Available online at www.sciencedirect.com

Resuscitation

journal homepage: www.elsevier.com/locate/resuscitation

Clinical paper

# Association between county-level cardiopulmonary resuscitation training and changes in Survival Outcomes after out-of-hospital cardiac arrest over 5 years: A multilevel analysis

*Young Sun Ro*[a], *Kyoung Jun Song*[a,b,*], *Sang Do Shin*[a,c], *Ki Jeong Hong*[a,c], *Jeong Ho Park*[a,c,d], *So Yeon Kong*[a], *Sung-Il Cho*[e]

[a] *Laboratory of Emergency Medical Services, Seoul National University Hospital Biomedical Research Institute, Seoul, Republic of Korea*
[b] *Department of Emergency Medicine, Seoul National University Boramae Medical Center, Seoul, Republic of Korea*
[c] *Department of Emergency Medicine, Seoul National University College of Medicine, Seoul, Republic of Korea*
[d] *National Fire Agency, Sejong, Republic of Korea*
[e] *Department of Epidemiology, Graduate School of Public Health, Seoul National University, Seoul, Republic of Korea*

## Abstract

**Introduction:** Associations between neighbourhood environments and survival outcomes after out-of-hospital cardiac arrests (OHCAs) have been proposed. The purpose of this study was to examine the association between county-level cardiopulmonary resuscitation (CPR) training rates and improvements in survival outcomes after OHCA over 5 years.

**Methods:** Emergency medical service (EMS)-treated OHCAs with cardiac etiology between 2012 and 2016 were analyzed, excluding cases witnessed by EMS providers. The main exposure of interest was county-level CPR training rate defined as the proportions of residents having received CPR training, which was measured in 2016. The endpoint was survival with good neurological recovery. We compared the differences between outcomes from 2012 and 2016 according to quartile groups of counties by the CPR training rates using a difference-in-differences design.

**Results:** A total of 81,250 OHCAs in 254 counties were analyzed. The risk-adjusted good neurological recovery rates increased from 5.4% in 2012 to 7.1% in 2016 (adjusted rates difference: 1.6% (1.2–2.1)). The OHCAs that occurred in counties with the highest county-level CPR training rates were more likely to survive with good neurological recovery (adjusted rates: 5.2% in 2012 and 7.4% in 2016, difference: 2.2% (1.5–2.9)) than were those occurring in the lowest county-level CPR training counties (adjusted rates: 5.9% in 2012 and 6.0% in 2016, difference: 0.1% (−1.1 to 1.2)). The difference-in-differences was 2.1% (0.8–3.5).

**Conclusions:** There were moderate associations between county-level CPR training and improvements in good neurological recovery rates over 5 years in the counties.

**Keywords:** Out-of-hospital cardiac arrest, Bystander cardiopulmonary resuscitation, Survival

* Corresponding author at: Department of Emergency Medicine, Seoul National University Boramae Medical Center, 20 Boramae-Ro 5 gil, Dongjak-Gu, Seoul, 07061, Republic of Korea.

E-mail addresses: Ro.youngsun@gmail.com (Y.S. Ro), skciva@gmail.com (K.J. Song), sdshin@snu.ac.kr (S.D. Shin), emkjhong@gmail.com (K.J. Hong), timthe@gmail.com (J.H. Park), soyeon.kong@gmail.com (S.Y. Kong), scho@snu.ac.kr (S.-I. Cho).

https://doi.org/10.1016/j.resuscitation.2019.01.012
Received 20 July 2018; Received in revised form 1 December 2018; Accepted 9 January 2019
0300-9572/© 2019 Elsevier B.V. All rights reserved.

## Introduction

Bystander-initiated early cardiopulmonary resuscitation (CPR) is a crucial neighbourhood factor associated with significantly higher survival outcomes after out-of-hospital cardiac arrest (OHCA).[1–3] Despite various global and local efforts in compliance with recommendations for international committees, the provision of bystander CPR varies between communities, countries and continents.[2–5]

Neighbourhood and bystander factors are associated with the provision of bystander CPR and survival outcomes after OHCA.[6–11] OHCA patients who collapsed in a neighbourhood with higher CPR capacity were more likely to receive bystander CPR and achieve better survival outcomes than were those in a neighbourhood with lower CPR capacity.[7] Public health interventions including public CPR training programmes that are aimed at increasing neighbourhood CPR capacity not only produce better clinical outcomes for individual OHCA patients but also improve of neurological and survival outcomes after OHCA in the community. Although several studies have examined the effects of neighbourhood characteristics on bystander CPR and survival outcomes for OHCA victims,[3,6,7] there has been little evidence of the neighborhood CPR capacity and longitudinal trends of bystander CPR rates and survival outcomes after OHCA in the communities.

We hypothesized that neighbourhood CPR training rates at county level would be strongly associated with higher likelihoods of bystander CPR and better survival outcomes after OHCA as well as continued improvements in survival outcomes over a certain time period in the counties. The aims of this study were to assess how the proportions of residents with CPR training at county level affected bystander CPR and survival outcomes for OHCA victims and to evaluate the association between CPR training rates and changes in survival rates over 5 years in counties using a difference-in-differences design, independent of individual characteristics and neighbourhood socioeconomic status.

## Methods

### Study design, setting, and data collection

This was a cross-sectional study using the Korean Community Health Survey (CHS) and a nationwide OHCA registry in Korea (254 counties in 16 provinces with a total population of approximately 50 million people).

