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Original Article

Nurse-staffing level and quality of acute care services: Evidence from cross-national panel data analysis in OECD countries

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ABSTRACT

Background: Most of previous studies aimed to estimate the effect of nurse staffing on quality of acute hospital care have used stochastic methods and their results are mixed.**Objective:** To measure the magnitude of effect of nurse-staffing level on increasing quality of acute care services in long-run.**Data:** The number of practicing nurses' density per 1000 population as the proxy of nurse-staffing level and three Health Care Quality Indicators (HCQI) included 30-day mortality per 100 patients based on acute myocardial infarction (MORTAMIO), hemorrhagic stroke (MORTHSTO) and ischemic stroke (MORTISTO) were collected as a part of ongoing project by OECD.org in panels of 26 OECD countries over 2005–2015 period.**Method:** Panel data analysis.**Results:** There were committed relationships from nurse-staffing level to the enhancement of HCQI i.e. 1% increase in nurse-staffing level would reduce the rates of patient mortality based on MORTAMIO, MORTHSTO and MORTISTO by 0.65%, 0.60% and 0.80%, respectively. Furthermore, the role of nurse-staffing level in increasing overall HCQI were simulated at the highest level in Sweden (−3.53), Denmark (−3.31), Canada (−2.59), Netherlands (−2.33), Finland (−2.09), Switzerland (−1.72), Australia (−1.64) and United States (−1.53).**Conclusion:** A higher proportion of nurses-staffing level is associated with higher quality of acute care services in OECD countries. Also, the nursing characteristics of Sweden, Denmark, Canada, Netherlands, Finland, Switzerland, Australia and United States would be good patterns for other countries to maximize nursing outcomes in the care of patients with acute and life-threatening conditions by reducing the risk of complication, mortality and adverse clinical outcomes.© 2018 Chinese Nursing Association. Production and hosting by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

1. Introduction

By the enhancement in quality of health care services for patients with acute and life-threatening conditions, e.g. acute cardiovascular and myocardial infarction conditions, resulting from advances in rapid patient transfer and hospitalization, improved life support services, advanced medical/surgical treatments and techniques, applying modern health care technologies, optimization of staff characteristics in hospital, intensification in health education level and clinical skills, promoting leadership and health

management, moderated legislations and clinical instructions, there has been an obvious improvement in the prognosis of patients with severe and life-threatening conditions associated with lower risk of patient's death and disability during the last two decades – see OECD [1].

As the quality of acute hospital care remains central to the performance of health care systems [1], increasing the quality of acute care would restrain the growth of health care spending by dropping extra clinical procedures and this leads policy makers to allocate limited health care resources more wisely [2]. Hence, to surpass the quality of acute care and to reduce unnecessary health care expenditures, it is important for policy makers, care providers, health care professionals as well as researchers to seek for more efficient services with the aim of providing the needed acute care facilities, while looking for new methods to benchmark the quality

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of acute care services as a key element of health policy reformations.

Among the acute care team workers in hospital, nurse staffs play a critical role in care delivery to patients with acute conditions, i.e. controlling the acute decompensation situation, nurses' assessment and facilitating clinical diagnosis, clinical interventions, educating patients and caregivers, making the patients ready for hospital discharging, preventing of future decompensations and rehospitalization, rehabilitation, etc. Hence, it is important to measure the magnitude of the role of nurse-staffing level in increasing the quality of acute hospital care with the aim of optimizing patient care and health outcomes.

To our knowledge, numerous empirical studies have endeavored to simulate the plausible effect of nursing characteristics¹ on increasing the quality of acute care services, mostly measured by substantial risk of complication and adverse clinical outcomes² along with in-hospital patient mortality rates, and their results have been quite mixed.

Empirical studies have argued the significant effects of nurse-staffing level on the reduction of patient mortality and other adverse outcomes are included, but not limited to; Flood et al. [3], Hartz et al. [4], Krakauer et al. [5], Mannheim et al. [6], Iezzoni et al. [7], Silber et al. [8], Fridkin et al. [9], Archibald et al. [10], Blegen et al. [11], Kovner and Gergen [12], Lichtig et al. [13], Pronovost et al. [14], Robert et al. [15], Needleman et al. [16], Hurst [17], Estabrooks et al. [18], Seago et al. [19], Tourangeau et al. [20], Rafferty et al. [21], Unruh et al. [22], Kane et al. [23], Stratton [24], Schubert et al. [25], Friese et al. [26], Van den Heede et al. [27], Frith et al. [28], Harless and Mark [29], Lucero et al. [30], Mark and Harless [31], Needleman et al. [32], Twigg et al. [33], Schilling et al. [34], Park et al. [35], Schubert et al. [36], Carthon et al. [37], Liang et al. [38], McHugh and Chenjuan [39], Hickey et al. [40], Yakusheva et al. [41], Han et al. [42], Kang et al. [43], Twigg et al. [44], Aiken et al. [45], Cho et al. [46] and Kim and Bae [47].³

By contrast, results of the following studies have denied the existence of meaningful correlation between increasing in nurse-staffing level and in-hospital care outcomes; Wan and Shukla [48], Al-Haider and Wan [49], Bradbury et al. [50], Zimmerman et al. [51], Taunton et al. [52], Silber et al. [53], Iezzoni et al. [54], Iezzoni et al. [55], Silber and Rosenbaum [56], Numata et al. [57], Van den Heede et al. [58], West et al. [59], Talsma et al. [60] and Schreuders et al. [61].

Overall, most of previous studies have collected small samples of hospitalized patients with life-threatening conditions,⁴ generally focused on stationary data analysis approaches⁵ and dramatically have failed to include the alteration of these methods to consider the plausible effects of time variation on their results.

Across the traditional empirical studies in nursing science which typically rely on small samples of clinical observation, the following research article aims to investigate the magnitude of the plausible effect of the level of staffing by nurses in hospitals on increasing the quality of acute care services using the widest range of administrative cross-national statistics collected as a part of ongoing

project by OECD.org⁶ in panels of 26 OECD countries during the period of 2005–2015. Panel data analysis is conducted to simulate the statistically significant magnitudes of the role of nurse-staffing level on the enhancement of Health Care Quality Indicators (HCQI) with considering the plausible effect of time variation on our series.

2. Data description and analysis

In this study, the preference was given to “practicing nurses” which also considered as a key factor of health performances in European Core Health Indicators (ECHI). As nurse-staffing level can be measured by the number of nurses per patient or population, here the number of practicing professional nurses' density per 1000 inhabitants, head counts (NURSE) – included⁷; general care nurses, specialist nurses, clinical nurses, district nurses, nurse anesthetists, nurse educators, nurse practitioners and public health nurses – were used as the index of nurse staffing. The nurse staffing data was collected from OECD Health Statistics [62] in Health Care Resources Package for 26 countries⁸ over the period of 2005–2015. For the lack of data availability during the time the observations of nurse-staffing level were completed from other sources⁹ as well as Artificial Neural Networks (ANNs) method was applied to simulate missed data. The logarithm values of NURSE series were used in panel data analysis. Fig. 1 depicts the observations of practicing nurse's population per 1000 inhabitants in 2015 and changes between 2005 and 2015 among OECD countries.

