Rapid real-time tracking of non-pharmaceutical interventions and their association with SARS-CoV-2 positivity: The COVID-19 Pandemic Pulse Study

Steven J. Clipman[1], Amy P. Wesolowski[2], Dustin G. Gibson[1], Smisha Agarwal[1], Anastasia S. Lambrou[1], Gregory D. Kirk[2,3], Alain B. Labrique[1,2], Shruti H. Mehta[2], Sunil S. Solomon[2,3]

1. Department of International Health, Johns Hopkins Bloomberg School of Public Health, Baltimore, Maryland, United States of America
2. Department of Epidemiology, Johns Hopkins Bloomberg School of Public Health, Baltimore, Maryland, United States of America
3. Department of Medicine, Division of Infectious Diseases, Johns Hopkins University School of Medicine, Baltimore, Maryland, United States of America

Corresponding author:

Sunil Suhas Solomon, MBBS, PhD, MPH

Johns Hopkins University School of Medicine

1830 E. Monument St, Room 444

Baltimore, MD 21287

Phone: 443-287-9596

Email: sss@jhmi.edu

Summary: Strict social distancing was significantly associated with lower likelihood of ever testing positive for SARS-CoV-2 and attenuated the association between most forms of movement and positivity. Attending places of worship and using public transportation remained significantly associated with SARS-CoV-2 infection status.

Abstract

Background: Current mitigation strategies for severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) rely on population-wide adoption of non-pharmaceutical interventions (NPIs). Monitoring NPI adoption and their association with SARS-CoV-2 infection history can provide key information for public health.

Methods: We sampled 1,030 individuals in Maryland from June 17 – June 28, 2020 to capture socio-demographically and geographically resolved information about NPI adoption, access to SARS-CoV-2 testing, and examine associations with self-reported SARS-CoV-2 positivity.

Results: Overall, 92% reported traveling for essential services and 66% visited friends/family. Use of public transport was reported by 18%. In total, 68% reported strict social distancing indoors and 53% strict masking indoors; indoor social distancing was significantly associated with age, and race/ethnicity and income with masking. Overall, 55 participants (5.3%) self-reported ever testing positive for SARS-CoV-2 with strong dose-response relationships between several forms of movement frequency and SARS-CoV-2 positivity. In multivariable analysis, history of SARS-CoV-2 infection was negatively associated with strict social distancing (adjusted Odd Ratio for outdoor social distancing [aOR]: 0.10; 95% Confidence Interval: 0.03 – 0.33); only public transport use (aOR for ≥7 times vs. never: 4.29) and visiting a place of worship (aOR for ≥3 times vs. never: 16.0) remained significantly associated with SARS-CoV-2 infection after adjusting for strict social distancing and demographics.

Conclusions: These results support public health messaging that strict social distancing during most activities can reduce SARS-CoV-2 transmission. Additional considerations are needed for indoor activities with large numbers of persons (places of worship and public transportation) where even NPIs may not be possible or sufficient.

Keywords: SARS-CoV-2; transmission; non-pharmaceutical interventions; social distancing; testing; COVID-19

Introduction

The severe acute respiratory syndrome coronavirus 2 (SARS CoV-2) and associated coronavirus disease 2019 (COVID-19) pandemic continues to evolve at a rapid pace, having affected more than 23 million persons globally and more than 5.7 million in the US as of August 25, 2020 [1]. While there has been rapid progress in therapeutics [2, 3] and vaccine development [4, 5], nothing to date is a panacea. The primary means of curtailing transmission remains testing and contact tracing, and continued implementation of non-pharmaceutical interventions (NPIs) such as social distancing and masking [6, 7].

A growing number of reports have demonstrated the impact of social distancing on reducing SARS-CoV-2 transmission. Many of these reports have modeled these impacts using state- and/or county- level data on government-imposed interventions/restrictions or geolocation data from mobile phone users as a surrogate for social distancing and mobility [8-14]. While these analyses allow for examination of trends across multiple geographies and large sample sizes, they are ecological in nature and thus need to be supplemented by methods that can capture finer scale changes in behavior such as population-based surveys.

Monitoring trends in the adoption of NPIs via surveys may provide insight into the trajectory of local SARS-CoV-2 epidemics, information that can guide public health practice and policy [8]. Declining or poor levels of NPI adoption could signal an impending upsurge in cases indicating a need to mobilize resources to medical facilities and expand testing to facilitate early diagnosis and isolation. On the other hand, high levels of NPI adoption could support decisions related to re-opening businesses. Such approaches can also help to identify subgroups (e.g., race, income, age) who are differentially practicing social distancing or other preventive behaviors and can directly collect data to help distinguish between travel for essential services/employment versus leisure both of which will be important for eventual public health messaging. While some data collected via mobile phone applications may also be able to provide information on the type of location visited (e.g., a restaurant versus residence), there may still exist nuances in the reasons for travel (e.g., an employee vs. guest at a restaurant) that would be unavailable; further, information about the differences in travel by socio-demographic subgroups may not be always available. While surveys could capture this type of granular information at frequent intervals, to date most surveys have focused on symptoms, COVID-19 impacts and attitudes towards NPIs [15-17].

We used an online panel to rapidly sample persons in Maryland to capture granular information on NPI adoption, travel, access to SARS-CoV-2 testing, and associations with self-reported SARS-CoV-2 positivity.

