Nonpharmaceutical interventions reduce the incidence and mortality of COVID-19: A study based on the survey from the International COVID-19 Research Network (ICRN)

Received: 14 May 2022 | Accepted: 2 September 2022

DOI: 10.1002/jmv.28354

RESEARCH ARTICLE

JOURNAL OF MEDICAL VIROLOGY WILEY

Nonpharmaceutical interventions reduce the incidence and mortality of COVID-19: A study based on the survey from the International COVID-19 Research Network (ICRN)

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Abstract

The recently emerged novel coronavirus, "severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2)," caused a highly contagious disease called coronavirus disease 2019 (COVID-19). It has severely damaged the world's most developed countries and has turned into a major threat for low- and middle-income countries. Since its emergence in late 2019, medical interventions have been substantial, and most countries relied on public health measures collectively known as nonpharmaceutical interventions (NPIs). We aimed to centralize the accumulative knowledge of NPIs against COVID-19 for each country under one worldwide consortium. International COVID-19 Research Network collaborators developed a cross-sectional online survey to assess the implications of NPIs and sanitary supply on the incidence and mortality of COVID-19. The survey was conducted between January 1 and February 1, 2021, and participants from 92 countries/territories completed it. The association between NPIs, sanitation supplies, and incidence and mortality were examined by multivariate regression, with the log-transformed value of population as an offset value. The majority of countries/territories applied several preventive strategies, including social distancing (100.0%), quarantine (100.0%), isolation (98.9%), and school closure (97.8%). Individual-level preventive measures such as personal hygiene (100.0%) and wearing facial masks (94.6% at hospitals; 93.5% at mass transportation; 91.3% in mass gathering facilities) were also frequently applied. Quarantine at a designated place was negatively associated with incidence and mortality compared to home quarantine. Isolation at a designated place was also associated with reduced mortality compared to home isolation. Recommendations to use sanitizer for personal hygiene reduced incidence compared to the recommendation to use soap. Deprivation of masks was associated with increased incidence. Higher incidence and mortality were found in countries/territories with higher economic levels. Mask deprivation was pervasive regardless of economic level. NPIs against COVID-19 such as using sanitizer, quarantine, and isolation can decrease the incidence and mortality of COVID-19.

KEYWORDS

COVID-19, isolation, mask, nonpharmacologic interventions, quarantine, sanitizer

1 | INTRODUCTION

In December 2019, several cases of pneumonia of unknown origin were reported in Wuhan City, China. A novel strain of virus, later named as severe acute respiratory syndrome coronavirus 2 (SARS-CoV2), was isolated from some of the patients.[1] Since then, the disease caused by the new coronavirus infection, later labeled as COVID-19, has infected more than 500 million people worldwide, with more than 6 million deaths until 15 April, 2022.[2]

Although a vaccination program is currently in progress, several SARS-CoV2 variants that can evade acquired immunity have risen.[3] Strategies for prevention inevitably still depend on nonpharmacologic interventions (NPIs), including preventive behaviors of individuals such as wearing facial masks and personal hygiene, simultaneously as governments continue their efforts to roll out vaccination for variants of SARS-CoV2.[4,5]

It has been demonstrated that lockdown is an effective NPI to fight against the pandemic.[4–6] For instance, a recent study across 11 European nations indicated that lockdowns have significantly reduced COVID-19 transmission.[7] A study on the transmission of COVID-19 and influenza in Hong Kong also presented the effectiveness of staying at home during the pandemic against disease transmission.[4] However, not all nations have observed the benefits of NPIs, and the detailed policies for lockdown also differed by nations. An analysis of the effects of physical distancing policies in 149 countries or regions showed that although the policies effectively decreased the incidence rate of COVID-19, nations with a higher gross domestic product and a higher health security index are more likely to have benefited from such policies; NPIs, seemingly, are more likely to be effective in nations with better economic status and governance capacity against public health crisis.[8]

Besides the application of NPIs, other factors could have affected the rate of propagation of COVID-19. For instance, there was a worldwide shortage of facial masks during the early stage of the pandemic, which is one of the most important sanitary supplies for prevention.[9] Although it is well known that wearing facial masks can prevent the spread of infectious disease,[10] there are no estimates on whether the nationwide experience of mask shortage compromised the preventive measures against COVID-19 and ultimately affected the incidence and mortality. It is well known that there are heterogeneities in the national capacity of applying adequate NPIs against COVID-19 and controlling its propagation. There are inequalities in the spreading of COVID-19[11] due to differences in governance capacity[12] and systematic resilience during the crisis.[13]

Most previous studies have investigated a single NPI within a single city or country level, and the results of them remained controversial. Few studies compared the efficacy of different NPIs.[14–16] To the best of our knowledge, no global-scale research has examined and compared the effect of multiple NPIs and supply shortages on the spread and death of COVID-19. As such, we designed and established a scientific consortium called the International COVID-19 Research Network (ICRN). One of the central projects of ICRN is to build a database that would congregate the disease characteristics, various treatment modalities used and their outcomes, fatality, policy responses, and socioeconomic impacts of COVID-19. As part of this effort, we investigated the effectiveness of eight of NPIs (organization, COVID-19 screening, wearing facial masks, social distancing measures, school closure, facility closure, quarantine and isolation, personal hygiene) and shortages in personal hygiene items, on the transmission of COVID-19 in 92 countries/territories between January 1 and February 1, 2021.

2 | METHODS

2.1 | Study population—ICRN

As of June 2020, ICRN collaborators include 172 participants representing 160 countries/territories. Detailed information on the ICRN and which countries/territories are in the network is presented in Supporting Information: Tables S1 and S2 and Figure S1. In this study, we tried to investigate the factors that affect the incidence and number of deaths of COVID-19, including governmental policies, individual-level NPIs, economic status, and supply shortages, by analyzing nationwide COVID-19 status through ICRN collaborators.

2.2 | Survey method

ICRN and its expert panels developed a cross-sectional online survey called Life and Policy Interventions during the Era of COVID-19.

