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Geographic and demographic correlates of autism-related anti-vaccine beliefs on Twitter, 2009-15

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ABSTRACT

This study examines temporal trends, geographic distribution, and demographic correlates of anti-vaccine beliefs on Twitter, 2009–2015. A total of 549,972 tweets were downloaded and coded for the presence of anti-vaccine beliefs through a machine learning algorithm. Tweets with self-disclosed geographic information were resolved and United States Census data were collected for corresponding areas at the micropolitan/metropolitan level. Trends in number of anti-vaccine tweets were examined at the national and state levels over time. A least absolute shrinkage and selection operator regression model was used to determine census variables that were correlated with anti-vaccination tweet volume. Fifty percent of our sample of 549,972 tweets collected between 2009 and 2015 contained anti-vaccine beliefs. Anti-vaccine tweet volume increased after vaccine-related news coverage. California, Connecticut, Massachusetts, New York, and Pennsylvania had anti-vaccination tweet volume that deviated from the national average. Demographic characteristics explained 67% of variance in geographic clustering of anti-vaccine tweets, which were associated with a larger population and higher concentrations of women who recently gave birth, households with high income levels, men aged 40 to 44, and men with minimal college education. Monitoring anti-vaccination beliefs on Twitter can uncover vaccine-related concerns and misconceptions, serve as an indicator of shifts in public opinion, and equip pediatricians to refute anti-vaccine arguments. Real-time interventions are needed to counter anti-vaccination beliefs online. Identifying clusters of anti-vaccination beliefs can help public health professionals disseminate targeted/tailored interventions to geographic locations and demographic sectors of the population.

1. Introduction

Recent outbreaks of previously eradicated, vaccine-preventable diseases such as measles and pertussis are a public health concern (Adams et al., 2016; Phadke et al., 2016; Winter et al., 2014; Zipprich et al., 2015). These outbreaks have been linked to parental delay or refusal of vaccines over anti-immunization related beliefs (Gust et al., 2008; Salmon et al., 2005; World Health Organization, n.d.). Anti-vaccination beliefs represent diverse elements and characteristics in relation to vaccines, which manifest themselves in a wide range of negative attitudes ranging from being fully against vaccines to expressing hesitancy about them (Gust et al., 2005). These beliefs are driven by distrust of government/the pharmaceutical industry (Larson et al., 2014), lack of perceived need, and doubts about vaccine safety and potential side effects (Chen and DeStefano, 1998; Chen and Hibbs, 1998; Smailbegovic et al., 2003). Of particular interest are misconceptions linking preservatives in children's vaccines, especially thimerosal, to autism spectrum disorder [ASD; (Hviid et al., 2003)]. ASD is a developmental disorder characterized by communication, social, and behavioral impairments (Centers for Disease Control and Prevention, 2015; Phadke et al., 2016) and affects one in 68 eight-year-old children (Christensen et al., 2016).

Delay of vaccines involves individualized vaccine administration schedules against the official recommendations of the Advisory Committee on Immunization Practices (ACIP) on appropriate ages, number of doses, and intervals between doses, which can

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compromise vaccine effectiveness (Centers for Disease Control and Prevention, 2004; Plotkin, 2011). In 2005, missed doses accounted for two-thirds of a 28% non-compliance rate with ACIP's recommendations among children 19–35 months (Luman et al., 2008). Other forms of non-compliance include delays up to six months for four or more vaccines in the first two years of life (Luman et al., 2005).

One measure of parental refusal of vaccines is the rate of nonmedical exemptions from mandated school immunizations (Salmon et al., 2005). Currently, District of Columbia and all states except Mississippi and West Virginia grant religious exemptions and 18 states grant philosophical exemptions (National Conference of State Legislatures, 2016). Data show a 6% annual increase in nonmedical exemptions in states that offer belief-based exemptions but no significant changes in religious exemptions (Omer et al., 2006). Further, nonmedical exemptions vary within states to create geographic clusters where rates of unvaccinated children are likely to increase (Omer et al., 2008, 2009; Richards et al., 2013; Smith et al., 2004). For example, in 2015–2016, county-level exemptions for kindergarten-aged children in Washington ranged from 1.0% to 17.0% (Washington State Department of Health, 2016).

Nonmedical exemptions are associated with acquisition and transmission of vaccine-preventable diseases (Feikin et al., 2000; Salmon et al., 1999). In a nationwide retrospective cohort study, exempt children were 35 times more likely to acquire measles than nonexempt children (Salmon et al., 1999). Another state-level retrospective cohort study showed that exempt children were 22.2 and 5.9 times more likely to acquire measles and pertussis than vaccinated children (Feikin et al., 2000). Beyond risks to exempt children, clusters of nonmedical exemptions pose risks to the community. Omer and colleagues found that geographic/temporal clusters of pertussis cases were 2.7 times more likely to overlap with exemption clusters after covariate adjustments (Omer et al., 2008). Similarly, incidence rates of measles and pertussis in vaccinated children were associated with the frequency of exempt children in a county [relative risk 1.6 and 1.9; (Feikin et al., 2000)].