Methods

Study Setting

As of June 30, 2020, Maryland had nearly 68,000 confirmed COVID-19 cases, more than 3,200 deaths; the current positive test proportion is 4.56% [18]. Community transmission has been sustained since March 12, 2020 [18] and statewide stay-at-home orders were implemented from March 30 to May 15, 2020. As of April 18, 2020, Maryland required face coverings on public transit and within retail outlets for employees and customers. Stage Two of phased reopening began on June 12, 2020, allowing indoor restaurant dining to resume at 50% capacity; on June 19, 2020, gyms, retail stores, salons, barbershops, nail salons, amusement parks, outdoor pools, and indoor worship services were permitted to open with capacity restrictions [19].

Study Sample

Participants were recruited from across Maryland from June 17 – June 28, 2020 using Dynata (https://www.dynata.com), one of the largest first-party global data platforms. Dynata maintains a database of potential participants who are randomized to specific surveys if they meet the specified demographic targets of the survey; participants receive modest compensation for participation. Security checks and quality verifications are used to verify identity and prevent duplication before participants begin surveys. These include digital fingerprinting to prevent duplication, spot checking via third party verification to prove identity and a dedicated panelist quality team. Dynata staff are active in multiple online research quality initiatives including the European Society for Opinion and Marketing Research (ESOMAR).

We provided Dynata with quotas for age, gender, race, and income based on the population composition of Maryland. Quotas were monitored through the Dynata internal router system and self-reported survey data. Dynata distributed survey invitations to 2,322 persons. Of these, 1,466 visited the survey site and responded to at least one question – 109 started but did not complete the survey and 310 responses were excluded for non-eligibility (age <18 years or residence outside Maryland). We further excluded 17 participants who did not provide a response to ever being tested for SARS-CoV-2, for a final sample size of 1,030 (target = 1000).

Survey

The electronic survey was based on a combination of existing COVID-19 surveys and new questions on sociodemographic characteristics, adoption of NPIs (including social distancing and mask wearing) and access to SARS-CoV-2 testing. All questions were asked with respect to the prior two weeks. To understand social distancing practices, participants were asked about the types and frequency with which they visited places/locations in the prior two weeks including indoor locations such as large gatherings, homes of friends and family members, gyms, salons, grocery stores, pharmacies, restaurants, places of worship, and outdoor locations such as beaches and pools. Participants were also asked about social distancing practices and mask wearing at these locations.

Statistical Analysis

Chi square tests and Mann-Whitney tests were used to compare categorical and continuous variables, respectively. Logistic regression was used to identify variables associated with ever testing positive for SARS-CoV-2 infection. Variables of interest included demographics, mobility patterns including types of outdoor and indoor locations visited in the prior two weeks, and adoption of masking and social distancing. Variables were considered for inclusion in multivariable models if they held biological significance, were statistically significant in univariable models ($p<0.05$) and/or had significant variable importance scores as determined by machine learning feature selection using random forest with a Boruta wrapper algorithm [20]. As a sensitivity analyses, we restricted the outcome to self-report of a recent (prior 2 weeks) SARS-CoV-2 positive test.

Ethical Clearance

The study was approved by the Institutional Review Board of the Johns Hopkins Bloomberg School of Public Health (IRB00012413) and all participants consented to participate.

Results

Characteristics of study population

The median age was 43 years and 55% were women. The majority (n=618 [60%]) were White; 239 (23%) and 74 (7%) self-identified as Black/African American and Hispanic/Latino, respectively (Table 1). About 69% of the participants reported attending college or possessing a graduate degree, and the majority (55%) reported a household income less than $70,000. There were 303 (29%) respondents who reported working outside of their home. Participants were sampled from all 24 counties in Maryland with the largest proportion from the most populous counties. In general, sociodemographic characteristics of the study sample were reflective of the Maryland state population (Supplemental Figure S1).

Recent movement

Overall, 990 (96%) participants reported leaving their home at least once during the prior two weeks. Of these, almost all (92%) reported traveling for essential services (e.g., grocery store or pharmacy) at least once and 40% reported going 3 or more times in the prior two weeks. Following travel for essential services, the next most frequented places were visiting friends/family (66%), indoor venues such as bars, salons or restaurants (49%) and outdoor venues such as beaches or pools (25%) (Figure 1; Supplementary Figure S2). Among those who reported travel, 18% and 15% reported using public transport and visiting a place of worship, respectively. Activities were positively correlated with one another (Supplementary Figure S3). There were 5% who reported engaging in all activities. About a quarter (26%) reported attending at least one gathering of 10 or more people in the prior two weeks, of whom 8% reported attending 3 or more; 104 (10%) reported attending at least one gathering of 100 or more.

Adoption of non-pharmaceutical interventions

The majority reported practicing social distancing when visiting indoor and outdoor locations, although adoption of social distancing increased with age. For example, 81% of those over the age of 65 reported always practicing social distancing at outdoor activities compared to 58% of those aged 18-24 ($p<0.001$; Figure 2). About half (53%) reported that they always wore a mask when visiting indoor and outdoor locations; 17% and 19% reported never wearing a mask when visiting indoor or outdoor locations, respectively. While age was not significantly associated with self-reported mask use, race and income were. About three-fourths (72%) of Blacks reported always wearing a mask outdoors compared to 44% of Whites ($p<0.001$). Further, 62% of those earning household income less than $20,000/year reported always wearing a mask outdoors compared to 48% of those with household income of $70,000 or greater ($p=0.018$).

