

Original Article



Healthcare Workforce Response to The Coronavirus Disease Outbreak in Daegu, Korea: A Multi-Center, Cross-Sectional Survey

Hyun Hee Kwon ^{1,*}, Hye In Kim ^{2,*}, Ki Tae Kwon ^{3,t}, Soyeon Hwang ³, Shin-Woo Kim ⁴, Yoonjung Kim ⁴, Hyun ah Kim ^{5,t}, Miri Hyun ⁵, Hyo-Lim Hong ¹, Min Jung Kim ⁶, Jian Hur ⁷, and Kyung Soo Hong ⁷

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Corresponding Authors:

Ki Tae Kwon, MD, PhD

Division of Infectious Diseases, Kyungpook National University Chilgok Hospital, 807, Hoguk-ro, Buk-gu, Daegu 41404, Korea.

Tel: +82-53-200-2616

Fax: +82-53-200-3862

Email: ktkwon@knu.ac.kr

Hyun ah Kim, MD, PhD

Department of Infectious Diseases, Keimyung University Dongsan Hospital, Keimyung University School of Medicine, 1035 Dalgubeol-daero, Dalseogu, Daegu 42601, Korea.

Tel: +82-53-258-7731

Fax: +82-53-258-4953

Email: hyunah1118@dsmc.or.kr

*These authors contributed equally to this work as co-first authors.

^tThese authors contributed equally to this work as co-corresponding authors.

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¹Department of Internal Medicine, Catholic University of Daegu, School of Medicine, Daegu, Korea

²Department of Infectious Diseases, Daegu Fatima Hospital, Daegu, Korea

³Division of Infectious Diseases, Department of Internal Medicine, Kyungpook National University Chilgok Hospital, School of Medicine, Kyungpook National University, Daegu, Korea

⁴Division of Infectious Diseases, Department of Internal Medicine, School of Medicine, Kyungpook National University, Kyungpook National University Hospital, Daegu, Korea

⁵Department of Infectious Diseases, Keimyung University Dongsan Medical Center, Daegu, Korea

⁶Department of Internal Medicine, Daegu Veterans Hospital, Daegu, Korea

⁷Department of Internal Medicine, Yeungnam University Medical Center, Daegu, Korea

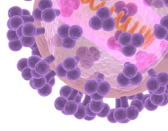
ABSTRACT

Background: Securing an available healthcare workforce is critical to respond to coronavirus disease 2019 (COVID-19); however, research investigating Korea's COVID-19 staffing response is rare. To present the fundamental data of healthcare staff in response to the surge in COVID-19 cases, we investigated the healthcare workforce response in Daegu, South Korea, which experienced the first largest outbreak of COVID-19 outside of China.

Materials and Methods: In response to the COVID-19 outbreak, this retrospective cross-sectional study analyzed data on the scale and characteristics of healthcare workers (HCWs). Additionally, it analyzed the clinical and epidemiological characteristics of HCWs infected with COVID-19 in six major teaching hospitals (five tertiary and one secondary) in Daegu from January 19 to April 30, 2020.

Results: During this study period, only 1.3% (n = 611) of the total hospitalized patients (n = 48,807) were COVID-19 inpatients, but they occupied 6.0% (n = 303) of the total hospital beds (n = 5,056), and 23.7% (n = 3,471) of all HCWs (n = 14,651) worked in response to COVID-19. HCWs participating in COVID-19-related works comprised 50.6% (n = 1,203) of doctors (n = 2,379), 26.3% (n = 1,571) of nurses (n = 5,982), and 11.4% (n = 697) of other HCWs (n = 6,108). Only 0.3% (n = 51) of HCWs (n = 14,651) developed COVID-19 infections from community-acquired (66.7%) or hospital-acquired (29.4%). Nurses were affected predominantly (33.3%), followed by doctors (9.8%), caregivers (7.8%), radiographers (5.9%), and others (45.1%), including nurse aides and administrative, facility maintenance, telephone appointment centers, and convenience store staff. All HCWs infected with COVID-19 recovered completely. The 32.7% (n = 333) of individuals (n = 1,018) exposed to HCWs who had COVID-19 were quarantined, and only one case of secondary transmission among them occurred.

