World Medical and Health Policy

Statewide COVID-19 Stay-at-Home Orders and Population Mobility in the United States

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Many jurisdictions enacted stay-at-home orders (also called shelter-in-place orders, safer-at-home orders, or lockdowns) when SARS-CoV-2 began spreading in the United States. Based on Google mobility data, every state had substantially fewer visits to transit stations, retail and recreation facilities, workplaces, grocery stores, and pharmacies by the end of March 2020 than in the previous two months. The mean decrease in visitation rates across destination categories was about 30 percent in states without stay-at-home orders and 40 percent in states with stay-at-home orders. Similarly, there were fewer routing requests received by Apple in large cities for public transportation, walking, and driving, with a 10 percentage point greater mean reduction in metropolitan areas under statewide stay-at-home orders. The pandemic led to large decreases in mobility even in states without legal restrictions on travel, but statewide orders were effective public health policy tools for reducing human movement below the level achieved through voluntary behavior change.

KEY WORDS: coronavirus, transportation, health behavior

Introduction

The public health measures used to prevent and control the transmission of infectious diseases include a variety of nonpharmaceutical interventions (NPIs). For contagious infections, one of the most valuable NPIs is limiting the number of contacts between potentially infected individuals and those who might be susceptible to the pathogen. During an epidemic or a pandemic of an infectious disease, public health prevention and control interventions may include restrictions on local and international travel and trade (Jacobsen, 2018). Some forms of "social distancing" or "physical distancing" may be voluntary, but others may be mandated by governments and enforceable by law.

One way to reduce contacts is to separate infectious individuals from the general population. Measures used to prevent individuals who have a confirmed diagnosis of an infectious disease from infecting caregivers, other health-care staff, and other patients have typically been described as *isolation* (Wilder-Smith & Freedman, 2020). Isolation protocols in hospitals may require patients to be treated in negative pressure rooms, and personnel who enter the treatment room may need to wear full protective gear, including gloves, gowns, eye protection, and face masks or shields.

doi: 10.1002/wmh3.350

A second option is to restrict the movements of apparently healthy contacts of infected individuals so that those individuals will not be at risk of infecting others if there is a period of contagiousness before the onset of symptoms. This approach is generally referred to as *quarantine,* and it typically involves healthy contacts of infected individuals being required to stay away from others until they become ill (at which time they may be considered to be under isolation rather than being quarantined) or enough time has passed that there is no risk that they are contagious even in the absence of symptoms (Parmet & Sinha, 2020). Quarantine is usually applied to primary contacts, defined as individuals who are known to have had contact with a case. Quarantine may also be applied to secondary contacts, who are individuals known to have had contact with a primary contact of a case. Quarantine often occurs at home, but it is also legal to confine quarantined individuals at another location. Quarantine measures imposed inequitably, without transparency, or for longer than strictly necessary may raise ethical concerns about human rights violations (Passaro, 2018; Wynia, 2007).

The SARS-CoV-2 pandemic required a rethinking of the options for controlling the spread of a pathogen within borders and across borders (Cohen & Kupferschmidt, 2020). China banned travel out of heavily affected cities and implemented lockdowns on millions of residents (Fang, Wang, & Yang, 2020; Kraemer et al., 2020), Italy implemented quarantines in a few towns in the north before expanding those restrictions nationwide (Paterlini, 2020), and other countries also moved quickly to identify the options for slowing the rate of new infections, whether through national edicts or locally imposed rules.

Isolation and quarantine measures typically are applied to just a few patients and the few individuals who may have had contact with those patients, and it is unusual to quarantine an entire neighborhood or town. Because implementation of widespread restrictions on movement in response to a pandemic has historically been rare (Barbisch, Koenig, & Shih, 2015), there were few examples of large-scale mobility limitations to draw on when the novel coronavirus emerged. There was also limited evidence of whether such measures would be acceptable to the public and whether the proportion of the population in areas under movement restriction orders who strictly adhered to the required behavior changes would be sufficient to significantly reduce the transmission rate.