SARS-CoV-2 Infection and Access to Testing

Overall, 55 participants (5.3%) self-reported ever testing positive for SARS-CoV-2 infection. Participants who self-reported having tested positive were significantly more likely to be male, younger, self-identify as Black/African American or Hispanic/Latino, and be required to travel outside of home for work (Table 1). The distribution of self-reported SARS-CoV-2 positivity by Maryland County is presented in Supplementary Figure S4.

In the prior two weeks, 102 persons reported wanting or needing a SARS-CoV-2 test, of whom 62 (61%) were able to get a test, 18 (29%) of whom tested positive. Sixteen (89%) reported subsequent hospitalization (See Supplementary Figure S5). While 18 (29%) reported getting a test the same day they wanted/needed it, about a third (34%) reported waiting 3 or more days. Over half (53%) reported waiting 3 or more days to receive a test result; 7 (11%) had not received their results at the time of the survey.

Association between prior SARS-CoV-2 infection status, travel history and adoption of NPIs

In unadjusted analysis, self-reported history of SARS-CoV-2 infection was significantly more frequent among those who were younger, male, Black/African American or Hispanic/Latino ($p<0.05$ for all; Table 2). SARS-CoV-2 infection was also significantly more common among those who reported using public transportation, attending a place of worship, visiting friends or family, attending gatherings of more than 10 people and more than 100 people, and visiting indoor or outdoor venues where people gather ($p<0.05$ for all; Supplementary Figure S6). Infection was significantly less common in those who reported strict social distancing indoors and outdoors ($p<0.05$ for both).

In multivariable analysis, history of SARS-CoV-2 infection remained significantly more likely among younger respondents, those who took public transportation (adjusted odds ratio [aOR] for 3 or more times vs. none: 4.3; 95% confidence interval [CI]: 1.1 – 16.5), and those who visited a place of worship (aOR for those who visited ≥ 7 times vs. none: 16.0; 95% CI: 6.0 – 42.7), and significantly less common among those who always practiced social distancing (aOR for indoor social distancing: 0.32; 95% CI: 0.10 – 0.98; aOR for outdoor social distancing: 0.10; 95% CI: 0.03 – 0.33) (Table 2). Associations were similar in sensitivity analyses of self-reported SARS-CoV-2 infection in the prior 2 weeks (Supplementary Table S7).

Discussion

We utilized an online panel survey to provide a rapid, cost-efficient snapshot of travel patterns and NPI adoption across population subgroups in Maryland. These data indicate that non-essential travel and uneven NPI adoption could influence community transmission of SARS-CoV-2 infection. Over two thirds of the respondents reported recent travel for non-essential services; self-reported SARS-CoV-2 infection was significantly more common among those who reported using public transport or visiting places of worship and significantly less common among those who always practiced social distancing. Significant differences in NPI adoption were observed by age, race and income suggesting that communication campaigns should tailor messaging to specific subgroups.

Positive dose-response relationships were demonstrated between recent movement and prior SARS-CoV-2 infection. The more frequently an individual participated in an activity, the more likely they were to have tested positive. Additionally, consistent with ecologic analyses [21], lower levels of SARS-CoV-2 positivity were observed among those always practicing social distancing. Indeed, when adjusting for movement types, social distancing and other demographic factors associated with positivity, most associations between recent movement and SARS-CoV-2 positivity were no longer statistically significant. This supports public health messaging that incorporating appropriate NPIs while visiting indoor and outdoor venues helps reduce SARS-CoV-2 transmission. Importantly, this was not the case for using public transport and visiting a place of worship in the prior 2 weeks which remained significantly associated with SARS-CoV-2 positivity even after adjustment. Of course, while mask use is mandated for public transport, social distancing may be challenging and use of public transport may reflect necessity vs. personal choice. While in Maryland, many religious gatherings moved to remote services, indoor religious gatherings were allowable in Maryland with restrictions at the time of the survey. We specifically surveyed about physically visiting places of worship but were unable to discriminate the reasons why persons attended a place of worship (e.g., service vs. food distribution vs. Narcotics Anonymous). It is important to note that data on movement and NPI adoption, albeit self-reported, was limited to the prior two-weeks to minimize recall bias.

While these data demonstrated a negative association between consistent indoor mask use and ever testing positive for SARS-CoV-2, this association failed to achieve statistical significance. Collection of data related to mask use is nuanced as several factors can affect the efficacy of masks that are challenging to collect such as fit, type of mask, frequency of touching/adjusting mask, etc. Further, guidance on mask use has been evolving since March with the CDC only endorsing mask use on April 3, 2020 which could have affected associations with ever testing positive. In sensitivity analyses that restricted analyses to recent SARS-CoV-2 infection, consistent indoor mask use was significantly associated with a lower likelihood of infection.