Based on data availability, three main HCQI were selected from OECD Health Statistics [65] as the proxies for quality of acute care services which covered 45 years old and over admitted patients and verifies age-sex standardized rate per 100 patients included: thirty-day in-hospital and out-of-hospital mortality rates in patient based on a) acute myocardial infarction (MORTAMIO) ICD-9 410 or ICD-10 I21, I22 diagnosis codes, b) hemorrhagic stroke (MORTHSTO) ICD-9 430–432 or ICD-10 I60–I62 diagnosis codes, and c) ischemic stroke (MORTISTO) ICD-9 433, 434, and 436 or ICD10 I63–I64 diagnosis codes. The logarithm values of MORTAMIO, MORTHSTO and MORTISTO series were applied in panel data analysis. Moreover, ANNs method was used to predict the missed observations and to reduce the plausible effects of missed data on our results. Figs. 2–4 depict the amounts of HCQI in 2015 and changes from 2005 to 2015 across OECD countries.

3. Panel data analysis

According to the available data in 26 OECD countries during 2005–2015 period, we have the opportunity to investigate the magnitude of plausible relationship from nurse-staffing level to HCQI in cross-national framework using the technique of panel data analysis. To do this, it is necessary to find the needed information about the statistical behaviors of our series during the time in the context of unit root test, followed by the possibility of long-

¹ Based on nurse's workload hours per patient, number of nurses per patient as well as the number of nurses per population.

² For instance, ICU length of stay, failure-to-rescue (FTR), bloodstream infections, gastrointestinal tract bleeding, cardiac arrest etc.

³ The summary of previous studies argued the existence of sincere relationship from nursing characteristics relative ratios to various patient outcomes in acute care is available in [Appendix](#).

⁴ Controlled to several acute care (quality) indicators such as the inceptive patient risk factors, adverse outcomes and in-hospital patient mortality ratios.

⁵ Multilevel and longitudinal regression analysis, case-control models and other types of cross-sectional data analysis.

⁶ The project aims to measure and monitor the quality of acute care services in national expert panels for evaluation and recommendation related to the care of patients with acute conditions.

⁷ The nursing variable was excluded from the number of midwives (unless they work most of the time as nurses), paramedical practitioners, university lecturers, vocational education teachers, associate professional nurses, associate professional midwives, nursing aides and medical assistants – see OECD Health Statistics [62].

⁸ Included: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Iceland, Ireland, Israel, Italy, Japan, Korea, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Slovak Republic, Spain, Sweden, Switzerland, United Kingdom and United States.

⁹ The missed observations of France, Portugal, Slovak Republic, and United States as well as Italy were completed from Refs. [63,64], respectively.

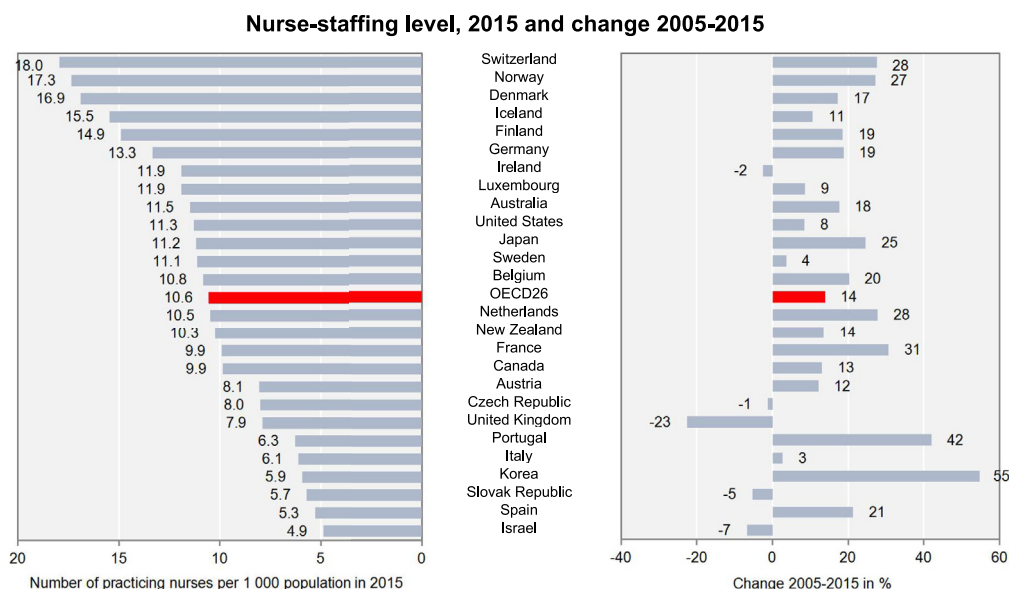


Fig. 1. Number of practicing nurses per 1000 inhabitants, 2015 and change 2005–2015.

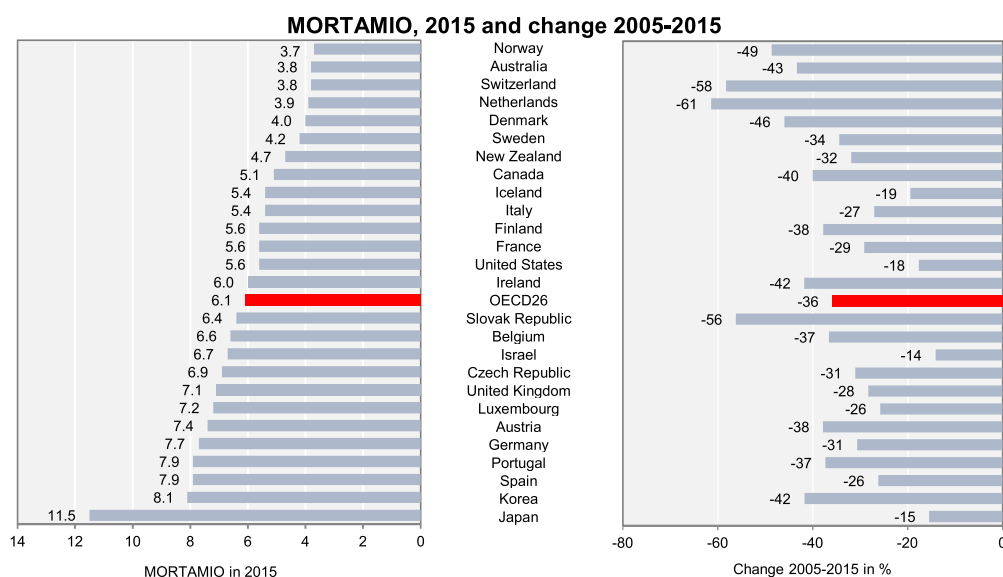


Fig. 2. Thirty-day mortality per 100 patients after admission to hospital for acute myocardial infarction (AMI) based on unlinked data, 2015 and change 2005–2015.

run relationship between variables in cointegration analysis as well as simulating the significant magnitudes of the effect of nursing characteristics on increasing the quality of acute care services in OECD countries.