In the United States, the first coronavirus-related activity restrictions were issued on March 12, 2020, when a community within New Rochelle, New York, was declared to be a "containment area." A traditional quarantine order would require individuals presumed to be exposed to stay at home. This containment order was not intended to limit individual movement. Instead, it mandated the closure of schools and large gathering places within the zone, including religious buildings (Chappell, 2020). Residents were allowed to enter and leave the containment zone, but they were not allowed to gather in large groups within the designated geographic area.

On March 16, 2020, a "shelter-in-place" order was issued for six counties in the San Francisco Bay Area (Allday, 2020). *Shelter in place* was a term many Californians were familiar with due to its use during wildfires and other natural disasters, active

shooter drills, and other short-term emergency situations. In those contexts, "shelter in place" means "stay where you are," but that was not what the COVID-19 orders were asking residents to do. The order did not require individuals to stay where they happened to be located when the order was released. Residents were allowed to leave home for essential purposes, including food, medical care, and outdoor exercise, and people working at businesses deemed to be "essential"—such as grocery stores, hospitals, pharmacies, veterinary clinics, utilities, hardware stores, auto repair shops, funeral homes, and warehouses and distribution facilities—were allowed to continue onsite work.

Within a few weeks after the first shelter-in-place orders were issued in the United States there was a shift toward this type of decree generally being referred to as a *stay-at-home* order (Opam, 2020). The new language was required because stay-at-home orders that apply to whole nations or entire states or provinces are not traditional quarantine measures due to most individuals under the orders not being confirmed contacts of individuals with confirmed infections. Later on, some governors and mayors began using the term *safer-at-home* to describe their orders. Colloquially, the term *lockdown* was also used. However, as of the end of April 2020 the terminology remained unsettled and somewhat confusing.

The first statewide order in the United States that restricted mobility to reduce the transmission of coronavirus was issued by California's governor on March 19, 2020, and it required all residents to remain at home except when engaging in essential activities (Friedson, McNichols, Sabia, & Dave, 2020). This was quickly followed by statewide orders restricting nonessential travel outside the home in Illinois and New Jersey on March 21, New York on March 22, and six additional states on March 23 (Connecticut, Louisiana, Ohio, Oregon, Washington, and West Virginia).

As testing showed that local transmission of SARS-CoV-2 was occurring in jurisdictions across the United States, local- and state-issued stay-at-home orders became increasingly common. Although there was no national directive mandating that states implement particular coronavirus control actions, the number of states with statewide stay-at-home orders increased from 9 on March 23, 2020 to 21 on March 26, 30 on March 30, and 41 on April 3 (Mervosh, Lu, & Swales, 2020). This piecemeal action led to calls for more coordinated decision making across states with respect to measures that might limit the spread of the novel coronavirus (Haffajee & Mello, 2020).

Part of the hesitancy some government officials expressed about implementing and enforcing stay-at-home measures was uncertainty about their effectiveness. For example, when defending the decision not to implement a stay-at-home order, Governor Asa Hutchinson of Arkansas said he continued to ask himself "Are you accomplishing anything by doing that order?" (Brantley, 2020). The lack of an evidence base about what types of restrictions are necessary, how long the restrictions must stay in place to be effective, and how stay-at-home orders should be enforced made decision making difficult (Gostin & Wiley, 2020). Computer models could predict outcomes of "lockdowns" based on various sets of parameters (Sjödin, Wilder-Smith, Osman, Farooq, & Rocklöv, 2020), but the scarcity of

real-world data about the impact of large-scale mobility restrictions meant that there was considerable uncertainty about the validity of the models' projections.

An important limitation of the computer models was that they could not predict whether residents would actually adhere to guidelines or mandates, especially in places with small police forces that did not have the means (or, in some cases, the desire) to fine, arrest, and imprison people who violated the orders. Evidence about the effectiveness of stay-at-home orders at generating population-level behavior change will be critical for enabling policymakers to make informed decisions about when to implement stay-at-home orders, when they can safely be relaxed, and how they should be enforced. This paper examines how mobility patterns changed during the early stages of community spread of SARS-CoV-2 in the United States and the extent to which stay-at-home orders were effective at generating behavior change.

