ORIGINAL ARTICLE

State-Level Stay-at-Home Orders and Objectively Measured Movement in the United States During the COVID-19 Pandemic

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ABSTRACT

Objective: Social distancing has been one of the primary interventions used to slow the spread of COVID-19 during the ongoing pandemic. Although statewide stay-at-home orders in the United States received a large degree of media and political attention, relatively little peer-reviewed research has examined the impacts of such orders on social distancing behaviors.

Method: This study used daily GPS-derived movement from 2858 counties in the United States from March 1 to May 7, 2020, to test the degree to which changes in state-level stay-at-home orders were associated with movement outside the home.

Results: From early March to early April, people in counties with state-level stay-at-home orders decreased their movement significantly more than counties without state-level stay-at-home orders; 3.1% more people stayed within 1 mile of home, and 1.6% fewer vehicle miles were driven per day. From early April to early May, people in counties within states that ended their stay-at-home orders increased their movement significantly more than counties in states whose stay-at-home orders remained in place; 1.2% fewer people remained within 1 mile of home, and 6.2% more vehicle miles were driven per day. The magnitude of changes associated with state-level stay-at-home orders was many times smaller than the total changes in movement across all counties over the same periods.

Conclusions: Stay-at-home orders were associated with greater social distancing but accounted for only part of this behavioral change. Research on behavior change would be useful to determine additional interventions that could support social distancing during the COVID-19 pandemic.

Key words: COVID-19, social distancing, movement behavior, stay-at-home orders.

INTRODUCTION

The coronavirus disease of 2019 (COVID-19) pandemic had resulted in more than 1.7 million infections and more than 100,000 deaths in the United States as of June 1, 2020 (1,2). Because of the lack of pharmacological interventions, social distancing (3,4) became the primary strategy available to mitigate the spread of disease in the United States and globally during the first months of the pandemic. State and local governments enacted limitations on business and movement to reduce travel outside the home, with the goal of slowing the rate of infection (4). Stay-at-home orders became a focus of public health and political decision making based on the assumption that such orders determine people's behavior.

Should we expect that government orders would change people's movement? On the one hand, public health interventions can change behavior (5), and top-down mandates during a public health emergency may spur people to action. For example, stay-at-home orders may increase people's perceived risk of COVID-19 spread and outcomes and result in behavioral change, in line with the health belief model (5). On the other hand, health-relevant behaviors are determined by a number of factors (6), and people's movement could be unrelated to such orders. Decades of research have illustrated the challenges associated with changing health-relevant behaviors, as well as maintaining such change over time (5,6). Early evidence suggests that changes in people's movement did not correspond to when stay-at-home orders were enacted or ended (7,8), which may reflect wide heterogeneity in the timing, enforceability, and public support for stay-at-home orders at the state level. The extent to which people's movement outside the home is associated with changes in stay-at-home orders is an open question with direct relevance to future public health decision making. This study examined whether state-level stay-at-home orders were associated with changes in movement, as well as the magnitude of change associated with such orders compared with total change in people's behavior.

METHODS

Study Design

The current study used movement data from March 1 to May 7, 2020, collected using GPS-enabled devices and made accessible for research purposes by Cuebiq (https://www.cuebiq.com) and Streetlight Data (https://www.streetlightdata.com). Daily data from Streetlight were made available starting March 1, which was used as the start of the study period. Data were aggregated at the county level; no individual-level data were used for this study. US counties were included if they had both sources of movement

CI = confidence interval, **COVID-19** = coronavirus disease of 2019

SDC Supplemental Digital Content

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data ($N = 2858$; 92.1%). The total population of these counties accounted for roughly 322.5 million Americans in 2019, approximately 98.2% of the US population (~328.2 million). Streetlight did not include movement data on any counties in Alaska ($n = 29$) and Hawaii ($n = 5$), or 247 additional counties in the continental United States. Cuebiq data did not provide data for two additional counties. See a list of excluded counties (Supplemental Digital Content, http://links.lww.com/PSYMED/A710).