In Korea, the emergency medical services (EMS) system is exclusively operated by the National Fire Agency. EMS providers are not allowed to stop administering CPR at the scene and must transport all EMS-assessed OHCA patients to the nearest emergency department (ED). The nationwide OHCA registry, which captures all EMS-assessed OHCA patients, was constructed in 2006 using an EMS run sheet, an EMS cardiac arrest registry for Utstein factors, a dispatcher CPR registry, and the medical record review for hospital care and outcomes.

The Korean CHS is a nationwide, county-based, cross-sectional household-level survey from the Korea Centers for Disease Control and Prevention (CDC) that has been annually conducted since 2008. It is conducted by 254 county health authorities to gather health-related information, including health care utilization, health behavior, and health-related knowledge such as CPR awareness and experiences of CPR training. A total of 228,452 participants responded to the survey of 247 items between September and November 2016 (0.6% of approximately 42 million populations of aged ≥19), who were members of representatively selected households sampled using probability proportional to size and systematic sampling method. An average of 920 adults in each county participated in the survey. All surveys were administered by trained interviewers using structured survey forms in a face-to-face interview according to a strong quality management programme and survey protocol.[7,11]

The EMS division of the Ministry of Health and Welfare financially supports the 16 provincial governments for public CPR campaigns and training for laypersons and the first responders to increase bystander CPR. CPR training programmes are provided by hospitals, fire departments, academic and scientific societies, non-governmental organizations, and branches of the Red Cross.[7] The total number of layperson CPR trainees was 299,138 in 2013, 419,804 in 2014, 601,066 in 2015 and 606,284 in 2016. Enforcement of the EMS Act requires mandatory training of first responders, including firefighters, police officers, sports facility managers, safety guards, lifeguards, school health teachers, workplace safety employees, managers of nursing homes and public transportation vehicle drivers.[12] A total of 157,853 first responders participated in the CPR and AED training course from 2013 to 2016. The National Fire Agency implemented a nationwide dispatcher-assisted bystander CPR programme in 2012.

### Study population

All EMS-treated OHCA patients with presumed cardiac etiology between 2012 and 2016 were included. Cases that were witnessed by EMS personnel and cases with unknown information regarding neurological outcomes were excluded.

### Main outcomes

The primary and secondary outcomes were good neurological recovery and survival at discharge from the hospital, as identified by a medical record review. The tertiary outcome was provision of bystander CPR, which was defined as a layperson or a first responder performed CPR regardless of dispatcher-provided CPR instructions. An EMS provider identified bystander CPR provision at the scene, confirmed with the EMS cardiac arrest registry.

### Variables and measurements

The main exposure of interest was the neighbourhood CPR training rate for each county, calculated as the proportions of residents having received on-site group CPR training for 40 minutes or longer in the county using a question from the 2016 Korean CHS.[7] To compare the patient- and county-level characteristics across the counties with various county-level CPR training rates, the main exposure was classified by quartiles based on the number of counties: the highest (Q1), higher (Q2), lower (Q3), and lowest (Q4) counties.

We collected demographic factors and EMS factors, including date of arrest, address of arrest incident, age, gender, past medical history (diabetes mellitus, hypertension, heart disease, and stroke), witnessed status, location of arrest (public vs. private), primary electrocardiogram at the scene, prehospital defibrillation, and EMS response time (interval from call to EMS arrival at the scene); and we

collected county-level factors, including urbanization level of the county (metropolitan city, urban, and rural area), the proportion of highly educated residents in the county (quartile), and the Carstairs deprivation index of arrest incident county. The quartile-grouped county-level CPR training rates were merged with individual patient information using the addresses of the arrest incident location.

### *Statistical analysis*

To test the associations of individual factors (level 1) and county-level factors (level 2) with the study outcomes, generalized linear mixed models for multilevel logistic regression analysis were used after controlling for potential confounders including both individual-level factors (age, gender, past medical history (diabetes mellitus, hypertension, heart disease, and stroke), bystander witnessed, and location of arrest) and county-level factors (urbanization, the proportion of highly educated residents, and the Carstairs deprivation index of the arrest incident county).

The adjusted odds ratios (AORs) and 95% confidence intervals (95% CIs) of the exposure variables on study outcomes were calculated in the study population among whom the cardiac arrest occurred in 2016. The county-level CPR training rate for each county was analyzed as categorical variable based on quartiles, as well as continuous variable. For quartiles, AORs on study outcomes were calculated with the lowest (Q4) county-level CPR training rate group as reference. Alternatively, for continuous variable, AORs on study outcomes per 10% increment in county-level CPR training rate were also calculated to assess intuitively how much the bystander CPR rate and survival outcomes can be improved by increasing the CPR training rate in a county.

We calculated the risk-adjusted rates and 95% CIs of study outcomes by year in each quartile group of counties, after adjustment for abovementioned potential confounders of individual and county levels, to compare the study outcomes between years and the county groups with various CPR training rates. And then, we calculated the differences in risk-adjusted rates and 95% CIs between 2012 and 2016 (over a 5-year period) in each quartile group of counties, to measure the trends of survival outcomes after OHCA and bystander CPR provision over 5 years in each county group with various county-level CPR training rates. We also calculated difference-in-differences of risk-adjusted rates between exposure groups using multilevel linear regression analyses with the interaction term (county-level CPR training × year) to evaluate if the increase of survival outcomes and bystander CPR rates over the 5-year period varied between the county-level CPR training rate in a county.

For sensitivity analysis, the final multivariable logistic regression interaction analyses were conducted for OHCA events occurring between 2013 and 2016 (a 4-year period), between 2014 and 2016 (a 3-year period), and between 2015 and 2016 (a 2-year period).