Conclusion: The COVID-19 pandemic has necessitated significant staffing and facility usage, which is disproportionate to the relatively low number of COVID-19 inpatients, imposing a



ORCID iDs

- Hyun Hee Kwon 
<https://orcid.org/0000-0002-8509-3968>
- Hye In Kim 
<https://orcid.org/0000-0001-7162-4150>
- Ki Tae Kwon 
<https://orcid.org/0000-0003-4666-0672>
- Soyoon Hwang 
<https://orcid.org/0000-0003-3618-174X>
- Shin-Woo Kim 
<https://orcid.org/0000-0002-3755-8249>
- Yoonjung Kim 
<https://orcid.org/0000-0002-7454-4014>
- Hyun ah Kim 
<http://orcid.org/0000-0002-9125-7156>
- Miri Hyun 
<https://orcid.org/0000-0003-0062-342X>
- Hyo-Lim Hong 
<https://orcid.org/0000-0003-2147-1381>
- Min Jung Kim 
<https://orcid.org/0000-0002-2637-7979>
- Jian Hur 
<https://orcid.org/0000-0003-3219-8368>
- Kyung Soo Hong 
<https://orcid.org/0000-0003-2931-6861>

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Conflict of Interest

No conflict of interest.

Author Contributions

Conceptualization: KTK, HAK, HHK. Data curation: HIK, SH, SWK, YK, MH, HLH, MJK, JH, KSH. Formal analysis: KTK, MH, HLH. Investigation: KTK, MJK, JH, KSH. Writing - original draft: HIK, HHK, KTK. Writing - review & editing: KTK, KHA, SH, SWK, YJK.

substantial burden on healthcare resources. Therefore, beyond the current reimbursement level of the Korean National Health Insurance, a new type of rewarding system is needed to prepare hospitals for the emerging outbreaks of infectious diseases. Keeping HCWs safe from COVID-19 is crucial for maintaining the healthcare workforce during a sudden massive outbreak. Further studies are needed to determine the standards of required HCWs through detailed research on the working hours and intensity of HCWs responding to COVID-19.

Keywords: SARS-CoV-2; Health personnel; Infection control; Personal protective equipment; Health facilities

INTRODUCTION

In 2020, countries worldwide were unprepared when the coronavirus disease 2019 (COVID-19) pandemic struck them; a massive outbreak of COVID-19 within a short period led to the collapse of healthcare systems [1, 2]. To prevent similar future collapses, various policies and measures have been enacted by countries to maintain and enhance the competencies of healthcare workers (HCWs), who are regarded as essential to effective anti-COVID-19 policy efforts [3]. During the pandemic, a “shortage of available HCWs” has been reported as the most common reason for disruptions in healthcare services [4, 5]. HCWs play a pivotal role in the COVID-19 response; however, a rapid spike of COVID-19 patients within a short period of time creates a serious staff shortage [6]. Ensuring proper staffing is critical for managing infected patients, preventing secondary transmission to other patients and staff, and controlling the rapid spread throughout the community [7].

Because of inconsistent reporting, the exact number of COVID-19 cases and deaths among healthcare providers is unknown; however, the International Council of Nurses (ICN) reported that 572,578 HCWs from 32 countries contracted severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) as of August 2020, accounting for 10.0% of all cases [8]. Similarly, the World Health Organization (WHO) reported that 14.0% of COVID-19 patients in Europe and America were HCWs [9]. The ICN estimated that at least two million HCWs worldwide had contracted the infection based on these data. The WHO estimated that more than 30,000 HCWs had died of COVID-19 in February 2021 [10]. Many HCWs were exposed to COVID-19 early in the pandemic. In China, 3,300 HCWs were infected and at least 22 had died of COVID-19 by March and February 2020, respectively. In Italy, 20.0% of HCWs were infected, and some of them died [11]. The infection spread among HCWs was attributed to inappropriate use of personal protection equipment (PPE), prolonged exposure to COVID-19 from many patients, shortage of PPE, lack of knowledge about infection prevention, low test sensitivity, and patients lying about epidemiological associations [12]. Moreover, HCWs may have an increased risk of COVID-19 owing to their close contact with highly infectious patients and exposure to undiagnosed or subclinical infectious cases [13].

