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Title: Geographic access to United States SARS-CoV-2 testing sites highlights healthcare disparities and may bias transmission estimates

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Highlights

We paired high-resolution travel-time metrics with a SARS-CoV-2 testing location database in the United States. Median travel time to testing sites is longer in counties with lower population density, and a higher percent of minority and uninsured individuals. Differential geographic accessibility to testing can recapitulate healthcare disparities and bias transmission estimates.

Text

Uniform access to SARS-CoV-2 testing is crucial for controlling the COVID-19 epidemic[1]. Lack of testing can result in the epidemic spreading undetected[2] and increase the risk of extensive local transmission. The United States (US) has been slow to develop reliable diagnostic tests and, while there has been recent improvement in testing capabilities[3], large-scale testing remains a serious concern.

Inequalities in geographic accessibility to healthcare in the US have been documented to cause negative health outcomes for seasonal influenza transmission and other diseases[4]. Further, travel time negatively impacts healthcare-seeking behavior[5]. The deployment of SARS-CoV-2 testing within existing medical infrastructure, while logistically efficient, may exacerbate this disparity in health outcomes[6] and underestimate disease burden in disadvantaged populations.

Geographic accessibility to SARS-CoV-2 testing sites, to our knowledge, has not been systematically quantified. Therefore, we evaluated whether testing sites were equally accessible to populations across the US, leveraging two public SARS-CoV-2 testing site datasets and a high-resolution map of travel times.

American Community Survey (2014-2018) data for contiguous US states were used to tabulate county-level covariates including population, population density ($\ln \frac{mean\ population}{census\ block}$), median income, percent uninsured and percent minority ($1 - percent\ Non\ Hispanic\ White$).

A national database of SARS-CoV-2 testing sites was curated using the Carbon Health (N = 5,376) and CodersAgainstCovid (N = 1,547) datasets (accessed April 7, 2020). Carbon Health (carbonhealth.com/covid-19-testing-centers) prospectively called urgent care centers and hospitals on publicly listed telephone numbers starting March 17, 2020 to ask whether SARS-CoV-19 testing was being offered. Additionally, a verified, non-exhaustive collection of publicly documented and user-entered testing sites were included. CodersAgainstCovid identified urgent care centers, hospitals, drive-throughs, health departments and other facility types prospectively starting March 15, 2020, through volunteer-verified "webscraping" and crowdsourcing (https://codersagainstcovid.org/).

We identified and geocoded (R v.3.6.2 *ggmap* v3.0.0) 6,236 unique sites (687 excluded following manual de-duplication and cleaning). Related site ontologies were collapsed into meta-ontologies (e.g. Urgent with Immediate Care). To date, this is the largest database of US testing sites known to the authors. To evaluate completeness (as of April 20, 2020), we identified public

testing sites listed in sample areas: 34 in Illinois (https://www.dph.illinois.gov/covid19/covid-19-testing-sites), 5 in Colorado (https://covid19.colorado.gov/testing-covid-19) and 104 in West Virginia (https://www.wvhealthconnection.com/covid-19). Our database included 169, 85 and 60 sites in each area, respectively. We confirmed our database identified at least one site in every city in Texas operating a drive-through (https://www.dshs.state.tx.us/coronavirus/testing.aspx).

We used published friction-based travel times[7] between approximately 1 km^2 gridded cells in the US, accounting for topography and the most efficient non-air travel method. Median travel times for the shortest path to testing sites across all grid cells in each county (N=3,108) were calculated using the Dijkstra algorithm[8].

Generalized linear models (R *stats* v3.6.2) were used to estimate the correlation of population density, percent minority, percent uninsured and median income on median travel time, by county. We also tested for potential interactions between population density and percent minority or percent uninsured. Influential counties with a Cook's distance measure over $4/N$ were excluded (up to N=175).