Detailed information is presented in Supporting Information: Figure S2. The first part of the survey consists of questions on demographic information of countries/territories included in the survey. The second part of the survey was information on country-specific guidelines and screening for COVID-19. The subsequent sections were specific for data regarding masks, social distancing, changes, and adaptation of the educational system and facilities in response to COVID-19. Additionally, the survey assessed the country-specific quarantine and personal hygiene guidelines. Finally, it inquired about the presence of protective supplies shortage. On average, the questionnaire needed 30 min to self-complete. Our data team was responsible for collecting the data and the analysis. This team was supervised by the co-first authors and corresponding authors.

Data collection mainly took place between January 1 and February 1, 2021. Additional responses were gathered afterward. As a result, we were able to synthesize data from 92 countries/territories. Once the data collection was complete, all the answers and results were entered into a secure and password-protected Excel sheet. Since any personal data from each collaborator was not asked, collected data was strictly secondary.

The research was approved by the Institutional Review Board at Severance Hospital in October 2020 (IRB No. 4-2020-0998).

2.3 | Data collection

COVID-19 status of countries and territories including the number of cases, number of deaths, and number of diagnostic tests for COVID-19 were retrieved from: https://ourworldindata.org/coronavirus, which is published online at OurWorldInData.org.[17] Population of participating countries/territories were extracted from the World-ometer, accessed February 26, 2022, https://www.worldometers.info/population/.[18] Information on economic status was classified into four categories according to the classification of the World Bank classification on 2020; low-income countries (LICs), middle-LICs (MLICs), middle-high-income countries (MHICs), and high-income countries (HICs).[19] Geographical classification of each country/territory was in line with the classification given by Global Burden of Disease (GBD).[20]

Information on NPIs against COVID-19 was collected via the self-completed online survey. The questions for policies and situations were classified into nine categories: organization, COVID-19 screening, wearing facial masks, social distancing measures, school closure, facility closure, quarantine and isolation, personal hygiene, and shortages in personal hygiene items.

2.4 | Statistical analysis

For descriptive analysis, we provided means and standard deviations of log-transformed values for continuous variables and frequency and proportion for categorical variables. Kruskal–Wallis *H*-test and Fisher's exact test was used to compare descriptive statistics between subgroups. For trend analysis, the linear-by-linear method was performed for categorical variables, and Jonckheere's trend test for continuous variables.[21]

The effects of variables on the incidence and the number of deaths of COVID-19 were analyzed by multivariate regression analysis after adjusting for income, population, and the number of tested individuals.[22] Log-transformed values of confirmed cases and the number of deaths were used as the main outcome variables of linear regression with a log-transformed value of the total population as an offset value. To test the short-term and long-term effects, we set two different time points for evaluation: 14 and 28 days after implementation.

In all statistical analyses, a two-tailed p value of <0.05 was considered significant. Statistical analyses were performed using the SPSS for Windows version 25.0 (SPSS Inc.; IBM Corporation) and R version 4.0.2 (R Core Team).

3 | RESULTS

3.1 | General characteristics of countries and territories included in the survey

Among 172 ICRN collaborators, 98 collaborators filled out the survey. Two survey responses were obtained from Bulgaria, and three were from Italy. Survey data for Japan, Mongolia, and Korea were filed out by two collaborators each. Therefore, among 160 countries/territories in ICRN, 92 countries/territories replied and completed the online survey, which covered almost all regions classified by GBD except for Oceania (Table 1). The average number of confirmed COVID-19 cases among them was 953 574 at 2 weeks after the index date, and 1 011 936 at 4 weeks after the index date. The mean value of confirmed death due to COVID-19 was 20 374 at 2 weeks after the index date, and 21 920 at 4 weeks after the index date. Most countries/territories were classified as HICs (43.5%), followed by MHICs (26.1%), MLICs (18.5%), and LICs (12.0%).

Most countries/territories had a central organization responsible for COVID-19 control (90.2%). Also, most countries/territories had screening guidelines (89.1%) and screening centers (88.8%) for COVID-19. Item shortage was pervasive during the COVID-19 pandemic: more than half of the respondents reported personal protective equipment (P.P.E.) shortage (68.5%) and mask shortage (62.0%). Food and drink shortages (14.1%) and shortages in other materials (13.0%) were relatively less common than shortages in P.P.E. and facial masks.

All countries/territories applied enforcement of social distancing (100.0%), personal hygiene (100.0%), and quarantine (100.0%). Isolation, (98.9%), school closure (97.8%), wearing facial masks (94.6% at the hospital; 93.5% at mass transportation; 91.3% in mass gathering facilities), and facility closure (57.6% for mass transportation; 46.8% for hospital; 90.2% for mass gathering facilities) were commonly applied (Table 1). The majority of countries/territories implemented forced social distancing in large gatherings (76.1%), while social distancing in friends (forced 20.0%; recommended 80%), and others (forced 46.2%; recommended 53.8%)

TABLE 1 General characteristics of countries and territories included in the survey

	Total N/mean	(%)/SD
Total (*n* = 92)	92	(100)
Log(Case) (*n* = 92)[a]		
14 days after the index date	5.054	1.056
28 days after the index date	5.092	1.055
Log(Death) (*n* = 91)[a]		
14 days after the index date	3.269	1.137
28 days after the index date	3.310	1.138
Log(Test) (*n* = 63)[a]		
14 days after the index date	6.526	0.729
28 days after the index date	6.561	0.752
Log(Population) (*n* = 92)	7.131	0.704
Income (*n* = 92)		
Low income	11	(12.0)
Middle low income	17	(18.5)
Middle high income	24	(26.1)
High income	40	(43.5)
GBD regions (*n* = 92)		
Central Europe, Eastern Europe, and Central Asia	17	(18.5)
Central Asia	4	(4.3)
Central Europe	11	(12.0)
Eastern Europe	2	(2.2)
High income	24	(26.1)
Australasia	1	(1.1)
High-income Asia Pacific	4	(4.3)
High-income North America	2	(2.2)
Southern Latin America	1	(1.1)
Western Europe	16	(16.3)
Latin America and the Caribbean	8	(8.7)
Andean Latin America	1	(1.1)
Caribbean	2	(2.2)
Central Latin America	3	(3.3)
Tropical Latin America	2	(2.2)
North Africa and the Middle East	15	(16.3)
North Africa and the Middle East	15	(16.3)
South Asia	3	(3.3)
South Asia	3	(3.3)
Sub-Saharan Africa	17	(18.5)
Central sub-Saharan Africa	1	(1.1)
Eastern sub-Saharan Africa	5	(5.4)
Southern sub-Saharan Africa	2	(2.2)
Western sub-Saharan Africa	9	(9.8)
Southeast Asia, East Asia, and Oceania	8	(8.7)
East Asia	3	(3.3)
Southeast Asia	5	(5.4)
Oceania	0	(0.0)