Following the first case of COVID-19 in Daegu, Korea, on February 18, 2020, a massive outbreak occurred for the first time outside China; as healthcare facilities in Daegu were unprepared, they were overwhelmed by the need for a COVID-19 response, which prompted health authorities enforced several innovative measures, including drive-through screening centers, designation of COVID-19 hospitals, implementation of community treatment centers, restructuring of the healthcare system, mandatory universal face-mask policy, and rapid large-scale testing [14]. Through these measures, the epidemic was controlled without

serious infections of HCWs [15-18]. Many HCWs in Daegu committed to participating in the COVID-19 response during this period; however, the number of those involved in the COVID-19 response and the characteristics of those who developed COVID-19 in Daegu have not been investigated. Therefore, this study analyzed the scale and characteristics of healthcare staff needed to respond effectively to a COVID-19 outbreak, and the clinical and epidemiological features of HCWs who developed COVID-19 infection in six major teaching hospitals in Daegu that had experienced the outbreak with insufficient preparation. The ultimate goals of this study were to determine how to manage a healthcare workforce for pandemic response and to present foundational data on infection control among HCWs.

MATERIALS AND METHODS

1. Study design

This retrospective cross-sectional study analyzed data on the scale and characteristics of essential HCWs in response to the COVID-19 outbreak. Further, it analyzed the clinical and epidemiological characteristics of HCWs infected with COVID-19 in six major teaching hospitals (*i.e.*, five tertiary and one secondary) in Daegu, Korea, during the COVID-19 outbreak from January 19 to April 30, 2020.

Data were collected from the infection control departments at each hospital, and the data included the total number of (1) inpatients and hospitalized COVID-19 patients; (2) hospital beds and dedicated beds for COVID-19 inpatients [general ward (GW) and intensive care unit (ICU)]; (3) doctors, nurses, and other HCWs; (4) doctors, nurses, and other HCWs participating in the COVID-19 response and (5) HCWs in the emergency department (ED), COVID-19 GW and ICU, and screening centers during the study period. Doctors, nurses, and other HCWs involved in the COVID-19 response were categorized according to their units: ED, COVID-19 GW, ICU, and other. We surveyed the number of HCWs dispatched to community treatment centers or designated COVID-19 hospitals and the number of staff members assigned to hospital-entrance control.

The epidemiology and impact of COVID-19 on HCWs were investigated. The number of HCWs with COVID-19 infection, occupation, route of infection, work unit at the time of infection, number of persons exposed to HCWs infected with COVID-19, number of persons quarantined, and number of secondary transmission cases were surveyed. We investigated the clinical characteristics of HCWs infected with COVID-19, including sex, age, severity at time of diagnosis, severity at the peak illness, duration of treatment, the average length of isolation, and outcome.

All hospitals implemented stringent infection control policies: strict restriction of entrance to the facility, mandatory universal mask policy within hospitals, aggressive use of appropriate personal protective equipment (PPE), extensive SARS-CoV-2 reverse transcription-polymerase chain reaction (RT-PCR) screening testing, screening center operation, contact tracing, surveillance of disease onset, and monitoring of symptoms for all HCWs, inpatients, and caregivers.

2. Ethics statement

The Daegu Joint Institutional Review Board approved this retrospective, cross-sectional study and waived the requirement for any informed consent (DGIRB 2020-06-010).

3. Statistical analysis

In this study, only basic statistics such as number, ratio, mean, standard deviation, and interquartile range were obtained.

