Hospital nurse staffing and patient outcomes in Chile: a multilevel cross-sectional study

Linda H Aiken, Marta Simonetti, Douglas M Sloane, Consuelo Cerón, Paz Soto, David Bravo, Alejandra Galiano, Jere R Behrman, Herbert L Smith, Matthew D McHugh, Eileen T Lake

Summary

Background Unrest in Chile over inequalities has underscored the need to improve public hospitals. Nursing has been overlooked as a solution to quality and access concerns, and nurse staffing is poor by international standards. Using Chile's new diagnosis-related groups system and surveys of nurses and patients, we provide information to policy makers on feasibility, net costs, and estimated improved outcomes associated with increasing nursing resources in public hospitals.

Methods For this multilevel cross-sectional study, we used data from surveys of hospital nurses to measure staffing and work environments in public and private Chilean adult high-complexity hospitals, which were linked with patient satisfaction survey and discharge data from the national diagnosis-related groups database for inpatients. All adult patients on medical and surgical units whose conditions permitted and who had been hospitalised for more than 48 h were invited to participate in the patient experience survey until 50 responses were obtained in each hospital. We estimated associations between nurse staffing and work environment quality with inpatient 30-day mortality, 30-day readmission, length of stay (LOS), patient experience, and care quality using multilevel random-effects logistic regression models and zero-truncated negative binomial regression models, with clustering of patients within hospitals.

Findings We collected and analysed surveys of 1652 hospital nurses from 40 hospitals (34 public and six private), satisfaction surveys of 2013 patients, and discharge data for 761948 inpatients. Nurse staffing was significantly related to all outcomes, including mortality, after adjusting for patient characteristics, and the work environment was related to patient experience and nurses' quality assessments. Each patient added to nurses' workloads increased mortality (odds ratio 1·04, 95% CI 1·01–1·07, p<0·01), readmissions (1·02, 1·01–1·03, p<0·01), and LOS (incident rate ratio 1·04, 95% CI 1·01–1·06, p<0·05). Nurse workloads across hospitals varied from six to 24 patients per nurse. Patients in hospitals with 18 patients per nurse, compared with those in hospitals with eight patients per nurse, had 41% higher odds of dying, 20% higher odds of being readmitted, 41% higher odds of staying longer, and 68% lower odds of rating their hospital highly. We estimated that savings from reduced readmissions and shorter stays would exceed the costs of adding nurses by US$1·2 million and $5·4 million if the additional nurses resulted in average workloads of 12 or ten patients per nurse, respectively.

Interpretation Improved hospital nurse staffing in Chile was associated with lower inpatient mortality, higher patient satisfaction, fewer readmissions, and shorter hospital stays, suggesting that greater investments in nurses could return higher quality of care and greater value.

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Center for Health Outcomes and Policy Research, University of Pennsylvania School of Nursing and the Leonard Davis Institute of Health Economics, Philadelphia, PA, USA (Prof L H Aiken PhD, Prof M D McHugh PhD, Prof E T Lake PhD, Prof D M Sloane PhD); **Universidad de los Andes, Chile, Escuela de Enfermería, Santiago, Chile** (M Simonetti PhD, C Cerón MSc); **Escuela de enfermería, Pontificia Universidad Católica de Chile, Santiago, Chile** (Prof P Soto MHA); **Centro UC Encuestas y Estudios Longitudinales, Pontificia Universidad Católica de Chile, Santiago, Chile** (Prof D Bravo MA); **Clínica Universidad de los Andes, Chile, Santiago, Chile** (A Galiano MPH); **Ronald O Perelman Center for Political Science and Economics** (Prof J R Behrman PhD) **and Population Studies Center** (Prof L H Aiken, Prof J R Behrman, Prof M D McHugh, Prof H L Smith PhD), **University of Pennsylvania, Philadelphia, PA, USA**

Correspondence to:
Prof Linda H Aiken, Center for Health Outcomes and Policy Research, University of Pennsylvania School of Nursing, Philadelphia, PA 19104, USA
laiken@nursing.upenn.edu

Introduction

Two-thirds of Chile's hospital beds serve poor and middle-class citizens. Waiting lists for elective surgery are common, and public satisfaction with health care is declining.[1,2] Past governmental plans to improve public hospital quality have overlooked improving the nursing workforce as a solution, instead recommending patient-to-nurse ratios substantially worse than international standards, illustrated by safe nurse staffing laws in California (USA) and Queensland (Australia) of no more than five patients per nurse, and bedside-care staff mixes with low percentages of nurses.[3] Moreover, Chile has one of the lowest nurses-to-doctors ratios among countries of the Organisation for Economic Co-operation and Development (OECD), with close to 1·2 nurses per doctor in Chile compared with an average in OECD countries of three nurses per doctor, which is considered the standard for productivity.[4]

