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Short communication

Negative sentiments toward novel coronavirus (COVID-19) vaccines

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ABSTRACT

Addressing negative vaccine sentiments is paramount to COVID-19 prevention efforts. However, assessing population sentiments is challenging due to the desirability bias that can emerge when directly asking respondents for their opinions on vaccination. Social media data, containing people's unfiltered thoughts, have the potential to offer valuable insights that could guide vaccine promotion messaging. We extracted one week's (4/5–4/11, 2020) worth of COVID-19 vaccine posts on Twitter (tweets) from the U.S. (N = 208,973) and segmented tweets with negative sentiments toward COVID-19 vaccines (n = 14,794). We imputed location based on Twitter users' self-reported state of residence. We found that states in the South had significantly higher prevalence of negative tweets compared to states in other parts of the country, and higher-income states reported lower prevalence of negative tweets. Our findings suggest the existence of negative vaccine sentiments and geographic variability in these opinions, warranting tailored vaccine promotion efforts, particularly for the southern U.S.

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1. Introduction

At over thirty-one million cases and over half a million deaths, the novel coronavirus (COVID-19) pandemic is having devastating impacts on health and well-being across the United States [1]. In response to the pandemic, there was a pharmaceutical race to develop efficacious vaccines for COVID-19 with multiple vaccines being granted Emergency Use Authorization (EUA) at the end of 2020 [2]. While the first vaccines were being developed, concurrently in the media, there was discourse occurring on the feasibility of mass distribution [3]. However, what was absent from these dialogues was thoughtful commentary on vaccine sentiments particularly in historically underserved communities. Even with an uptick in these types of conversations during vaccine rollout, we still do not have a comprehensive understanding of where negative vaccine sentiments are concentrated and what sentiments are driving hesitancy.

The existence of negative vaccine sentiments, people's negative feelings, beliefs, attitudes, and opinions about vaccination [4,5], is not a new phenomenon, and vaccine hesitancy has existed for over a century. But fueled by mis-information and distrust of the government [6], negative vaccine sentiments have been surging over

the past decade [7]. Communities that are more likely to be distrustful of vaccines include the poor, less educated, and communities of color [8,9]. These groups have increased exposure to infectious diseases, such as COVID-19 (e.g., due to being disproportionately represented among front line workers) but also have reasons to be suspicious considering their experiences of medical abuse and neglect. Although the "Tuskegee Study of Untreated Syphilis in the Negro Male," is treated as a historical case study in ethics, the consequences, such as medical distrust in southern communities, are still present [10]. Coupled with limited access, insufficient infrastructure, rurality, and poverty, it is unsurprising that the southern United States holds sub-optimal levels of elective vaccination (e.g., influenza, HPV, etc.) [8,11], including COVID-19 vaccination [12,13].

Social media and online forums with real-time monitoring can inform public health efforts aimed at promoting vaccine confidence and reducing negative sentiments by offering insight into current perceptions [14]. Considering the broad usage of Twitter, and that many social interactions have moved online during the period of "stay at home" orders, we analyzed Twitter posts (tweets) related to the novel coronavirus vaccine to better understand the scope of negative vaccine sentiments across the country. We conducted state-level analysis on negative COVID-19 vaccine tweets to assess if such trends of negative opinions may be present across multiple states. We test two hypotheses that are informed from prior vaccine research: 1) the southern United States will have more tweets expressing negative sentiments toward

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COVID-19 vaccination compared to non-southern states, and 2) higher-income states will witness lower prevalence of these negative tweets as compared to lower-income states.

2. Methods

2.1. Data

Twitter is an online social media platform where users share short (maximum 280 characters) messages called tweets. Twitter has 152 million daily users and more than 500 million daily new posts. The United States has the largest national number of Twitter users, estimated at ~47 million [15]. Using the Sysomos software, on May 1, 2020, we extracted one week’s (April 5 to April 11, 2020) worth of English language tweets from the United States, containing the phrases “COVID-19”, “coronavirus” or “SARS-CoV-2”, and referring to vaccine. This produced a sample of 208,973 tweets. We selected this study period to capture a public response to the event where Bill Gates went on TV and talked about a potential COVID vaccine in early April 2020. Search terms to identify the topic of vaccine were “vaccination,” “vaccine,” and “vaccinate.” We imputed the location of tweets based on Twitter users’ self-reported state of residence. After finalizing our initial data sample, we extracted tweets expressing negative sentiments on COVID-19 vaccines through a keyword search (n = 14,794). This keyword list was derived by Twitter hashtags routinely used by individuals with negative opinions on vaccines and supplemented by newer hashtags related specifically to the COVID-19 vaccine. Examples include “NoVax”, “NewWorldOrder”, and “VaccinesKill.” A complete list is provided in the Appendix.