RESULTS

1. Hospital beds and workforce response to COVID-19 outbreak during the study period

During this study period, the proportion of COVID-19 patients was 1.3% (n = 611) of all the hospitalized patients (n = 48,807). Besides, 6.0% (n = 303) of the total hospital beds (n = 5,056) were occupied by COVID-19 inpatients. Detailed information about the hospital beds for COVID-19 inpatients at each hospital is presented in **Table 1**.

Of the total HCWs (n = 14,651) in all participating hospitals, 23.7% (n = 3,471) worked in response to the COVID-19 outbreak. Among the 3,471 HCWs responding to the COVID-19 outbreak, the proportion of doctors, nurses, and other HCWs was 34.3% (n = 1,203), 44.7% (n = 1,571), and 20.0% (n = 697), respectively. Overall, 50.6% of doctors, 26.3% of nurses, and 11.4% of other HCWs responded to the COVID-19 pandemic. Detailed information about the healthcare workforce's response to the COVID-19 outbreak is presented in **Table 2**. The working places of doctors were distributed in emergency rooms (ER) (11.7%), COVID-19 ICU (8.8%), GW (23.4%), and screening center (SC) (58.4%), respectively, whereas that the working places of nurses were distributed as ER (18.8%), COVID-19 ICU (19.5%), GW

Table 1. Dedicated hospital beds for COVID-19 inpatients during the study period

Variables	Total (%)	Hospital A (%)	Hospital B (%)	Hospital C (%)	Hospital D (%)	Hospital E (%)	Hospital F (%)
Total number of admitted patients	48,807 (100.0)	10,823 (22.2)	7,782 (15.9)	9,903 (20.3)	7,024 (14.4)	7,943 (16.3)	5,332 (10.9)
Number of admitted COVID-19 patients	611 (1.3)	70 (0.6)	100 (1.3)	43 (0.4)	143 (2.0)	151 (1.9)	104 (2.0)
Total number of hospital beds	5,056 (100.0)	635 (12.6)	914 (18.1)	997 (19.7)	879 (17.4)	975 (19.3)	665 (13.2)
Number of dedicated beds for COVID-19 patients	303 (6.0)	23 (3.6)	46 (5.0)	11 (1.1)	134 (6.5)	17 (1.7)	72 (10.8)
COVID-19 ICU	56 (18.5)	5 (21.7)	12 (26.1)	4 (36.4)	9 (6.7)	10 (58.8)	16 (22.2)
COVID-19 GW	247 (81.5)	18 (78.3)	34 (73.9)	7 (63.6)	125 (93.3)	7 (41.2)	56 (77.8)

COVID-19, coronavirus disease 2019; ICU, intensive care unit; GW, general ward.