[a]Index date means the date when each survey result was received. Index dates are dispersed between December 26, 2020 and February 5, 2021.

was often recommended only rather than forced. The quarantine was more likely to be forced in most countries/territories (63.7%). Most countries/territories considered 2 weeks or more (75.8%) as an adequate quarantine duration. Isolation policy was more likely to be forced in most countries/territories (69.6%), and only one nation did not apply isolation (1.1%; Yemen). Most countries/territories considered more than 2 weeks (72.5%) as adequate isolation duration. For personal hand hygiene, more than half of countries/territories recommended washing hands with soap (50.5%), while some recommended using soap or sanitizer (29.7%), or sanitizer only (19.8%; Table 1).

Since many countries/territories started school closure (97.8%), most of them started alternative learning courses through online classes (83.5%), while only a few of them prepared no alternative class (11.0%) or depended on education by parents (5.5%; Table 1).

3.2 | Association between national economic status, NPIs, and incidence and mortality of COVID-19

The incidence and number of deaths due to COVID-19 differed by national economic status: incidence and number of deaths were the highest in MHICs and the lowest in LICs (Table 2). The number of individuals who underwent screening tests was also associated with economic status: the number of tested individuals was the highest in HICs and the lowest in LICs (Table 2).

The majority of MLICs, MHICs, and HICs implemented mask policies at mass transportation, at hospitals, and at mass gathering facilities, while relatively few countries/territories in LICs implemented mask policies at mass transportation and at mass gathering facilities (Table 2).

The policy for hospital closure was heterogeneous by economic status ($p < 0.050$). Many MLICs and MHICs closed hospitals regardless of COVID-19 patient visits (closed without visits; 64.7% and 54.2%, respectively). However, most LICs and HICs did not close hospitals regardless of COVID-19 patient visits (not closed; 63.6% and 67.5% respectively). The quarantine policy also showed a difference by economic level ($p = 0.015$). There was no significant

TABLE 2 Association between income and other factors

	Total		Low income		Middle low income		Middle high income		High income			
	N or mean	(%) or SD	*N* or mean	(%) or SD	*N* or mean	(%) or SD	*N* or mean	(%) or SD	*N* or mean	(%) or SD	*p* Value[a]	*p* Value for trend[b]
Total (n = 92)	92	(100)	11	(12.0)	17	(18.5)	24	(26.1)	40	(43.5)		
Log(Case) (n = 92)[c]												
14 days after the index date	5.054	1.056	3.886	0.633	5.023	0.869	5.364	0.739	5.201	1.184	<0.001	0.001
28 days after the index date	5.072	1.055	3.931	0.637	5.061	0.859	5.409	0.721	5.236	1.192	<0.001	0.001
Log(Death) (n = 91)[c]												
14 days after the index date	3.268	1.136	2.306	0.767	3.147	1.089	3.588	0.981	3.397	0.467	0.006	0.014
28 days after the index date	3.310	1.137	2.342	0.771	3.188	1.089	3.631	0.968	3.437	0.485	0.006	0.011
Log(Case Fatality rate) (n = 91)[c]												
14 days after the index date	−1.822	0.384	−1.581	0.469	−1.876	0.374	−1.777	0.339	−1.895	0.371	0.135	0.123
28 days after the index date	−1.820	0.387	−1.588	0.472	−1.872	0.392	−1.778	0.339	−1.890	0.374	0.185	0.164
Log(Test) (n = 63)[c]												
14 days after index date	6.526	0.729	5.811	0.656	6.463	0.783	6.356	0.666	6.680	0.732	0.093	0.022
28 days after index date	6.562	0.752	5.536	0.690	6.482	0.785	6.458	0.643	6.741	0.742	0.033	0.008
Log(Population) (n = 92)	7.131	0.704	7.067	0.500	7.438	0.803	7.134	0.727	7.016	0.678	0.300	0.251
Organization (n = 92)												
Central organization	83	(90.2)	9	(81.8)	16	(94.1)	20	(83.3)	38	(95.0)	0.286	0.322
Screening (n = 92)												
Screening guideline	82	(89.1)	10	(90.9)	16	(94.1)	20	(83.3)	36	(90.0)	0.810	0.876
Screening center	81	(88.8)	10	(90.9)	16	(94.1)	20	(83.3)	35	(87.5)	0.777	0.653
Mask (n = 92)												
Mask place												
Mass transportation	86	(93.5)	8	(72.7)	17	(100.0)	24	(100.0)	37	(92.5)	0.022	0.234
Hospital (patient)	87	(94.6)	9	(81.8)	17	(100.0)	24	(100.0)	37	(92.5)	0.106	0.670
Mass gathering facilities	84	(91.3)	7	(63.6)	16	(94.1)	24	(100.0)	37	(92.5)	0.009	0.035
Mask type in general											0.177	0.828
No guideline	44	(47.8)	7	(63.6)	6	(35.3)	10	(41.7)	20	(52.5)		
Cloth	9	(9.8)	1	(9.1)	3	(17.6)	3	(12.5)	2	(5.0)		

TABLE 2 (Continued)