We collated 6,236 SARS-Cov-2 testing sites in the contiguous US states. Testing sites (**Supplementary Table 1**) were often affiliated with medical centers (43%) and urgent care (47%), and were infrequently drive-through (3%). Testing sites were spatially clustered (Moran's I=0.037, z=61.4, $p<10^{-5}$), around US urban centers (**Supplementary Figure 1)**.

The travel time from each 1 km^2 grid cell to the nearest US testing site is spatially heterogeneous at the national and state level (**Figure 1A, 1B and 1C**). Thirty percent of the population live in a county (N = 1,920) with a median travel time over 20 minutes, though with pronounced regional differences (**Figure 1D**) ranging from 5% to 86%.

Population density, a determinant of population distribution, was associated with a shorter median county-level travel time (**Table 2**). While controlling for population density as a potential confounder, percent minority was associated with an increase in travel time, as was percent uninsured. These associations remained when also adjusting for median income. We found a significant negative interaction between percent uninsured and population density ($p<0.01$) suggesting that the disparity of longer rural travel times is greater in counties where a higher proportion of the population is uninsured. Percent minority and population density did not interact statistically.

Using two large, national datasets of SARS-CoV-2 testing sites paired with estimates of travel times, we demonstrate an uneven distribution of critical public health resources. The testing site distribution recapitulates structural disparities, including inequities among minority, uninsured, and rural groups, which may further perpetuate disparities as the pandemic progresses. Differential accessibility to testing may lead to biases in estimation of disease incidence and potentially delay identification of COVID-19 hot spots. In the absence of representative testing, syndromic surveillance tools may provide early warning signals, and augment targeted-testing and other public health interventions.

Despite efforts to ensure comprehensiveness, in some regions our dataset may be missing testing sites (e.g. West Virginia). While some additional testing sites have been created, given recent difficulties scaling up, we believe our database remains representative[9]. There remains potential for differential missingness of sites in areas with reduced "webscraping" visibility or sites specifically placed to address inaccessibility. Nevertheless, this work highlights the need for comprehensive resources and the utility of data sharing during a pandemic.

The travel time metric used here accounts for the presence of public transportation and routine traffic. Early evidence shows widespread variability in mobility reductions during the epidemic[10]. Our estimates of differential access present a conservative picture of inequality in the US which may be worse if public transit closures and private transportation were also modeled. Additionally, our models do not examine other, non-geographic barriers to SARS-CoV-2 testing access (e.g. economic), nor geography for residents in Alaska and Hawaii. Travel time, for example, is shorter for urban uninsured minority groups, and therefore does not explain the below average testing rates in disadvantaged urban areas (e.g. Philadelphia).

In summary, reduced geographic access to SARS-CoV-2 testing sites is associated with sociodemographic factors that, in turn, are linked to poor structural access to care and health outcomes. The location of future testing sites should explicitly account for travel time and sociodemographic predictors, in addition to other public health testing requirements.

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Figure Legends and Tables

Table 1: Generalized Linear Regression models. Associations between covariates and median travel time in minutes by county in the 48 contiguous US states and DC.

	Model 1	**Model 2**	**Model 3**	**Model 4**
Intercept	61.45 ***	59.99 ***	56.29 ***	51.36 ***
	[59.82, 63.08]	[58.34, 61.64]	[54.17, 58.41]	[47.70, 55.03]
Log of Population Density	-13.41 ***	-14.14 ***	-12.94 ***	-14.13 ***
	[-14.02, -12.79]	[-14.76, -13.52]	[-13.56, -12.32]	[-14.78, -13.47]
Percent Minority (%)		0.15 ***		0.13 ***
		[0.12, 0.18]		[0.10, 0.17]
Percent Uninsured (%)			0.41 ***	0.23 **
			[0.30, 0.53]	[0.09, 0.38]
Median Income ($10,000's)				2.52 ***
				[1.46, 3.59]
N	2942	2934	2942	2931
AIC	24321.32	24192.59	24291.55	24097.61
Pseudo R2	0.38	0.41	0.39	0.41

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$.