Research in over 20 countries and multiple systematic reviews have supported significant associations of hospital nurse staffing and work environments with lower mortality,[5–10] fewer complications,[11] higher patient satisfaction,[12,13] and fewer readmissions and shorter stays.[14,15] Similar research has not been done in Latin

Research in context

Evidence before this study

We searched PubMed for original research articles published in English between Jan 1, 1985, and March 1, 2020, with the following search terms (separately and in combination): "nursing", "staffing", "nurse-to-patient ratios", and "staffing mandate". We also did a manual search based on bibliographies of relevant papers. Many research papers and multiple systematic reviews have concluded that there is an association between the number of patients that hospital nurses care for and risk-adjusted 30-day mortality. This association has been validated in multiple countries with differently organised and financed health care. Most studies have been retrospective observational studies with cross-sectional data. Many of them control for non-nursing factors that might explain the association, but causality has yet to be convincingly determined. Non-mortality patient outcomes have also been found in many large studies to be associated with hospital nurse staffing, including patient satisfaction, complications such as poor glycaemic control, hospital acquired infections, falls, and pressure ulcers. These findings are more mixed than those of mortality, perhaps because outcomes are defined differently, and controls vary markedly between studies. Relatively few multi-hospital studies include empirical measures of the work environment. Although some evidence exists that both nurse staffing and the quality of nurse work environments are associated with measures of hospital productivity such as readmissions and length of stay, few published studies assessed whether improved patient outcomes associated with better nurse staffing and work environments are associated with savings that could offset the costs of greater investments in nurses.

Added value of this study

To our knowledge, this is the largest study to date in Latin America on the association of hospital nursing resources with patient outcomes and hospital productivity. We show the value of Chile's new diagnosis-related groups system to inform important national health-care policies by assessing hospital performance and contributions of nurses to reducing preventable hospital deaths and reducing inpatient days through avoided readmissions and shorter hospital stays. We use findings of this large, rigorous study to evaluate different (hypothetical) policy scenarios to inform policy makers about the feasibility and costs of improving hospital nurse staffing. This translational element of the study addresses an ongoing policy debate in multiple jurisdictions around the world, providing some of the first empirical evidence that improved nurse staffing might not only save lives and improve care quality and patient satisfaction, but also result in savings through avoided hospital days that offset the costs of additional nurses and might result in a more productive use of expensive hospital capacity.

Implications of all the available evidence

Florence Nightingale reportedly said that if we have good evidence and do not act upon it, we are going backwards. The large amount of evidence supporting an association between better hospital nurse staffing and work environments and better patient outcomes is enough to warrant action. The most important next step in research is to implement improvements in nursing resources through large-scale interventions designed to include rigorous prospective policy evaluations, which would enable the field to make progress in understanding the causal connection and value of nursing resources for patient outcomes.

America. Determining the associations of hospital nurse staffing and work environments in Chile with clinical and productivity outcomes is particularly important.[16] First, Chile is producing more nurses than those who are currently employed. In this study, the term nurse refers to fully qualified professional or registered nurses, all of whom are required in Chile to have a bachelor's degree. Second, more jobs for nurses might result in fewer inpatient deaths and not be costly if there are large savings in avoided readmissions and shorter stays. Finally, more jobs for nurses can help build the middle class, an important step towards reducing inequalities. Here, in the International Year of the Nurse and Midwife, we report results of the first large-scale study on the associations of hospital nurse staffing with patient outcomes and care costs in Latin America.

Methods

Study design and data sources

For this multilevel cross-sectional study, we used data from three sources collected between May, 2017, and October, 2018, with the same protocol, instruments, and measures validated in previous Nurse Forecasting (RN4CAST) studies. RN4CAST is the largest study of its kind on nursing care and patient outcomes in the USA, Europe, Asia, South Africa, Australia, and Chile. RN4CAST has been implemented in 30 countries.[17,18]

Survey data were collected from nurses recruited from 40 of 45 public and private general adult high-complexity hospitals, excluding specialty hospitals, participating in the patient diagnosis-related groups (DRGs) system.[19] Patterned after the US DRG system, Chile DRGs began to be implemented in 2009; at the time of data collection, not all hospitals were participating. Before the DRG system, no standardised system of collecting hospital patient data existed in Chile. We required access to standardised patient data from hospitals for our analyses, hence the exclusion of hospitals that did not participate in the DRG system at the time of the study. The nurse survey instrument was ten pages long and consisted of 33 items that allowed us to measure hospital organisational attributes, managerial policies, staffing and resource availability,

job satisfaction and burnout, and nurse-assessed patient outcomes.