These analyses could not establish temporality between exposures and SARS-CoV-2 positivity and may reflect that those who tested positive were more likely to practice these behaviors when they were infected or that they changed their behaviors after testing positive because of altered risk perception. Sensitivity analyses demonstrating similar associations with recent SARS-CoV-2 infection and dose-response associations observed suggest that reverse causality does not likely explain these associations. Regardless of directionality, these findings have implications for community transmission risk particularly in light of incomplete understanding of viral shedding and infectiousness among infected persons and the role and duration of acquired immunity on protection from SARS-CoV-2 reinfection [22-25]. Of interest, these data were collected just as Maryland began to relax restrictions and the state witnessed an uptick [18] in cases about a month after the survey particularly among younger persons, the strata who reported maximum mobility in this survey.

Aside from the widescale adoption of NPIs, early diagnosis, appropriate contact tracing measures, and isolation and/or referral to care are critical to curtailing SARS-CoV-2 transmission [22]. It is vital that all persons who seek a test are able to obtain one with minimal delays followed by prompt receipt of results. In this sample, almost 40 percent of those who wanted a test were not able to get one; even in those tested, there were significant delays and over half waited three or more days for results. To effectively curb transmission, these delays need to be addressed.

We were limited in our ability to generalize results because the sample cannot necessarily be considered to be representative of Maryland state. Indeed, self-reported positivity was more than double that estimated among those 18 and older by case-count data (2.5%) [26]. It is important to note, however, that there has not yet been a seroprevalence study in Maryland and that case count data are subject to many biases including who can access a test and how this access has changed over time. Most seroprevalence studies have demonstrated that prevalence is 6-24 times higher than what has been estimated by case count data [27]. Regardless, it is important to note that by using quotas for various key demographic characteristics, online samples such as this one can be structured to recruit samples with demographic distributions comparable to the target population [28]. Notably, despite the higher overall prevalence than case count data based prevalence, the self-reported positivity rates reflect the distribution of cases in Maryland [18], with higher positivity among men, Hispanic, African-American, and younger populations. Also, of importance, the proportion of respondents in the sample who reported taking the flu vaccine last year was 53.1% (data not shown) compared to 52.3% estimated by the CDC [29] in the 2018-19 flu season suggesting this approach yields similar results as other commonly used approaches such as random digit dialing.

We were additionally limited because individuals required internet connectivity to participate; however, internet access has been improving and has been facilitated by recent discounts offered by major providers. It is estimated that 86% of Maryland residents have internet connectivity [30]. The sample also likely misses homeless populations and very low-income groups, two populations where NPI adoption may be especially challenging [31]. Among those with internet connectivity, it is not possible to sample randomly and the "frame error" of those willing to participate in such panels is likely large but cannot be proven to be systematic.

Despite these limitations, several advantages of the approach are also noteworthy. This sample of 1,030 respondents was recruited in under two weeks at a cost of $3,000. In a rapidly evolving epidemic where behaviors are constantly changing, this approach did not require face-to-face visits maximizing participant safety and minimizing administration costs. Finally, any biases will likely remain constant over time allowing for examining trends longitudinally in serial cross-sectional samples using the same method. To monitor these trends, we developed an online interactive dashboard (sclipman.github.io/PandemicPulse).

In conclusion, we present a rapid cost-efficient approach of monitoring NPI adoption and adherence which can help inform public health response. While our survey illustrated this approach within a single state, the rapidity and efficiency of this methodology can be replicated in other settings recognizing the highly variable and geographically localized SARS-CoV-2 transmission patterns and risk mitigation responses. Repeating these surveys over time can further unveil additional insights around changes in population behaviors potentially informing adaptive responses to evolving disease dynamics. Overall, these data continue to highlight the role of movement and social distancing on SARS-CoV-2 transmission risk and support public health messaging that strict social distancing during most activities can mitigate SARS-CoV-2 transmission. In Maryland, these data support targeted messaging to young adults given high rates of positivity and lower rates of NPI adoption; establishing partnerships with faith-based organizations could also be critical to curbing spread. Moreover, measures need to be implemented to make public transportation safe and to improve access to SARS-CoV-2 testing. Continued monitoring of NPI adoption, access to testing and the subsequent impact on SARS-CoV-2 transmission in Maryland as well as more broadly will be critical for pandemic control.

NOTES

Acknowledgements

We would like to gratefully acknowledge the contributions of Mr. Adebola Adegbesan who worked closely with our team in the recruitment of the study sample, as well as the contributions of Ms. Hannah Manley, who assisted with data cleaning.

Funding

This work was supported by the Johns Hopkins COVID-19 Research Response Program. APW is funded by a Career Award at the Scientific Interface by the Burroughs Wellcome Fund and by the National Library of Medicine of the National Institutes of Health [DP2LM013102]. SSS is funded by DP2DA040244. The content is solely the responsibility of the authors and does not necessarily represent the official views of the Johns Hopkins University or the National Institutes of Health.

Potential Conflicts of Interest

S.M. reports personal fees from Gilead Sciences, outside the submitted work. S.S. reports grants/products and advisory board fees from Gilead Sciences, and grants/products from Abbott Diagnostics, outside the submitted work. All other authors have no potential conflicts.