All variables included in the final model were assessed for multicollinearity; however, no significant collinearity was detected. All statistical analyses were conducted using SAS software, version 9.4 (SAS Institute Inc., Cary, NC, USA).

### *Ethics statements*

The study was approved by the Institutional Review Boards of the Seoul National University Hospital (IRB No. 1103-153-357) and the Korea Centers for Disease Control and Prevention (IRB No. 2012-07CON-01-2C).

## Results

### *Demographic findings*

Among 135,518 EMS-assessed OHCA patients during the study period, 81,250 were analyzed, excluding those with non-cardiac aetiology (n = 36,938), patients who did not receive any resuscitative efforts (n = 10,245), and patients whose events were witnessed by EMS providers (n = 7085) (Fig. 1).

The individual characteristics of the study population according to the quartiles of county-level CPR training rates in counties are shown in Table 1. Number of counties for each quartile group were 63 and 64 counties. Of 81,250 OHCA patients with presumed cardiac origin, 2935 (3.6%) survived with good neurological recovery, 4972 (6.1%) survived to hospital discharge, and 40,944 (50.4%) received bystander CPR. OHCA events occurring in Q1 (the highest) county-level CPR training group counties were more likely to receive bystander CPR, survive to discharge, and have good neurological outcome than were those occurring in Q4 (the lowest) group counties.

### *Multivariable multilevel logistic regression analysis*

Among patients with arrests in 2016, AORs (95% CIs) for good neurological outcome were 1.99 (1.10–3.62) for the Q1 (the highest)

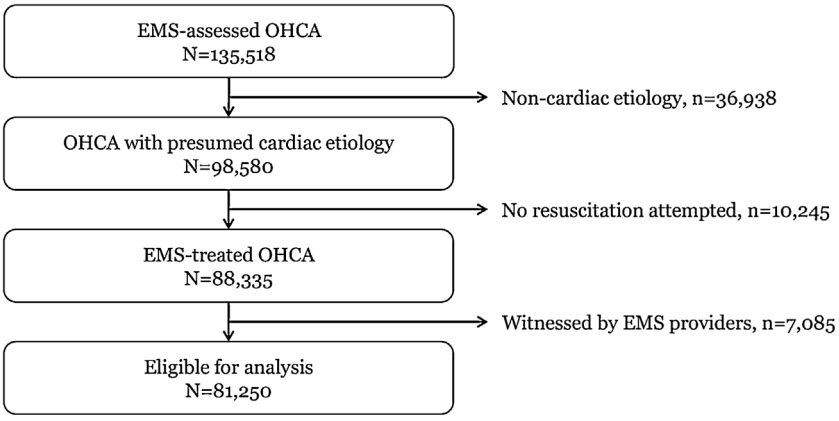


**Fig. 1 – Patient flow.**
**EMS: emergency medical service; OHCA, out-of-hospital cardiac arrest; CPR: cardiopulmonary resuscitation.**

**Table 1 – Demographics of all eligible out-of-hospital cardiac arrests by county-level CPR training rate.**

| | Total | County-level neighbourhood CPR training rate | | | |
|---|---|---|---|---|---|
| | N (%) | Q1 (49.–61.9%) n* = 63 N (%) | Q2 (45.7–49.5%) n* = 64 N (%) | Q3 (39.2–45.6%) n* = 64 N (%) | Q4 (19.1–39.1%) n* = 63 N (%) |
| Total | 81,250 | 25,079 | 26,971 | 19,129 | 10,071 |
| Age, year, median (IQR) | 72 (58–80) | 71 (56–80) | 71 (57–80) | 73 (59–81) | 74 (62–82) |
| Age, elderly | 29,881 (36.8) | 10,108 (40.3) | 10,179 (37.7) | 6,627 (34.6) | 2,967 (29.5) |
| Gender, female | 29,772 (36.6) | 9,154 (36.5) | 9,951 (36.9) | 6,952 (36.3) | 3,715 (36.9) |
| Past medical history | | | | | |
| Diabetes mellitus | 16,716 (20.6) | 5,391 (21.5) | 5,847 (21.7) | 3,853 (20.1) | 1,625 (16.1) |
| Hypertension | 25,554 (31.5) | 8,162 (32.5) | 8,920 (33.1) | 5,916 (30.9) | 2,556 (25.4) |
| Heart disease | 11,590 (14.3) | 3,623 (14.4) | 3,990 (14.8) | 2,709 (14.2) | 1,268 (12.6) |
| Stroke | 7,013 (8.6) | 2,234 (8.9) | 2,293 (8.5) | 1,725 (9.0) | 761 (7.6) |
| Urbanization level | | | | | |
| Metropolitan city | 45,948 (56.6) | 18,565 (74.0) | 16,800 (62.3) | 9,034 (47.2) | 1,549 (15.4) |
| Urban area | 24,414 (30.0) | 5,804 (23.1) | 9,130 (33.9) | 6,708 (35.1) | 2,772 (27.5) |
| Rural area | 10,888 (13.4) | 710 (2.8) | 1,041 (3.9) | 3,387 (17.7) | 5,750 (57.1) |
| Public place | 14,184 (17.5) | 4,572 (18.2) | 4,698 (17.4) | 3,321 (17.4) | 1,593 (15.8) |
| Witnessed | 35,446 (43.6) | 11,258 (44.9) | 11,739 (43.5) | 8,216 (43.0) | 4,233 (42.0) |
| Bystander CPR | 40,944 (50.4) | 13,222 (52.7) | 13,626 (50.5) | 9,444 (49.4) | 4,652 (46.2) |
| With CPR instruction | 31,059 (38.2) | 9,918 (39.5) | 10,441 (38.7) | 7,328 (38.3) | 3,372 (33.5) |
| Without CPR instruction | 9,885 (12.2) | 3,304 (13.2) | 3,185 (11.8) | 2,116 (11.1) | 1,280 (12.7) |
| Primary shockable rhythm at the scene | 12,454 (15.3) | 4,180 (16.7) | 4,252 (15.8) | 2,811 (14.7) | 1,211 (12.0) |
| Bystander defibrillation | 596 (0.7) | 186 (0.7) | 179 (0.7) | 153 (0.8) | 78 (0.8) |
| EMS defibrillation | 18,149 (22.3) | 5,828 (23.2) | 6,003 (22.3) | 4,247 (22.2) | 2,071 (20.6) |
| EMS response time interval, min, median (IQR) | 7 (5–10) | 7 (5–9) | 6 (5–9) | 7 (5–10) | 9 (6–13) |
| Survival outcomes by year | | | | | |
| Survival to discharge | 4,972 (6.1) | 1,856 (7.4) | 1,863 (6.9) | 1,015 (5.3) | 238 (2.4) |
| Good neurological recovery | 2,935 (3.6) | 1,096 (4.4) | 1,124 (4.2) | 573 (3.0) | 142 (1.4) |