Table 2. Healthcare workforce response to COVID-19 outbreak

Variables	Total (%)	Hospital A (%)	Hospital B (%)	Hospital C (%)	Hospital D (%)	Hospital E (%)	Hospital F (%)
Total number of HCWs	14,651 (100.0)	1,705 (11.6)	3,352 (22.9)	3,034 (20.7)	2,280 (15.6)	2,591 (17.7)	1,689 (11.5)
Doctors	2,379 (16.2)	334 (19.6)	630 (18.8)	455 (15.0)	341 (15.0)	402 (15.5)	217 (12.8)
Nurses	5,982 (40.8)	739 (43.3)	1,022 (30.5)	1,251 (41.2)	980 (43.0)	1,188 (45.9)	802 (47.5)
Other HCWs	6,108 (41.7)	632 (37.1)	1,700 (50.7)	1,328 (43.8)	777 (34.1)	1,001 (38.6)	670 (39.7)
HCWs in response to COVID-19 outbreaks	3,471 (23.7)	350 (20.5)	861 (25.7)	739 (24.4)	570 (25)	554 (21.4)	397 (23.5)
Category according to occupation							
Doctors	1,203 (34.3)	178 (50.9)	197 (23.0)	315 (42.6)	165 (28.9)	157 (28.3)	191 (43.7)
Nurses	1,571 (44.7)	134 (38.3)	436 (50.6)	313 (42.4)	234 (41.1)	291 (52.5)	133 (30.4)
Other HCWs	697 (20.0)	38 (10.9)	228 (26.9)	119 (16.1)	171 (30.0)	76 (13.7)	73 (16.7)
Category according to departments							
Emergency Room	568 (17.0)	64 (18.3)	132 (15.3)	114 (19.1)	58 (10.2)	107 (20.5)	93 (21.3)
COVID-19 ICU	483 (14.5)	71 (20.3)	177 (20.6)	69 (11.6)	31 (5.4)	49 (9.4)	86 (19.7)
COVID-19 GW	1,041 (31.2)	74 (21.1)	427 (49.6)	57 (9.6)	181 (31.7)	179 (34.3)	123 (28.1)
COVID-19 SC	1,114 (33.4)	141 (40.3)	125 (14.5)	420 (70.5)	98 (17.2)	195 (37.4)	135 (30.9)
Others	305 (9.1)	0 (0.0)	0 (0.0)	79 (13.3)	202 (35.4)	24 (4.6)	0 (0.0)
HCWs for entrance control	1,874 (12.8)	118 (6.9)	78 (2.3)	486 (16.0)	740 (32.5)	202 (7.8)	250 (14.8)
Dispatched HCWs ^a	234 (1.6)	28 (1.6)	93 (2.8)	83 (2.7)	0 (0.0)	20 (0.8)	10 (0.6)

^aDedicated healthcare facilities designated by the government for COVID-19 patients.

COVID-19, coronavirus disease 2019; HCWs, healthcare workers; ICU, intensive care unit; GW, general ward; SC, screening center.

(36.3%), and SC (21.7%), respectively. Detailed information on the work assignments of HCWs by occupation is provided in **Supplementary Table 1**.

2. Epidemiology and clinical characteristics of HCWs infected with COVID-19

Of the 14,561 HCWs, 0.3% (n = 51) developed COVID-19 infections. Nurses were the most affected (33.3%), followed by physicians (9.8%), caregivers (7.8%), radiographers (5.9%), and other HCWs (45.1%), including nurse aides and administrative, facilities, telephone appointment centers, and convenience store staff. Specific religion (n = 18) was the most common presumed infection route of community-acquired infections (n = 35), followed by household contacts (n = 8), other close contacts (n = 1), and unknown (n = 8). Whereas the most common presumed infection route of hospital-acquired infection (n = 15) was close contact with patients or caregivers (n = 14) with confirmed COVID-19, followed by close contact with infected HCWs (n = 1). A total of 1,018 people were exposed to infected HCWs; the most common category of exposure was that of nurse (33.5%), followed by patients (24.6%), family caregivers (9.6%), and physicians (9.4%). Among the people exposed, 32.7% were quarantined, including 146 nurses (43.7%), 64 patients (19.2%), and 30 doctors (9.0%). One case of secondary transmission from a COVID-19-infected HCW occurred. Detailed information about the epidemiology and impact of COVID-19 on HCWs is presented in **Table 3**.