2.2. Defining geographic regions

The United States South is home to eight states, namely Alabama, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, and Texas [16]. Populations in these states are more likely to be culturally conservative, reside in rural settings, and have insufficient access to healthcare [17]. Other states were assigned to geographic regions as defined by the United States Census Bureau: Northeast, Midwest, and West [18].

2.3. Standardizing rates of tweets

To account for state population size, we calculated the prevalence of negative COVID-19 vaccine tweets per 10,000 population. We adopted state-level population size from the 2019 United States Census Bureau estimates.

2.4. State level income

We identified higher-income states as those with per capita income that was above the national median (2019) and lower-income states as those below the national median.

2.5. Statistical analyses

We performed t-tests to examine whether the number, prevalence, and percentage of negative COVID-19 vaccine tweets were different in the southern United States as compared with other geographic regions, and if there were statistically significant differences in these metrics between higher-income and lower-income states. We used Stata 16 (StataCorp LLC, College Station, TX) to analyze our data and Python to plot our state-level gradient heat map.

2.6. Statement

The University of Alabama at Birmingham Institutional Review Board deemed this study as non-human subjects research and therefore exempt (IRB-#300005071).

Table 1

Tweets expressing negative COVID-19 vaccine sentiments by geographic region and state.

State	Number of Tweets	Prevalence per 10,000 Population ^a	Percentage ^b (%)
Northeast			
Connecticut	96	0.27	6.40
Maine	56	0.42	8.13
Massachusetts	163	0.24	4.04
New Hampshire	38	0.28	7.00
New Jersey	200	0.23	5.22
New York	592	0.30	4.48
Pennsylvania	376	0.29	5.87
Rhode Island	38	0.36	7.88
Vermont	11	0.18	3.83
Average	174	0.28	5.87
Midwest			
Illinois	273	0.22	5.10
Indiana	216	0.32	9.24
Iowa	64	0.20	6.50
Kansas	71	0.24	7.64
Michigan	372	0.37	8.38
Minnesota	167	0.30	6.79
Missouri	205	0.33	7.23
Nebraska	57	0.29	7.38
North Dakota	13	0.17	6.28
Ohio	373	0.32	7.59
South Dakota	24	0.27	8.82
Wisconsin	179	0.31	9.32
Average	168	0.28	7.52
South			
Alabama	200	0.41	9.04
Arkansas	104	0.34	10.45
Delaware	19	0.20	5.74
Florida	1156	0.54	7.85
Georgia	359	0.34	6.94
Kentucky	146	0.33	7.27
Louisiana	151	0.32	7.74
Maryland	137	0.23	5.40
Mississippi	102	0.34	10.03
North Carolina	379	0.36	7.59
Oklahoma	160	0.40	9.03
South Carolina	209	0.41	8.47
Tennessee	373	0.55	9.31
Texas	1555	0.54	8.46
Virginia	208	0.24	6.01
West Virginia	56	0.31	7.60
Average	332	0.37	7.93
West			
Alaska	41	0.56	6.89
Arizona	357	0.49	7.68
California	1133	0.29	4.99
Colorado	218	0.38	6.42
Hawaii	42	0.30	7.69
Idaho	66	0.37	7.48
Montana	61	0.57	8.51
Nevada	177	0.57	7.42
New Mexico	50	0.24	6.31
Oregon	169	0.40	6.61
Utah	50	0.16	6.02
Washington	202	0.27	4.86
Wyoming	51	0.88	9.92
Average	201	0.42	6.99

Notes.

^a Prevalence of negative vaccine tweets per 10,000 population was calculated using the following formula: .

^b Percentage of all vaccine related tweets that expressed negative sentiments toward COVID-19 vaccines.

3. Results

Of our full sample (N = 208,973), 81.47 % (n = 170,268) tweets were associated with a user account that reported state location and were therefore included in the regional analysis; 7.08 % (n = 14,794) of vaccine related tweets expressed negative sentiments toward the COVID-19 vaccine.

In Table 1, we present the number and percentage of negative vaccine tweets, segmented by region and state. For each geographic region, we report state-level data as well as the average values across the region. We found wide variability across states. For example, in our sample, Utah had a prevalence of 0.16 negative tweet per 10,000 people while Wyoming had a prevalence of 0.88 tweet. Vermont had the lowest percentage of vaccine tweets expressing negative opinions (3.83 %) while Arkansas had the high-

est at 10.45 %. The five states with the highest percentage of vaccine tweets containing negative sentiments were Arkansas (10.45 %), Mississippi (10.03 %), Wyoming (9.92 %), Wisconsin (9.32 %), and Tennessee (9.31 %). When examining tweets by region, we found that while the Northeast, Midwest, and West had approximately 200 negative tweets per state, Twitter users residing in the South posted notably more, averaging about 332 (66 % more) negative COVID-19 vaccine tweets per southern state. A few examples of negative COVID-19 vaccine tweets are:

Isn't it unbelievable that so quickly there's a vaccine for #coronavirus & testing for it???? What a #Hoax What a Joke! Flu season is over... #WakeUpAmerica #Truth.
Beware!!! They are setting the stage to force vaccinations.
It is all about the NOW and the money for Gate and Fauci on the 'new vaccine!'

