first one to five days in hospital indicated a mortality risk, but mainly with no statistical significance. Regarding the main exposure variables, in most cases the proportional hazard assumption was not violated, as the p-values in the test based on the Schoenfeld residuals were mainly above 0.05.

Analyses with lower cut-points (<85 %) for days with exposure to nurse understaffing or limited nursing work experience also showed similar HRs, statistically non-significant, as in the main analyses (Supplementary file 1, Table A4). The analyses based on higher cut-points (<95 %) (Supplementary file 1, Table A5) and a larger proportion of days defined as being exposed to nurse understaffing or limited nursing work experience, showed a few statistically significant associations. Exposures to limited nursing work experience within the first five days in hospital were associated with a higher mortality risk among those with hospitals stays lasting more than five days. For example, compared to patients with no exposure, patients with one and five days of exposure to a low proportion of nurses with >3 years of in-hospital work experience were at an increased mortality risk (HR 1.20, 95 % CI 1.06–1.35 and HR 1.26, 95 % CI 1.07–1.48, respectively) (Supplementary file 1, Table A5).

Table 2
Exposure to nurse understaffing and limited nursing work experience during the first, first three and first five days in hospital and risk of death: analyses stratified by minimum length of stay.

Samples stratified according to minimum length of stay	Number of exposure days	Nurse understaffing				Limited nursing work experience							
		Low nursing hours relative to planned hours				Low proportion of nurses with >3 years of in-hospital work experience				Low proportion of nurses aged >25			
		Number of deaths	HR	95 % CI		Number of deaths	HR	95 % CI		Number of deaths	HR	95 % CI	
>1-day stay													
	0 (ref.)	3697	1.00			3287	1.00			3634	1.00		
	1	240	1.13	0.99	1.29	650	1.00	0.91	1.09	303	1.02	0.91	1.15
>3-day stay													
	0 (ref.)	2364	1.00			1940	1.00			2309	1.00		
	1	261	1.08	0.94	1.23	354	1.04	0.93	1.17	222	1.12	0.98	1.29
	2	72	1.01	0.79	1.28	214	1.06	0.92	1.22	121	1.05	0.88	1.27
	3	18	1.17	0.74	1.87	207	1.13	0.97	1.30	63	0.98	0.76	1.27
>5-day stay													
	0 (ref.)	1645	1.00			1283	1.00			1613	1.00		
	1	270	1.14	1.00	1.30	292	1.05	0.92	1.19	189	1.09	0.93	1.27
	2	81	0.96	0.76	1.21	170	0.99	0.84	1.16	116	1.15	0.95	1.39
	3	18	0.65	0.41	1.04	107	1.04	0.85	1.27	53	1.01	0.76	1.33
	4	9	1.13	0.58	2.19	90	**1.27**	**1.02**	**1.58**	35	0.97	0.69	1.35
	5	4	2.51	0.93	6.75	85	1.03	0.82	1.29	21	1.03	0.67	1.59

Separate analyses for the three exposure variables. Adjusted for sex, age, comorbidities, weekend admissions, cumulative proportion of days in intensive care unit, current year, current type of hospital division, and current unit as a random effect.
Statistically significant HR (hazard ratio) with 95 % CIs (confidence intervals) in boldface.

Table 3
Cumulative proportion of days with exposure to nurse understaffing and limited nursing work experience prior to current day and risk of death.

	HR	95 % CI		p-Value
Low nursing hours relative to planned hours	**1.05**	**1.01**	**1.10**	**0.017**
Low proportion of nurses with >3 years of in-hospital work experience	1.00	0.98	1.02	0.882
Low proportion of nurses aged >25	1.00	0.97	1.03	0.935

Separate analyses for the three exposure variables. Adjusted for sex, age, comorbidities, weekend admissions, cumulative proportion of days in intensive care unit, current year, current type of hospital division, and current unit as random effect.
Hazard ratios (HRs) are shown per every 20 % increase in exposure variable, which corresponds to one day of average-length hospital stay (5 days).
Statistically significant HR (hazard ratio) with 95 % CIs (confidence intervals) in boldface.

