Int Arch Occup Environ Health (2015) 88:477–484
DOI 10.1007/s00420-014-0977-y

ORIGINAL ARTICLE

California's nurse-to-patient ratio law and occupational injury

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Received: 18 October 2013 / Accepted: 3 September 2014 / Published online: 13 September 2014

Abstract
Objective To determine whether state-mandated minimum nurse-to-patient staffing ratios in California hospitals had an effect on reported occupational injury and illness rates.
Methods The difference-in-differences method was applied: The change in injury rates among hospital nurses after implementation of the law in California was compared to the change in 49 other states and the District of Columbia combined. Data were drawn from the US Bureau of Labor Statistics and the California Employment Development Department, including numerator estimates of injury and illness cases and denominator estimates of the number of registered nurses (RNs) and licensed practical nurses (LPNs) employed in hospitals. Confidence intervals (CIs) for rates were constructed based on assumptions that favored the null hypothesis.
Results The most probable difference-in-differences estimate indicated that the California law was associated with 55.57 fewer occupational injuries and illnesses per 10,000 RNs per year, a value 31.6 % lower than the expected rate without the law. The most probable reduction for LPNs was 33.6 %. Analyses of CIs suggested that these reductions were unlikely to be due to chance.
Conclusions Despite significant data restrictions and corresponding methodological limitations, the evidence suggests that the law was effective in reducing occupational injury and illness rates for both RNs and LPNs. Whether these 31.6 and 33.6 % reductions are maintained over time remains to be seen.

Keywords Legislation · Job-related injury · Illness · Ratios

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Introduction

The first state-mandated nurse-to-patient staffing standards in acute care hospitals were implemented in California in 2004 (Coffman et al. 2002; Spetz 2004). By February 2013, fourteen additional states and the District of Columbia (DC) had adopted policies related to nurse staffing (American Nurses Association 2013), but California remains the only state with mandated minimum ratios. The stated intent of the law was to improve patient outcomes and patient safety (California Department of Health Services 2003). Observational studies before 2004 indicated that low nurse-to-patient ratios were associated with higher rates of pneumonia, cardiac arrest, and failure-to-rescue (Needleman et al. 2002). The safety of nurses was not mentioned in the

law or in the official government document delineating "reasons" for the law (California Department of Health Services 2003).

We are not aware of any studies of the effect of the law on nurse injuries or on workers compensation claims, but there are numerous studies on other possible effects. Donaldson et al. (2005) and Bolton et al. (2007) found significant increases of employment for registered nurses (RNs); Serratt et al. (2011, 2012) showed that staffing increased the most at hospitals with relatively poor baseline staffing. Spetz (2008) and Spetz and Herrera (2010) found significant and persistent improvement in most aspects of job satisfaction, while Aiken et al. (2010) reported that hospital nurses in California were more satisfied with their work environment than hospital nurses in New Jersey and Pennsylvania. Munnich (2013) and Mark et al. (2009) reported differential wage growth of 4.3–7.8 % among RNs in California, which may have reduced operating margins at some hospitals (Reiter et al. 2012). Studies of patient outcomes have generally reported statistically insignificant changes. For example, Donaldson et al. (2005) and Bolton et al. (2007) found no effect on patient falls or pressure ulcers. Difference-in-differences analyses by Mark et al. (2013) and Spetz et al. (2013), and an instrumental variable analysis by Cook et al. (2012), found small and inconsistent effects on six measures of potentially preventable patient safety-related events.