Table 3. Epidemiology and impact of healthcare workers with COVID-19

Variables	Total (%)	Hospital A (%)	Hospital B (%)	Hospital C (%)	Hospital D (%)	Hospital E (%)	Hospital F (%)
HCWs with COVID-19	51 (100.0)	4 (7.8)	5 (9.8)	11 (21.6)	13 (25.5)	7 (13.7)	11 (21.6)
Occupation							
Doctors	5 (9.8)	0 (0.0)	0 (0.0)	1 (9.1)	2 (15.4)	0 (0.0)	2 (18.2)
Nurses	17 (33.3)	0 (0.0)	3 (60.0)	4 (36.4)	3 (23.1)	1 (14.3)	6 (54.5)
Caregiver	4 (7.8)	2 (50.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (18.2)
Radiologic technician	3 (5.9)	0 (0.0)	0 (0.0)	1 (9.1)	0 (0.0)	1 (14.3)	1 (9.1)
Other HCWs	22 (43.1)	2 (50)	2 (40)	5 (45.4)	8 (61.5)	5 (71.4)	0 (0.0)
Route of contagion							
Community acquired	35 (68.6)	4 (100)	3 (60.0)	11 (100)	11 (84.6)	5 (71.4)	1 (9.1)
Hospital acquired	16 (31.4)	0 (0.0)	2 (40.0)	0 (0.0)	2 (15.4)	2 (28.6)	10 (90.9)
Work unit when they were infected with COVID-19							
COVID-19 ICU	1 (2.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (14.3)	0 (0.0)
COVID-19 general ward	1 (2.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (14.3)	0 (0.0)
Emergency room	2 (3.9)	0 (0.0)	0 (0.0)	1 (9.1)	0 (0.0)	0 (0.0)	1 (9.1)
General ward	22 (43.1)	2 (50.0)	3 (60.0)	2 (18.1)	6 (46.2)	0 (0.0)	9 (81.8)
Others	25 (49.0)	2 (50.0)	2 (40.0)	8 (72.7)	7 (53.8)	5 (71.4)	1 (9.1)
Number of persons exposed to HCWs with COVID-19	1,018 (100.0)	266 (26.1)	8 (0.8)	136 (13.4)	468 (46)	90 (8.8)	50 (4.9)
Doctors	96 (9.4)	43 (16.2)	0 (0.0)	12 (8.8)	27 (5.8)	4 (4.5)	10 (20.0)
Nurses	341 (33.5)	85 (32)	3 (37.5)	44 (32.4)	129 (27.6)	66 (73.3)	14 (28.0)
Other HCWs	196 (19.3)	45 (16.9)	5 (62.5)	39 (28.7)	67 (14.3)	20 (22.2)	20 (40.0)
Patients	250 (24.6)	52 (19.5)	0 (0.0)	38 (27.9)	154 (32.9)	0 (0.0)	6 (12.0)
Guardians	98 (9.6)	25 (9.4)	0 (0.0)	3 (2.2)	70 (14.9)	0 (0.0)	0 (0.0)
Others	37 (3.6)	16 (6.0)	0 (0.0)	0 (0.0)	21 (4.5)	0 (0.0)	0 (0.0)
Number of persons quarantined among persons exposed to HCWs who had COVID-19	333 (32.7)	33 (9.9)	8 (2.4)	136 (40.9)	53 (15.9)	49 (14.7)	54 (16.2)
Doctors	30 (9.0)	0 (0.0)	0 (0.0)	12 (8.8)	11 (20.8)	1 (2.0)	6 (11.1)
Nurses	146 (43.9)	0 (0.0)	3 (37.5)	44 (32.4)	33 (62.3)	41 (83.7)	25 (46.3)
Other HCWs	75 (22.5)	0 (0.0)	5 (62.5)	39 (28.7)	9 (16.9)	7 (14.3)	15 (27.8)
Patients	64 (19.2)	20 (60.6)	0 (0.0)	38 (27.9)	0 (0.0)	0 (0.0)	6 (11.1)
Guardians	3 (0.9)	0 (0.0)	0 (0.0)	3 (2.2)	0 (0.0)	0 (0.0)	0 (0.0)
Others	15 (4.5)	13 (39.4)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (3.7)
Number of secondary transmission case from HCWs who had COVID-19	1 (100)	0 (0.0)	0 (0.0)	0 (0.0)	1 (100.0)	0 (0.0)	0 (0.0)

COVID-19, coronavirus disease 2019; HCWs, healthcare workers; ICU, intensive care unit; GW, general ward; SC, screening center.