3.1. Unit root test

Unit root or integration tests are the necessary steps in panel data analysis to consider the effect of time on our series and to find the information about how variables behave during the sample period. Statistically, panel unit root tests examine whether a pooled variable is stationary (with constant mean and variance during the time variation) or non-stationary (mean and variance vary during the time) and possesses a unit root. The stationary null hypothesis is defined as the presence of a unit root or stationarity according to

intercept and trend stationarity based on the test models. The results of four different panel unit root tests are presented in Table 1.

In general, unit root results confirm that all our series were non-stationary, and integration of series was sensitive to trend presentation. According to significant statistics of 1st difference of unit root tests presented in Table 1, it is arguable that all series were integrated in order one $I(1)$ means that the amounts of our series were correlated with their last year digits and this open the way to cointegration analysis.

3.2. Cointegration analysis

The next step is to find whether nurse-staffing level and acute care indicators were cointegrated in long-run or not. The results of Pedroni (Engle-Granger based) co-integration test are reported in

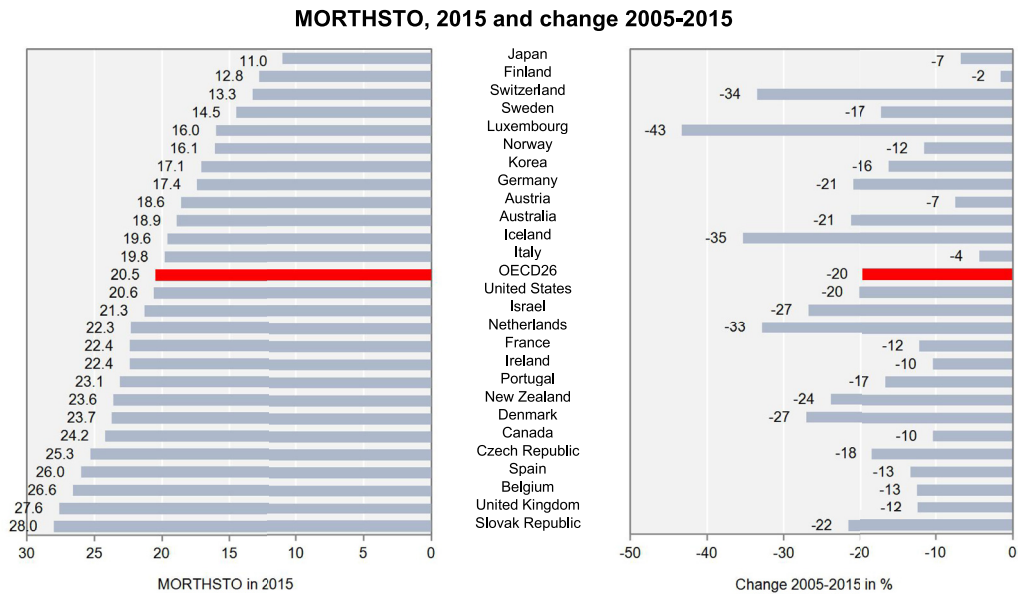


Fig. 3. Thirty-day mortality per 100 patients after admission to hospital for hemorrhagic stroke based on unlinked data, 2015 and change 2005–2015.

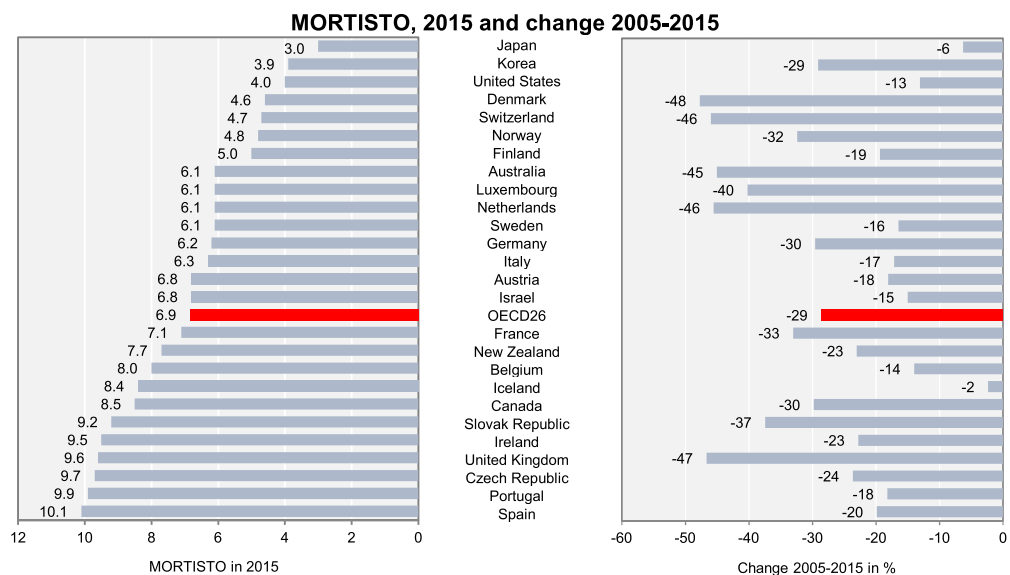


Fig. 4. Thirty-day mortality per 100 patients after admission to hospital for ischemic stroke based on unlinked data, 2015 and change 2005–2015.

Table 2. Results of panel cointegration test verify that there existed statistically significant cointegration relationships between NURES and HCQI in OECD countries during 2005–2015 period.

To have a more precise conclusion about cointegration relationship between our variables individually in each country, we estimate cointegration in pooled data using Johansen-Fisher test. The results of pooled cointegration test in cross units are presented in Table 3 and confirm that there existed a long-run relationship between NURSE and MORTAMIO in about 85% of OECD countries, included Australia, Austria, Canada, Denmark, Finland, France, Germany, Iceland, Israel, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Slovak Republic, Spain, Sweden, Switzerland, United Kingdom and United States, while there was no meaningful relationship in Belgium, Czech Republic, Ireland and

South Korea. Likewise, NURSE and MORTHSTO were cointegrated in Belgium, Czech Republic, Denmark, Finland, France, Iceland, Ireland, Israel, Italy, Japan, South Korea, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Slovak Republic, Spain, Sweden, Switzerland, United Kingdom and United States (85% of OECD countries). There was no cointegration relationship between NURSE and MORTHSTO in Australia, Austria, Canada and Germany.