Q: quartile; IQR: interquartile range; CPR: cardiopulmonary resuscitation; EMS: emergency medical services.
n* refers number of communities.

group, 2.49 (1.39–4.44) for the Q2 (higher) group, and 1.12 (1.07–3.47) for the Q3 (lower) group, compared with the Q4 (the lowest) group. OHCA patients whose arrest occurred in counties with higher county-level CPR training rate were more likely to survive with good neurological outcomes, survive to discharge, and receive bystander CPR than were those in counties with the lowest county-level CPR training rate (Table 2).

The rates of good neurological recovery and survival to discharge in 2016 were higher than those in 2012 (risk-adjusted rate difference (95% CI): 1.6% (1.2–2.1) for good neurological recovery and 1.0% (0.5–1.6) for survival to discharge). The risk-adjusted rate difference (95% CI) for bystander CPR was 29.7% (28.6–30.9). Considering the differences in the risk-adjusted rates between 2016 and 2012 in each group, the Q1 (the highest) and Q2 (higher) groups demonstrated higher increases in rates of good neurological recovery and survival to discharge over 5 years than did those in the Q4 (the lowest) group (difference-in-differences for good neurological recovery: 2.1% (0.8–3.5)) for Q1 and 2.8% (1.5–4.2) for the Q2 group; for survival to discharge: 1.7% (0.0–3.5)) for Q1 and 3.2% (1.5–5.0) for the Q2 group). However, there were no significant differences in the increase of bystander CPR rates over 5 years by groups for county-level CPR training rate (Table 3).

### *Sensitivity analysis*

Among OHCA patients whose events occurred between 2013 and 2016 (over 4-year period), the increase of risk-adjusted rates were 1.5% (1.0–1.9) for good neurological recovery, 1.1% (0.6–1.6) for survival to discharge, and 18.1% (16.9–19.2) for bystander CPR provision. The increase in risk-adjusted rates over 4 years in each community group compared to those in the Q4 (the lowest) group (difference-in-differences), Q1 (the highest) and Q2 (higher) groups demonstrated the higher increases for rates of good neurological recovery (difference-in-differences for good neurological recovery: 1.6% (0.2–2.9)) for Q1 and 2.2 (0.5–3.9) for the Q2 group). These trends were maintained; however, magnitudes were lower when the interval of time was reduced to a 3-year interval and a 2-year interval (Table 4).

## Discussion

This large study of over 80,000 OHCA shows that the county-level CPR training improved neurological outcomes after OHCA, independent of individual characteristics and neighbourhood socioeconomic status. The major strength of this study was that we measured the proportion of residents having received CPR training in a county through face-to-face interviews (a total of 228,452 participants in 254 counties), compared with similar studies which used the total number of trainees as proxy measure of neighbourhood CPR training rate. As far as we know the present study is one of the largest studies of its kind and the first evidence of the association between the county-level CPR training and longitudinal trends of neurological outcomes after OHCA. In counties with higher proportions of residents having