Measures

Movement Behavior

Daily movement was assessed using two outcomes, the *percentage of people staying within 1 mile of home* and *vehicle miles traveled*. Both outcomes used data from millions of individual GPS-enabled devices aggregated at the county level by Cuebiq and Streetlight Data. Cuebiq data measured the maximum distance people traveled from their homes (<300 ft, between 330 ft and 1 mile, between 1 and 10 miles, and >10 miles). Daily estimates of percentage of people staying within 1 mile of home were used for the current study. Streetlight data measured vehicle miles traveled, derived using a proprietary algorithm applied to the Cuebiq Mobility Index, a continuous measure of movement calculated separately from the distance people traveled from home. Change in vehicle miles was benchmarked to the vehicle miles traveled during the baseline period. Data were averaged during three periods: March 1–7, April 1–7, and May 1–7. March 1–7 was used as the baseline period. These dates were after the first recorded cases in the United States in late January (2), but notably were before when the United States first reached 1000 total cases (March 11) (2) or a national state of emergency was declared because of COVID-19 (March 13). April 1–7 was used because it was the period that roughly corresponded to the least movement outside the home during the study dates. May 1–7 was used as the final period under investigation for which data were available at the time of analysis. Study outcomes included changes in the weekly averages of the movement outcomes from March to April and from April to May. Seven-day moving averages were calculated using the average of each date, along with the 3 days before and after it. Values were coded as missing if 4 or more days of data was unavailable.

Stay-at-Home Orders

Public media sources were used to collect data on state-level stay-at-home orders (or similar orders; e.g., shelter-in-place). For the March to April period, counties were coded as being in a state that enacted a stay-at-home order (85.2%) or not (14.8%). For the April to May period, counties were coded as being in a state with a stay-at-home order that remained in place on May 7 (43.4%) or no stay-at-home order on May 7 (56.6%). The latter group included counties in states that ended their stay-at-home order or never enacted a stay-at-home order. Counties were also coded by the date when stay-at-home orders were enacted or ended to create additional categories. See Supplemental Digital Content, http://links.lww.com/PSYMED/A710, for a list of these categories and full stay-at-home order data.

County-Level Covariates

Data from the 2019 County Health Rankings & Roadmaps were used for county-level demographic and socioeconomic covariates. Variables included county-level population, percentage of the population defined as rural, median household income, and percentage of the county population with a college degree. These data were derived from American Community Survey, Small Area Income and Poverty Estimates, and Census Population Estimates

Data Analysis

This study used multiple regression models to test whether changes in movement were associated with state-level stay-at-home orders. The first set of models examined whether counties in states that enacted a stay-at-home order saw a greater decrease in movement outside the home from the first week of March to the first week of April. The second set of models examined whether counties in states that ended their stay-at-home orders before May 7 saw a greater increase in movement outside the home from the first week of April to the first week of May. Models first examined the bivariate association between stay-at-home orders and change in movement, then examined this association when adjusting for covariates at the county level: population, rurality, education, household income, and baseline movement. Analyses were conducted in SPSS version 26.

RESULTS

There were baseline differences between counties in states that enacted a stay-at-home compared with those that did not at the start of the study period. Counties in states that enacted a stay-at-home order had significantly fewer people remaining within 1 mile of home (26.3% compared with 27.9%, $t = 6.13$, $p < .001$) and significantly more vehicle miles being traveled at baseline (5.5 million compared with 2.4 million, $t = 4.63$, $p < .001$) during the first week of March. Similarly, counties in states that enacted a stay-at-home order were more populated ($t = 4.66$, $p < .001$) and less rural ($t = 4.28$, $p < .001$).

Decreases in County-Level Movement From March to April

From the first week of March to the first week of April, counties in states that enacted a stay-at-home order had 3.1% more people remain within 1 mile of home (95% confidence interval [CI] 2.6%–3.6%, $p < .001$) and 1.6% fewer vehicle miles traveled (95% CI = 0.6%–2.6%, $p = .002$) compared with counties in states that did not enact a stay-at-home order. This difference was 7.1 times smaller than the total increase in people staying within 1 mile of home (21.9%) and 40.2 times smaller than the total decrease in vehicle miles people traveled (64.3%) during the same period. These results were relatively unchanged when adjusting for county-level population, rurality, education, household income, and baseline movement (Table 1). When examining changes in daily movement during the entire period from early March to early April, decreases in movement stabilized by approximately March 23, 4 days earlier than the average date on which states issued a stay-at-home order (Figure 1).