	Total		Low income		Middle low income		Middle high income		High income			
	N or mean	(%) or SD	*N* or mean	(%) or SD	*N* or mean	(%) or SD	*N* or mean	(%) or SD	*N* or mean	(%) or SD	*p* Value[a]	*p* Value for trend[b]
Dental	29	(31.5)	2	(18.2)	4	(23.5)	9	(37.5)	14	(35.0)		
FFP1	1	(1.1)	0	(0.0)	0	(0.0)	0	(0.0)	1	(2.5)		
FFP2	7	(7.6)	1	(9.1)	4	(23.5)	2	(8.3)	0	(0.0)		
FFP3	2	(2.2)	0	(0.0)	0	(0.0)	0	(0.0)	2	(5.0)		
Mask for healthcare workers[e]											0.264	0.217
No guideline	31	(33.7)	5	(45.5)	3	(17.6)	8	(33.3)	14	(37.5)		
Cloth	6	(6.5)	1	(9.1)	2	(11.8)	1	(4.2)	2	(5.0)		
Dental	16	(17.4)	0	(0.0)	1	(5.9)	6	(25.0)	9	(22.5)		
FFP1	11	(12.0)	1	(9.1)	2	(11.8)	2	(8.3)	6	(15.0)		
FFP2	4	(4.3)	0	(0.0)	3	(17.6)	0	(0.0)	1	(2.5)		
FFP3	24	(26.1)	4	(36.4)	6	(35.3)	7	(29.2)	7	(17.5)		
Social distance												
Social distance promote ($n = 21$)	92	(100.0)	11	(100.0)	17	(100.0)	24	(100.0)	40	(100.0)	NA	NA
Social distance type												
Friends ($n = 90$)											0.979	0.898
Recommended	72	(80.0)	7	(77.8)	14	(82.4)	20	(83.3)	31	(77.5)		
Forced	18	(20.0)	2	(22.2)	3	(17.6)	4	(16.7)	9	(22.5)		
Large gatherings ($n = 92$)											0.459	1.000
Recommended	22	(23.9)	3	(27.3)	5	(29.4)	3	(12.5)	11	(27.5)		
Forced	70	(76.1)	8	(72.7)	12	(70.6)	21	(87.5)	29	(72.5)		
Others ($n = 39$)											0.116	0.401
Recommended	21	(53.8)	6	(75.0)	4	(66.7)	3	(25.0)	8	(61.5)		
Forced	18	(46.2)	2	(25.0)	2	(33.3)	9	(75.0)	5	(38.5)		
Social distance depth ($n = 91$)											0.525	0.622
1 m	18	(19.8)	3	(27.3)	5	(31.3)	3	(12.5)	7	(17.5)		
1.5 m	15	(16.5)	0	(0.0)	3	(18.8)	4	(16.7)	8	(20.0)		
2 m or more	58	(63.7)	8	(72.7)	8	(50.0)	17	(70.8)	25	(62.5)		

(Continues)

TABLE 2 (Continued)

	Total		Low income		Middle low income		Middle high income		High income			
	N or mean	(%) or SD	N or mean	(%) or SD	N or mean	(%) or SD	N or mean	(%) or SD	N or mean	(%) or SD	p Value[a]	p Value for trend[b]
School close[f]												
School stop (n = 92)	90	(97.8)	11	(100.0)	17	(100.0)	24	(100.0)	38	(95.0)	0.771	0.340
School alternative (n = 91)											0.029	0.047
No online/offline class	10	(11.0)	2	(18.2)	0	(0.0)	3	(12.5)	5	(12.8)		
Online class	76	(83.5)	6	(54.5)	16	(94.1)	21	(87.5)	33	(84.6)		
Education by parents	5	(5.5)	3	(27.3)	1	(5.9)	0	(0.0)	1	(2.6)		
Facility close (n = 92)												
Closed mass transportation											0.203	0.478
Not closed	39	(42.4)	5	(45.5)	6	(35.3)	7	(29.2)	21	(52.5)		
After COVID patient Visit	4	(4.3)	0	(0.0)	2	(11.8)	2	(8.3)	0	(0.0)		
Without Visit	49	(53.3)	6	(54.5)	9	(52.9)	15	(62.5)	19	(47.5)		
Closed Hospital											0.050	0.175
Not Closed	49	(53.3)	7	(63.6)	5	(29.4)	10	(41.7)	27	(67.5)		
After COVID patient Visit	2	(2.2)	0	(0.0)	1	(5.9)	1	(4.2)	0	(0.0)		
Without visit	41	(44.6)	4	(36.4)	11	(64.7)	13	(54.2)	13	(32.5)		
Closed mass gathering facilities											0.386	0.652
Not closed	9	(9.8)	3	(27.3)	1	(5.9)	1	(4.2)	4	(10.0)		
After COVID patient visit	15	(16.3)	0	(0.0)	4	(23.5)	4	(16.7)	7	(17.5)		
Without visit	68	(73.9)	8	(72.7)	12	(70.6)	19	(79.2)	29	(72.5)		
Quarantine and Isolation												
Quarantine rules (n = 91)											0.015	0.027
No rules	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)		
Recommended	21	(23.1)	5	(45.5)	5	(29.4)	2	(8.3)	9	(23.1)		
Recommended and forced	12	(13.2)	2	(18.2)	5	(29.4)	3	(12.5)	2	(5.1)		
Forced	58	(63.7)	4	(36.4)	7	(41.2)	19	(79.2)	28	(71.8)		
Quarantine duration (n = 91)											0.576	0.640
1 week	22	(24.2)	3	(30.0)	3	(17.6)	4	(16.7)	12	(30.0)		
2 weeks or more	69	(75.8)	7	(70.0)	14	(82.4)	20	(83.3)	28	(70.0)		

TABLE 2 (Continued)