Anti-vaccination beliefs either directly or indirectly (through vaccination perceived risks) predict underimmunization (Betsch et al., 2010; Brewer et al., 2007; Gust et al., 2004). However, research on the characteristics of individuals who hold anti-vaccination beliefs remains limited (Kata, 2012). Studies show that women and highly educated and high socio-economic parents are more likely to be concerned about vaccine safety and to delay/refuse childhood vaccines (Freed et al., 2010; Smith et al., 2010; Song, 2014). These results are largely based on survey methods that are subject to social desirability biases (Krumpal, 2013). Conversely, Web 2.0 affords an uncensored platform for disseminating vaccine-related beliefs (Witteman and Zikmund-Fisher, 2012). More importantly, parents who are concerned about vaccine safety and delay/refuse vaccines often seek health information online (Gust et al., 2005; Smith et al., 2010). Online sources are considered horizontal media sources (McCombs et al., 2014) where people choose to be exposed to beliefs and opinions similar to their own, creating an echo chamber and increasing the polarization around vaccines (Witteman and Zikmund-Fisher, 2012).

Researchers have documented the prevalence and content of anti-vaccination websites (Bean, 2011; Wolfe and Sharp, 2005). However, little is known about anti-vaccination beliefs on social media sites such as Twitter. The literature thus far has been limited to review articles on the potential role of social media in vaccination beliefs and behavior (Betsch et al., 2012; Dredze et al., 2016; Kata, 2012). Love and colleagues conducted, to our knowledge, the only data-driven study of the source, tone, and accuracy of 2580 reposted/shared vaccination tweets (Love et al., 2013). The sample included all vaccine-related tweets (e.g., adult vaccines) and was limited to reposted/shared tweets over one week.

Twitter is a platform for health-related information (Scanfield et al., 2010) and exposure to vaccine-related information on social media has been associated with vaccine-related behavior (Avery and Lariscy, 2014). Further, geo-tagged Twitter data allow researchers to identify geographical regions where anti-vaccination beliefs are predominant. The primary goal of this study is to examine variations in anti-vaccine beliefs that link vaccines to ASD by geographic distribution and demographics on Twitter. Specifically, we examined prevalence of anti-vaccine beliefs tied to ASD from 2009 to 2015 in U.S. micropolitan and metropolitan areas, as well as in entire states. Finally, we examined the association between micro/metro-specific demographic characteristics and geographic distribution of anti-vaccine tweets.

2. Methods

2.1. Data collection

We used Social Studio's Radian6 (Kim et al., 2013; Stavrakantonakis et al., 2012) application programming interface (API) to identify publicly available tweets that contained at least one ASD and one vaccine-related search keyword. We used search keywords that were culled from previous literature (Diresta and Lotan, 2015; Offit, 2008) to retrieve tweets from Radian6 that mentioned ASD and vaccines. Search keywords were vaccine, vaccinated, immunization, mmr vaccine, mmrvaccine, #b1less, #hearus, heavy metals, leaky gut, mercury, ethylmercury, methylmercury, thimerosal, preservative, dpt, diphtheria-pertussis-tetanus, pharmaceutical companies, big pharma, autism, autistic, asperger. We also included slang and misspellings of search keywords (i.e., vacinne, vacine, antivax, anti vax, aspie, asberger, assberger, asd). Finally, we included hashtags that journalists described in their coverage of anti-vaccination beliefs on Twitter (i.e., cdcwhistleblower, cdc whistleblower, sb277).

A total of 549,972 tweets (including retweets) from 01/01/2009 to 08/21/2015 were returned and downloaded. To ensure search accuracy, two researchers coded a random sample of 550 tweets. We found that 540 tweets mentioned vaccines and ASD, a 98.2% accuracy for the search keywords adopted.

2.2. Data coding

We adopted a machine learning approach to identify tweets that expressed anti-vaccine beliefs. We used “anti-vaccine” as an umbrella term to capture a wide range of negative beliefs about vaccines. This approach allowed us to manually annotate a manageable number of tweets to build an algorithm that then coded the entire dataset.

To train the algorithm, two researchers coded 2000 tweets into two categories: (1) Anti-vaccine and (2) Other, which consisted of tweets that were pro-vaccines and neutral (i.e., tweets that did not make a judgment about ASD and vaccines). Anti-vaccine tweets portrayed vaccines as dangerous, ineffective or negative, and mentioned a potential causal link to ASD. Examples of tweets that fell into the anti-vaccine category include: “CDC whistleblower confesses to publishing fraudulent data to obfuscate link between vaccines and autism,” and “RT @_____: Autism is primarily caused by mercury present in vaccines.” Examples of tweets that fell into the other category include: “NEWS: The Lancet revokes 1998 Wakefield et al. paper associating MMR to autism and GI problems. On February 2, …”; “Additional evidence of no link between Autism and thimerosal, a preservative used in vaccines. New national study published in Medscape Today,” “Could too many vaccines too early lead to #autism? Latest study says no