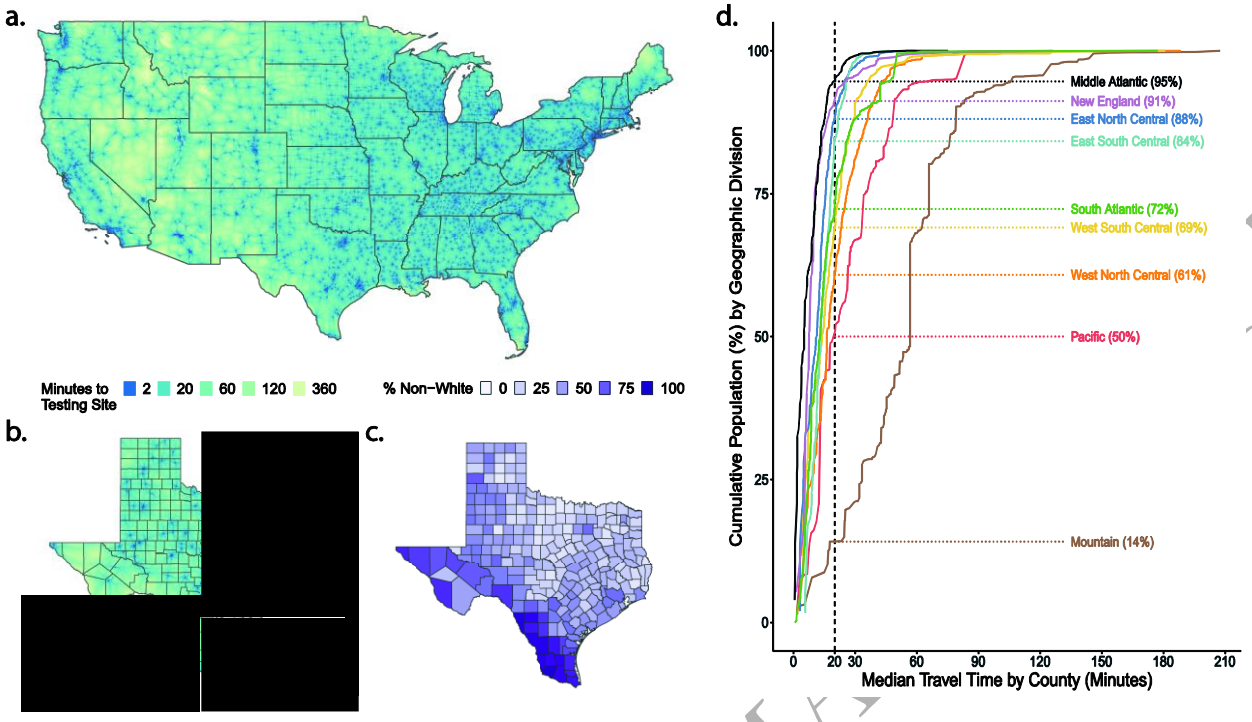

Figure 1. Distribution of SARS-CoV-2 testing sites. A) Travel time to the nearest testing site per 1 km^2 area (shorter travel time in darker blue) in the 48 contiguous US states plus DC. B) Travel time as in Panel A enlarged to show detail in the state of Texas. C) Percent minority ($1 -$ *percent Non Hispanic White*) by county in Texas. D) Median travel time by county versus the cumulative population for each geographic region (excluding two outlier counties). Vertical dashed line at 20 minute median travel time. Horizontal dotted lines indicate cumulative population percentage in that region (in parenthesis) residing in counties with less than 20 minutes median travel time.

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Data and Code availability: Mean travel time to testing center by county, sociodemographic variables and code for main analyses will be available (LINK: XX). Raster of travel times to testing sites will be available openly (LINK: XX). For access to the Carbon Health dataset, please email: coviddata@carbonhealth.com. For access to the CodersAgainstCOVID dataset, visit: github.com/codersagainstcovidorg.