We were interested in the association between nursing work conditions and occupational injuries and illnesses. Nahrgang et al. (2011) presented a model and supporting meta-analysis of the mechanisms whereby conditions of employment contribute to occupational injuries. Several of these mechanisms are relevant to nurse staffing in acute care hospitals. The first involves "job demands" that may include hazards, physical demands, and complexity. We hypothesized that all three would be alleviated with fewer patients per nurse. For example, Clarke et al. (2002) found that needle-stick injuries among nurses were twofold higher in hospital units reporting as understaffed or having poor organizational climates, suggesting greater hazard when nurses are not allowed adequate time for proper insertion and equipment disposal. Nursing can also be physically demanding; Yip (2001) reported that "frequent repositioning of patients" and assisting "patients, while walking" were risk factors for back injuries. Trinkoff et al. (2003) found that nurses with greater perceived physical demands reported more musculoskeletal problems than nurses with lesser perceived demands. Better staffing should decrease physical demands related to repositioning and assisting patients. Nursing in acute care hospitals is complex work; with fewer patients per nurse, more time is available for nurses to provide person-focused care, including medication administration and patient education. The second mechanism for occupational injuries described in Nahrgang et al. (2011) involves job satisfaction. Several studies reviewed by Lagerström et al. (1998) linked higher job satisfaction to fewer back injuries. For example, Ready et al. (1993) found job satisfaction to be a strong predictor of back injuries among Canadian nurses independent of personal characteristics such as weight and smoking. Spetz (2008), Spetz and Herrera (2010), and Aiken et al. (2010) all reported improved job satisfaction among nurses after implementation of the California law, suggesting the possibility of a favorable effect on back injuries. Finally, in the Lagerström et al. (1998) literature review, several studies were discussed that presented evidence that higher "staff density" predicted fewer back injuries among nurses. Based on this framework, we hypothesized that the California nurse staffing regulations would be temporally associated with a reduction in occupational injuries and illnesses among nurses in California, relative to other states without such regulations.

Methods

We take the difference-in-differences approach whereby the change in injury and illness rates before and after implementation of the law within California are compared to changes in injury rates in the 49 other states and DC combined (Stock and Watson 2003; Angrist and Pischke 2009). (For ease of discussion, we will henceforth use "injury" to denote "injury and illness"). The difference-in-differences approach originated with John Snow, who compared decreases in cholera mortality rates in a region serviced by one water company that changed its water supply from 1849 to 1852 with another company's region, where the water source did not change (Angrist and Pischke 2009). The difference-in-differences approach attempts to mimic a randomized trial, based on the assumption that a policy change is enacted independent of the underlying temporal trend in that population's outcomes. In our case, we compare the average change over time in the treatment group (California) versus the average change over time in the control group (the other 49 states and DC). In recent years, the difference-in-differences approach has been used to assess the impact of state laws governing minimum wages, drunk driving, and Medicaid (Stock and Watson 2003; Angrist and Pischke 2009).

Our data were obtained from the US Bureau of Labor Statistics' (BLS) Survey of Occupational Injuries and Illnesses (SOII) and the California Employment Development Department's (CEDD) data used for the SOII. For 1994 through 2010, these data are representative samples of roughly 200,000 private firms and establishments across the USA and California. We used data on nonfatal injury

and illness cases involving days away from work because only these events have information on specific occupations (BLS 2013). We obtained separate data on RNs and licensed practical nurses (LPNs; also called licensed vocational nurses). LPNs can earn licenses in 12–15 months, whereas RN licensure requires at least 2 years for an Associate Degree and 4 years for a Bachelor's Degree (which is the preferred credential for most hospitals). RNs must supervise LPN activity, making RNs the predominant nursing occupation in acute care facilities. Although the SOII has known limitations, it has been used in hundreds of studies on occupational injury (Google Scholar, accessed September 4, 2013), including studies of nurses (Charney and Schirmer 2007; Leigh et al. 2008).

We obtained means and relative standard errors for numbers of injuries for California alone and for the 50 states and DC combined, for all RNs and LPNs employed by private hospitals, excluding state and local hospitals. BLS did not supply data on the 49 states and DC combined or occupation-specific rates. By subtracting the mean numbers for California from the mean numbers from the 50 states plus DC combined, we estimated mean numbers for the 49 states plus DC combined. Standard errors cannot be subtracted in the same way. Numbers of injuries can fluctuate due to increasing or decreasing employment, which puts more or fewer people at risk for job-related injury, so we converted numbers to occupation-specific rates using annual denominators from BLS' survey of Occupational Employment Statistics (for the entire USA) and by CEDD (for California alone). These denominator estimates are based on the same crosswalk of Standard Industrial Classification (SIC) codes for 1999–2001 and North American Industry Classification System (NAICS) codes for 2002–2009; they include all types of hospitals, including state and local government hospitals, which are excluded from the SOII.