Survey data were collected from patients in the same hospitals, using a five-page instrument with 22 items from the Hospital Consumer Assessment of Healthcare Provider and Systems patient experience and satisfaction survey, translated and validated in Spanish.[20]

We used de-identified DRG patient discharge data for public hospitals to measure patient outcomes. All hospitals with DRG data in 2017 (when the study began) were invited to participate, and all nurses in adult medical-surgical units were asked to participate. Patients who were physically and mentally able to complete the survey and who were hospitalised for 2 or more days—and thus had been exposed to the care environment—were recruited from the same units to complete the patient survey, done until 50 patients in each hospital had responded. Patient discharge data were available only for public hospitals; private hospitals were not included in analyses on mortality, readmissions, and length of stay (LOS). Our data allowed us to investigate how two of the most important nursing resources in hospitals—nurse staffing and nurse work environments—were related to patient outcomes and to nurse and patient reports on hospital quality and patient safety.

The study was approved by human subjects review committees at the University of Pennsylvania (Philadelphia, PA, USA), Universidad de los Andes (Santiago, Chile), and participating hospitals. Nurses and patients were informed about the purpose of the survey, that survey participation was voluntary and anonymous, and that by filling out the survey they were giving their consent for the information they provided to be used for research.

Nursing resource measures

Nurse staffing was measured by asking each nurse how many patients they had cared for on their last shift. We created an average hospital-level ratio from these nurse-level ratios. The nurse work environment was measured with the internationally validated Practice Environment Scale of the Nursing Work Index (PES-NWI).[21] The PES-NWI measures modifiable organisational behaviours through five subscales: managerial support for nursing (five items), nurse participation in hospital affairs (nine items), doctor–nurse relations (three items), promotion of care quality (ten items), and staffing and resource adequacy (four items). We measured the hospital environment by averaging nurse responses in each hospital to items comprising four of these subscales. We omitted staffing and resource adequacy because it was highly correlated with the direct measure of patient-to-nurse ratio workloads.

Patient and nurse outcome measures

The outcome variables from DRG data included mortality, readmission, and LOS. Mortality and readmission were binary variables that distinguished patients who died in the hospital within 30 days of being admitted from those who had not, and patients discharged alive and readmitted within 30 days from those discharged alive and not readmitted within 30 days. LOS was a continuous variable indicating how many days patients stayed in the hospital. In our analyses of LOS, we excluded patients with LOS longer than 90 days, because most of these patients were long-term care patients, often staying many months and even years in the hospital because of lack of long-term care placements; their exclusion did not affect regression results. We report LOS results only for surgical patients because previous work revealed that LOS for medical patients was not associated with either staffing or the work environment.[22] Additional outcomes were derived from the patient survey and dichotomised to facilitate their presentation and interpretation: patient ratings of their hospitals on a 10-point scale (contrasting patients rating their hospital lower than 7 with patients rating it 7 or higher) and whether patients would (or would not) definitely recommend their hospital.

The nurse surveys also provided measures related to patient-care quality: nurse reports of care quality in their units (contrasting poor or fair *vs* good or excellent reports); patient safety grades (from A [best] to F [worst], contrasting C, D, or F *vs* A or B); and whether nurses would (or would not) definitely recommend their hospital to friends and family, were (or were not) confident that patients could manage their care after discharge, and were (or were not) confident that management will resolve nurse-reported patient problems.

Additional measures—control variables

Additional measures were used to control for potentially confounding factors. When we analysed 30-day mortality, readmissions, and LOS, we controlled for patient's sex, age, mortality risk, illness severity, and whether any of 31 patient comorbidities were present on admission, following Elixhauser and colleagues.[23] We used more than 500 dummy variables for DRGs—coded 1 if they were present and 0 if they were not—to account for patients' illness severity. In analysing LOS, we included these variables in our models as separate predictors. For the analysis of mortality and readmission outcomes, we used propensity scores derived from all of the aforementioned predictor variables.[24,25] These propensity scores, derived by use of fitted values from separate logistic regressions of mortality and readmissions on each patient's distinct characteristics, avoid strong assumptions about how the outcomes were related to the predictor variables. The C-statistic was 0·92 for mortality and 0·79 for readmission, with values over 0·7, indicating a good model.