Increases in County-Level Movement From April to May

From the first week of April to the first week of May, counties in states that ended their stay-at-home orders by May 7 saw 1.2% fewer people remain within 1 mile of home (95% CI = 1.0%–1.4%, $p < .001$) and 6.2% more vehicle miles traveled (95% CI = 4.6%–7.9%, $p < .001$) compared with counties in states that maintained their stay-at-home orders. This difference was 8.2 times smaller than the total decrease in people staying within 1 mile of home (9.8%) and 9.1 times smaller than the total increase in vehicle miles traveled (56.6%) during the same period. These results were relatively unchanged when adjusting for county-level population, rurality, education, household income, and baseline movement (Table 1). When examining changes in daily movement during the entire period from early April to early May, increases in movement began in mid-April, before the earliest date that state-level stay-at-home orders were ended, April 26 (Figure 2). The results suggest that stay-at-home orders were significantly associated with change in movement, but these effects were small in

TABLE 1. The Association Between Changes in State-Level Stay-at-Home Orders and Movement Behavior

	Bivariate Associations		Adjusting for Covariates	
	B	95% CI	*B*	95% CI
Movement associated with enacting a stay-at-home order				
Increase in % remaining within 1 mile of home	3.10**	2.61–3.60	2.91**	2.61–3.22
Decrease in % of vehicle miles traveled	1.60**	0.58–2.61	2.56**	1.85–3.26
Movement associated with ending a stay-at-home order				
Decrease in % remaining within 1 mile of home	1.20**	1.04–1.36	1.58**	1.42–1.74
Increase in % of vehicle miles traveled	6.25**	4.62–7.87	7.25**	5.56–8.94

N = 2858.

Movement associated with enacting a stay-at-home order assessed changes in movement from the first week of March to the first week of April for counties in states that enacted a stay-at-home order compared with those that did not. *Movement associated with ending a stay-at-home order* assessed changes from the first week of April to the first week of March for counties in states whose stay-at-home order remained in place on May 7, 2020, compared with those that did not. Models adding covariates included county-level baseline movement, population, rurality, household income, and education as additional predictors.

CI = confidence interval.

*$p < .05$.

**$p < .01$.

magnitude compared with the total change in movement during the two study periods (Figure 3).

DISCUSSION

The current study examined the association between state-level stay-at-home orders and changes in movement outside the home in 2858 US counties. People decreased their movement more from March to April in counties whose states enacted stay-at-home orders. People increased their movement more from April to May in counties within states that ended their stay-at-home orders or did not have them to begin with. State-level stay-at-home orders were associated with significantly less movement, but the magnitude of the decrease in movement accounted for by stay-at-home orders was many times smaller than the total reduction in movement. Changes in daily movement occurred before the earliest date that stay-at-home orders were enacted or ended, suggesting stay-at-home orders played only a part in shaping the overall pattern of behavior change. These findings match well with recent evidence that the rate of hospitalizations in late March 2020 from COVID-19 slowed several days earlier than would be expected based on the date of stay-at-home orders in four states (9), suggesting that social distancing increased before such orders. Stay-at-home orders alone are likely insufficient to change behavior to the degree observed during the study period. Future efforts to promote social distancing would likely benefit from additional public health interventions to supplement state-level stay-at-home orders.

These results highlight the importance of using objectively measured movement to assess the extent to which people travel