	Total		Low income		Middle low income		Middle high income		High income			
	N or mean	(%) or SD	*N* or mean	(%) or SD	*N* or mean	(%) or SD	*N* or mean	(%) or SD	*N* or mean	(%) or SD	*p* Value[a]	*p* Value for trend[b]
Quarantine place ($n = 91$)											0.583	0.141
Home	32	(35.2)	3	(30.0)	3	(17.6)	8	(33.3)	17	(45.0)		
Designated place[d]	18	(19.8)	2	(20.0)	5	(29.4)	4	(16.7)	7	(17.5)		
Home, designated place	41	(45.1)	5	(50.0)	9	(52.9)	12	(50.0)	15	(37.5)		
Isolation rules ($n = 92$)											0.354	0.170
No rules	1	(1.1)	1	(9.1)	0	(0.0)	0	(0.0)	0	(0.0)		
Recommended	17	(18.5)	3	(27.3)	3	(17.6)	3	(12.5)	8	(20.0)		
Recommended and Forced	10	(10.9)	1	(9.1)	4	(23.5)	2	(8.3)	3	(7.5)		
Forced	64	(69.6)	6	(54.5)	10	(58.8)	19	(79.2)	29	(72.5)		
Isolation duration ($n = 91$)											0.716	1.000
1 week	25	(27.5)	4	(36.4)	4	(23.5)	5	(20.8)	12	(30.8)		
2 weeks or more	66	(72.5)	7	(63.6)	13	(76.5)	19	(79.2)	27	(69.2)		
Isolation place ($n = 91$)											0.028	0.206
Home	24	(26.4)	0	(0.0)	4	(23.5)	4	(16.7)	16	(40.0)		
Designated place[d]	23	(25.3)	5	(50.0)	7	(41.2)	5	(20.8)	6	(15.0)		
Home, designated place	44	(48.4)	5	(50.0)	6	(35.3)	15	(62.5)	18	(45.0)		
Personal hygiene												
Hand hygiene ($n = 92$)	92	(100.0)	11	(100.0)	17	(100.0)	24	(100.0)	39	(100.0)	NA	NA
Hand hygiene type ($n = 91$)											0.804	1.000
Soap	46	(50.5)	5	(50.0)	9	(52.9)	14	(58.3)	18	(45.0)		
Sanitizer	18	(19.8)	1	(10.0)	2	(11.8)	5	(20.8)	10	(25.0)		
Soap or Sanitizer	27	(29.7)	4	(40.0)	6	(35.3)	5	(20.8)	12	(30.0)		
Item shortage ($n = 92$)												
Mask	57	(62.0)	9	(81.8)	9	(52.9)	13	(54.2)	26	(65.0)	0.370	0.762
P.P.E.	63	(68.5)	9	(81.8)	15	(88.2)	15	(62.5)	24	(60.0)	0.130	0.042

(Continues)

TABLE 2 (Continued)

	Total		Low income		Middle low income		Middle high income		High income			
	N or mean	(%) or SD	N or mean	(%) or SD	N or mean	(%) or SD	N or mean	(%) or SD	N or mean	(%) or SD	p Value[a]	p Value for trend[b]
Food and Drink	13	(14.1)	4	(36.4)	1	(5.9)	5	(20.8)	3	(7.5)	0.056	0.088
Other	12	(13.0)	5	(45.5)	2	(11.8)	3	(12.5)	2	(5.0)	0.009	0.003

Abbreviations: COVID, coronavirus disease 2019; P.P.E., personal protective equipment.

[a]Kruskall–Wallis test or Fisher's exact test was conducted.

[b]Jonckheere's trend test or linear-by-linear method was conducted.

[c]Index date means the date when the survey was received. Index dates are dispersed between December 26, 2020 and February 5, 2021.

[d]Home is not considered as a designated place.

[e]In case of no comment when asked if there were any other guidelines for wearing a mask other than the above-mentioned places (mass transportation, hospital, mass gathering facilities), the recommendation of a mask to be worn in general cases was used instead.

[f]There were some cases where online education and education by parents both exist, and in this case, it was considered an online class.

difference in the implementation of isolation, but the place for isolation showed a significant difference ($p = 0.028$).

Item shortage, especially lack of P.P.E. (p value for trend = 0.042) and other goods (p value for trend = 0.003) was more prominent in countries/territories with lower economic status, while mask deprivation was pervasive regardless of income groups (LICs 81.8%; MLICs 52.9%; MHICs 54.2%; HICs 65.0%). There was no significant difference in the presence of the central organization, screening protocol, social distancing, and personal hygiene.

3.3 | Association between national characteristics, preventive measures, sanitary item supply, and incidence of COVID-19

Incidence of COVID-19 was higher in countries/territories with higher economic status: MLICs, MHICs, and HICs showed significantly higher incidence compared to LICs (Figure 1). Countries/territories implementing a social distancing policy of 1.5 m and 2 m or more showed higher incidence than countries/territories with a social distancing policy of 1 m (Figure 1, $\beta = 0.154$, $p = 0.024$; $\beta = 0.156$, $p = 0.034$ at social distancing policy of 1.5 m; $\beta = 0.155$, $p = 0.023$; $\beta = 0.167$, $p = 0.023$ at social distancing policy of 2 m or more; Supporting Information: Table S3). Closing mass gathering facilities after COVID-19 patient visits were associated with increased cases compared to not closing (Figure 1, $\beta = 0.193$, $p = 0.024$; $\beta = 0.212$, $p = 0.021$; Supporting Information: Table S3). Quarantine policy at a designated place was negatively associated with incidence (Figure 1, $\beta = -0.154$, $p = 0.022$; $\beta = -0.166$, $p = 0.016$; Supporting Information: Table S3), compared to home quarantine. Recommendations to use sanitizer for personal hygiene reduced incidence compared to the recommendation to use soap (Figure 1, $\beta = -0.124$, $p = 0.031$; $\beta = -0.128$, $p = 0.038$; Supporting Information: Table S3). Lack of mask supply was linked with increased incidence of COVID-19 (Figure 1, $\beta = 0.176$, $p = 0.030$; $\beta = 0.229$, $p = 0.008$; Supporting Information: Table S3).

3.4 | Association between preventive measures, sanitary item supply, and mortality of COVID-19

Deaths from COVID-19 were higher in countries/territories with higher economic status: MHICs and HICs showed significantly higher incidence compared to LICs (Figure 2). Quarantine and isolation at a designated place were associated with lower percentages of deaths compared to home quarantine/isolation (Figure 2, $\beta = -0.224$, $p = 0.019$, $\beta = -0.226$, $p = 0.018$ at quarantine; $\beta = -0.445$, $p < 0.001$, $\beta = -0.458$, $p < 0.001$ at isolation; Supporting Information: Table S4). Isolation at home or designated place was also negatively associated with death compared to isolation at home (Figure 2, $\beta = -0.189$, $p = 0.025$; $\beta = -0.190$, $p = 0.027$; Supporting Information: Table S4).