The results were largely similar when those who were treated in the intensive care unit during their first days in hospital were excluded (Supplementary file 1, Table A6). In the analyses with no intensive care unit stays, compared to patients with no exposure, exposure to understaffing during the first day in hospital was statistically significantly associated with a higher mortality risk (HR 1.15, 95 % CI 1.01–1.32).

3.3. Exposure to nurse understaffing or limited nursing work experience during the first 30 days in hospital

We found an association between the cumulative proportion of days with low nursing hours relative to planned hours and the risk of death; each 20 % increase in the proportion of understaffed days – which corresponded to one day of an average-length hospital stay – was associated with an increased, 1.05-fold mortality risk (95 % CI, 1.01–1.10) (Table 3). Exposure to limited nursing work experience, measured as cumulative proportions, was unrelated to mortality; both HRs were 1.00 and neither were statistically significant (Table 3). The HRs were also quite similar when we used lower cut-points (<85 %) in the main exposure variables, whereas when we used higher cut-points (<95 %), we found no associations between exposure variables and mortality risk. The results were also quite similar among the patients with no intensive care unit stays (Supplementary file 1, Table A7).

Exposure to a combination of both nurse understaffing and limited nursing work experience was not associated with mortality risk (Supplementary file 1, Table A8). However, we found statistically significant interactions between exposures to limited nursing work experience – measured as low proportion of nurses with >3 years of experience and low proportion of nurses aged over 25 – and comorbidity score ($p < 0.001$ and $p = 0.002$). We found no other interactions (Table 4). Regarding exposures to limited nursing work experience and comorbidity, the risk of death increased in accordance with the comorbidity score. Every 20 % increase in the proportion of days exposed to limited nursing work experience (low proportion of nurses with >3 years of in-hospital experience and low proportion of nurses aged over 25) was associated with a higher mortality risk among patients with two or more points in the Charlson Comorbidity Index (HR 1.05, 95 % CI 1.02–1.08 and HR 1.05, 95 % CI 1.00–1.10, respectively). When exposed to nurse understaffing or limited nursing work experience, the risk of mortality did not increase in accordance with older age groups.

4. Discussion

This register-based study in one hospital district in Finland from 2013 to 2019 found that nurse understaffing – measured as the cumulative proportion of days with low nursing hours relative to planned hours – slightly increased the risk of mortality among patients. Another staff indicator – limited nursing work experience – was not generally associated with mortality risk. However, the interaction analyses suggested that patients with more comorbidities were at an increased risk of mortality due to limited nursing work experience.

4.1. Comparisons to prior studies

We used a relatively new method to assess nurse understaffing, available in the routine of hospital administration data for scheduling working hours and expressed as low nursing hours per planned hours. We are aware of one previous study conducted in the UK that suggests that a greater fill-rate of registered nurses is associated with lower inpatient mortality rates at the ward level (Zaranko et al., 2023). The associated risk with patient mortality in our study is in line with the findings of prior studies that have used longitudinal patient-level data in different country contexts (Needleman et al., 2020; Rochefort et al., 2020; Griffiths et al., 2019; Musy et al., 2021). However, the HRs are not directly comparable due to the different study designs. For example, in our study, every 20 % increase in the proportion of days with nurse understaffing was associated with a 1.05-fold mortality risk, whereas in a prior Canadian study, every 5 % increase in the proportion of understaffed shifts since admission was related to a 1.01-fold mortality risk (Rochefort et al., 2020).

The results also suggest that exposure to nurses' limited work experience during the first five days in hospital was associated with

Table 4
Cumulative proportion of days with exposure to nurse understaffing and limited nursing work experience prior to current day and risk of death: analyses stratified by age groups, comorbidities and weekend admissions.