To implement the difference-in-difference method, let *diffCArate* represent the difference in the mean injury rate before and after the law within California; let *diffUSCArate* represent the difference in the mean injury rate before and after the law within the other 49 states plus DC. To test for statistical significance, we constructed confidence intervals (CIs) including standard errors for the 49 states plus DC combined based on reasonable assumptions (below). We conducted tests based upon these constructed intervals. If the lower CI for *diffCArate* was above the upper CI for *diffUSCArate*, we concluded that the law reduced injury rates in California. A preferred method would be to test the statistical significance of the difference between the differences (*diffCArate–diffUSCArate*). Comparisons of CIs are more conservative than direct tests of the statistical significance of differences in means (Austin and Hux 2002), but estimating the standard error for differences in means requires estimating the covariance of differences in injury rates for California and the rest of the USA. This would require even more than the five assumptions above. Moreover given a national labor market and national regulation of occupational safety, it is implausible that these rates are uncorrelated.

The construction of standard errors and CIs required information on several variables: mean number of injuries (X); mean number of employees (Y); standard error, relative standard error, and variance for number injuries [SEX, RSEX, Var(X)]; standard error, relative standard error, and variance for number of employees [SEY, RSEY, Var(Y)]; standard error, relative standard error, and variance for ratio of number of injuries to number of employees [SE (X/Y), RSE(X/Y), Var(X/Y)]; covariances between X and Y; and covariances for X/Y before the law and after the law. The BLS and the CEDD provided only mean numbers and relative standard errors for injuries (X) for California (CA) and for the 50 states plus DC (USA); mean number employed and relative standard errors for the 50 states plus DC; and mean number employed for California. Using this information, we calculated standard errors and variances for numbers of injuries (X) for California (alone) and for the USA, and mean numbers for the 49 states plus DC (USA–California). We estimated all other means and standard errors using assumptions below.

Our approach required five assumptions. A longer version of the paper available from the authors provides detailed justification for these assumptions.

1. Relative standard errors for employment (RSEY) for the USA equaled the average relative standard error from 2000 to 2009.
2. The relative standard error for injuries (RSEX) for the 49 states plus DC (USA–California) equaled 1.13 times the relative standard error for the USA, as California contributed approximately 13 % of all US injuries.
3. The RSEY for California equaled the ratio of relative standard error for injuries (RSEX) for California to the RSEX for the USA, times the relative standard error for employment (RSEY) for the USA. The RSEY for the rest of the USA equaled the product of the ratio of the RSEX for the rest of the USA to the RSEX for the USA, times the RSEY for the USA.
4. To estimate the variance of the injury rate, we used this formula: $\mathrm{Var}(X/Y) = \left(\left(Y^2\right) \times Var(X) + \left(X^2\right) \times Var(Y)\right)/\left(Y^4\right)$ (Casella and Berger 2002). We assumed the covariance was zero, an assumption that favored the null hypothesis that there was no difference.
5. We assumed that the covariance between the injury rate before and after the law was zero. This assumption may be untenable, given consistent temporal trends in injury rates, but it also favored the null hypothesis.

Table 1 Comparisons for registered nurses

	Average injury rate[a]		Difference ("before"–"after" law)	95 % confidence interval for the difference	
	Before law	After law		Lower bound	Upper bound
Comparison #1: average injury rate 00–03 versus 05–08					
California	175.71	98.61	77.10	35.608	118.592
USA–California	123.89	102.35	21.53	12.446	30.614
Difference-in-difference (percent reduction from California "before" law)			55.57 (31.6 %)		
Comparison #2: average injury rate 01–03 versus 05–07					
California	163.30	97.71	65.59	18.508	112.672
USA–California	119.16	105.60	13.56	4.447	22.673
Difference-in-difference (percent reduction from California "before" law)			52.02 (31.9 %)		
Comparison #3: average injury rate 99–03 versus 05–09					
California	169.96	100.81	69.16	27.22	111.13
USA–California	121.24	101.91	19.33	10.71	27.95
Difference-in-difference (percent reduction from California "before" law)			49.83 (29.3 %)		