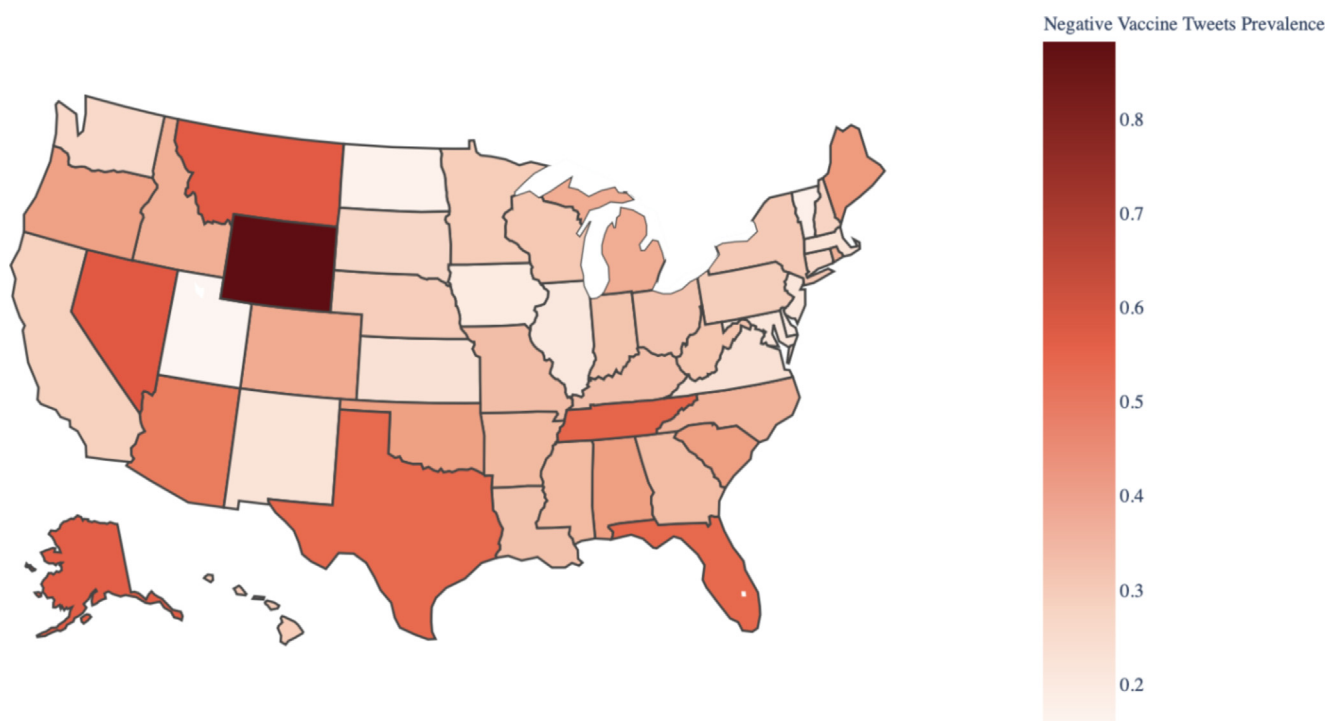


Fig. 1. Heat map of state-by-state prevalence of negative COVID-19 vaccine tweets on Twitter.

Table 2
 Variations in negative COVID-19 vaccine tweets by Deep South region and state-level per capita income.

	Number of Negative Vaccine Tweets ^a	Prevalence per 10,000 Population ^b	Percentage ^c (%)
Region			
Deep South ^d	514 (539)	0.41 (0.09)	8.26 (0.97)
Other States	176 (199)	0.33 (0.14)	7.00 (1.58)
p-value	0.003***	0.150	0.040**
Per Capita Income (2019 USD)^e			
High-Income ^f	181 (238)	0.31 (0.14)	6.41 (1.56)
Low-Income	280 (349)	0.38 (0.11)	8.00 (1.10)
p-value	0.250	0.040**	<0.001***

Notes.
 * p < 0.1; ** p < 0.05; *** p < 0.01.
 Standard deviations are included in parentheses.
^a Number of negative vaccine tweets posted between April 4th and April 11th, 2020.
^b Prevalence of negative vaccine tweets per 10,000 population was calculated using the following formula: .
^c Percentage of all vaccine related tweets that expressed negative sentiments.
^d States in the Deep South include Alabama, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, and Texas.
^e Data from the United States Bureau of Economic Analysis.
^f High-income states are 25 states with per capita income higher than the national median; low-income states are those with per capita income lower than the national median.