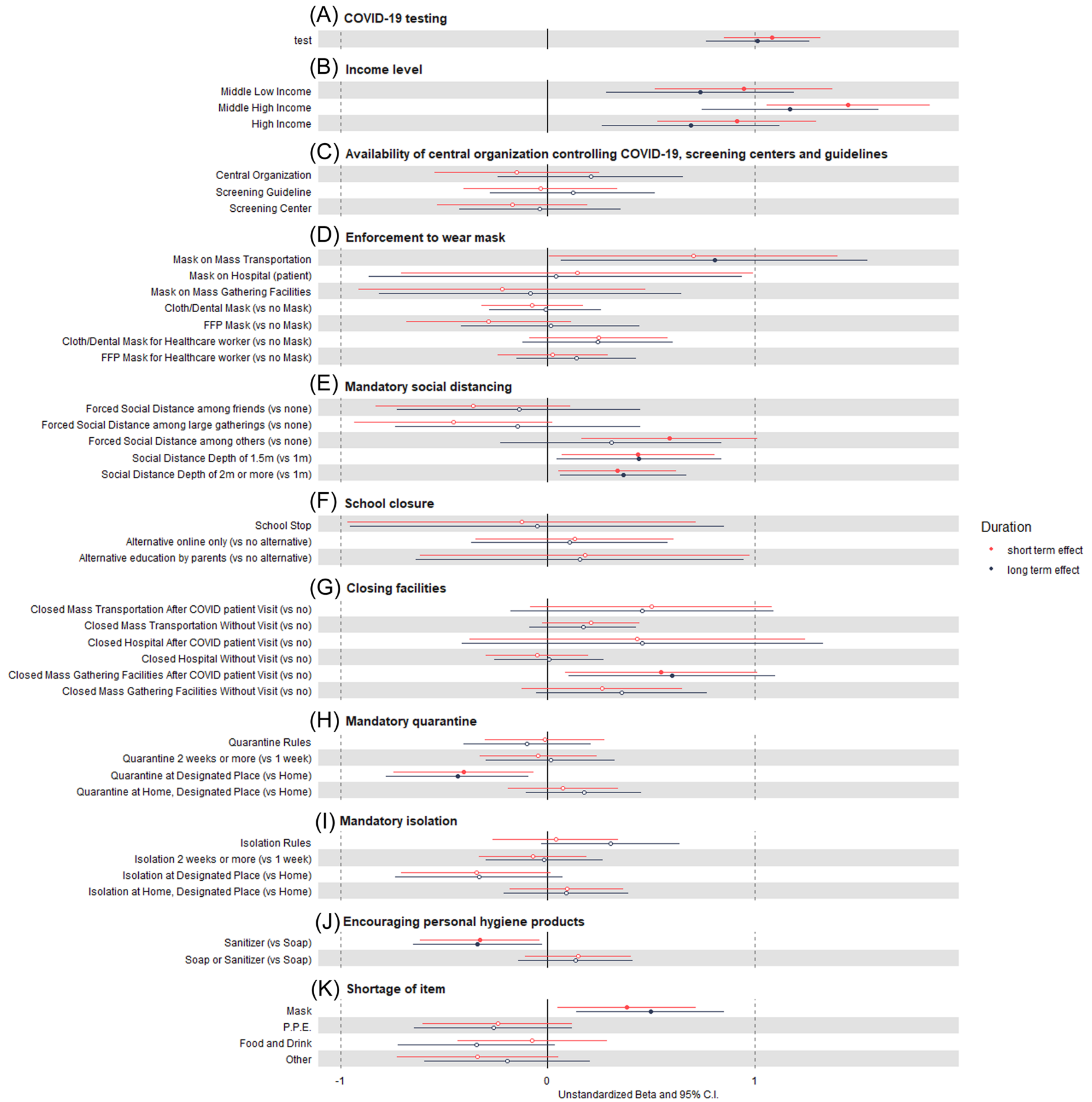

FIGURE 1 Association between COVID-19 confirmed cases and (A) COVID-19 testing, (B) Income level, (C) Availability of central organization controlling COVID-19, screening centers and guidelines, (D) Enforcement to wear mask, (E) Mandatory social distancing, (F) School closure, (G) Closing facilities, (H) Mandatory quarantine, (I) Mandatory isolation, (J) Encouraging personal hygiene products, and (K) Shortage of item. Short- and long-term effects represent confirmed COVID-19 cases after 14 and 28 days from intervention implementation, respectively. Detailed descriptions found in Supporting Information: Table S3. COVID-19, coronavirus disease 2019, P.P.E., personal protective equipment.

4 | DISCUSSION

In this study, we found that widely introduced NPIs in 92 countries/territories were negatively associated with the incidence and number of deaths of COVID-19. Active testing resulted in an increase in the incidence and the number of deaths of COVID-19. Countries/territories with higher income were more likely to report more cases and deaths compared to countries/territories with lower income. Countries/territories with quarantine at designated places presented lower incidence and number of deaths compared to countries/territories with quarantine at home. Using sanitizer was negatively associated with confirmed cases but using soap did not decrease the incidence. Deprivation of masks was also associated with increased incidence.

These results are concurrent with previous studies that indicated the effectiveness of public health interventions against COVID-19.[5,7,8] It has been proven that physical distancing interventions, including quarantine,[23,24] are effective in decreasing the incidence of infectious diseases. Before the initiation of the vaccination program, physical