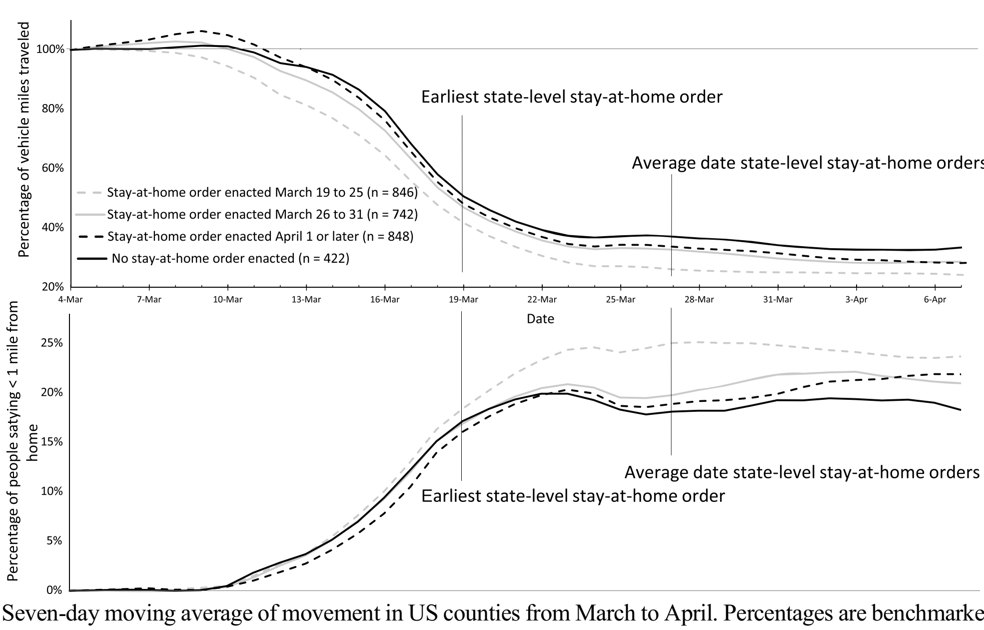

FIGURE 1. Seven-day moving average of movement in US counties from March to April. Percentages are benchmarked to the first week of March.

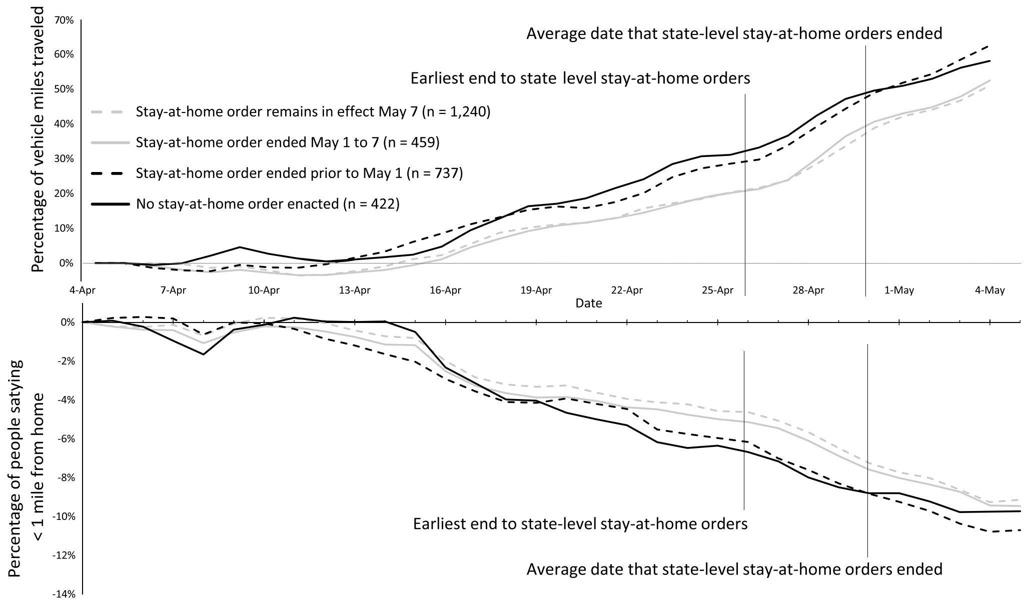

FIGURE 2. Seven-day moving average of movement in US counties from April to May. Percentages are benchmarked to the first week of April.

outside their home rather than making inferences based on state-level stay-at-home orders. A state ending a stay-at-home order, for example, does not mean people immediately revert to their prepandemic travel routines in that state. If stay-at-home orders are assumed to drive the majority of people's behavior, movement would be expected to revert to prepandemic levels in states that ended such orders. This assumption, however, would lead to spurious conclusions regarding viral transmission risk associated with movement outside the home. For example, if movement behavior remained similar among states with different stay-at-home orders, similar infection rates among those states would give the impression that increased movement outside the home was unrelated to increased rate of infection.