When we investigated patient-reported outcomes, we controlled for their self-reported health (dummy variables for excellent, very good, good, fair, and poor health). For nurse-reported outcomes, we controlled for

nurse's sex, age, years of experience in their hospital and their unit, and whether they worked a day or night shift.

Statistical analysis

We first used descriptive statistics (means, percentages, SDs and ranges) to show the numbers and characteristics of patients and nurses surveyed and of patients discharged from study hospitals, and to show nurse staffing and work environments across hospitals. We then assessed the percentage (*PCT*) of patients who died and the odds of dying in hospital within 30 days of admission—calculated as *PCT*/(100–*PCT*)—and odds ratios (ORs) indicating how they differ in hospitals with different staffing and work environments, before and after adjusting for potential confounders. We assessed these same descriptive statistics for readmissions, excluding patients who were not discharged alive. Because LOS is a count (number of days) rather than a binary variable, we assessed the mean LOS for selected surgical patients and incident rate ratios (IRRs) that indicate how much expected LOS differs for surgical patients in hospitals with different staffing and work environments. ORs for mortality and readmission are exponentiated coefficients from multilevel random-effects logistic regression models with clustering of patients within hospitals. The IRRs for LOS were derived by exponentiating coefficients from zero-truncated negative binomial regression models, which were necessary because the LOS measure included no zeros (LOS >1 day) and was overdispersed (ie, variance in LOS was higher than mean LOS).

Regarding care quality and safety reported by nurses and patients, we assessed percentages and odds of nurses giving unfavourable responses to these outcomes, and ORs indicating relationships between nurse staffing, work environments, and likelihood of unfavourable responses. We did similar assessments for patient-reported outcomes, and we used the same random-effects models used to investigate mortality and readmissions, though here the only control was for patients' self-reported health. We used the same types of models to examine nurse-reported outcomes but, because nurse work environment has a subjective component, the association of the hospital-level work environment measure with nurse-reported outcomes was artificially inflated. Therefore, models for nurse-reported outcomes included a nurse-level measure of work environment along with the hospital-level measure, which helped to disentangle them.[18]

We calculated how many additional nurses would be required in each hospital to meet average nurse workloads of 14, 12, and ten or fewer patients per nurse by comparing observed with required staffing ratios at each staffing threshold. Then, we applied a cost calculated by the median monthly income of a medical-surgical nurse obtained from the 2018 Chilean benchmark report on registered nurse wages to have an annual cost estimate for each additional nurse.[26] The average cost of a patient readmission and patient stay per day was obtained from data available from the public health-care payer in Chile (*Fondo Nacional de Salud*).[27] We produced the estimates of reduced number of hospitalisation days and readmissions by using the coefficients from our regression models to generate predicted values at alternative minimum staffing levels to estimate the cost of adding nurses to decrease average nurse workloads to 14, 12, and ten or fewer patients. We assessed the savings from avoided readmissions and shorter LOS that

	Value	Range across hospitals
Characteristics of nurses surveyed		
Nurses surveyed	1652	NA
Hospitals*	40	NA
Nurses per hospital	41 (19)	12–83
Age, years	31·7 (1·9)	27·8–36·0
Experience, years	6·6 (1·6)	2·4–9·7
Sex		
Female	88% (7)	74–100
Male	12% (7)	0–26
Distribution per shift		
Day shift	48% (10)	25–67
Night shift	47% (11)	21–70
Other shift	5% (10)	0–47
Characteristics of hospitals derived from the nurses surveyed		
Patient to nurse ratio	14·1 (4·2)	5·9–24·3
Work environment score	2·7 (0·2)	2·2–3·2
Characteristics of patients surveyed		
Patients surveyed	2013	NA
Hospitals	40	NA
Patients per hospital	50 (3)	43–58
Patient-reported health		
Excellent or very good health	19% (8)	4–36
Good or fair health	73% (7)	63–96
Poor health	8% (5)	0–9
Characteristics of patients discharged		
Patients discharged	761 948	NA
Hospitals	34	NA
Discharges per hospital	22 410 (9175)	8922–45 973
Mortality rate	4% (1)	1–6
Readmission rate	12% (2)	8–17
Length of stay, days		
Hospital level	8 (1)	6–11
Patient level	8 (14)	1–90

Data are n, mean (SD), or percentage (SD). NA=not applicable. *The Chilean hospitals in this study included 34 public and six private hospitals; the mean patient-to-nurse ratio was 14·7 in public hospitals and 8·7 in private hospitals; the mean work environment scores were the same in public and private hospitals; patient discharge data were available only from the public hospitals.