Table 4. Clinical characteristics of healthcare workers with COVID-19 in Daegu

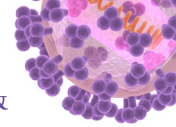
Variables	Number (%)
Total	51 (100.0)
Gender	
Male	19 (37.3)
Female	32 (62.7)
Age (mean ± standard deviation)	35.4 ± 12.9 years
Severity at the time of diagnosis	
Asymptomatic	12 (23.5)
Mild	34 (66.7)
Pneumonia	4 (7.8)
Severe pneumonia	1 (2.0)
Maximum severity	
Asymptomatic	12 (23.5)
Mild	32 (62.7)
Pneumonia	4 (7.8)
Severe pneumonia	3 (5.9)
Treatment outcome	
Recovery	51 (100.0)
Median isolation period (interquartile range)	25 days (16 - 35)

COVID-19, coronavirus disease 2019.

Thirty-two (62.7%) patients were women, and 19 (37.3%) were men, with a mean age of 35.4 ± 12.9 years. The disease severity was mainly asymptomatic (23.5%) to mild (66.7%), and all patients recovered. Detailed information regarding the clinical characteristics of HCWs infected with COVID-19 is presented in **Table 4**.

DISCUSSION

During this study, the cumulative number of COVID-19 in Daegu was 6,852 [19]. Most of them were asymptomatic to mild cases and were isolated in community treatment centers that compensated for hospital bed shortages [20, 21]. Only 8.9% (n = 611) of them (n = 6,852) were hospitalized in participating hospitals, and they were only 1.3% of the entire hospitalized patients (n = 48,807). However, 6.0% (n = 303) of the total hospital beds (n = 5,056) were occupied by COVID-19 patients, and 23.7% (n = 3,471) of the total HCWs (n = 14,651) worked in response to COVID-19. Therefore, all hospitals that participated in this study should have rapidly created dedicated hospital beds for COVID-19 inpatients by using portable negative pressure machines [22]. The COVID-19 pandemic requires many more beds and staffing per patient than would normally be necessary; thus, COVID-19 patient care is burdensome for healthcare facilities [23]. The number of HCWs required increases as the severity of COVID-19 increases [23]. Once an HCW contracts the virus, many people within the facility are identified as contacts, some of whom are quarantined, ultimately disrupting routine hospital operations [24]. Consequently, this situation adds to the burden on healthcare facilities, particularly imposing substantial burdens on healthcare resources. Therefore, beyond the Korean National Health Insurance Service reimbursement level, a new type of reward system needed to prepare hospitals for emerging outbreak of infectious diseases. In response to COVID-19 pandemic, some rewards for dedicated hospital beds for COVID-19 patients and infection control allowances for HCWs have been provided temporarily. Establishing a comprehensive workforce plan for future pandemics at the hospital, local, and national levels are also necessary.



Redeployment of HCWs is one of the recommendations for augmenting staff capacity with internal hospital resources [25]. In this study, about half of the entire doctor population was involved in COVID-19 response regardless of their specialty. Patients with COVID-19 at the COVID-19 ICU, GW, and ER were mainly treated by attending physicians specializing in infectious diseases, pulmonology, critical care, emergency medicine, and internal medicine residents. Additionally, doctors in other departments were mainly collecting samples at screening centers [23]. The deployment of a flexible physician workforce was required to create surge capacity for COVID-19 care and ensure and sustain routine hospital care [26]. Registered nurses, the largest component of the hospital workforce, played a critical role in caring for patients during the pandemic [27]. Furthermore, they were primarily involved in the COVID-19 response in this study. There was a study which analyzed personnel recruitment ads and found that nurses were the most frequently recruited; frontline HCWs were in greater demand than managers or other decision-making positions [28]. Apart from the physicians and nurses, 697 HCWs (20.0%) were involved in the COVID-19 response, including radiographers, laboratory technicians, nurse aides, cleaning staff, transport staff, and hospital administration staff. Middle managers alternately played the leading role in entrance control. Some HCWs were dispatched to a COVID-19 designated hospital in Daegu [18].