	Age groups	HR	95 % CI		Charlson Comorbidity Index score	HR	95 % CI		Weekend admission	HR	95 % CI	
Nurse understaffing:												
Low nursing hours relative to planned hours	16–50	1.01	0.81	1.25	0	1.04	0.99	1.11	No	1.07	1.02	1.13
	51–70	**1.11**	**1.02**	**1.20**	1	1.02	0.85	1.23	Yes	0.98	0.89	1.08
	71+0.260	1.03	0.98	1.09	2+0.475	1.07	1.00	1.15				
p-Value for interaction									0.272			
Limited nursing work experience:												
Low proportion of nurses with >3 years of in-hospital work experience	16–50	1.09	0.98	1.21	0	0.96	0.93	0.99	No	1.01	0.98	1.03
	51–70	1.02	0.98	1.07	1	1.00	0.90	1.11	Yes	0.99	0.94	1.03
	71+0.583	0.99	0.96	1.02	2+<0.001	**1.05**	**1.02**	**1.08**				
p-Value for interaction									0.755			
Low proportion of nurses aged >25	16–50	1.08	0.92	1.25	0	0.96	0.91	1.00	No	1.00	0.96	1.04
	51–70	**1.07**	**1.01**	**1.14**	1	1.00	0.87	1.15	Yes	1.01	0.95	1.07
	71+0.073	0.97	0.93	1.01	2+0.002	**1.05**	**1.00**	**1.10**				
p-Value for interaction									0.507			

Separate analyses for the three exposure variables in different subgroups based on age, comorbidity score and weekend admission. Depending on model, adjusted for sex, age, comorbidities, weekend admissions, cumulative proportion of days in intensive care unit, current year, current type of hospital division, and current unit as random effect.
Hazard ratios (HRs) are shown per every 20 % increase in exposure variable, which corresponds to one day of average-length hospital stay (5 days).
Statistically significant HR (hazard ratio) with 95 % CIs (confidence intervals) in boldface.

increased mortality among those with a hospital stay lasting more than five days. Otherwise, in contrast to some prior studies on nurse understaffing (Needleman et al., 2011; Needleman et al., 2020; Griffiths et al., 2019), in our study, nurse understaffing or limited nursing work experience during the first day, the first three days or the first five days of inpatient stay was not consistently or statistically significantly associated with a mortality risk when the analyses were restricted to patients staying in the hospital more than one, three or five days, respectively. These analyses were also somewhat sensitive to the thresholds used when defining days with exposure to nurse understaffing or limited nursing work experience.

In a recent Canadian study, the average work experience of nurses was not associated with the overall mortality risk among patients (Rochefort et al., 2020), whereas a UK-based study found that higher seniority levels of registered nurses were associated with lower inpatient mortality rates (Zaranko et al., 2023). Our analyses contribute to this scarcely studied topic (Audet et al., 2018) by suggesting that limited nursing work experience may be harmful in specific situations, especially for patients with more comorbid health conditions. Overall, our results suggest it would be important to pay attention to the proportion and distribution of experienced nurses in hospital units as well as to other factors that may threaten patient safety and personnel turnover in hospitals. The proportion of nurses with longer experience may affect the overall nursing environment and quality of care in hospital units as they mentor those with limited experience and provide them with opportunities to learn and practice (McHugh and Lake, 2010).

4.2. Strengths and limitations

The strength of this study is its large, rich administrative dataset from an entire hospital district covering seven years, a follow-up period that is still quite rare in this research field. Furthermore, as prior studies have been from other country contexts with different health-care systems, the fact that this study was carried out in Finland is also a strength. In Finland, the majority of specialized health care is provided in public hospitals, which means that the data of the current study largely represented the total hospital patient population within a given region. Overall, there seemed to be no major shortages in nursing resources in relation to the target levels in the hospital units, as the median of daily nursing hours in relation to planned hours was 97 %. In this study, the risk of in-hospital mortality and the proportion of patients treated in intensive care units were lower than those in previous studies based on other country contexts (Needleman et al., 2020; Rochefort et al., 2020; Griffiths et al., 2019; Musy et al., 2021).

The indicator of nurse understaffing – measured as low proportion of nursing hours relative to planned hours – appeared to be predictive of mortality at the patient level. The main advantage of this variable is that it could be easily constructed from routine payroll data and used as a routine tool in hospitals. It does not require calculating patient hours in a unit as a comparison to nursing hours nor does it require nurses to manually evaluate patients' care needs, which may be subject to personal bias.