**Table 2 – Multivariable multilevel logistic regression analysis of outcomes among patients with arrests in 2016.**

| | Outcomes n/N (%) | Crude OR (95% CI) | Adjusted OR[a] (95% CI) |
|---|---|---|---|
| Good neurological recovery | | | |
| Total | 786/17,506 (4.5) | | |
| County-level CPR training rate | | | |
| Q1 (49.6–61.9%) | 288/5,412 (5.3) | 4.86 (2.68–8.83) | 1.99 (1.10–3.62) |
| Q2 (45.7–49.5%) | 327/5,955 (5.5) | 4.90 (2.71–8.88) | 2.49 (1.39–4.44) |
| Q3 (39.2–45.6%) | 145/4,022 (3.6) | 3.00 (1.61–5.57) | 1.93 (1.07–3.47) |
| Q4 (19.1–39.1%) | 26/2,117 (1.2) | 1.00 | 1.00 |
| 10% increment in the rate | | 1.97 (1.61–2.41) | 1.18 (0.99–1.40) |
| Survival to discharge | | | |
| Total | 1,211/17,506 (6.9) | | |
| County-level CPR training rate | | | |
| Q1 (49.6 to 61.9%) | 442/5,412 (8.2) | 4.19 (2.66–6.60) | 1.77 (1.20–2.62) |
| Q2 (45.7–49.5%) | 491/5,955 (8.2) | 4.24 (2.71–6.64) | 2.11 (1.45–3.08) |
| Q3 (39.2–45.6%) | 232/4,022 (5.8) | 2.63 (1.63–4.22) | 1.69 (1.14–2.51) |
| Q4 (19.1–39.1%) | 46/2,117 (2.2) | 1.00 | 1.00 |
| 10% increment in the rate | | 1.94 (1.63–2.31) | 1.19 (1.03–1.38) |
| Bystander CPR | | | |
| Total | 10,761/17,506 (61.5) | | |
| County-level CPR training rate | | | |
| Q1 (49.6–61.9%) | 3,453/5,412 (63.8) | 1.16 (1.04–1.29) | 1.29 (1.13–1.48) |
| Q2 (45.7–49.5%) | 3,633/5,955 (61.0) | 1.05 (0.93–1.18) | 1.14 (1.01–1.30) |
| Q3 (39.2–45.6%) | 2,403/4,022 (59.7) | 0.99 (0.86–1.12) | 1.05 (0.92–1.20) |
| Q4 (19.1–39.1%) | 1,272/2,117 (60.1) | 1.00 | 1.00 |
| 10% increment in the rate | | 1.07 (1.01–1.14) | 1.12 (1.04–1.21) |

OR: odds ratio; 95% CI: 95% confidence interval; CPR: cardiopulmonary resuscitation.

[a] Adjusted for age, gender, past medical history (diabetes mellitus, hypertension, heart disease and stroke), witnessed, location of arrest, community urbanization level, the proportion of highly educated residents and the Carstairs deprivation index of the arrest incident community.

**Table 3 – Risk-adjusted rates of study outcomes by county-level CPR training rate and year.**

| | Year | | Difference (2016 vs. 2012) | Difference-in-differences |
|---|---|---|---|---|
| | 2012 Adjusted rate (95% CI) | 2016 Adjusted rate (95% CI) | Adjusted rate (95% CI) | Adjusted rate (95% CI) |
| Good neurological recovery | | | | |
| Total | 5.4 (4.9 to 6.0) | 7.1 (6.5 to 7.6) | 1.6 (1.2 to 2.1) | |
| County-level CPR training rate | | | | |
| Q1 (49.6 to 61.9%) | 5.2 (4.4 to 5.9) | 7.4 (6.6 to 8.1) | 2.2 (1.5 to 2.9) | 2.1 (0.8 to 3.5) |
| Q2 (45.7 to 49.5%) | 5.1 (4.4 to 5.9) | 8.0 (7.3 to 8.7) | 2.9 (2.2 to 3.6) | 2.8 (1.5 to 4.2) |
| Q3 (39.2 to 45.6%) | 5.5 (4.8 to 6.3) | 6.9 (6.2 to 7.7) | 1.4 (0.6 to 2.2) | 1.3 (−0.1 to 2.8) |
| Q4 (19.1 to 39.1%) | 5.9 (4.9 to 6.9) | 6.0 (5.0 to 7.0) | 0.1 (−1.1 to 1.2) | Reference |
| Survival to discharge | | | | |
| Total | 10.0 (9.3 to 10.8) | 11.1 (10.4 to 11.8) | 1.0 (0.5 to 1.6) | |
| County-level CPR training rate | | | | |
| Q1 (49.6 to 61.9%) | 10.1 (9.0 to 11.1) | 11.3 (10.3 to 12.3) | 1.2 (0.3 to 2.1) | 1.7 (0.0 to 3.5) |
| Q2 (45.7 to 49.5%) | 9.4 (8.4 to 10.4) | 12.1 (11.2 to 13.1) | 2.7 (1.8 to 3.6) | 3.2 (1.5 to 5.0) |
| Q3 (39.2 to 45.6%) | 10.2 (9.2 to 11.3) | 11.0 (10.0 to 12.0) | 0.8 (−0.3 to 1.8) | 1.3 (−0.5 to 3.1) |
| Q4 (19.1 to 39.1%) | 10.5 (9.1 to 11.8) | 10.0 (8.7 to 11.2) | −0.5 (−2.0 to 0.9) | Reference |
| Bystander CPR | | | | |
| Total | 35.3 (33.7 to 36.8) | 65.0 (63.5 to 66.5) | 29.7 (28.6 to 30.9) | |
| County-level CPR training rate | | | | |
| Q1 (49.6 to 61.9%) | 36.8 (34.6 to 39.1) | 66.9 (64.8 to 69.0) | 30.1 (28.2 to 32.0) | −4.3 (−7.8 to −0.8) |
| Q2 (45.7 to 49.5%) | 38.7 (36.6 to 40.9) | 64.8 (62.8 to 66.9) | 26.1 (24.3 to 27.9) | −8.3 (−11.7 to −4.8) |
| Q3 (39.2 to 45.6%) | 35.6 (33.3 to 37.8) | 64.0 (61.9 to 66.1) | 28.4 (26.3 to 30.6) | −5.9 (−9.6 to −2.2) |
| Q4 (19.1 to 39.1%) | 30.0 (27.1 to 32.9) | 64.4 (61.6 to 67.1) | 34.3 (31.4 to 37.3) | Reference |

CI: 95% confidence interval; Q: quartile; CPR: cardiopulmonary resuscitation.

Adjusted for age, gender, past medical history (diabetes mellitus, hypertension, heart disease and stroke), witnessed, location of arrest, community urbanization level, the proportion of highly educated residents, the Carstairs deprivation index and interaction term.