As of March 24, 2020 — a month after the massive outbreak in Daegu — a total of 121 HCWs had been infected with COVID-19 in the entire area (14 doctors, 56 nurses, 51 nurse aides), accounting for 1.8% of all 6,620 COVID-19 patients in the area [15]. This infection rate was low, considering that HCWs account for 10% of all COVID-19 cases worldwide [15, 29]. Nevertheless, the incidence of COVID-19 infection per 1,000 HCWs in the Daegu area was 4.42, which was higher than the incidence (2.72) of COVID-19 per 1,000 HCWs in the general population. In this study, the incidence was 3.48 per 1,000 HCWs, which is lower than the incidence among the entire HCW population in Daegu but higher than that of the general population [15]. These results may be attributable to this study involving one general and five tertiary hospital that have the highest infection-control capacity in Daegu. In terms of infection route, two-thirds of the cases were acquired in the community, presumably because the massive outbreak in Daegu was mainly linked to a specific religion [30]. Infected HCWs can infect their coworkers, patients, or caregivers; therefore, contact tracing and mandatory quarantine of close contacts are essential. Among the 1,018 identified contacts, 333 HCWs with close contact were quarantined. Fortunately, only one of them developed an infection. However, more epidemiological personnel are required to manage many contacts. Routine hospital operations would have been hindered if many staff members had been quarantined. In Australia, at least 536 HCWs were infected in the first six months of the outbreak, which accounted for 6.0% of all confirmed cases. This rate was 2.7-fold higher than that among the general population [31]. During the 21 COVID-19 waves, 131 HCWs were infected, and 1,656 were quarantined. One of these waves led to the closure of one hospital, and 1,200 people were quarantined from this hospital alone [31]. In this study, nurses, primarily women, were the predominant group among HCWs who developed COVID-19. As the infections were linked to a specific religious group, the mean age was young (35.4 ± 12.9); consequently, all patients recovered.

This study highlights the importance of HCWs in ensuring routine healthcare system operation during the COVID-19 pandemic. The results revealed the risk of workforce shortages and inadequate skills, and the importance of protecting healthcare personnel. The COVID-19 pandemic has highlighted the significance of assessing, protecting, and caring for the healthcare workforce and the need to make strategic investments in healthcare

personnel to secure an adequate number of competent and motivated HCWs [32]. The costs for mobilizing more healthcare personnel and adequately supporting them for the COVID-19 response not only support the healthcare system in engaging in immediate response but also act as an investment for cultivating competencies in the healthcare personnel who will lay the foundation of global health security in the future [33].

This study has some limitations. First, the study enumerated all personnel involved in COVID-19 care, as opposed to using a standardized value: therefore, it is difficult to quantify the actual required staff size. However, this can be considered the size of healthcare staff who had been at risk of COVID-19 infection due to direct patient exposure in the early days of the COVID-19 pandemic. Second, only teaching hospitals in Daegu were surveyed; hence, the survey did not explore all the healthcare facilities in the region. However, this sample involved the six largest teaching hospitals in Daegu that played pivotal roles in the COVID-19 response by promptly converting their wards and ICUs for COVID-19 care. Despite these limitations, this study sheds significant light on the detailed size and characteristics of HCWs involved in the COVID-19 response in extensive healthcare facilities in Daegu during an outbreak that struck an unprepared city.

In conclusion, the surge in COVID-19 patients required much more human resources than the typical situation in all participating hospitals. Therefore, it is necessary to establish a comprehensive workforce plan for future pandemics at the hospital, local, and national levels, and a new reward standard for hospitals that goes beyond the current reimbursement level of the Korean National Health Insurance Service. Despite the large number of healthcare personnel committed to COVID-19 care, COVID-19 infection among healthcare personnel was low in six major teaching hospitals that treated severe COVID-19 patients in the Daegu region due to the strict infection control measures. Keeping HCWs safe from COVID-19 is crucial for maintaining the healthcare workforce during a sudden massive outbreak. Because community-acquired infections are two times higher than hospital-acquired infections, healthcare personnel must strictly adhere to routine infection-control measures, monitor their symptoms, and promptly seek testing as necessary. Through detailed research on the working hours and intensity of HCWs responding COVID-19, further studies are needed to determine the standard of required HCWs.

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SUPPLEMENTARY MATERIAL

Supplementary Table 1

Departments of healthcare workers by occupation

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