States with the highest prevalence of negative vaccine tweets were Wyoming (0.88), Nevada (0.57), Montana (0.57), Alaska (0.56), and Tennessee (0.55). The five states with lowest prevalence of these tweets were Utah (0.16), North Dakota (0.17), Vermont (0.18), Delaware (0.20), and Iowa (0.20). Fig. 1 is a heatmap illustrating the state-by-state prevalence of negative vaccine tweets per 10,000 population.

In Table 2, we present data that indicates the southern region had significantly more negative vaccine tweets ($p < 0.001$) as well as a higher percentage of these negative tweets ($p = 0.04$), compared with the rest of the United States. Higher-income states had lower prevalence of vaccine tweets expressing negative opinions ($p = 0.04$) and lower percentage of these tweets ($p < 0.001$) compared to lower-income states.

4. Discussion

We found support for both hypotheses. The southern United States had statistically more tweets expressing negative sentiments toward COVID-19 vaccines compared to non-southern states (and, southern states had, on average, more negative vaccine tweets compared to other Census regions), and higher-income states had significantly lower prevalence of these negative vaccine tweets as compared to lower-income states. Our results have implications for strategies promoting vaccine confidence. Specifically, in our data, poorer southern states held higher levels of negative vaccination-related sentiments, and that skepticism may be partially influencing the lower rates of COVID-19 vaccine uptake [19,20]. While negative opinions on vaccine is of concern, in poorer southern states, vaccines may not be reaching much of their population, namely residents who live in rural communities without access to a state health department or commercial pharmacy. Preliminary research has already identified disparities in COVID-19 related deaths, with African American or Black citizens being disproportionately represented in mortality statistics [21], and these populations live and work across the rural south. Thus, if public health professionals do not address negative vaccine sentiments, health disparities may become exacerbated, harming already underserved communities across the southern United States.

Additionally, regional differences in negative vaccine sentiments, that leads to an imbalance in uptake, could make it more difficult to attain herd immunity. If people opt out of COVID-19 vaccination due to skepticism, distrust, or fear, we should expect ongoing outbreaks, as has been noted with measles in areas of California where parents refused to vaccinate their young children [22], and continued COVID-19 related morbidity and mortality.

Findings should be applied considering the limitations of our study. First, we were unable to screen for automatically generated tweets. Twitter users' state locations were self-reported; therefore, it is possible that some Twitter users may have reported an inaccurate location. Some Twitter users may have posted multiple negative vaccine tweets over the course of the week, and because of this behavior, those sentiments may be over-represented in our sample. Since we used a defined word list to identify negative sentiments in COVID-19 vaccine tweets, it is likely that some relevant tweets were not identified and thus not included in our sample. Twitter users' opinions and sentiments may not represent the views of non-Twitter users, affecting generalizability.

Future research using social media data to assess vaccine sentiments could compare the prevalence of negative sentiments to positive/confident sentiments and monitor trends over time to potentially identify events in the media that influenced sentiments. Our study only assessed the prevalence of negative vaccine tweets, future studies are needed to analyze the content of these tweets to identify different themes of these negative sentiments, such as mistrust of the government or conspiracy theory.

5. Conclusions

Our findings illustrate that not only do negative sentiments toward COVID-19 vaccines exist, but also that there is geographic variability in the pervasiveness of this opinion. Southern states and states with lower income were associated with higher prevalence of negative COVID-19 vaccine sentiments. This is of concern, since these states are already underserved and hold some of the lowest rates of elective vaccination in the nation. Finding culturally acceptable methods to promote vaccine confidence may improve population health in these states.

Data availability

Data will be made available on request.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. Research reported in this publication was supported by the University of Alabama at Birmingham School of Public Health Back of the Envelope Award for RS.

Appendix

Search terms for COVID-19: "COVID19", "coronavirus", "COVID-19", and "SARS-CoV-2".

Search terms for vaccine: "vaccine", "vaccinate", and "vaccination".

Search terms to identify anti-vaccine sentiments: "NewWorldOrderVirus", "NewWorldOrder", "NWO", "SayNoToBillGates", "NoVax", "ArrestBillGates", "propoganda", "plandemics", "microchip", "GatesVirus", "forced vaccination", "WakeUpAmerica", "VaccinesKill", "RightToChoose", "MyBodyMyChoice", "LeanTheRisk", "JustAsking", "VaccinesCauseAutism", "VaccinesCauseAIDs", "VaccinesUncovered", "VaccineTruth", "CDCWhistleBlower", "HearThisWell", "HHSlawsuit".

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