**Table 4 – Sensitivity analysis for the risk-adjusted rates of study outcomes by year.**

| | Year 2013 and 2016 | | Year 2014 and 2016 | | Year 2015 and 2016 | |
|---|---|---|---|---|---|---|
| | Difference (2016 vs. 2013) Adjusted rate (95% CI) | Difference-in-difference Adjusted rate (95% CI) | Difference (2016 vs. 2014) Adjusted rate (95% CI) | Difference-in-difference Adjusted rate (95% CI) | Difference (2016 vs. 2015) Adjusted rate (95% CI) | Difference-in-differences Adjusted rate (95% CI) |
| Good neurological recovery | | | | | | |
| Total | 1.5 (1.0 to 1.9) | | 0.6 (0.2 to 1.1) | | 0.2 (−0.2 to 0.7) | |
| County-level CPR training | | | | | | |
| Q1 (49.6 to 61.9%) | 1.7 (1.0 to 2.5) | 1.6 (0.2 to 2.9) | 1.0 (0.3 to 1.7) | 1.2 (−0.2 to 2.6) | 0.6 (−0.1 to 1.3) | 1.3 (0.0 to 2.7) |
| Q2 (45.7 to 49.5%) | 2.4 (1.7 to 3.1) | 2.2 (0.9 to 3.6) | 1.2 (0.5 to 1.9) | 1.4 (0.1 to 2.8) | 0.9 (0.2 to 1.6) | 1.6 (0.3 to 3.0) |
| Q3 (39.2 to 45.6%) | 1.5 (0.7 to 2.3) | 1.3 (−0.1 to 2.7) | 0.6 (−0.3 to 1.4) | 0.8 (−0.6 to 2.2) | 0.2 (−0.7 to 1.0) | 0.9 (−0.5 to 2.4) |
| Q4 (19.1 to 39.1%) | 0.2 (−1.0 to 1.3) | Reference | −0.2 (−1.4 to 0.9) | Reference | −0.7 (−1.9 to 0.4) | Reference |
| Survival to discharge | | | | | | |
| Total | 1.1 (0.6 to 1.6) | | 0.9 (0.4 to 1.4) | | 0.5 (0.0 to 1.0) | |
| County-level CPR training | | | | | | |
| Q1 (49.6 to 61.9%) | 1.5 (0.6 to 2.4) | 1.5 (−0.2 to 3.2) | 1.1 (0.2 to 2.0) | 1.0 (−0.6 to 2.7) | 0.8 (−0.1 to 1.6) | 1.2 (−0.4 to 2.9) |
| Q2 (45.7 to 49.5%) | 2.2 (1.3 to 3.1) | 2.2 (0.5 to 3.9) | 1.2 (0.4 to 2.1) | 1.1 (−0.5 to 2.8) | 1.3 (0.5 to 2.2) | 1.8 (0.1 to 3.4) |
| Q3 (39.2 to 45.6%) | 0.7 (−0.4 to 1.7) | 0.6 (−1.1 to 2.4) | 1.1 (0.1 to 2.2) | 1.1 (−0.7 to 2.8) | 0.3 (−0.7 to 1.4) | 0.8 (−0.9 to 2.5) |
| Q4 (19.1 to 39.1%) | 0.0 (−1.4 to 1.5) | Reference | 0.1 (−1.3 to 1.5) | Reference | −0.5 (−1.9 to 0.9) | Reference |
| Bystander CPR | | | | | | |
| Total | 18.1 (16.9 to 19.2) | | 9.5 (8.4 to 10.6) | | 3.7 (2.7 to 4.8) | |
| County-level CPR training rate | | | | | | |
| Q1 (49.6 to 61.9%) | 18.2 (16.4 to 20.1) | −2.3 (−5.8 to 1.3) | 8.8 (7.0 to 10.7) | −3.1 (−6.6 to 0.4) | 3.5 (1.7 to 5.3) | −0.9 (−4.3 to 2.6) |
| Q2 (45.7 to 49.5%) | 17.8 (16.0 to 19.6) | −2.7 (−6.2 to 0.8) | 9.6 (7.8 to 11.3) | −2.4 (−5.9 to 1.0) | 3.6 (1.9 to 5.3) | −0.8 (−4.2 to 2.6) |
| Q3 (39.2 to 45.6%) | 15.7 (13.5 to 17.8) | −4.8 (−8.5 to −1.2) | 7.7 (5.5 to 9.8) | −4.3 (−7.9 to −0.7) | 3.5 (1.4 to 5.6) | −0.8 (−4.4 to 2.7) |
| Q4 (19.1 to 39.1%) | 20.5 (17.5 to 23.5) | Reference | 12.0 (9.0 to 14.9) | Reference | 4.4 (1.5 to 7.3) | Reference |

CI: 95% confidence interval; Q: quartile; CPR: cardiopulmonary resuscitation.
Adjusted for age, gender, past medical history (diabetes mellitus, hypertension, heart disease and stroke), witnessed, location of arrest, community urbanization level, the proportion of highly educated residents, the Carstairs deprivation index and interaction term.

received CPR training, bystanders of OHCA were more likely to perform CPR and the OHCA patients were more likely to survive with good neurological recovery. Furthermore, the county-level CPR training was associated with higher likelihoods of continued improvements of survival outcomes after OHCA over a 5-year period. Therefore, our study emphasizes the importance of public training of CPR to improve clinical outcomes for OHCA patients.