We only focused on days with nurse understaffing in this study, whereas some prior studies have also identified days or shifts with both low and high staffing levels or workload (Musy et al., 2021; Fagerström et al., 2018). Nursing resources may also be different on weekends and a night or afternoon shift during the week. In the daily-based data for the current study, nursing hours were higher than planned in some of the unit-days. It may be assumed, however, that there is always a reason for staffing levels being higher than planned on certain unit-days, for example, due to a higher number of patients or operations. Cases of understaffing in turn more often reflect the real staff shortage.

There are limitations related to the three exposure variables. The measures of nurse understaffing and limited nursing work experience might have been obscured by the fact that most of the hospital units treated both inpatients and outpatients, whereas our follow-up focused on only inpatients. A limitation related to the indicator based on nursing hours compared to target hours is that some hospital units may have problems hiring personnel and working hours may be planned for only the employees who are available. In addition, short-term substitutes from temporary agencies may also have been used, and their working hours are not recorded in the shift-scheduling system. Statistics on the use of temporary agencies in health care are limited, but overall, this is not common in specialized health care in Finland. During the study years, the hospital district reported problems in recruiting specialist doctors, but in more recent years this problem has also concerned other occupations, such as nurses. The shortage of employees in social and health care has also increased in recent years at the national level (Tevameri, 2022). This study covered 2013–2019 and did not include the COVID-19 pandemic years. Since the global pandemic, the nursing resource situation has become even more difficult, both in Finland and internationally (Poon et al., 2022). Shortages of nursing professionals may also create pressure for nurses with limited work experience, as they may be given too much responsibility. Future studies should focus on these issues with more recent data and more specific information on nursing work experience.

Another limitation of this study is that unlike some prior studies (Rochefort et al., 2020; Griffiths et al., 2019; Musy et al., 2021), we had no information on admission type (urgent or elective) or the severity of the patient's status measured at the time of the admission. However, we used the Charlson Comorbidity Index as an indicator of severity, which has been proved to predict mortality in other studies (Quan et al., 2011; Pylväläinen et al., 2019). The patients in our data may have either already been diagnosed on admission to hospital or been diagnosed later during their stay. For most of the hospital stays, the diagnosis dates were the same as the discharge dates, and so we assigned all the diagnoses for the whole hospital stay. However, we did not account for patient diagnoses recorded during possible prior hospital stays. Admissions on weekends were included as a covariate and may partly account for the urgent cases.

5. Conclusions

This study showed that nurse understaffing may increase mortality risk in hospitals even in a Nordic-type welfare state — where a relatively large range of public health care and other services and benefits are funded by high taxation. Limited nursing work experience may particularly affect patients with comorbid health problems. Our results suggest that administrative data on planned and realized working hours could be a potential way to evaluate understaffing in hospitals.

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CRediT authorship contribution statement

Laura Peutere: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Jaana Pentti:** Writing – review & editing, Methodology, Conceptualization. **Annina Ropponen:** Writing – review & editing, Supervision, Resources, Project administration, Funding acquisition, Conceptualization. **Mika Kivimäki:** Writing – review & editing, Methodology, Funding acquisition, Conceptualization. **Mikko Härmä:** Writing – review & editing, Funding acquisition, Conceptualization. **Oxana Krutova:** Writing – review & editing, Conceptualization. **Jenni Ervasti:** Writing – review & editing, Funding acquisition, Conceptualization. **Aki Koskinen:** Writing – review & editing, Data curation. **Marianna Virtanen:** Writing – review & editing, Supervision, Methodology, Funding acquisition, Conceptualization.

Data availability

The data that support the findings of this study are available from the hospital district, but restrictions apply to their availability. As the data were used under license for the current study, they are not publicly available. However, the data can be made available by the authors upon reasonable request and with the permission of the hospital district. The statistical codes can also be provided upon request.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijnurstu.2023.104628.

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