[a] Average injury rates were calculated per 10,000 registered nurses per year

Most of the provisions of the California law went into effect on January 1, 2004; all provisions went into effect (after unsuccessful legal challenges) in April 2005. Three sets of "before and after" comparison years were considered: 2000–2003 versus 2005–2008; 2001–2003 versus 2005–2007; and 1999–2003 versus 2005–2009. On the one hand, including more years of data may increase statistical power, but on the other hand, including years further removed from the implementation date allows for more extraneous influences on injury rates, i.e., the data become more "noisy." Balancing these considerations, we chose 2000–2003 versus 2005–2008 as our primary comparison. The pivotal 2004 year was excluded because the law was only partially implemented in that year.

Results

Raw data provided by BLS and CEDD are available in an appendix from the authors. The total number of injuries among hospital RNs in California decreased from high values of 1,831 and 2,491 in 1999 and 2000, respectively, to low values of 1,520 and 1,650 in 2008 and 2009, respectively. Employment of hospital RNs in California rose steadily across this period from 124,600 and 114,640 to 150,092 and 150,752 in 1999, 2000, 2008, and 2009, respectively. Occupational injury rates among hospital RNs in California gradually fell from 147 and 217 per 10,000 employees in 1999 and 2000 to 101 and 109 per 10,000 employees in 2008 and 2009. Similar trends were apparent for the entire USA without California as well as for LPNs: numbers of injuries decreased; employment increased; and rates decreased.

Table 1 presents "before and after" the law comparisons for RNs. Three sets of comparison years were considered: 2000–2003 versus 2005–2008 (comparison #1); 2001–2003 versus 2005–2007 (#2); and 1999–2003 versus 2005–2009 (#3). Within each panel, estimates of temporal differences are compared between California and the rest of the USA. In every comparison, the difference-in-difference estimates were positive, indicating that the law was associated with an absolute reduction in the reported injury rate. The fourth column of numbers provides 95 % CIs for the estimated pre-post differences. In comparison #1, we estimated that the law was associated with a 31.6 % reduction in the injury rate among hospital RNs in California (55.57/175.71), relative to the mean pre-law injury rate. The lack of overlap between the CIs for California and the rest of the USA suggests that this 31.6 % reduction was statistically significant.

For other temporal comparisons, there was slight overlap of the corresponding CIs for California and the rest of the USA, but the effect estimates were very similar to comparison #1. Specifically, the law was associated with 31.9 and 29.3 % reductions in the injury rate among hospital RNs in California, based on comparisons #2 and #3, respectively.

Table 2 Comparisons for licensed practical nurses

	Average injury rate[a]		Difference ("before"–"after" law)	95 % confidence interval for the difference	
	Before law	After law		Lower bound	Upper bound
Comparison #1: average injury rate 00–03 versus 05–08					
California	244.27	90.27	154.01	80.397	227.623
USA–California	167.86	107.07	60.78	44.058	77.502
Difference-in-difference (percent reduction from California "before" law)			93.23 (33.6 %)		
Comparison #2: average injury rate 01–03 versus 05–07					
California	209.18	97.00	112.17	39.908	184.432
USA–California	164.64	112.93	51.71	34.894	68.529
Difference-in-difference (percent reduction from California "before" law)			60.47 (28.9 %)		
Comparison #3; average injury rate 99–03 versus 05–09					
California	229.95	90.67	139.28	67.213	211.347
USA–California	171.00	103.67	68.33	51.509	85.151
Difference-in-difference (percent reduction from California "before" law)			70.95 (30.9 %)		

[a] Average injury rates were calculated per 10,000 licensed practical nurses per year