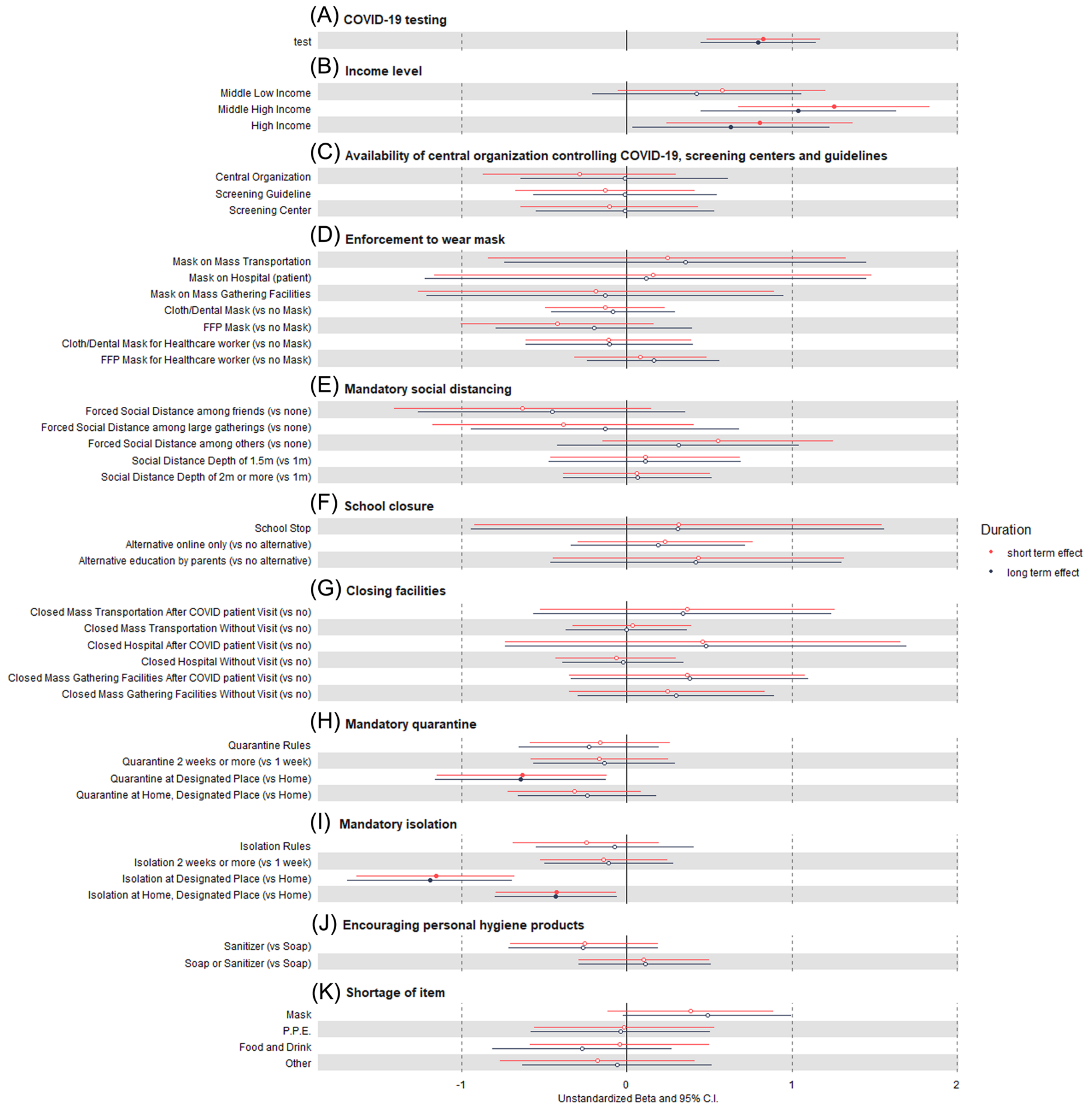

FIGURE 2 Association between the mortality of COVID-19 and (A) COVID-19 testing, (B) Income level, (C) Availability of central organization controlling COVID-19, screening centers and guidelines, (D) Enforcement to wear mask, (E) Mandatory social distancing, (F) School closure, (G) Closing facilities, (H) Mandatory quarantine, (I) Mandatory isolation, (J) Encouraging personal hygeine products, and (K) Shortage of item. Short- and long-term effects represent confirmed COVID-19 mortality after 14 and 28 days from intervention implementation, respectively. Detailed descriptions found in Supporting Information: Table S4. COVID-19, coronavirus disease 2019, P.P.E., personal protective equipment.

distancing was the most effective preventive intervention against emerging infectious diseases.[4,25] Our results reaffirm previous evidence that suggests the effect of NPIs during the pandemic on emerging infectious diseases.

Quarantine and isolation strategies are not homogeneous across the countries/territories, with differences in duration, location, and detailed method of quarantine and isolation.[26] In our study, we compared home restrictions to staying in designated facilities, and the effect of inhibiting the spread of infection was more significant when using designated facilities than when using a home. Quarantine at a designated facilities was negatively associated with incidence and mortality compared to home quarantine. Isolation at a designated place was also associated with reduced mortality compared to home isolation. Despite some arguments that compulsory quarantine or isolation may do more harm than good,[27] our result claims that these policies can be very effective in dealing with contagious diseases like COVID-19, if they are along with the designated place.

The shortage of masks was one of the NPIs that diversely presented among GBD regions ($p < 0.009$; Supporting Information: Table S5). Some regions had no lack of mask supply; nevertheless, more than half of the countries/territories complained about the shortage of masks, regardless of their economic status (Table 2). Although numerous countries/territories experienced mask shortages during the early stage of the pandemic, only a few of them with central organizations for controlling COVID-19 have established strategies to expand their supply procurement capacities. For instance, the South Korean government initiated a "dynamic response system," which includes demand planning and management, production capacity planning and expansion, and strategic production planning, which relieved supply shortages and prevented further propagation of COVID-19.[28] Due to the continuous lack of masks occurring in most countries/territories, the mask policy may not be enough to suppress the spread of disease. It could be interpreted from our results that albeit implementing the mask policy, the effect of it on the suppression of disease propagation was limited unless the mask shortage is not resolved. In addition, because the mask was not worn properly, implementing a mask policy may not have shown any effect on preventing the spread of infection. During the spread of COVID-19, people often reused masks, and studies on reusing them were also frequently conducted.[29,30] However, a comprehensive review of the mask-wearing policy emphasizes that masks alone are not effective and citizens should be accompanied by other preventive measures such as adequate personal hygiene to see the effect of wearing a mask.[31,32] Therefore, in a global epidemic situation, it will be important to ensure that masks are sufficient and to guide them to wear masks correctly.