References

1. Center for Systems Science and Engineering (CSSE) at Johns Hopkins University (JHU). COVID-19 Dashboard. Available at: https://coronavirus.jhu.edu/us-map. Accessed July 20, 2020.
2. Beigel JH, Tomashek KM, Dodd LE, et al. Remdesivir for the Treatment of Covid-19 - Preliminary Report. N Engl J Med **2020**.
3. Horby P, Lim WS, Emberson JR, et al. Dexamethasone in Hospitalized Patients with Covid-19 - Preliminary Report. N Engl J Med **2020**.
4. Jackson LA, Anderson EJ, Rouphael NG, et al. An mRNA Vaccine against SARS-CoV-2 - Preliminary Report. N Engl J Med **2020**.
5. Zhu FC, Li YH, Guan XH, et al. Safety, tolerability, and immunogenicity of a recombinant adenovirus type-5 vectored COVID-19 vaccine: a dose-escalation, open-label, non-randomised, first-in-human trial. Lancet **2020**; 395(10240): 1845-54.
6. Brooks JT, Butler JC, Redfield RR. Universal Masking to Prevent SARS-CoV-2 Transmission-The Time Is Now. Jama **2020**.
7. Kissler SM, Tedijanto C, Goldstein E, Grad YH, Lipsitch M. Projecting the transmission dynamics of SARS-CoV-2 through the postpandemic period. Science **2020**; 368(6493): 860-8.
8. Andersen M. Early Evidence on Social Distancing in Response to COVID-19 in the United States. SSRN **2020**.

9. Delen D, Eryarsoy E, Davazdahemami B. No Place Like Home: Cross-National Data Analysis of the Efficacy of Social Distancing During the COVID-19 Pandemic. JMIR Public Health Surveill **2020**; 6(2): e19862.

10. Kissler SM, Tedijanto C, Lipsitch M, Grad Y. Social distancing strategies for curbing the COVID-19 epidemic. medRxiv **2020**: 2020.03.22.20041079.

11. Mehari Y. The Role of Social Trsut in Citizen Mobility During COVID-19. SSRN **2020**.

12. Courtemanche C, Garuccio J, Le A, Pinkston J, Yelowitz A. Strong Social Distancing Measures In The United States Reduced The COVID-19 Growth Rate. Health Aff (Millwood) **2020**; 39(7): 1237-46.

13. McGrail DJ, Dai J, McAndrews KM, Kalluri R. Enacting national social distancing policies corresponds with dramatic reduction in COVID19 infection rates. PLoS One **2020**; 15(7): e0236619.

14. Teslya A, Pham TM, Godijk NG, Kretzschmar ME, Bootsma MCJ, Rozhnova G. Impact of self-imposed prevention measures and short-term government-imposed social distancing on mitigating and delaying a COVID-19 epidemic: A modelling study. PLoS Med **2020**; 17(7): e1003166.

15. Arie K, Marco A, Dan B, et al. Tracking the Effect of the COVID-19 Pandemic on the Lives of American Households. Survey Research Methods **2020**; 14(2).

16. Bruine de Bruin W, Bennett D. Relationships Between Initial COVID-19 Risk Perceptions and Protective Health Behaviors: A National Survey. Am J Prev Med **2020**; 59(2): 157-67.

17. Canning D, Karra M, Dayalu R, Guo M, Bloom DE. The association between age, COVID-19 symptoms, and social distancing behavior in the United States. medRxiv : the preprint server for health sciences **2020**: 2020.04.19.20065219.

18. Maryland Department of Health and Mental Hygiene. Coronavirus Disease 2019 (COVID-19) Outbreak. Available at: https://coronavirus.maryland.gov/. Accessed July 20, 2020.

19. The Office of Governor Larry Hogan. The Hogan Administration's COVID-19 Response. Available at: https://governor.maryland.gov/coronavirus/. Accessed July 20, 2020.

20. Kursa MB, Rudnicki WR. Feature Selection with the Boruta Package. Journal of Statistical Software; Vol 1, Issue 11 (2010) **2010**.

21. VoPham T, Weaver MD, Hart JE, Ton M, White E, Newcomb PA. Effect of social distancing on COVID-19 incidence and mortality in the US. medRxiv **2020**: 2020.06.10.20127589.

22. Kucharski AJ, Klepac P, Conlan AJK, et al. Effectiveness of isolation, testing, contact tracing, and physical distancing on reducing transmission of SARS-CoV-2 in different settings: a mathematical modelling study. Lancet Infect Dis **2020**.

23. Lin Q, Zhu L, Ni Z, Meng H, You L. Duration of serum neutralizing antibodies for SARS-CoV-2: Lessons from SARS-CoV infection. J Microbiol Immunol Infect **2020**.

24. Long Q-X, Tang X-J, Shi Q-L, et al. Clinical and immunological assessment of asymptomatic SARS-CoV-2 infections. Nature Medicine **2020**.

25. Seow J, Graham C, Merrick B, et al. Longitudinal evaluation and decline of antibody responses in SARS-CoV-2 infection. medRxiv **2020**: 2020.07.09.20148429.

26. Whitman JD, Hiatt J, Mowery CT, et al. Test performance evaluation of SARS-CoV-2 serological assays. medRxiv **2020**: 2020.04.25.20074856.

27. Havers FP, Reed C, Lim T, et al. Seroprevalence of Antibodies to SARS-CoV-2 in 10 Sites in the United States, March 23-May 12, 2020. JAMA Internal Medicine **2020**.