There are limitations to the current study. First, this study did not directly assess the number of close-proximity contacts people had outside their homes. Movement behavior is likely to be highly correlated with such contacts, but it is also possible for people to be outside the home and maintain social distancing principles. Similarly, this study did not assess mask-wearing behavior. Wearing masks has been shown to reduce viral transmission curing closer contact situations (10), and accounting for mask wearing in addition to movement would be useful when studying rates of viral transmission. Second, this study tested the association between movement and only one type of public health action (state-level stay-at-home-orders). There were a number of other public health actions that may have affected people's behavior. Third, the current study used data aggregated at the county-level. Studies of individuals' behavior may provide more information about how people's social distancing behaviors changed in response to state-level stay-at-home orders. Fourth, the current study used movement during March 1–7 as the baseline period. Changes in movement behaviors from March to May likely include seasonal changes in movement behavior that are obscuring the proportion of change in movement solely related to the pandemic and state-level stay-at-home orders. Finally, the current results are aggregated at the county level and need to be interpreted within

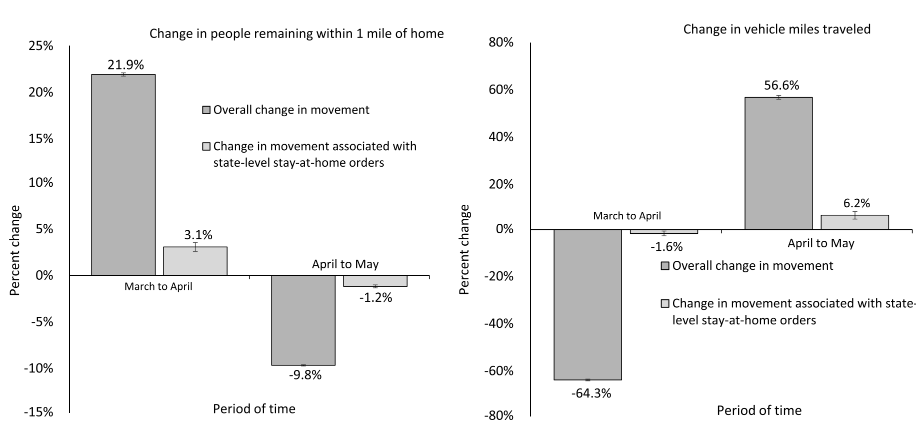

FIGURE 3. Comparing the overall magnitude of changes in movement with changes in movement associated with state-level stay-at-home orders. Error bars represent 95% confidence intervals.

that context. Future studies would benefit from examining how state-level stay-at-home orders may impact behavior at the individual level.

The small but significant change in social distancing behavior associated with state-wide stay-at-home orders matches well with what would be expected from an intervention targeting a multiply-determined health behavior. Interventions are most successful when they target various levels that influence behavior (11), and state-level stay-at-home orders by definition operate at a single level. Changes in movement are undoubtedly affected by numerous variables beyond whether a state enacts or ends a stay-at-home order. For example, people in states without stay-at-home order may have been influenced by other states that enacted such orders—increasing their perception of danger related to COVID-19—or other government actions, such as the closure of schools or restaurants. A similar process could operate at a national level, in which the way that trusted public officials discussed the danger (or lack of danger) related to the pandemic influenced people's behavior, regardless of their local or state ordinances. Finally, people's movement outside the home might also be related to types and amount of commercial activities that are open outside the home (e.g., restaurants and gyms), beyond whether or not a stay-at-home order is in effect.

Given empirical evidence linking movement and conventional health behaviors (e.g., smoking and physical activity) (12), previous social and behavioral scientific research (11,13) on health behavior (14) and health behavior change (5,6,15) could be productively used to promote social distancing behaviors if it becomes necessary to do so in the future. For example, intervening across multiple levels—at the level of the individual, neighborhood, and nation—would likely be more effective than interventions exclusively addressing only the state level (16). Such efforts would align well with social ecological models of behavior change (11). In addition, more consistent messaging from public officials regarding the importance of social distancing and the dangers posed by COVID-19 could increase the perception of threat associated with COVID-19, improving health-protective behaviors that reduce viral transmission, such as reduced movement outside the home. Internationally, countries such as France and South Korea have also enacted fines or criminal penalties for those who did not follow stay-at-home orders (17,18). It is possible that consistent enforcement of stay-at-home orders could amplify the effect of such orders, although the data from this study cannot speak to this directly. Regardless of the specific method, if hospitalizations from COVID-19 begin to increase and approach levels that health care systems cannot sustain, it will likely necessitate the use of new public health efforts to increase social distancing, and these results suggest the importance additional public health interventions to supplement state-level stay-at-home orders.