Methods

Google's *COVID-19 Community Mobility Reports* present state-specific information about trends in Google users' locations over time (Google, 2020). We merged these data with information on the date of enactment of stay-at-home orders in order to compare visits to various types of destinations in states that had and had not implemented stay-at-home orders by March 29, 2020 (Mervosh et al., 2020). In our analysis, change in visits reflects the change in visits by March 29, 2020, relative to the median visitation rate between January 3 and February 6, 2020. We use this date in part due to data availability as of the writing of this manuscript in April 2020, but also because March 29 was a date when only about half of states had issued stay-at-home orders so the impacts of policy differences could be examined.

The rate of decrease in travel to various types of locations was accessed for 51 observations (50 states plus the District of Columbia). The mean rates of decrease for destinations was calculated for states with and without stay-at-home orders. Tests for differences in the mean rates of decrease in visits were conducted using independent samples *t* tests. For states without statewide stay-at-home orders, we also used *t* tests to compare differences in visitation rates based on whether local (city or county) stay-at-home orders had been initiated anywhere within the state as of March 29.

Apple's *Apple COVID-19 Mobility Trends Reports* present data about changes in the rate of Apple Map route requests in selected cities around the world, including 15 metropolitan areas in the United States: Atlanta, Baltimore, Boston, Chicago, Dallas, Denver, Detroit, Houston, Los Angeles, Miami, New York City, Philadelphia, San Francisco (Bay Area), Seattle, and Washington DC (Apple, 2020). Routing requests are generated when a customer uses an Apple Map application to generate a pathway between a starting location and a destination. Users can select which modes of transportation are desired for the trip. To be consistent with the analysis of Google's statewide mobility data, we examined changes in Apple's city data through March 29, 2020. Changes in the frequency of

routing requests for different modes of transportation are reported relative to a baseline date of January 13, 2020.

Results

Based on Google's mobility data, every state had substantially decreased visits to public spaces by March 29, 2020, compared with approximately 6 weeks earlier (Table 1). However, there were larger reductions in visits in states that issued stay-at-home orders before the end of this observation period. Significant differences between 26 states with a statewide stay-at-home order and the 25 without a statewide order were observed for all destination categories, including transit stations, such as bus and train stations (−53 percent versus −39 percent); retail and recreation facilities, such as restaurants, cafes, and shopping centers (−51 percent versus −42 percent); workplaces (−38 percent versus −34 percent); grocery stores and pharmacies (−27 percent versus −15 percent); and parks, including national and local parks, public beaches and marinas, plazas, and public gardens (−10 percent versus +26 percent).

Many states exempted parks from the stay-at-home restrictions, and some actively promoted outdoor exercise, so visits to parks did not follow the pattern of other destinations. Excluding parks, states without a stay-at-home order had mean average decreases in visitation rates across destination categories of 32.6 percent. In states with stay-at-home orders, the mean decrease in visitation rates across the same categories was 9.9 percentage points lower at 42.5 percent.

Among the 25 states that had not implemented statewide stay-at-home orders, 13 states had some cities and/or counties that had enacted local stay-at-home orders. Google's mobility data show that mobility behaviors in the 13 states with stay-at-home orders applying to only part of the state's residents were not statistically different than those in states without stay-at-home orders in all jurisdictions (Table 2). This observation suggests that local orders had limited impact on changing statewide behavioral patterns.

The data from Apple further support the observations from the Google data (Table 3). Routing requests across all three modes of transportation decreased substantially in all 15 cities, falling by at least 55 percent even in states without

Table 1. Mean Change in Visits to Various Destinations by State Between Mid-February and March 29, 2020, Based on Whether a Statewide Stay-at-Home Order Was or Was Not in Effect as of March 29

Destination	States without stay-at-home orders ($n = 25$)	States with stay-at-home orders ($n = 26$)	Difference	p value
Transit stations	−39.6%	−53.2%	−13.6%	<.01
Retail and recreation	−41.2%	−51.3%	−10.1%	<.01
Workplaces	−33.9%	−38.4%	−4.5%	<.01
Grocery and pharmacy	−15.5%	−26.9%	−11.3%	<.01
Parks	+25.8%	−9.7%	−35.5%	<.01
Means (with parks)	−20.9%	−35.9%	−15.0%	—
Means (without parks)	−32.6%	−42.5%	−9.9%	—

Note: Data source: Google COVID-19 Community Mobility Reports.