Table 1: **Selected characteristics of nurses, patients, and hospitals in the study sample**

	Patients	Odds	Unadjusted effects	p value	Adjusted effects	p value
Mortality	3·78% (28 833/761 948)	0·039	..	..	..	..
Staffing OR (95% CI)	..	..	1·01 (0·99–1·04)	0·42	1·04 (1·01–1·07)	0·0054
Work environment OR (95% CI)	..	..	1·02 (0·92–1·13)	0·71	0·95 (0·85–1·07)	0·40
Readmission	12·12% (88 409/729 449)	0·139	..	..	..	..
Staffing OR (95% CI)	..	..	1·01 (0·99–1·03)	0·35	1·02 (1·01–1·03)	0·0003
Work environment OR (95% CI)	..	..	0·99 (0·91–1·08)	0·90	0·99 (0·95–1·04)	0·74
Length of stay (surgical patients)*	..	..	..	..	..	..
Staffing IRR (95% CI)	..	..	1·02 (1·00 – 1·05)	0·093	1·04 (1·01–1·06)	0·012
Work environment IRR (95% CI)	..	..	0·90 (0·81 – 1·00)	0·043	0·90 (0·81–1·01)	0·067

Data are % (n/N), unless otherwise specified. ORs from both unadjusted and adjusted models for mortality and readmissions were estimated with random-effects binomial regression models. IRRs in models for length of stay were estimated with zero-truncated negative binomial regression models. The adjusted models controlled for patient's sex, age, and severity of illness, by use of dummy variables for 31 comorbidities that were present on admission and for over 500 patient diagnosis-related groups.
The models for length of stay also controlled for whether the patient died before discharge and for the ratio of TENS (*Técnico en Enfermería de Nivel Superior*) to nurses, because it had a significant effect across the different groups of patients on length of stay but not on the other two outcomes. IRR=incident rate ratio. OR=odds ratio. *Mean length of stay for surgical patients was 10·0 days.

Table 2: **Effects of nurse staffing and the nurse work environment on patient deaths, readmissions, and length of stay**

would result from the addition of more nurses. We used Stata, version 16, and MlWin, version 3.01, for statistical analyses.

Role of the funding source

The funder had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Results

Of the 45 hospitals (37 public and eight private) invited to participate, 40 (88%) agreed (34 public and six private). This hospital sample comprises 75% of patient discharges among all general adult high-complexity hospitals in Chile. Of the 2173 nurses in adult medical-surgical units invited to participate, 1652 nurses (76%) responded, an average of 41 nurses per hospital. Response rates varied by hospital from 53% to 100%. 2013 patients were recruited from the same units to complete the patient survey. We used discharge data for 761 948 adult medical-surgical patients, an average of 22 419 per hospital. In the analyses of LOS, 527 (<1%) patients with LOS longer than 90 days were excluded.

Participating nurses were on average 32 years old (range 28–36 years across hospitals), with an average of 7 years of experience (2–10; table 1). Nurses were predominantly women—88% overall (74–100)—and similar percentages worked day (48%) and night shifts (47%). Nurses were caring for 14 patients on average on their last shift (six to 24 patients). The average work environment score (ranging from 1 [very poor] to 4 [very good]) was 2·7 (2·2–3·2).

Overall, 19% of patients surveyed reported being in excellent or very good health, 73% reported good or fair health, and 8% reported poor health (table 1). 4% of patients died within 30 days of hospital admission, 12% were readmitted within 30 days after discharge, and the average LOS was 8 days. These percentages ranged considerably across hospitals (table 1).

Table 2 shows the percentages and odds of patients dying or being readmitted and their mean LOS, and the estimated effects of staffing and work environment on these three outcomes. The average LOS for surgical patients (*vs* all patients in table 1) was 10·0 days. The corresponding odds of dying were 0·039, and the odds of being readmitted were 0·139, which imply that 39 patients died in hospital and 139 were readmitted for every 1000 who were not. The unadjusted ORs indicate how these odds varied across hospitals for every unit difference in average workloads and environments before controlling for patient characteristics, and the unadjusted IRRs indicate how much the odds on staying one additional day varied. With unadjusted values, only the effect of the work environment on LOS was significant. However, after adjusting for patient characteristics, the effect of the work environment on LOS was not significant, whereas nurse workloads (but not work environments) were significantly related to all three outcomes (table 2).