Table 2 presents similar results for LPNs. Whereas mean rates before and after the law, shown in the first two columns of numbers, were higher than those for RNs, the difference-in-differences numbers and percentage reductions were similar. For the first panel, comparing 2000–2003 with 2005–2008, the difference-in-differences for LPNs were 93.23 per 10,000 employees, a 33.6 % reduction from the mean pre-law injury rate in California. The lower bound of the CI for California (80.397) was above the upper bound for the rest of the USA (77.502), suggesting statistical significance for the difference-in-differences estimate. However, in other time comparisons, CIs overlapped more for LPNs than for RNs. For hospital LPNs, we estimated law-associated rate reductions of 28.9 % for comparison #2 and 30.9 % for comparison #3.

We also conducted a simpler, second analysis, by assuming that relative standard errors for statistics for which the BLS had data were the same as those for statistics for which BLS did not have data. Specifically, we assumed that the relative standard error for the "before and after" mean difference in California was equal to the average relative standard error for injuries in California from 2001 to 2008. We also assumed that the relative standard error for the "before and after" mean difference for the rest of the USA was equal to the average relative standard error for all US injuries from 2001 to 2008.

In this second, simpler approach, we (1) substituted the BLS average relative standard error for injuries in California from 2001 to 2008 for the relative standard error for the "before and after" mean difference in California and (2) substituted the BLS average relative standard error for all US injuries from 2001 to 2008 for the relative standard error for the "before and after" mean difference for the rest of the USA. We found no overlapping CIs, suggesting a significant effect of the staffing law in all comparisons. All calculations in both tables are available from the authors.

Discussion

Comparing the pre-post differences in occupational illness and injury rates between California and the rest of the USA, we found that implementation of nurse-to-patient ratio standards in California in 2004–2005 was associated with a statistically significant reduction in injury rates among both RNs and LPNs, based on the lack of overlap in the CIs for our primary temporal comparison (2000–2003 vs. 2005–2008). In two other temporal comparisons for RNs, the magnitude of the overlap was small, representing <5 % of the width of the CI. For LPNs, the two comparisons with overlap represented <20 % of the width of the CI. These findings suggest that the law may have resulted in lower injury and illness rates for both RNs and LPNs, although the statistical evidence for LPNs was weaker than that for RNs. Based on our primary comparison (2000–2003 vs. 2005–2008), the occupational injury rate in California

dropped by 31.6 % for hospital RNs and by 33.6 % for hospital LPNs. Alternative estimates that varied the combinations of years before and after the law suggested percentage reductions from 29 to 34 %.

These reductions occurred in the context of well-established downward trends in national occupational illness and injury rates for all SOII industries and occupations combined, as well as within specific industries and occupations, such as hospitals and healthcare (BLS 2012; OSHA 2013). Causes of these declines include new workplace standards for safety and health and greater attention to workplace safety. The difference-in-differences technique that we applied is designed to mitigate simple confounding effects, such as temporal trends (Stock and Watson 2003; Angrist and Pischke 2009). If similar time trends apply to occupational illness and injury rates among hospital nurses in California and the rest of the USA, then the difference-in-differences technique removes their effects.

Hospital groups argue against expanding the California law to other states for several reasons including the additional costs of hiring more nurses and the loss of managerial discretion to allocate workforces (Schultz 2013). In addition, the evidence that legally mandated ratios improve patient outcomes—the stated purpose of the law—is very limited. Other obstacles to enactment in other states include relatively weak nurses unions (at least compared to California) and policy environments that are less favorable to government regulation.

There has been some debate about hospital compliance with the law. Union and hospital representatives disagree over whether current penalties and enforcement activities are adequate. The law allows the California Department of Public Health (CDPH) to impose a maximum fine of $25,000 per violation (Jofre 2008), but the first penalties were imposed in 2007. According to one news agency, penalties are generally only assessed when patients are judged to be in "immediate jeopardy" due to poor care (California Healthline 2011). However, previous studies demonstrated substantial increases in nurse staffing in 2004–2005, especially at hospitals with low baseline staffing (Serratt et al. 2011, 2012), and overall nurse-reported compliance of at least 88 % (Aiken et al. 2010).