Moreover, a cointegration relationship was found between NURSE and MORTISTO in the following countries (85% of total OECD countries); Australia, Canada, Czech Republic, Denmark, Finland, France, Iceland, Ireland, Israel, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Slovak Republic, Spain, Sweden, Switzerland, United Kingdom and United States, whereas there was no committed relationship in Austria, Belgium,

Table 1
Panel unit root test results (26 OECD countries, 2005–2015).

Null hypothesis: Unit root	Level			1st Difference
	Intercept	Intercept and trend	None	Intercept
NURSE				
Levin, Lin & Chu t-stat	−3.25**	−10.16**	4.02	−10.38**
Im, Pesaran and Shin W-stat	1.60	−1.34		−4.23**
ADF – Choi Z-stat	43.10	79.52**	14.04	109.71**
PP – Choi Z-stat	66.27	70.55*	27.49	138.79**
MORTAMIO				
Levin, Lin & Chu t-stat	−4.23**	−3.77**	−8.16**	−6.67**
Im, Pesaran and Shin W-stat	1.88	1.02		−3.09**
ADF – Choi Z-stat	37.45	37.64	157.04**	93.82**
PP – Choi Z-stat	75.60**	47.59	343.93**	160.80**
MORTHSTO				
Levin, Lin & Chu t-stat	−0.35	−2.49**	−7.40**	−6.73**
Im, Pesaran and Shin W-stat	2.80	0.74		−3.61**
ADF – Choi Z-stat	26.31	51.76	117.32**	109.62**
PP – Choi Z-stat	64.36	125.74**	212.85**	247.56**
MORTSITO				
Levin, Lin & Chu t-stat	−0.47**	−4.51**	−8.02**	−7.36**
Im, Pesaran and Shin W-stat	3.72	0.22		−3.64**
ADF – Choi Z-stat	24.24	56.15	132.48**	101.45**
PP – Choi Z-stat	60.75	90.51**	290.74**	207.29**

Notes: Null hypothesis: No integration. * $P < 0.05$ and ** $P < 0.01$. The optimum lag lengths were selected based on SIC from 0 to 3 to ensure that the residuals were white noise. Newey-West automatic criterion was selected for calculating bandwidth and Bartlett window was used for estimating kernel in the test value calculations. Probabilities for Fisher-PP tests were computed using an asymptotic Chi-square distribution and an asymptotic normal distribution was assumed for other tests. Levin, Lin and Chu test assumes common $AR(1)$ coefficient with trend and other tests allow for individual $AR(1)$ coefficients and trend presentations in the test models.

Table 2
Pedroni (Engle-Granger based) cointegration test (26 OECD countries, 2005–2015).

Cointegration test between	Pedroni's criteria	Unweighted		Weighted		Conclusion
		Statistic	Prob.	Statistic	Prob.	
NURSE & MORTAMIO	Panel v-Statistic	5.737725	0.0000	1.594936	0.0554	Cointegrated
	Panel rho-Statistic	2.913921	0.9982	2.507957	0.9939	
	Panel PP-Statistic	−0.56913	0.2846	−2.44938	0.0072	
	Panel ADF-Statistic	−3.80163	0.0001	−4.48683	0.0000	
	Group rho-Statistic	4.47596	1.0000			
	Group PP-Statistic	−1.79509	0.0363			
	Group ADF-Statistic	−4.85285	0.0000			
NURSE & MORTHSTO	Panel v-Statistic	9.18051	0.0000	3.355845	0.0004	Cointegrated
	Panel rho-Statistic	2.46894	0.9932	2.125003	0.9832	
	Panel PP-Statistic	−0.65727	0.2555	−2.39355	0.0083	
	Panel ADF-Statistic	−2.07773	0.0189	−2.88419	0.0020	
	Group rho-Statistic	4.080001	1.0000			
	Group PP-Statistic	−1.37009	0.0853			
	Group ADF-Statistic	−3.14436	0.0008			
NURSE & MORTSITO	Panel v-Statistic	3.075641	0.0011	0.286937	0.3871	Cointegrated
	Panel rho-Statistic	3.112457	0.9991	2.801282	0.9975	
	Panel PP-Statistic	−0.12294	0.4511	−1.93369	0.0266	
	Panel ADF-Statistic	−3.11164	0.0009	−3.96101	0.0000	
	Group rho-Statistic	4.011035	1.0000			
	Group PP-Statistic	−1.79761	0.0361			
	Group ADF-Statistic	−1.87986	0.0301			

Notes: Null hypothesis: No cointegration. Trend assumption: Deterministic intercept and trend group-statistics. Common AR coefficient calculated within-dimension, and individual AR coefficients estimated between-dimension. The optimum lag lengths were selected based on SIC from 0 to 9. Newey-West automatic criterion was selected for calculating bandwidth with Bartlett window.

Germany and South Korea.

3.3. Dynamic long-run analysis

Based on the results of Pedroni panel cointegration test in the

last step, there existed long-run relationships between nurse-staffing level and HCQI in OECD countries. In here, the magnitudes of effect of NURSE on MORTAMIO, MORTHSTO and MORTSITO are simulated using dynamic long-run analysis in panel and pooled models based on the assumption that both NURSE and HCQI

Table 3

Fisher (combined Johansen) panel cointegration test for individual countries (26 OECD countries, 2005–2015).