Adjusted ORs imply that every unit increase in workload increases the odds of patients dying by a factor of 1·04 and of being readmitted by a factor of 1·02. Because nurse workloads range across hospitals from six to 24 patients per nurse and the ORs are multiplicative, these imply very large differences. In hospitals in which nurses care for 18 rather than eight patients (corresponding to hospitals at the 84th *vs* 16th percentile of staffing), the odds of a patient dying are higher by a factor of $1{\cdot}039^9=1{\cdot}41$, or 41%, and of being readmitted are higher by a factor of $1{\cdot}020^9=1{\cdot}20$, or 20%. The adjusted IRR for LOS of 1·04 implies that patients in hospitals in which nurse staffing was one patient per nurse higher would have stays that were, on average, higher by a factor of 1·03, whereas hospitals in which nurses care for 18 rather than eight patients would have stays that were longer by a factor of $1{\cdot}039^9=1{\cdot}41$, or 41% longer.

	Value	Odds	Unadjusted effects				Adjusted effects			
			Staffing OR (95% CI)	p value	Work environment OR (95% CI)	p value	Staffing OR (95% CI)	p value	Work environment OR (95% CI)	p value
Nurse reports										
Quality of care on unit is poor or fair	26% (419/1620)	0·35	1·10 (1·04–1·16)	0·0004	0·65 (0·54–0·79)	<0·0001	1·10 (1·04–1·16)	0·0006	0·65 (0·53–0·80)	<0·0001
Safety grade C, D, or F	48% (776/1618)	0·92	1·08 (1·02–1·14)	0·0076	0·55 (0·45–0·68)	<0·0001	1·08 (1·02–1·14)	0·0091	0·55 (0·44–0·68)	<0·0001
Would not definitely recommend to friends or family	82% (1328/1620)	4·56	1·10 (1·02–1·18)	0·0087	0·58 (0·44–0·76)	0·0001	1·11 (1·03–1·20)	0·0040	0·57 (0·43–0·75)	0·0001
Not confident that patients can manage care	63% (1019/1619)	1·70	1·12 (1·06–1·17)	<0·0001	0·72 (0·60–0·86)	0·0002	1·12 (1·07–1·18)	<0·0001	0·72 (0·61–0·87)	0·0004
Not confident that management will resolve problems	76% (1231/1613)	3·17	1·11 (1·05–1·17)	0·0001	0·52 (0·43–0·64)	<0·0001	1·11 (1·05–1·17)	0·0003	0·52 (0·43–0·64)	<0·0001
Patient reports										
Rate hospital lower than 7 on a 10-point scale	15% (303/1959)	0·17	1·07 (1·03–1·11)	0·0016	0·84 (0·70–1·00)	0·052	1·06 (1·01–1·10)	0·0084	0·87 (0·73–1·05)	0·14
Would not definitely recommend their hospital	31% (602/1943)	0·45	1·05 (1·01–1·10)	0·015	0·86 (0·72–1·04)	0·11	1·05 (1·00–1·10)	0·032	0·88 (0·73–1·06)	0·19

Data are % (n/N), unless otherwise specified. The adjusted models involving the nurse reports controlled for nurse's sex, age, years of experience in their hospital and on their unit, and whether the last shift they worked on was a day shift, night shift, or some other shift. The multilevel random-effects binomial regression models used to estimate the hospital-level effects of staffing and work environments also included a nurse-level measure of the work environment. The adjusted models for patient reports controlled for patients' self-reported health. OR=odds ratio.

Table 3: **Nurse and patient reports of patient care quality and safety, and the effects that nurse staffing and the nurse work environment have on them**

Roughly a fourth of nurses surveyed reported fair or poor quality of care; almost half gave their hospitals unfavourable safety grades of C, D, or F; and between six and eight in ten nurses would not definitely recommend their hospitals, were not confident that patients could manage their care after discharge, and were not confident that hospital management would resolve nurse-reported patient-care problems (table 3). Patient reports were somewhat more favourable, perhaps partly because the wording of the patient-survey questions was different than that in the nurse surveys. Only 15% of patients rated their hospital lower than 7 on a 10-point scale, and just over 30% would not recommend their hospital.

The ORs indicating the effects of hospital-level staffing and work environments on the odds of nurses giving unfavourable reports were similar before and after adjusting for nurse characteristics, including nurse-level reports of their work environment. The ORs related to staffing were significant for all nurse-reported outcomes, with adjusted ORs ranging from 1·08 to 1·12 (table 3). The ORs indicating the effect of the nurse work environment were significant for all nurse-reported outcomes as well, and the adjusted ORs ranged from 0·52 to 0·72. Here as well, the ORs reflecting one-unit differences in staffing give a somewhat deflated estimate of the staffing effect, but both the staffing and work environment effects are sizable. For example, in the care-quality rating, the adjusted ORs of 1·10 for staffing and 0·65 for the work environment imply that nurses in hospitals in which the average nurse cares for 18 rather than eight patients would have higher odds of reporting poor or fair quality care by a factor of $1{\cdot}098^9=2{\cdot}32$, and nurses in hospitals with hospital-level work environment scores of 3 rather than 2·5 would have lower odds of reporting poor or fair quality, by a factor of $0{\cdot}653^{0.5}=0{\cdot}81$, or by 19%.