Table 2. Mean Change in Visits to Various Destinations by State Between Mid-February and March 29, 2020, Based on Whether a State Without a Statewide Stay-at-Home Order Had Any Local (City or County) Stay-at-Home Orders in Effect as of March 29

Destination	States with no stay-at-home orders ($n = 12$)	States with local stay-at-home orders ($n = 13$)	Difference	p value
Transit stations	−38.8%	−40.5%	−1.7%	.78
Retail and recreation	−41.5%	−41.0%	+0.5%	.87
Workplaces	−33.8%	−34.0%	−0.3%	.93
Grocery and pharmacy	−15.0%	−16.0%	−1.0%	.73
Parks	+39.5%	+13.1%	−26.4%	.15
Means (with parks)	−17.9%	−23.7%	−5.8%	—
Means (without parks)	−32.3%	−32.9%	−0.6%	—

Note: Data source: Google COVID-19 Community Mobility Reports.

stay-at-home orders. However, cities in states with stay-at-home orders had decreases in routing requests that were 6.8 to 12.2 percentage points greater than those occurring through voluntary behavior change. The mean difference in mobility trends across categories, −10.0 percent, is very similar to the mean difference found in the Google data, −9.9 percent.

Discussion

The observed differences in statewide mobility patterns provide evidence that stay-at-home orders are effective in reducing population-level movement below the rate that can be achieved by individuals voluntarily changing their behaviors. The observed differences in movement within cities from the Apple data further support the greater effectiveness of statewide orders over local ones. The limited effectiveness of local orders is likely the result of economic integration across jurisdictions. Suppose that County A issues a stay-at-home order while adjacent County B remains open for business. Residents of County A who work in County B will continue to drive to work, and some businesses that primarily operate in County A will shift their work to County B. Residents of County A who are unable to engage locally in commercial and other activities that are not allowed in County A may choose to travel to County B for shopping and entertainment. While travel

Table 3. Mean Change in Routing Requests by Mode of Transportation Between January 13 and March 29, 2020, Based on Whether a Statewide Stay-at-Home Order Was or Was Not in Effect as of March 29

Travel mode	Cities in states without statewide stay-at-home orders ($n = 7$)	Cities in states with statewide stay-at-home orders ($n = 8$)	Difference	p value
Transit	−67.8%	−80.0%	−12.2%	<.01
Walking	−55.2%	−66.3%	−11.1%	.06
Driving	−58.9%	−65.7%	−6.8%	.02
Means	−60.6%	−70.7%	−10.0%	—

Note: Data source: Apple COVID-19 Mobility Trends Reports.

to some types of destinations within County A may decrease under the stay-at-home order, some individuals will travel even farther than typical to access goods and services.

Our analysis also shows that even in states without statewide mobility orders residents made substantially fewer trips away from home as alarm about the threat of COVID-19 in the United States grew. This suggests that many individuals and households will choose to continue to limit their own mobility voluntarily as long as cases of COVID-19 are occurring locally, and that expectation is consistent with other studies (Andersen, 2020; Engle, Stromme, & Zhou, 2020). If SARS-CoV-2 transmission is still occurring in a city or county when a state- or local-level stay-at-home order is lifted, mobility patterns are unlikely to immediately rebound to prepandemic levels. Voluntary reductions in travel to public spaces are likely to continue, even as governments allow individuals to resume more of their usual prepandemic routines.