Countries	NURSE & MORTAMIO			NURSE & MORTHSTO			NURSE & MORTSITO		
	1# Prob.	2# Prob.	Conclusion	1# Prob.	2# Prob.	Conclusion	1# Prob.	2# Prob.	Conclusion
Australia	0.00***	0.01**	Cointegrated	0.15	0.18	No	0.00***	0.00***	Cointegrated
Austria	0.09*	0.17	Cointegrated	0.13	0.20	No	0.68	0.71	No
Belgium	0.16	0.27	No	0.05*	0.08*	Cointegrated	0.55	0.43	No
Canada	0.06*	0.12	Cointegrated	0.15	0.28	No	0.00***	0.00***	Cointegrated
Czech Republic	0.32	0.24	No	0.00***	0.00***	Cointegrated	0.10*	0.20	Cointegrated
Denmark	0.00***	0.00***	Cointegrated	0.00***	0.01**	Cointegrated	0.00***	0.00***	Cointegrated
Finland	0.00***	0.01**	Cointegrated	0.00***	0.01**	Cointegrated	0.08*	0.17	Cointegrated
France	0.00***	0.00***	Cointegrated	0.00***	0.00***	Cointegrated	0.00***	0.00***	Cointegrated
Germany	0.09*	0.13	Cointegrated	0.19	0.17	No	0.15	0.28	No
Iceland	0.10*	0.15	Cointegrated	0.01**	0.02**	Cointegrated	0.06*	0.10	Cointegrated
Ireland	0.42	0.60	No	0.08*	0.14	Cointegrated	0.06*	0.10	Cointegrated
Israel	0.01**	0.02**	Cointegrated	0.03**	0.03**	Cointegrated	0.02**	0.04**	Cointegrated
Italy	0.00***	0.00***	Cointegrated	0.03**	0.05**	Cointegrated	0.00***	0.00***	Cointegrated
Japan	0.00***	0.00***	Cointegrated	0.00***	0.00***	Cointegrated	0.00***	0.00***	Cointegrated
Korea	0.62	0.30	No	0.00***	0.00***	Cointegrated	0.29	0.39	No
Luxembourg	0.01**	0.02**	Cointegrated	0.00***	0.00***	Cointegrated	0.00***	0.00***	Cointegrated
Netherlands	0.00***	0.00***	Cointegrated	0.00***	0.00***	Cointegrated	0.05**	0.05*	Cointegrated
New Zealand	0.10	0.02**	Cointegrated	0.03**	0.03**	Cointegrated	0.20	0.07*	Cointegrated
Norway	0.01**	0.02**	Cointegrated	0.01**	0.04**	Cointegrated	0.03**	0.07*	Cointegrated
Portugal	0.00***	0.0***	Cointegrated	0.00***	0.00***	Cointegrated	0.00***	0.00***	Cointegrated
Slovak Republic	0.00***	0.00***	Cointegrated	0.00***	0.00***	Cointegrated	0.00***	0.00***	Cointegrated
Spain	0.01**	0.02**	Cointegrated	0.00***	0.00***	Cointegrated	0.04**	0.05**	Cointegrated
Sweden	0.04**	0.04**	Cointegrated	0.05*	0.05*	Cointegrated	0.02***	0.05*	Cointegrated
Switzerland	0.16	0.02**	Cointegrated	0.01**	0.00***	Cointegrated	0.10*	0.14	Cointegrated
United Kingdom	0.02**	0.05*	Cointegrated	0.00***	0.00***	Cointegrated	0.00***	0.00***	Cointegrated
United States	0.00***	0.00***	Cointegrated	0.00***	0.00***	Cointegrated	0.03**	0.06*	Cointegrated

Notes: Null hypothesis: No co-integration. * $P < 0.10$, ** $P < 0.05$ and *** $P < 0.01$. 1# means the probability of hypothesis no cointegration test in panel with intercept and trend in CE, linear trend in VAR. 2# means the probability of hypothesis no cointegration test in panel with intercept and trend in CE, no trend in VAR. The lags interval in first differences were 2. Probabilities were calculated based on MacKinnon-Haug-Michelis [66] P -values.

were significantly cointegrated – see Table 2. Results of dynamic long-run panel model verify that the long-run elasticity of practicing nurses level on MORTAMIO, MORTHSTO and MORTISTO were -0.6466 , -0.6039 and -0.7993 in OECD countries, respectively. Thus, with 1% increase in the number of practicing nurses per 1000 inhabitant, the number of thirty-day mortality after hospitalization per 100 patients for AMI-based, hemorrhagic stroke-based and ischemic stroke-based would decrease by 0.65%, 0.60% and 0.80%, respectively. Results of dynamic long-run panel model are available in Table 4.

According to the results of Fisher (combined Johansen) panel cointegration test for individual cross sections, there existed long-run relationships between nurse-staffing level and quality of

acute care indexes in slightly more than 85% of individual OECD countries. Here, dynamic long-run model analysis based on pooled data framework is applied to find the magnitude of the effect of NURSE on MORTAMIO, MORTHSTO and MORTISTO in every individual country where there was a significant cointegration relationship between our variables resulting from Fisher panel cointegration test. Results of dynamic long-run model based on pooled EGLS with cross-sectional weights in 26 OECD countries over the period of 2005–2015 can be found in Table 5 and Fig. 5.

As can be seen, the highest magnitude of effect of nursing characteristics on relative AMI patient mortality reduction in the following 30 days after hospitalization (NURSE → MORTAMIO) was found in Austria with -4.27 – means that 1% increase in the

Table 4

Dynamic long-run model: panel EGLS with cross-sectional weights (26 OECD countries, 2005–2015).

	Coefficient	Std. Error	t-Statistic	Prob.	R-squared	Durbin-Watson
Dependent variable: MORTAMIO						
Constant	0.413242	0.098787	4.183156	0.0000	0.994203	2.133099
MORTAMIO(-1)	0.866942	0.020522	42.2444	0.0000		
NURSE	-0.08604	0.030582	-2.81344	0.0053		
Long run elasticity: $-0.08604/(1-0.866942) = -0.6466$						
Dependent variable: MORTHSTO						
Constant	1.294306	0.182512	7.091631	0.0000	0.991880	2.240896
MORTHSTO(-1)	0.705677	0.039890	17.69057	0.0000		
NURSE	-0.177765	0.033363	-5.32818	0.0000		
Long run elasticity: $-0.177765/(1-0.705677) = -0.6039$						
Dependent variable: MORTSITO						
Constant	0.275727	0.112296	2.455361	0.0148	0.993478	2.204367
MORTSITO(-1)	0.919805	0.023064	39.88053	0.0000		
NURSE	-0.064100	0.036102	-1.77551	0.0771		
Long run elasticity: $-0.064100/(1-0.919805) = -0.7993$						

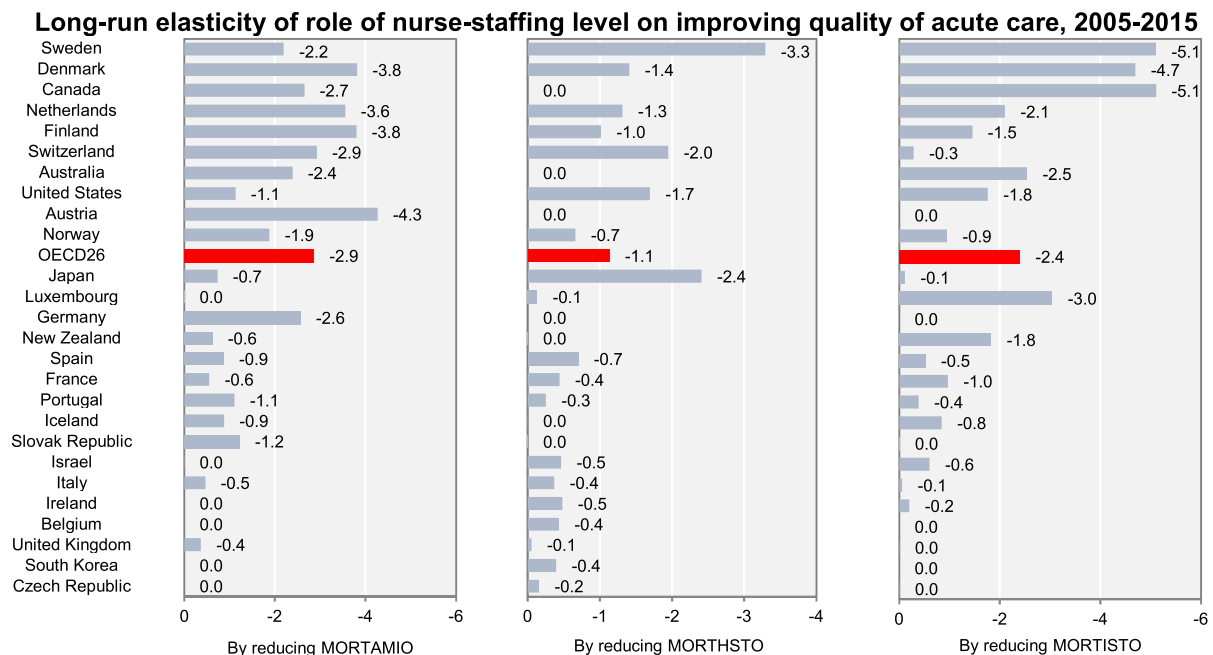
Notes: The optimum lag lengths were selected using SIC.