The effects of staffing for patients were similar to those for nurses (table 3). After adjustment, we found that a unit increase in nurse workloads increased the odds of patients giving low ratings to their hospital (OR 1·06, 95% CI 1·01–1·10) and being unwilling to definitely recommend their hospital (1·05, 1·00–1·10). These adjusted ORs imply that, compared with patients in hospitals where nurses care for eight patients, those in hospitals where nurses care for 18 patients would have higher odds of giving low ratings by a factor of $1{\cdot}06^9=1{\cdot}68$, or 68% higher, and higher odds of not definitely recommending their hospital by a factor of $1{\cdot}05^9=1{\cdot}55$, or 55% higher. Although patients in hospitals with better work environments had lower odds of giving unfavourable reports, as expected, these differences were not significant after adjustment.

Table 4 provides estimates of the costs of adding nurses to poorly staffed hospitals so that, in all hospitals, workloads averaged 14, 12, or ten patients per nurse, and the savings that would be achieved as a result of fewer readmissions and shorter LOS that would ensue under the assumption that our estimates reflect causal relations. Data from all public hospitals, including those more recently adopting DRGs, were used to produce national estimates for policy purposes of the costs of improving nurse staffing. Assuming numbers of hospital patients would be the same as in the study period, the additional nurses who would be required to reduce workloads in each hospital to 14 patients per nurse would be

342 nurses, to 12 would be 665, and to ten would be 1118 (table 4). We calculated an estimated salary expenditure of $30 000 per nurse per year on the basis of current salaries, resulting in an estimated annual cost ranging from $10·3 million to $33·5 million annually. If these additional nurses, on the basis of our model estimates, resulted in fewer readmissions and shorter hospital stays, the savings would exceed the costs by an estimated $1·2 million if the additional nurses resulted in average workloads of 12 patients per nurse and $5·4 million with a resulting average workload of ten patients per nurse.

	Target of 14 patients per nurse	Target of 12 patients per nurse	Target of 10 patients per nurse
Number of additional nurses needed	342	665	1118
Annual cost of additional nurses*	$10 260 000	$19 950 000	$33 540 000
Readmissions			
Readmissions avoided	1352	2215	3450
Savings from readmissions avoided†	$3 812 640	$6 246 300	$9 729 000
Net cost or net savings	$6 447 360 cost	$13 703 700 cost	$23 811 000 cost
Length of stay			
Days avoided	14 272	42 187	82 761
Savings from days avoided‡	$5 030 880	$14 870 917	$29 173 252
Net cost or net savings	$5 229 120 cost	$5 079 083 cost	$4 366 748 cost
Combined readmissions and length of stay			
Net cost or net savings	$1 416 480 cost	$1 167 217 savings	$5 362 252 savings

Cost and savings given in US dollars. *On the basis of $30 000 per nurse. †On the basis of $2820 per readmission. ‡On the basis of $352·5 per day.

Table 4: **Costs of adding nurses to hospitals in Chile, and savings resulting from fewer readmissions and shorter lengths of stay**

Discussion

To our knowledge, this was the first detailed study of hospital nurse resources in Chile, and it revealed that Chilean hospitals have low density of nurses by international standards.[12] On average, hospital nurses care for 14·1 patients each—8·7 patients in private hospitals and 14·7 patients in public hospitals. Patients and nurses alike rated private hospitals more favourably than public hospitals.

Nurse workloads across public hospitals vary substantially, from nine to 24 patients per nurse, a remarkable difference in a public hospital system. Every additional patient added to the average nurse's workload increased patients' risk of in-hospital death by 4%. Patients in hospitals with 18 patients per nurse, compared with those in hospitals with eight patients per nurse, had 41% higher risk of death, were 20% more likely to be readmitted within 30 days of discharge, had stays that were 41% longer, and were 68% less likely to rate the hospital highly and 55% less likely to recommend the hospital to family and friends.