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REFERENCES

1. Lai CC, Shih TP, Ko WC, Tang HJ, Hsueh PR. Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and coronavirus disease-2019 (COVID-19): the epidemic and the challenges. Int J Antimicrob Agents 2020;55:105924.
2. Center for Disease Control and Prevention. Coronavirus disease 2019 (COVID-19): cases in the U.S. Available at: https://www.cdc.gov/coronavirus/2019-ncov/cases-updates/cases-in-us.html/. Accessed June 1, 2020.
3. Center for Disease Control and Prevention. Social distancing. Available at: https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/social-distancing.html. Accessed June 1, 2020.
4. Koo JR, Cook AR, Park M, Sun Y, Sun H, Lim JT, Tam C, Dickens BL. Interventions to mitigate early spread of SARS-CoV-2 in Singapore: a modelling study. Lancet Infect Dis 2020;20:678–88.
5. Glanz K, Bishop DB. The role of behavioral science theory in development and implementation of public health interventions. Annu Rev Public Health 2010;31:399–418.
6. Kelly MP, Barker M. Why is changing health-related behaviour so difficult? Public Health 2016;136:109–16.
7. Malone C, Bourassa KJ. Americans didn't wait for their governors to tell them to stay home because of COVID-19. FiveThirtyEight 2020. Available at: https://fivethirtyeight.com/features/americans-didnt-wait-for-their-governors-to-tell-them-to-stay-home-because-of-covid-19/. Accessed June 1, 2020.
8. Dance GJX, Gamio L. As coronavirus restrictions lift, millions in U.S are leaving home again. *New York Times* 2020. Available at: https://www.nytimes.com/interactive/2020/05/12/us/coronavirus-reopening-shutdown.html. Accessed June 1, 2020.
9. Sen S, Karaca-Mandic P, Georgiou A. Association of stay-at-home orders with COVID-19 hospitalizations in 4 states. JAMA 2020;323:2522–4.
10. Liang M, Gao L, Cheng C, Zhou Q, Uy JP, Heiner K, Sun C. Efficacy of face mask in preventing respiratory virus transmission: a systematic review and meta-analysis. Travel Med Infect Dis 2020;36:101751.
11. Sallis JF, Owen N, Fisher E. Ecological models of health behavior. Health Behav 2015;5:43–64.
12. Bourassa KJ, Sbarra DA, Caspi A, Moffitt TE. Social distancing as a health behavior: county-level movement in the United States during the COVID-19 pandemic is associated with conventional health behaviors. Ann Behav Med 2020;54:548–56.
13. West R, Michie S, Rubin GJ, Amlôt R. Applying principles of behaviour change to reduce SARS-CoV-2 transmission. Nat Hum Behav 2020;4:451–9.
14. Bavel JJV, Baicker K, Boggio PS, Capraro V, Cichocka A, Cikara M, Crockett MJ, Crum AJ, Douglas KM, Druckman JN, Drury J, Dube O, Ellemers N, Finkel EJ, Fowler JH, Gelfand M, Han S, Haslam A, Jetten J, Kitayama S, Mobbs D, Napper LE, Packer DJ, Pennycook G, Peters E, Petty RE, Rand DG, Reicher SD, Schnall S, Shariff A, Skitka LJ, Smith SS, Sunstein CR, Tabri N, Tucker JA, Linden SV, Lange PV, Weeden KA, Wohl MJA, Zaki J, Zion SR, Willer R. Using social and behavioural science to support COVID-19 pandemic response. Nat Hum Behav 2020;4:460–71.
15. Glanz K, Rimer BK, Viswanath K. Health Behavior and Health Education. San Francisco, CA: Josey Bass; 2008.
16. Richard L, Gauvin L, Raine K. Ecological models revisited: their uses and evolution in health promotion over two decades. Annu Rev Public Health 2011;32:307–26.
17. Shin H. South Korea warns of deportation, jail for quarantine violators. Reuters 2020. Available at: https://www.reuters.com/article/us-health-coronavirus-southkorea-cases/south-korea-warns-of-deportation-jail-for-quarantine-violators-idUSKBN21D06C. Accessed December 2, 2020.
18. Adamson T, Cook L, Petrequin S. France Says People Must Stay Home to Slow Spread of Virus. Paris, France: AP; 2020. Available at: https://apnews.com/article/6a9e2e55e28da2c1c044472b64443032. Accessed December 2, 2020.