Table 5

Dynamic long-run model: pooled EGLS with cross-sectional weights (26 OECD countries, 2005–2015).

Magnitude of the effects of NURSE on:				
Countries	MORTAMIO	MORTHSTO	MORTSITO	Average
Australia	-2.394802	No	-2.540567	-1.645123
Austria	-4.270386	No	No	-1.423462
Belgium	No	-0.433687	No	-0.144562
Canada	-2.655155	No	-5.109757	-2.588304
Czech Republic	No	-0.159352	-0.001000	-0.053450
Denmark	-3.817515	-1.411338	-4.700353	-3.309735
Finland	-3.803239	-1.018222	-1.455975	-2.092479
France	-0.553727	-0.442155	-0.971785	-0.655889
Germany	-2.568517	No	No	-0.856172
Iceland	-0.880762	-0.001000	-0.845634	-0.575798
Ireland	No	-0.481107	-0.202999	-0.228035
Israel	-0.001000	-0.465849	-0.606930	-0.357926
Italy	-0.469460	-0.369834	-0.059015	-0.299436
Japan	-0.737505	-2.412907	-0.112725	-1.087712
South Korea	No	-0.397007	No	-0.132335
Luxembourg	-0.001000	-0.131635	-3.042050	-1.058228
Netherlands	-3.559183	-1.317256	-2.104474	-2.326971
New Zealand	-0.627484	-0.001000	-1.828409	-0.818964
Norway	-1.882276	-0.663075	-0.948334	-1.164561
Portugal	-1.112235	-0.255680	-0.385479	-0.584464
Slovak Republic	-1.222741	-0.001000	-0.001000	-0.408247
Spain	-0.874499	-0.703809	-0.523662	-0.700656
Sweden	-2.197104	-3.296191	-5.106942	-3.533412
Switzerland	-2.931531	-1.950279	-0.290726	-1.724178
United Kingdom	-0.368246	-0.055361	-0.001000	-0.141536
United States	-1.135291	-1.694031	-1.763588	-1.530970

Note: Dynamic long-run models for pooled variables were selected based on the long-run models used in Table 4 and SIC.

**Fig. 5.** The magnitudes of effect of 1% increase in practicing nurses per 1000 population on improving HCQI.

number of nurses per 1000 inhabitant would reduce AMI-based mortality about 4.27% per 100 patients –, followed by Denmark with -3.8, Finland with -3.80 and Netherlands with -3.56. At the other end of the range, by far the lowest ratios of practicing nurses to MORTAMIO reduction were found in Italy (-0.46), United Kingdom (-0.37), Israel and Luxembourg (both -0.00), as well as

Belgium, Czech Republic, Ireland and South Korea with non-significant cointegration relationship in long-run. For the rest of OECD countries, the range of NURSE → MORTAMIO coefficients was between -2.93 in Switzerland and -0.53 in France.

Among the OECD countries for which data are available, the highest magnitude of the role of practicing nurses on reducing the

average of hemorrhagic stroke-based mortality ratio per 100 patients (NURSE→MORTHSTO) was found in Sweden (−3.30), followed by Japan (−2.41), Switzerland (−1.95) and United States (−1.69), similarly means that 1% increase in the level of nurse-staffing drops the hemorrhagic stroke-based mortality about 3.30%, 2.41%, 2.41% and 1.95% in Sweden, Japan, Switzerland and United States, respectively. The amounts of these magnitudes for the rest of OECD countries were investigated between −1.41 in Denmark and −0.05 in United Kingdom, except in Australia, Austria, Iceland, Canada, Germany, New Zealand and Slovak Republic where there was no committed relationship from practicing nurses' ratio to MORTHSTO prevention.

Moving forward to ischemic stroke-based acute care context, Sweden, Canada, Denmark and Luxembourg had the highest magnitudes of nursing effect on the reduction of ischemic stroke-based mortality per 100 patients among the OECD countries. In another word, if nurse-staffing level rises in 1%, then MORTISTO ratio would decline about 8.68%, 5.11%, 4.70% and 3.40% in Sweden, Canada, Denmark and Luxembourg, respectively, in log-run. On the other hand, there was no evidence for considering the effect of increase in nurse staffing on reduction of MORTISTO in Austria, Belgium, Czech Republic, Germany, Slovak Republic, South Korea and United Kingdom. For the rest of OECD countries, the magnitudes of NURSE→MORTISTO had a range from −2.54 in Australia to −0.06 in Italy.

All in all, according to the results of dynamic long-run model based on pooled data analysis for each country, the role of nurse staffing in improvement of HCQI were simulated at the highest level in Sweden, Denmark, Canada, Netherlands, Finland, Switzerland, Australia and United States, compared to other OECD countries. As can be seen in Fig. 5, the effect of nurse staffing per 1000 inhabitants varied in different health care systems of OECD countries and followed by this country group which took the best records, Austria, Norway, Japan, Luxembourg, Germany, New Zealand, Spain, France, Portugal and Iceland were at the middle level of improvement in acute care services associated with nursing characteristics in OECD countries. By contrast, Slovak Republic, Israel, Italy, Ireland, Belgium, United Kingdom, South Korea and Czech Republic generally had the lowest level of enhancement in HCQI by practicing nurses.

4. Conclusion

There has been much interest in perceiving the magnitude of effect of nurse-staffing level on the quality of acute hospital care services, as the major accomplishments of health care systems, to surpass the level of care delivery and to reduce unnecessary health care expenditures. To our knowledge, most of studies aimed to analyze this relationship used stochastic methods and their results are mixed. This article undertook a new attempt to simulate the role of nurse-staffing level in quality of acute care service using the widest possible range of available data as a part of ongoing project by OECD.org.