One of the concerns about stay-at-home orders is that they are not effective at generating sustained behavior change. By the end of April, as there were more calls to "reopen the economy," cell phone data from the United States showed that individuals in places that were still under stay-at-home orders were beginning to make more trips away from home than they had in the middle of April (Zaveri, 2020). Law enforcement officers could have forced the closure of places where groups were congregating in violation of stay-at-home orders, but most government officials were reluctant to ask the police to break up those gatherings. Compliance with stay-at-home orders might be greater early in an epidemic before public goodwill and patience are expended. Coordinated and widespread orders are likely to be more effective than local ones at limiting the number of contacts between residents.

The associations between stay-at-home orders and epidemiological outcomes related to COVID-19 will need to be evaluated more fully later in the pandemic when more data are available. Location data from mobile phones, like the data used in this analysis, will be valuable for examining movement patterns and understanding how the pandemic has affected human behaviors, economics, and politics (Allcott et al., 2020; Barrios & Hochbert, 2020; Painter & Qiu, 2020).

Limitations

Our analysis focuses on the early weeks of the COVID-19 pandemic when awareness of substantial rates of community-spread of SARS-CoV-2 within the United States was first emerging. Due to the timing of this special issue, the analysis examines changes in movement behaviors only through March 2020. Mobility reports based on cell phone data may not be representative of mobility changes in the general population, as people who use cell phones may behave in systematically different ways than those who do not. Google's dataset includes aggregated data only from mobile phone users whose device settings allow their location history data to be used for this type of purpose, and those who opt in to sharing location data may not be representative of all mobile phone users. Apple's dataset includes only requests for directions from the Apple Maps application, and

those users may be systematically different from users of other mapping apps and operating systems. The data from Google and Apple, and the way Google classifies public locations into various categories, are not able to be independently verified.

A second limitation that it is not possible to examine the degree to which stay-at-home policies may have been implemented in response to observations about voluntary changes in mobility among constituents. Governors of states where a large proportion of residents voluntarily opted to restrict their own movement in March 2020 may have been more likely to implement stay-at-home orders early in the pandemic than governors of states where residents perceived the threat from COVID-19 to be minimal and did not substantially change their behaviors during March. Our analysis might, therefore, overestimate the impact of stay-at-home orders in states where clusters of COVID-19 detected early in the pandemic caused voluntary changes in movement behavior prior to the issuance of legal stay-at-home mandates. However, if this mechanism was driving the results, we might also expect there to be some differences evident in our analysis of how states without any stay-at-home orders compared to states with local stay-at-home orders. As per Table 2, we did not observe such differences.

Conclusions

As places that have been under stay-at-home orders begin to ease their restrictions, government authorities will need to create clear vocabulary about the exact activities that are allowed and not allowed at various stages of intensifying and relaxing activity constraints. Stay-at-home orders are not blanket mandates not to leave a place of residence. These orders must define which businesses, schools, and service providers may remain open or must close; explain what types of commercial and recreational activities are allowed; and specify details about what other activities are deemed to be essential, allowable, or banned. The language used with the public to describe these orders and the way they change over time will need to be simple, memorable, and unambiguous. For example, a color-coding system (red, orange, yellow, and green) may be suitable shorthand for the phases of movement restrictions, but only if the activities associated with each color are readily understood.

However, ending stay-at-home orders when many residents still perceive an infectious disease to be a threat in their communities may not lead to dramatic resurgences of social and economic activity, because reduced population movement during pandemics is a function of both voluntary and government-imposed behavior change. Our analysis found that movement decreased dramatically in the United States during the early emergence of the pandemic even in states without statewide stay-at-home orders. Future research that evaluates the dynamic effects of mobility restrictions over the duration of their implementation will be valuable for understanding their effectiveness during the various stages of a pandemic emergency.

As the COVID-19 epidemic evolves, information about human mobility trends may be valuable to policymakers who are making decisions about when to enact stay-at-home orders and how long to maintain legal restrictions on movement.

Identifying the specific measures that work best under various conditions to achieve public health and socioeconomic goals will improve the ability of communities and nations to respond quickly and effectively to future emerging infectious disease events.

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Notes

Conflicts of interest: None declared.

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