In counties in which more than half the residents have received CPR training (the Q1 group: 49.6–61.9% for CPR training rates), the adjusted good neurological recovery rate increased 2.2% (1.5–2.9) over a 5-year period and the adjusted survival rate increased 1.2% (0.3–2.1) from 2012 to 2016 (Table 3). The increases in neurological outcome rates over the 5-year period were significantly higher in the highest CPR training counties than in the lowest CPR training counties (difference-in-differences: 2.1% (0.8–3.5)). Furthermore, in the sensitivity analysis, the trends of rapid increases in the neurological recovery rates in those counties were maintained when calculating the differences for the 4-year period and the 3-year period (Table 4). In previous studies, neighbourhood factors, including socioeconomic factors and CPR training rates, were associated with the provision of bystander CPR, the use of bystander automated external defibrillator (AED) before EMS arrival and survival outcomes for OHCA patients.[6–11,13–15] Health authorities of the counties in the highest quartile of CPR training rates might have had initiatives and priorities in enhancing CPR capacity, including public CPR training programmes and chains of survival for OHCA in the counties. These efforts may have more rapidly increased the clinical outcomes for OHCA patients occurring in the counties than in other counties, even after adjusting for individual characteristics and neighbourhood socioeconomic status.

In this study, there was no significant difference-in-differences in bystander CPR rates over 5 years between counties. This might have been the result of a nationwide dispatcher-assisted bystander CPR programme in Korea that was implemented in 2012.[16,17] The bystander CPR rate during the study period was 50.4% and the dispatcher-assisted bystander CPR rate was 38.2%. Along with the increase in the bystander CPR rates for all counties, the dispatcher-assisted CPR programme resulted in a lowering of the regional variations in adjusted bystander CPR rates: from 30.0–38.7% in 2012 to 64.0–66.9% in 2016 (Table 3). Even though the dispatcher-provided CPR instructions enables an untrained layperson to perform CPR, the effect of the CPR instructions on survival outcomes for OHCAs might be maximized when trained bystanders perform CPR with dispatcher assistance by recalling CPR procedure and performing proper chest compression.[18,19] This might be one of the reasons why there were significant differences in improvements of clinical outcomes between counties with various CPR training rates but no significant difference-in-differences in bystander CPR rates.

There was evidence that public CPR training was associated with improved bystander CPR rates and clinical outcomes for OHCAs.[20,21] The present study found that the county-level CPR training was also associated with continuous improvements of clinical outcomes after OHCA. In Korea, through public campaigns and advocacy which were led by national and academic initiatives, the county-level CPR training rates (median 45.6%) have been rapidly increased and thus have been shown relatively higher CPR training rates than US and other countries.[7,22] However, it is still lower than Norway (90%),[23] and there is an opportunity for further increasing the county-level CPR training rate. Public CPR campaigns, public and targeted CPR training, and continuous CPR education every 2 years would improve layperson skill retention and confidence to perform a basic life support sequence for OHCA patients.[20,21,24,25]

### *Limitations*

This study had several limitations. First, we used self-reports of survey participants selected by representative sampling methods to measure county-level CPR training rates, defined as on-site group training for 40 min or longer. We did not collect information regarding the methods, duration or date of CPR training. The survey questionnaire may be interpreted differently by the respondents, even though trained interviewers gathered the survey information via face-to-face interview, possibly resulting in bias. Second, this study focused on a county-level factor that was associated with study outcomes, but there may be composition effects for individual CPR awareness and contextual-composition interaction effects. Third, we treated the county-level CPR training rates as continuous variables (addition to categorical variable) and calculated the ORs for study outcomes per 10% increment in the CPR training rate, because we believe that it is import for the public health policy makers to assess intuitively how much the bystander CPR rates and survival outcomes can be improved by increasing the CPR training rate in a county by a certain number (i.e. 10%). While there is an association between improved survival and a 10% increment in county-level CPR training rates, the association does not increase linearly across the quartiles (based on the ORs in Table 2). Therefore, these results should be interpreted with caution. Lastly, this study was an observational study. There may be potential unmeasured biases that were not controlled.

## Conclusions

County-level CPR training were associated with improved rates of bystander cardiopulmonary resuscitation and survival outcomes for out-of-hospital cardiac arrests with presumed cardiac etiologies. Furthermore, county-level CPR training rates were associated with continued improvements in survival outcomes over 5 years in the counties, independent of individual characteristics and neighbourhood socioeconomic status.

## Author contributions

Drs. Ro and Song had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: Drs. Ro, Song, and Shin.

Acquisition, analysis, or interpretation of data: Drs. Ro, Shin, Song, Hong, Park, Kong, and Cho.

Drafting of the manuscript: Drs. Ro and Song.

Critical revision of the manuscript for important intellectual content: Dr. Shin.

Statistical analysis: Drs. Ro, and Song.

Obtained funding: Dr. Shin.

Administrative, technical, or material support: Drs. Hong, Park, Kong, and Cho.

Study supervision: Drs. Shin and Cho.

Manuscript approval: all authors.

## Funding acknowledgement

This study was supported by the National Emergency Management Agency of Korea and the Korea Centers for Disease Control and Prevention. The study was funded by the Korea Centers for Disease Control and Prevention (2013–2016).

## Conflict of interest statement

There are no potential conflicts of interest for all authors in this study.