The number of practicing professional nurses' density per 1000 population as the proxy of nurse-staffing level together with 30-day in-hospital and out-of-hospital mortality per 100 patients based on AMI together with hemorrhagic and ischemic strokes as the indicators of quality of acute care were used in panels of 26 OECD countries over the period of 2005–2015. To present empirical evidence on the relationship between these variables with considering the plausible effects of time variation, statistical technique of panel data analysis was applied to inspect the existence of

relationships between nurse-staffing level and HCQI along with estimating the magnitudes of these relationships in long-run.

Results of panel data analysis supported that there were committed relationships from the level of practicing nurses to the enhancement of HCQI in long-run. Moreover, results of dynamic long-run panel models verified that 1% increase in the number of practicing nurses per 1000 inhabitant reduced the number of thirty-day mortality after hospitalization per 100 patients for AMI-based, hemorrhagic stroke-based and ischemic stroke-based by 0.65%, 0.60% and 0.80%, respectively. In individual OECD countries, result of Johansen-Fisher pooled cointegration test confirmed the existence of cointegration for the majority of OECD countries and the highest magnitudes of the effect of nurse staffing on reduction of: MORTAMIO were found in Austria (−4.27), Denmark (−3.8), Finland (−3.80) and Netherlands (−3.56), MORTHSTO were perceived in Sweden (−3.30), Japan (−2.41), Switzerland (−1.95) and United States (−1.69), MORTISTO were estimated in Sweden (−8.68), Canada (−5.11), Denmark (−4.70) and Luxembourg (−3.40). Overall, according to the results of dynamic long-run pooled models, the role of nurse staffing in improvement of total HCQI were simulated at the highest level in Sweden, Denmark, Canada, Netherlands, Finland, Switzerland, Australia and United States.

In conclusion, the findings of this study clarify the relationship between higher proportions of practicing nurses and higher quality of acute and life-threatening care services in OECD countries. Hence, this result alerts health policy makers about considering the deleterious effects of nursing shortage on increasing the risk of patient mortality and adverse clinical outcomes in OECD countries. Furthermore, as the role of nursing characteristics in improvement of patient outcomes in acute care services were estimated at the highest level in Sweden, Denmark, Canada, Netherlands, Finland, Switzerland, Australia and United States, the recommendations for the rest of countries are to pattern the nursing characteristics of this group of developed countries to maximize the efficiency of nursing care associated with improving patient outcomes as well as reducing the risk of complication, mortality and adverse clinical outcomes. Further researches are needed to investigate the plausible magnitude of effect of nurse-staffing level on other quality of health care indicators such as primary care, patient safety, mental health care, cancer care, etc. in cross-national level.

Conflicts of interest

The authors have declared that no conflicts of interest exist.

Authors' contributions

Both authors contributed to the study design and drafting of the paper. Amiri has done data analysis and both authors approved the final version of article.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ijnss.2018.11.010>.

Appendix. Summary of previous studies confirmed the significant effect of nursing-staff level on quality of acute care

Literature	Quality of care indicator	Observations and method	Summary of results
Flood et al. [3]	surgical and medical patients treated	500,000 patients with similar conditions over 1200 nonfederal US hospitals, hypothesis testing	Nurse → better patient outcomes.
Hartz et al. [4]	patient mortality ratio	3100 hospitals in US (1986), Health Care Financing Administration (HCFA) model	Nurse → mortality reduction between 113 and 119 per 1000 patient.
Krakauer et al. [5]	mortality rates in participated patients in the Medicare program	42,773 patients admitted to 84 hospitals in US (1987–1990), HCFA model	Nurse → lower risk-adjusted mortality rates.
Manheim et al. [6]	severity-adjusted Medicare hospital mortality rates	9 US census regions, cross-sectional analysis and case-control study	Nurse → lower hospital mortality rates.
Iezzoni et al. [7]	rates of complications	6 adults medical-surgical patient populations in California (1988) discharge data, case-control study	Nurse → better clinical outcomes.
Silber et al. [8]	complications rate, mortality rate and failure rate	2 groups of predictors patients, logit regression model and generalized linear model	Nurse → lower hospital mortality rates.
Fridkin et al. [9]	risk factors for central venous catheter-associated bloodstream infections (CVC–BSI) during a protracted outbreak	all patients who developed a CVC–BSI during the outbreak period (1992–1993), case-control and cohort studies	Nurse → reduction of risk factors below the critical levels.
Archibald et al. [10]	patient census on ICU nosocomial infection rate (MR)	microbiology records (1994–1995), case-control study	Nurse → lower patient census.
Blegen et al. [11]	adverse outcomes: unit rates of medication errors, patient falls, skin breakdown, patient and family complaints, infections and deaths.	US hospital observation, multivariate correlation cross-sectional analysis	1% increases in registered nurses declined rates of adverse outcomes up to 87.5%.
Kovner and Gergen [12]	hospital-level adverse event indicators	for patients aged 18 in 20% of US community hospitals included 589 acute-care hospitals in 10 states in 1993, case-control study	Nurse → lower adverse event indicators.
Lichtig et al. [13]	outcomes in acute care hospitals	California and New York hospitals, case-control study	Nurse → shorter lengths of stay and lower adverse outcome rates.
Pronovost et al. [14]	in-hospital mortality and hospital and ICU length of stay	all Maryland hospitals performed abdominal aortic surgery (1994–1996), case-control study	Nurse (in ICU) → better clinical outcomes of abdominal aortic surgery.
Robert et al. [15]	the risk factors for acquisition of nosocomial primary bloodstream infections (BSIs)	a 20-bed surgical intensive care unit (SICU) in a 1000-bed inner-city public hospital, nested case-control study	Nurse staffing composition was related to lower primary BSIs.
Needleman et al. [16]	length of stay, urinary tract infections, pneumonia, cardiac arrest and failure-to-rescue (FTR)	799 hospitals in 11 states in US (1997), cross-sectional regression analyses	Nurse → better care for hospitalized patients.
Hurst [17]	dependency-acuity-quality (DAQ)	347 hospital wards in UK, case-control study	Nurse → higher DAQ for hospitalized patients.
Estabrooks et al. [18]	30-day mortality rate for diagnoses of acute myocardial infarction, congestive heart failure, chronic obstructive pulmonary disease, pneumonia and stroke	18,142 patients discharged from 49 acute care hospitals in Alberta, Canada, (1998–1999), cross-sectional analysis	Hospital nursing characteristics reduced the risk of 30-day mortality of patients.
Seago et al. [19]	FTR rates	3 adult medical-surgical nursing units for 4 years (16 fiscal quarters), cross-sectional data analysis	Nurse → lower FTR.
Tourangeau et al. [20]	risk-adjusted 30-day hospital mortality rates for acute medical patients	Ontario, Canada discharge abstract database (2002–2003), backward regression analysis	Nurse → lower 30-day mortality rates.
Rafferty et al. [21]	patient mortality, FTR	3984 nurses and 118752 vascular surgery patients in 30 hospitals in England, cross-sectional analysis	Nurse → lower patient mortality and FTR.
Unruh et al. [22]	restraint use, incident reports and mortality	monthly data in six inpatient units (2004), fixed effects regression method	The lack of needed Registered Nurse (RN) per patient → lower quality of care.
Kane et al. [23]	mortality and adverse patient events	28 study units, random effects models	Nurse → lower mortality in ICUs and surgical units.
Stratton [24]	rates of occurrence of central line and bloodstream infections	7 academic children's hospitals, retrospective, correlational, linear mixed model	Nurse → lower central line and bloodstream infections.
Schubert et al. [25]	patient satisfaction, nurse-reported medication errors, patient falls and nosocomial infections	118 medical, surgical and gynecological units in 8 acute care hospitals in Switzerland, multi-hospital cross-sectional method	Nurse → higher patient outcomes.
Friese et al. [26]	30-day mortality in hospitalized cancer patients undergoing surgery	Pennsylvania for (1998–1999), logistic regression models	Nurse-staffing and educational preparation of RN → higher patient outcomes.
Van den Heede et al. [27]	postoperative cardiac surgery patients in-hospital mortality	75 general nursing units and 9054 patients in Belgium (2003), multilevel logistic regression models	RN in postoperative general nursing units → lower mortality.
Frith et al. [28]	adverse events and lengths of stay	35,000 patients from 11 medical-surgical units in 4 hospitals, cross-sectional analysis	RN → lower adverse events and shorter lengths of stay.
Harless and Mark [29]	in-hospital mortality ratio and surgical FTR ratio	11,945,276 adult inpatients at 283 hospitals in California general acute care hospitals (1996–200), longitudinal regression analysis	1% increase in RN staffing → 0.043 decrease in the mortality ratio.
Lucero et al. [30]	receipt of the wrong medication or dose, nosocomial infections and patient falls with injury in hospitals	10,184 staff nurses and 168 acute care hospitals in US (1999), cross-sectional analysis	Significant 30% reductions in adverse effects by 1% increases in RN.
Mark and Harless [31]	Medicare case mix index to adjust for patient acuity	579 hospitals in 13 states (2000–2006), case-control study	RN → higher quality of care.
Needleman et al. [32]	inpatient hospital mortality	197,961 admissions and 176,696 nursing shifts of 8 h each in 43 hospital units in US, Cox proportional-hazards models	Increased exposure to RNs in units → higher patient mortality.
Twigg et al. [33]	central nervous system complications, wound infections, pulmonary failure, urinary tract infection, pressure ulcer, pneumonia, deep vein thrombosis, gastrointestinal bleed, sepsis,	236,454 patient records and 150,925 nurse staffing records (4-year period) in Australia, case-control study	Nurse → reduction in the rates of mortality, central nervous system complications, pressure ulcers, deep vein thrombosis, sepsis,