28. Labrique A, Blynn E, Ahmed S, Gibson D, Pariyo G, Hyder AA. Health Surveys Using Mobile Phones in Developing Countries: Automated Active Strata Monitoring and Other Statistical Considerations for Improving Precision and Reducing Biases. J Med Internet Res **2017**; 19(5): e121.

29. Centers for Disease Control and Prevention. Flu vaccination coverage, United States, 2018–19 influenza season. Available at:

https://www.cdc.gov/flu/fluvaxview/coverage-1819estimates.htm. Accessed August 20, 2020.

30. Snyder TD, Brey Cd, Dillow SA. Digest of Education Statistics 2018. National Center for Education Statistics, **2018**.

31. Mosites E, Parker EM, Clarke KEN, et al. Assessment of SARS-CoV-2 Infection Prevalence in Homeless Shelters - Four U.S. Cities, March 27-April 15, 2020. MMWR Morb Mortal Wkly Rep **2020**; 69(17): 521-2.

Tables

Table 1. Characteristics of study sample by self-reported SARS-CoV-2 infection status

	Overall	Never Tested Positive for SARS-CoV-2	Ever Tested Positive for SARS-CoV-2
	n = 1,030	**n = 975**	**n = 55**
Median Age (IQR)	43 (32 – 57)	44 (34 – 57)	28 (22 – 35)
Median Household Size (IQR)	2 (2 – 4)	2 (2 – 4)	2 (1 – 4)
Gender, n (%)			
Female	563 (55%)	542 (95%)	21 (4%)
Male	461 (45%)	428 (92%)	33 (7%)
Other	5 (0.6%)	4 (80%)	1 (20%)
Race/Ethnicity, n (%)			
White/Caucasian	618 (60%)	598 (97%)	20 (3%)
Black/African American	239 (23%)	217 (91%)	22 (9%)
Hispanic/Latino	74 (7%)	65 (88%)	9 (12%)
Asian/Pacific Islander	52 (5%)	50 (96%)	2 (4%)
American Indian/Alaska Native	12 (1%)	10 (83%)	2 (17%)
Mixed/Other	35 (4%)	35 (100%)	0 (0%)
Educational Attainment, n (%)			
High school degree or less	212 (21%)	201 (95%)	11 (5%)
Associate degree	104 (10%)	99 (95%)	5 (5%)
Some college (no degree)	192 (19%)	188 (97%)	4 (2%)
Bachelor's degree	283 (27%)	263 (92%)	20 (7%)
Graduate degree	236 (23%)	221 (93%)	15 (6%)
Annual Household Income, n (%)			
< $20,000	113 (11%)	104 (92%)	9 (8%)
$20,000 – $39,000	162 (16%)	150 (93%)	12 (7%)
$40,000 – $49,000	96 (9%)	90 (94%)	6 (6%)
$50,000 – $69,000	200 (19%)	192 (96%)	8 (4%)
$70,000+	429 (42%)	409 (95%)	20 (5%)
Employment Status, n (%)			
Employed, working outside the home	303 (29%)	271 (89%)	32 (10%)
Employed, working from home	337 (33%)	324 (95%)	13 (4%)
Unemployed	191 (19%)	186 (96%)	5 (3%)
Retired	188 (18%)	184 (97%)	4 (2%)

Note: in column representing overall description, we have listed column percentage to reflect overall population characteristics; in the columns stratified by self-reported SARS-CoV-2 positivity status, we have listed row percentage to allow for comparison of self-reported positivity by various sub-groups. Overall column percentages may not sum to 100 if some participants elected not to answer a given question.

Table 2. Factors associated with ever testing positive for SARS-CoV-2 by univariable and multivariable logistic regression.

Variable	Ever Tested Positive OR (95% CI)	Ever Tested Positive aOR (95% CI)
Race/Ethnicity		
White (ref.)	-	-
Black/African American	3.03 (1.62 – 5.66)	1.06 (0.44 – 2.54)
Hispanic/Latino	4.14 (1.81 – 9.47)	2.75 (0.87 – 8.70)
Age (per 5-year increase)	0.69 (0.61 – 0.78)	0.84 (0.71 – 0.99)
Male Gender	2.00 (1.13 – 3.45)	1.55 (0.69 – 3.47)
Annual Household Income		
< $20,000 (ref.)	-	-
$20,000 – $39,000	0.92 (0.38 – 2.27)	-
$40,000 – $49,000	0.77 (0.26 – 2.25)	-
$50,000 – $69,000	0.48 (0.18 – 1.29)	-
$70,000+	0.57 (0.25 – 1.28)	-
Work Outside the Home	3.61 (2.08 – 6.29)	-
Practice Social Distancing Indoors		
Never (ref.)	-	-
Sometimes	0.71 (0.31 – 1.63)	0.26 (0.08 – 0.90)
Always	0.30 (0.14 – 0.67)	0.32 (0.10 – 0.99)
Practice Social Distancing Outdoors		
Never (ref.)	-	-
Sometimes	0.70 (0.28 – 1.73)	0.34 (0.10 – 1.19)
Always	0.19 (0.08 – 0.46)	0.10 (0.03 – 0.33)
Used Public Transport		
Never (ref.)	-	-
Once or twice	8.06 (3.80 – 17.1)	6.00 (2.13 -16.9)
3 – 7 times	12.2 (5.64 – 26.3)	3.80 (1.18 – 12.3)
More than 7 times	18.8 (7.59 – 46.4)	4.29 (1.12 – 16.5)
Attended Gathering of >10 People		
Never (ref.)	-	-
Once or twice	3.37 (1.56 – 7.25)	-
3 – 7 times	15.5 (7.22 – 33.4)	-
More than 7 times	28.7 (10.4 – 78.7)	-
Attended Gathering of >100 People		
Never (ref.)	-	-
Once or twice	6.51 (2.77 – 15.3)	-
3 – 7 times	26.4 (11.37 – 61.4)	-
More than 7 times	34.0 (13.2 – 87.7)	-
Visited Place of Worship		
Never (ref.)	-	-
Once or twice	2.91 (1.06 – 8.02)	1.41 (0.38 – 5.31)
3 or more times**	23.9 (12.5 – 45.9)	16.0 (5.97 – 42.7)
Visited Friends or Family		