The COVID-19 virus transmission is primarily through the droplets in the air, which are usually generated from speaking, coughing, or sneezing.[33,34] The transmission is also possible via respiratory droplets, which refers to droplets of 5–10 µm or less.[35] Droplets with sizes of 1–5 mm can usually be dispersed up to 2 m from the origin of infection.[36] Since droplets of 30 µm can spread up to 2.5 m away from the cougher, the respiratory droplets may even reach more than 2 m. The spread of the virus droplets can be prevented with a social distance of 2 m. But for the respiratory droplets, the social distancing of 2 m only is not sufficient.[37] In this case, wearing a mask is necessary since it can effectively diminish the generation of infectious aerosol from speaking or coughing. Therefore, the proper protection of a mask with a social distance of at least 2 m is reasonable to be regarded as effective protection.[38]

The Centers for Disease Control and Prevention has recommended not only using soap and water but also using alcohol-based (at least 60%) sanitizer.[39] Hand sanitizer products with alcohol-based formulations can inactivate viruses and denature proteins.[40] While the effect of hand sanitizer on nonenveloped viruses differs by the type of alcohol used, both isopropyl alcohol and ethyl alcohol are effective against enveloped viruses.[41] Therefore, using alcohol-based sanitizer can effectively prevent the spread of COVID-19, since coronavirus is an enveloped virus.[42]

When the occurrence of infectious diseases is viewed as an interaction between the host and the pathogen, the spread of infectious diseases is determined by the infectious reservoir, transmission path, and the pathogen's infectivity.[43] Eventually, from this point of view, measures to prevent the spread of infectious diseases are divided into four patterns; the elimination of the reservoir (isolation, quarantine), the reduction of infectivity (treatment of patients), disconnection of transmission pathways (social distancing, school closure, facility closure), and protection of sensitive people (personal hand hygiene, vaccination, mask wearing). Several studies have argued that measures taken regardless of symptom onset, such as masks wearing, social distancing, and reducing operating hours of public transportation, are effective.[32,44] In contrast, quarantine and isolation, which consider the symptom development, are treated as the most controversial public health measure.[45] Given the serious deprivation of personal freedom in the name of public health, quarantine and isolation expose tensions between social interests to protect citizens' health and individual civil liberties, such as privacy and prohibition of discrimination. These coercive public health measures can be only justified if the benefit to the public is greater than the burden or harm that quarantine or isolation can inflict on individuals' freedoms. Therefore, these policies should only be used if the disease is known to be contagious through extensive scientific research and should be limited to only people who are exposed to the disease.

What is noteworthy in the results of the study is that the elimination of the reservoir was the most effective preventive policy compared to other policies. This implies that quarantine and isolation may be a legitimate option rather than a coercive measure. These findings are in line with other previous studies that screening and examining people with symptoms faster and isolating those with symptoms are more important than implementing meaningless distancing policies.[46,47] For effective quarantine and isolation, it is important to treat the symptomatic group, the likely group to be infected, and the unexposed group differently. Therefore, faster examination of symptoms and appropriate measures for those who show symptoms should be taken with more emphasis rather than measures to alleviate COVID-19, regardless of symptom onset. An example of a policy that prioritizes the presence or risk of symptoms can be suggested in the mask policy. Howard et al.[44] argued that a limited number of masks should be provided first to those classified as risk groups showing symptoms. These policies considering symptoms will be very effective in the time of the spread of infectious diseases because mask shortages are frequently repeated.

Our study provides a comprehensive understanding of factors that are related to the incidence rate and the number of deaths from COVID-19 by analyzing data from 92 countries/territories. This is one of few studies that analyzed the association between multiple factors, including national characteristics, preventive policy implementation, supply shortages, and disease propagation during the current pandemic. Moreover, this policy is meaningful in that it reviewed the impact of NPIs worldwide before vaccination was widely implemented, and how it was effective to respond initially during the pandemic crisis.

However, our study has several limitations. First, as this study utilized a multivariate regression model for analyzing effects, reverse causation might have taken place. For instance, social distance depth and closure of mass gatherings were positively associated with the incidence rate. This association could be explained by reverse causation: countries/territories with an increasing number of confirmed cases are more likely to implement stronger policies on social distancing and facility closure.

Moreover, the effect we have estimated might not fully represent the trend of changing COVID-19 infections status, since numerous variants have emerged, which show different patterns of transmission and fatality from the original pathogen.[48] As behaviors of new variants are not fully understood, careful interpretation of our results is needed. Not only the variants but also sometimes different NPIs were applied within a country, and the interventions also changed over time. Further studies with more detailed data would help to reveal the relationship between NPIs and COVID-19.

Finally, since low- and middle-income countries (LMICs) had difficulty in managing the COVID-19 pandemic due to their lower resilience and capability for governance,[49] the estimated number of cases and death cases in LMICs might not be accurate. Our results show that countries/territories with higher income and higher number of tests are positively associated with incidence and number of deaths. This phenomenon could be explained by LMICs' lack of capability to test and cure COVID-19 patients, as the healthcare system of LMICs lacked the capability to withstand the current pandemic.[50] As they were not able to prioritize testing, quarantining, and curing suspected and confirmed COVID-19 patients, the incidence rate estimated from LMICs is not likely to fully represent the real-world status of COVID-19 infection.

5 | CONCLUSION

Our survey of 92 countries/territories provided a comprehensive understanding of the implementation of preventive strategies against COVID-19 and their effect on the incidence and the number of deaths of COVID-19. Our results from the collaborative network suggested that NPIs effectively decrease the incidence and the number of deaths of COVID-19, highlighting the importance of NPI implementation during an earlier stage of novel infectious disease. Further studies on the efficacy of NPIs against new variants of COVID-19 would provide a better understanding of appropriate preventive strategies against emerging variants.

AUTHOR CONTRIBUTIONS

Sung Hwi Hong and Jae Il Shin designed this study. Sung Hwi Hong and Jae Il Shin collected the data. Seung Hyun Park and Kwanghyun Kim performed the statistical analysis. Seung Hyun Park, Sung Hwi Hong, Kwanghyun Kim, and Jae Il Shin wrote the first draft of the manuscript. All authors had full access to all the study data. All authors reviewed, wrote, and approved the final version. The corresponding authors had final responsibility for the decision to submit for publication. ICRN collaborators are coauthor for this article.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Park SH, Hong SH, Kim K, et al. Nonpharmaceutical interventions reduce the incidence and mortality of COVID-19: a study based on the survey from the International COVID-19 Research Network (ICRN). *J Med Virol*. 2023;95:e28354. doi:10.1002/jmv.28354