(continued)

Literature	Quality of care indicator	Observations and method	Summary of results
Schilling et al. [34]	derangement, cardiac arrest, mortality, FTR and length of stay in-hospital mortality among elderly patients with hip fractures	13,343 patients 65 years or older with a primary diagnosis of hip fracture admitted to 39 Michigan hospitals (2003–2006), logistic regression method	gastrointestinal bleed, cardiac arrest, pneumonia and length of stay. Higher RN levels → lower in-hospital mortality among patients with hip fractures.
Park et al. [35]	FTR	quarterly data 42 hospitals, representing 759 nursing units and about 1 million inpatients in US, case-control study	Higher RN staffing was associated with lower FTR.
Schubert et al. [36]	inpatient mortality	71 acute care hospitals in Switzerland, logistic regression models	Nurse → lower patient mortality.
Carthon et al. [37]	30-day mortality and FTR in postsurgical outcomes for older black adults	99 adult nonfederal acute care hospitals in California, Pennsylvania, New Jersey, and Florida, cross-sectional analysis	Nurse → lower 30-day mortality rate.
Liang et al. [38]	patient mortality	108 wards selected from 32 hospitals in Taiwan (7 months), mixed effect logit model	Direct-nursing-care-hour, and nurse manpower declined patient deaths.
McHugh and Chenjuan [39]	30-day readmissions among Medicare patients with heart failure, acute myocardial infarction, and pneumonia	39,954 patients in California, New Jersey, and Pennsylvania hospitals, robust logistic regression	Nurse → better health outcomes.
Hickey et al. [40]	in-hospital mortality for cardiac surgery patients	38 hospitals for years 2009 and 2010 in US, Risk Adjustment for Congenital Heart Surgery method	Increase in critical care nurses with 11 years' clinical experience → lower patient mortality.
Yakusheva et al. [41]	patient clinical condition in acute care	1203 staff nurses matched with 7318 medical –surgical patients (2011), longitudinal analysis using a covariate-adjustment	Nurse → higher in-patient clinical outcomes.
Han et al. [42]	death occurred within 30 days in stroke inpatients	99,464 patients at 120 hospitals in South Korea (2010–2013), case-control study	Nurse (for stroke patients) → better patient outcomes, particularly for patients with cerebral infarction.
Kang et al. [43]	nurse-perceived patient adverse events: nosocomial infections and pressure sores	1816 nurses working in general inpatient units of 23 tertiary general hospitals in South Korea, multilevel logistic regression analysis	The elevated level of nursing workload increases the possibility of patient adverse events.
Twigg et al. [44]	in-hospital 30-day mortality, FTR, urinary tract infection, pressure injury, pneumonia, sepsis and falls with injury	11 acute care metropolitan hospitals in Western Australia 2009–2010, logistic regression modelling	Nurse → lower adverse outcomes.
Aiken et al. [45]	mortality rates, hospital ratings from patient and reports of inferior quality services	13,077 nurses in 243 hospitals, and 18,828 patients in 182 of the same hospitals in the 6 countries, generalized estimating equations (GEE) and logistic regression models	Professional nurses rate → better outcomes for patients.
Cho et al. [46]	length of stay of surgical patients in acute care hospitals	58 hospitals with 100 or more beds in South Korea (2008–2009), multilevel cross-sectional analysis	Nurse staffing and nurses' education levels → lower length of stay for surgical patients.
Kim and Bae [47]	nursing-sensitive outcomes (NSOs): urinary tract infection, upper gastrointestinal tract bleeding, deep vein thrombosis, hospital-acquired pneumonia, pressure ulcer, sepsis, cardiac arrest, CNS complication, in-hospital death, wound infection, derangement and pulmonary failure	46 tertiary hospitals in South Korea (2013–2014), multiple logistic regression	Nurse → higher patient outcomes.

Notes: “nurse →” means that there was a meaningful relationship from nurse-staffing proxies to. The systematic reviews studies were excluded from the consideration.

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