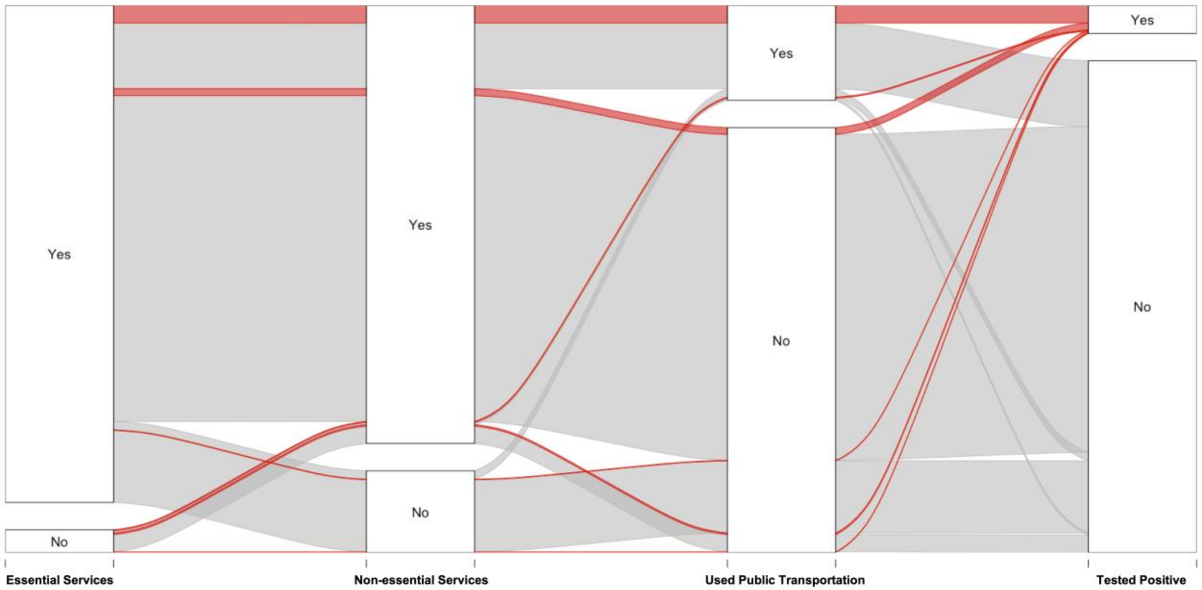
Never (ref.)	-	-
Once or twice	1.12 (0.52 – 2.42)	-
3 – 7 times	3.87 (1.77 – 8.46)	-
More than 7 times	5.42 (1.89 – 15.6)	-
Went to a Grocery Store/Pharmacy		
Never (ref.)	-	-
Once or twice	0.43 (0.17 – 1.13)	-
3 – 7 times	0.69 (0.27 – 1.81)	-
More than 7 times	2.23 (0.77 – 6.51)	-
Went to an Indoor Bar, Restaurant, Salon or Other Indoor Establishment		
Never (ref.)	-	-
Once or twice	1.10 (0.53 – 2.29)	-
3 – 7 times	4.14 (1.98 – 8.68)	-
More than 7 times	9.76 (3.83 – 24.9)	-
Went to a Beach, Pool or Other Outdoor Gathering Place		
Never (ref.)	-	-
Once or twice	2.45 (1.16 – 5.18)	-
3 – 7 times	9.30 (4.47 – 19.3)	-
More than 7 times	8.28 (2.56 – 26.7)	-
Mask Wearing in Public Indoors		
Never or sometimes	-	-
Always	0.63 (0.36 – 1.09)	-
Always Wear Mask in Public Outdoors		
Never or sometimes	-	-
Always	1.06 (0.61 – 1.85)	-
Number of Close Contacts Indoors		
0 (ref.)	-	-
1	3.96 (1.41 – 11.2)	-
2 – 5	4.46 (1.92 – 10.3)	-
6 – 10	4.87 (1.72 – 13.8)	-
>10	6.16 (1.72 – 22.0)	-
Number of Close Contacts Outdoors		
0 (ref.)	-	-
1	5.90 (2.00 – 17.4)	-
2 – 5	6.30 (2.54 – 15.6)	-
6 – 10	9.58 (3.31 – 27.7)	-
>10	4.26 (0.83 – 21.9)	-

Figure Legends

Figure 1. Sankey diagram showing participant mobility for essential and non-essential services and public transportation use in the past 2 weeks. Participant responses are depicted in each rectangular node with flows proportional to how many individuals responded, for example, individuals who responded “yes” to both essential services and non-essential services are reflected in the flow connecting the two “yes” nodes for these variables. Individuals who have ever tested positive for SARS-CoV-2 are shown in red, whereas all others are shown in grey. A total of 51 (5%) participants responded “yes” to all mobility questions and 39 (4%) responded “no” to all; 17 (31%) of those who tested positive for SARS-CoV-2 responded “yes” to all and 2 (4%) responded “no” to all. The thickness of the flow is directly proportional to the number of respondents who report that behavior.