Our findings of improvements in occupational safety are consistent with Spetz (2008), Spetz and Herrera (2010), and Aiken et al. (2010), all of whom found improvements or differences in job satisfaction associated with implementation of the California law, and the extensive literature linking job satisfaction to injuries (Lagerström et al. 1998; Barling et al. 2003; Ready et al. 1993). Our findings are also consistent with Nahrgang et al.'s (2011) model and meta-analysis linking hazards, physical demands, and complexity to injuries. On the other hand, our results contrast with findings of no consistent improvement in patient safety or outcomes (Donaldson et al. 2005; Bolton et al. 2007; Mark et al. 2013; Spetz et al. 2013; Cook et al. 2012; Donaldson and Shapiro 2010). However, fewer nurse injuries may not result in fewer adverse events involving patients.

Our study had several limitations. First, BLS was unable to provide estimates for all standard errors. BLS provided relative standard error estimates for numbers of injuries for California and for the entire USA, as well as numbers of nurses employed in hospitals in the USA. But this study required separate estimates for injury rates and for the 49 states plus DC; these estimates relied on five assumptions specified in the "Methods" section. A longer version of this paper available from the authors delineates strengths and limitations of each assumption. One deserves special comment. We used the standard formula for variance of ratios of two random variables, but we assumed covariances to be zero because of lack of data. These covariance assumptions were biased in favor of the null hypothesis; that is, these assumptions made it more difficult to find statistically significant results.

Second, California's workers compensation benefits were cut in the mid-2000s, leading some observers to speculate that reported injury rates for all occupations in California would drop (Reville et al. 2005). Underreporting is a well-recognized limitation of SOII data, especially for injuries or illnesses with insidious onsets or long latency periods, such as hearing loss and carpal tunnel syndrome (Ruser 2008). In a separate analysis, we found that there were no statistically significant difference-in-differences in injury rates for all industries and occupations combined between the USA and California, for any of our three temporal comparisons, suggesting that the change in California workers compensation benefits did not drive our results.

Third, 14 states enacted laws that may have impacted nurse-to-patient ratios after 2005. However, none of these states enacted laws mandating specific staffing ratios, making it less likely that they would have affected occupational injury rates. Fourth, the BLS data used to construct injury rates had denominators that included state and local hospitals, but the numerators did not. In an analysis available from the authors, we showed that since these constructions affected both California and US data in roughly the same proportion (i.e., 18 % of total US nurse employment was in state and local hospitals in 2009, the earliest year available, versus 20.4–21.5 % in California between 2004 and 2007), our results were unlikely to be biased by this numerator–denominator discrepancy.

Fifth, the BLS injury numbers are limited to cases that resulted in at least 1 day of work loss. Whereas these work loss cases are more severe and costly, they comprise only 30–35 % of all injuries and illnesses (Leigh 2011). A final limitation involves the years we analyzed. Our 29–34 % reduction estimates apply to the four or 5 years immediately after implementation of the law. There could be

attenuation in the law's effect over time if hospitals' compliance with the law decreases or if other occupational stressors increase (despite higher staffing levels) For example, the overall hospitalization rate in California in 2011 was 19 % below the national rate, suggesting that hospitalized patients in California might have higher average acuity than those in other states (http://hcupnet.ahrq.gov/).

Future research should attempt to replicate our findings with more recent data, and in other settings where nurse staffing has increased or decreased as a result of exogenous factors. To our knowledge, the California law and a similar law affecting public hospitals in Victoria, Australia (Gerdtz and Nelson 2007) are the first policy interventions that led to rapid, meaningful changes in nurse-to-patient ratios. However, hospital ownership changes, union-negotiated labor agreements, and changes in licensing or voluntary accreditation standards might also affect nurse staffing sufficiently to affect occupational injury rates.

Acknowledgments This study was funded in part by Grants from the National Institute for Occupational Safety and Health (U54OH007550-11, Dr. Leigh) and the California Department of Public Health (Agreement 09-11543, Drs. Romano and Leigh).

Conflict of interest None.

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