REFERENCES

1. Stromsoe A, Andersson B, Ekstrom L, et al. Education in cardiopulmonary resuscitation in Sweden and its clinical consequences. Resuscitation 2010;81:211–6.
2. Abella BS, Aufderheide TP, Eigel B, et al. Reducing barriers for implementation of bystander-initiated cardiopulmonary resuscitation: a scientific statement from the American Heart Association for healthcare providers, policymakers, and community leaders regarding the effectiveness of cardiopulmonary resuscitation. Circulation 2008;117:704–9.
3. Sasson C, Meischke H, Abella BS, et al. Increasing cardiopulmonary resuscitation provision in communities with low bystander cardiopulmonary resuscitation rates: a science advisory from the American Heart Association for healthcare providers, policymakers, public health departments, and community leaders. Circulation 2013;127:1342–50.
4. Masterson S, Stromsoe A, Cullinan J, Deasy C, Vellinga A. Apples to apples: can differences in out-of-hospital cardiac arrest incidence and outcomes between Sweden and Ireland be explained by core Utstein variables? Scand J Trauma Resusc Emerg Med 2018;26:37.
5. Kragholm K, Wissenberg M, Mortensen RN, et al. Bystander Efforts and 1-Year Outcomes in Out-of-Hospital Cardiac Arrest. N Engl J Med 2017;376:1737–47.
6. Vaillancourt C, Lui A, De Maio VJ, Wells GA, Stiell IG. Socioeconomic status influences bystander CPR and survival rates for out-of-hospital cardiac arrest victims. Resuscitation 2008;79:417–23.
7. Ro YS, Shin SD, Song KJ, et al. Public awareness and self-efficacy of cardiopulmonary resuscitation in communities and outcomes of out-of-hospital cardiac arrest: A multi-level analysis. Resuscitation 2016;102:17–24.
8. Sasson C, Magid DJ, Chan P, et al. Association of neighborhood characteristics with bystander-initiated CPR. N Engl J Med. 2012;367:1607–15.
9. Fosbol EL, Dupre ME, Strauss B, et al. Association of neighborhood characteristics with incidence of out-of-hospital cardiac arrest and rates of bystander-initiated CPR: implications for community-based education intervention. Resuscitation 2014;85:1512–7.

10. Mitchell MJ, Stubbs BA, Eisenberg MS. Socioeconomic status is associated with provision of bystander cardiopulmonary resuscitation. Prehosp Emerg Care 2009;13:478–86.
11. Lee SY, Ro YS, Shin SD, et al. Interaction effects between highly-educated neighborhoods and dispatcher-provided instructions on provision of bystander cardiopulmonary resuscitation. Resuscitation 2016;99:84–91.
12. Ko SY, Ro YS, Shin SD, Song KJ, Hong KJ, Kong SY. Effect of a first responder on survival outcomes after out-of-hospital cardiac arrest occurs during a period of exercise in a public place. PLoS One 2018;13:e0193361.
13. Ro YS, Shin SD, Song KJ, et al. A trend in epidemiology and outcomes of out-of-hospital cardiac arrest by urbanization level: a nationwide observational study from 2006 to 2010 in South Korea. Resuscitation 2013;84:547–57.
14. Andersen LW, Holmberg MJ, Granfeldt A, et al. Neighborhood characteristics, bystander automated external defibrillator use, and patient outcomes in public out-of-hospital cardiac arrest. Resuscitation 2018;126:72–9.
15. Ahn KO, Shin SD, Hwang SS, et al. Association between deprivation status at community level and outcomes from out-of-hospital cardiac arrest: a nationwide observational study. Resuscitation 2011;82:270–6.
16. Song KJ, Shin SD, Park CB, et al. Dispatcher-assisted bystander cardiopulmonary resuscitation in a metropolitan city: a before-after population-based study. Resuscitation 2014;85:34–41.
17. Ro YS, Shin SD, Lee YJ, et al. Effect of dispatcher-assisted cardiopulmonary resuscitation program and location of out-of-hospital cardiac arrest on survival and neurologic outcome. Ann Emerg Med. 201769(52e1).
18. Beard M, Swain A, Dunning A, Baine J, Burrowes C. How effectively can young people perform dispatcher-instructed cardiopulmonary resuscitation without training? Resuscitation 2015;90:138–42.
19. Lerner EB, Rea TD, Bobrow BJ, et al. Emergency medical service dispatch cardiopulmonary resuscitation prearrival instructions to improve survival from out-of-hospital cardiac arrest: a scientific statement from the American Heart Association. Circulation. 2012;125:648–55.
20. Wissenberg M, Lippert FK, Folke F, et al. Association of national initiatives to improve cardiac arrest management with rates of bystander intervention and patient survival after out-of-hospital cardiac arrest. JAMA 2013;310:1377–84.
21. Nielsen AM, Isbye DL, Lippert FK, Rasmussen LS. Persisting effect of community approaches to resuscitation. Resuscitation 2014;85:1450–4.
22. Anderson ML, Cox M, Al-Khatib SM, et al. Rates of cardiopulmonary resuscitation training in the United States. JAMA Intern Med 2014;174:194–201.
23. Bakke HK, Steinvik T, Angell J, Wisborg T. A nationwide survey of first aid training and encounters in Norway. BMC Emerg Med 2017;17:6.
24. Gonzalez-Salvado V, Abelairas-Gomez C, Pena-Gil C, et al. Basic life support training into cardiac rehabilitation programs: A chance to give back. A community intervention controlled manikin study. Resuscitation 2018;127:14–20.
25. Song KJ, Kim JB, Kim J, Kim C, Park SY, Lee CH, et al. Part 2. Adult basic life support: 2015 Korean Guidelines for Cardiopulmonary Resuscitation. Clin Exp Emerg Med 2016;(3):S10–6.