Nurse work environments vary significantly by hospital. Although work environments were not found to be associated with mortality, they were associated with patients' assessments of their hospitals and quality of care. In a previous larger study of 665 hospitals in the USA, we found that, although work nurse environments were not directly associated with mortality, an interaction between nurse staffing and work environments on mortality was documented, such that the association between staffing and mortality was greatest in hospitals with good work environments.[28] Our hospital sample in Chile was not large enough to test for interactions. But the association of patients' global perceptions of quality of their hospital experience with nurse work environments, along with validation from nurses' assessments of quality, is justification for giving attention to improving work environments. Future research examining the association between work environments and nurse outcomes such as job satisfaction, burnout, and intent to leave is warranted.

Chile has enough nurses, with nearly 6000 new nurses graduating every year, to meet estimated requirements for additional nurses needed to enact minimum staffing mandates at any of the three tested levels of 14, 12, or ten patients per nurse to improve staffing in public hospitals.[29] The average Chilean hospital nurse is 32 years old with fewer than 7 years of experience, in contrast to US nurses averaging 47 years of age and 18 years of experience and European hospital nurses who are also substantially older and more experienced than Chilean nurses.[30,31] This demographic profile suggests that Chilean hospital nurses have relatively short careers that could be extended if working conditions were improved.

Our findings suggest that Chile can afford to improve nurse staffing because savings from better outcomes more than offset the costs of additional nurses. If public policies similar to those in California, USA,[32] and Queensland, Australia,[33] were implemented to limit nurses to caring for ten or fewer patients per shift, we estimate that the cost of adding the estimated 1118 additional nurses required would be more than offset by savings achieved in avoided days in hospital. Avoided days in hospital would also enable more patients to be admitted, potentially reducing waiting lists for some surgeries, which has been a problem in Chile.

One limitation of our study is its cross-sectional design, which is insufficient to establish causal relationships between nursing resources and patient outcomes. However, previous research using hospital panel data has found similar relationships by use of longitudinal and cross-sectional analyses.[18] Additionally, some of our measures, such as the staffing and work environment measures produced by aggregating individual nurse reports to the hospital level and the nurse-reported and patient-reported outcome measures related to quality and safety, are at least partly subjective, which complicates their interpretation. All these measures, however, have been used and validated in several of our previous reports. Furthermore, we could not examine mortality

and productivity in private hospitals that do not contribute data to the national inpatient system, but our direct surveys of patients and nurses in both public and private hospitals provide evidence that better resources in private hospitals are associated with better care quality. A strength of our study is its rigorous patient risk adjustment enabled by Chile's new DRG system. Another strength is the inclusion of empirical measures of quality of nurse work environments, an important variable missing in most studies of hospital performance. The economic analysis does not correspond to a traditional cost-effective analysis but provides practical information to aid policy makers.

In the tradition of Florence Nightingale's influential empirical research showing that more British soldiers in the Crimean War died of poor hospital conditions than of battle wounds,[34] we provide additional evidence here that nurses not only save lives, but also contribute to the improved productive use of expensive hospital capacity. Using some of the same general research approaches undertaken by Nightingale, our research provides evidence that greater investments in nurses is a promising strategy to reduce variability in hospital quality, improve patient satisfaction and clinical outcomes, and enhance hospital productivity. Specifically, the implementation of required minimum nurse staffing standards in Chilean hospitals appears to be feasible and offers the potential for substantial improvements in quality of care and patient outcomes. If the Chilean Government acts to establish nurse staffing standards, this study provides a baseline against which to evaluate the outcomes and value of new investments in nursing.

Contributors

LHA, MS, CC, PS, AG, MDM, and ETL did the literature search. LHA, MS, CC, DB, JRB, HLS, MDM, and ETL designed the study. MS, CC, PS, DB, and AG collected data. LHA, DMS, DB, JRB, HLS, MDM, and ETL analysed data. DMS drafted parts of the manuscript. All authors contributed to the data interpretation, writing, and revisions of the report. LHA, MS, DMS, HLS, MDM, and ETL accessed and verified the data. All authors had full access to all data in the study, and the corresponding author had final responsibility for the decision to submit for publication.

Declaration of interests

We declare no competing interests.

Data sharing

Because of Data Use Agreements, we cannot share the patient DRG data. Inpatient hospital discharge data can be obtained directly from the Chilean Ministry of Health. The mechanism by which any person can request access to these data is called Transparency Law. Because of confidentiality agreements with participating hospitals and nurses, we can share only de-identified survey data with the permission of each hospital director and then only in the aggregate, without linking the identity of the hospital to its survey results. Requests for use of survey data under these conditions can be made to the corresponding author after June, 2022, and must be accompanied by a research proposal from a qualified researcher, a letter of support from a research institution, and a signed data use agreement by the researcher and their institution.

For the **Transparency Law** see http://transparencia.redsalud.gob.cl/transparencia/public/ssp/solicitud_informacion.html

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