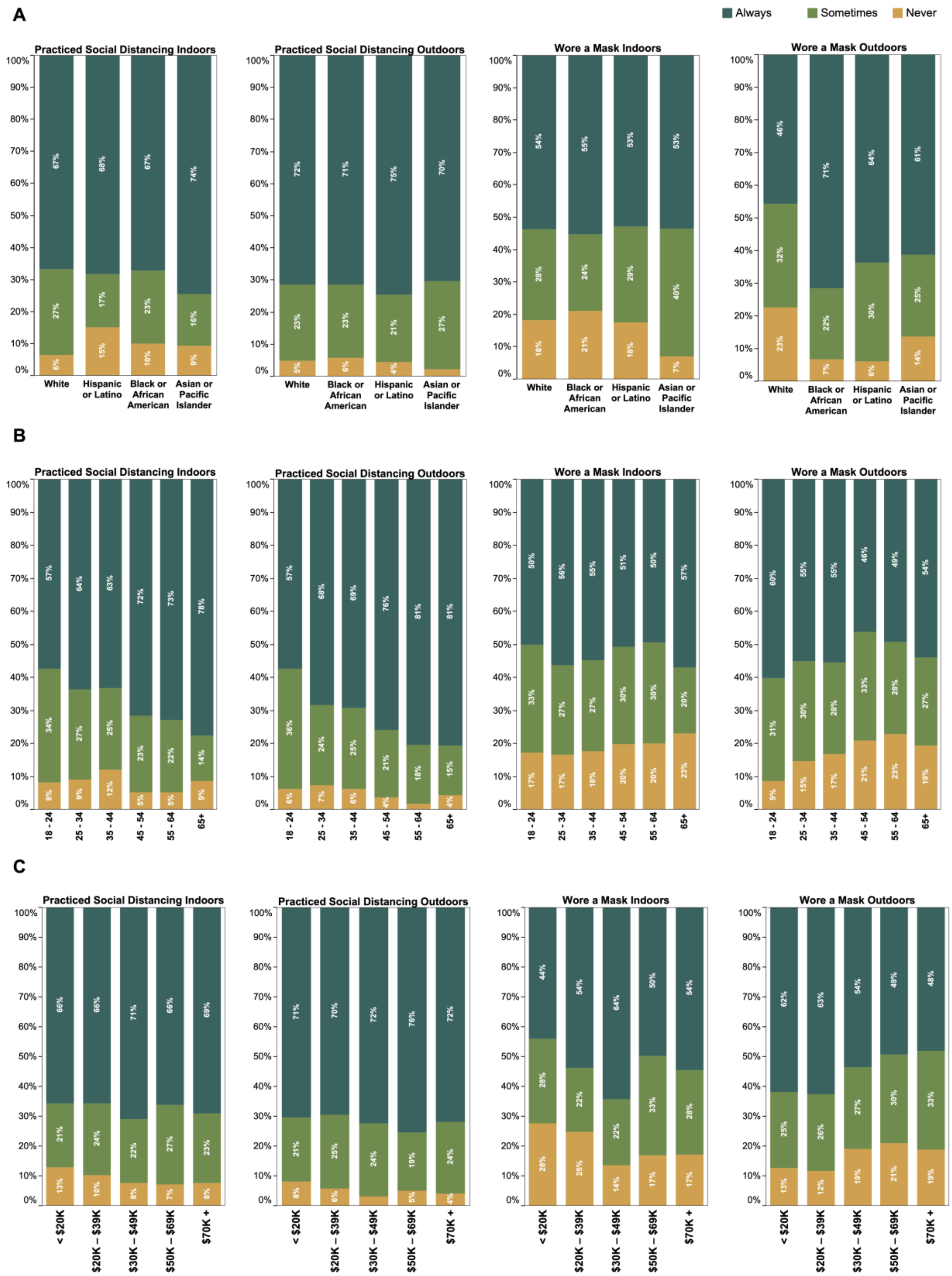
Figure 2. Self-reported uptake of non-pharmaceutical interventions in the prior 2 weeks by (A) race/ethnicity, (B) age, and (C) annual household income.

Figure 1



Yes
No
Yes
No
Yes
No
Yes
No
Essential Services
Non-essential Services
Used Public Transportation
Tested Positive

Figure 2


A
B
C
Always
Sometimes
Never
Practiced Social Distancing Indoors
Practiced Social Distancing Outdoors
Wore a Mask Indoors
Wore a Mask Outdoors
White
Hispanic or Latino
Black or African American
Asian or Pacific Islander
18 - 24
25 - 34
35 - 44
45 - 54
55 - 64
65+
< $20K
$20K – $39K
$30K – $49K
$50K – $69K
$70K +