


COMMENTARY



## Measles outbreaks and public attitudes towards vaccine exemptions: some cautions and strategies for addressing vaccine hesitancy

Sandra Crouse Quinn <sup>a,b</sup>, A. M. Jamison <sup>b</sup>, and V. S. Freimuth<sup>c</sup>

<sup>a</sup>Department of Family Science, School of Public Health, University of Maryland, College Park, MD, USA; <sup>b</sup>Center for Health Equity, School of Public Health, University of Maryland, College Park, MD, USA; <sup>c</sup>Center for Health And Risk Communication (Emerita), University of Georgia, Athens, GA, USA

### ABSTRACT

Today, the United States and countries throughout the world are experiencing measles outbreaks that have sickened thousands of children. From the Disneyland outbreak in 2014 to today, some states have responded with changes in laws on vaccine requirements and exemptions. In this article, we examine the history of vaccine laws, and using our 2015 survey data, explore to what extent the news coverage of the Disneyland outbreak altered parents' attitudes toward required vaccination and non-medical exemptions. We explore those results in the context of today's increasing polarized and politicized battle over vaccine laws, and consider how health care providers and policy makers can work to improve public attitudes about vaccines.

### ARTICLE HISTORY

Received 27 June 2019  
Accepted 12 July 2019

### KEYWORDS

Vaccine exemptions; vaccine hesitancy; measles; vaccine policy

### Introduction

In June 2019, the Centers for Disease Control and Prevention (CDC) reported 1,044 measles cases in 28 states.<sup>1</sup> With no end in sight, 2019 has already set the record for the highest annual case count since endemic measles was eliminated from the US in 2000.<sup>1</sup> These outbreaks are only the most recent example of how measles, one of the world's most contagious diseases, can spread through un- and under-vaccinated populations.<sup>2</sup> Outbreaks have drawn attention to the role of nonmedical vaccine exemptions in the spread of both measles and other vaccine preventable illnesses.<sup>3,4</sup> These nonmedical vaccine exemptions, or NMEs, are under increased scrutiny as medical professionals, citizen groups, and lawmakers debate how to balance individual choices against the state's obligations to protect public health.<sup>5</sup> To fully understand this debate, it is important to consider the history and evolution of vaccine policies, and relatedly, public attitudes. Our research led us to investigate how media coverage of an outbreak can influence and potentially modify public attitudes towards both NMEs and mandatory vaccination.

### Vaccine policies past and present

Currently, all states require evidence of immunization for children to attend a public school or state-licensed day care facility.<sup>6</sup> However, parents may obtain exemptions to exclude their child(ren) from these requirements. All states permit medical exemptions for children with health conditions that preclude vaccination.<sup>7</sup> Currently, all but five states (NY, ME, CA, MS, & WV) permit exemptions on religious grounds, and fifteen permitted exemptions for philosophical reasons.<sup>6</sup> Criteria for each

type of exemption vary by state. Religious exemptions may require a family to belong to a "religious group with bone fide objections to vaccination"; however, most major world religions have endorsed vaccination and only a handful of sects expressly forbid it.<sup>8</sup> Philosophical or "personal belief" exemptions encompass a broader set of beliefs. Many who obtain philosophical exemptions view mandatory vaccination as an infringement on their personal liberty, claiming that as parents, they should have the right to choose whether to vaccinate.<sup>5</sup> Others may seek a philosophical exemption out of concerns about vaccine safety.<sup>9</sup>

To understand the current patchwork of vaccine policies, it is necessary to understand the history of vaccination laws. There are no overarching federal laws that set vaccine requirements, instead, vaccine laws evolved state by state, in a piecemeal fashion, and remain under state authority today. In the mid-1800's, states began to require all children to attend school, but recognized that congregations of schoolchildren fuelled smallpox outbreaks.<sup>10</sup> In 1855, Massachusetts passed the first law mandating smallpox vaccination for school children.<sup>11</sup> Parents fought back and in 1894, the first documented medical exemption policy was introduced, also in Massachusetts.<sup>10</sup> As individuals resisted state efforts, the issue went to the Supreme Court. Two cases established a precedent for vaccine requirements: 1905's *Jacobson v. Massachusetts* upheld compulsory vaccination laws, and 1922's *Zucht v. King* specifically upheld the constitutionality of school-based vaccine requirements.<sup>10,12</sup>

In practice, for the first half of the 20th century, vaccine requirements were only loosely enforced, varied by school district, and were typically only triggered by a nearby outbreak.<sup>10</sup> It wasn't until several large-scale measles outbreaks swept through public schools in the 1960's and 1970's that states began to expand, enforce, and formalize state-wide policies.<sup>9</sup> By 1980, all 50 states

had vaccine requirement policies in place.<sup>10</sup> These new requirements galvanized resistance groups, and even as new laws were enacted, most included exemptions for parents based on medical or religious concerns.<sup>10</sup>

In the late 2010's, high-profile measles outbreaks brought renewed attention to the role of NMEs, prompting state legislatures to take action. Most states have acted to tighten vaccine requirements and eliminate certain forms of exemptions. Most notable of these new laws was California bill SB-277, passed in 2015 to end NMEs in the state.<sup>13</sup> In the past year, state legislatures in Washington, New York, and Maine have enacted new legislation to restrict NMEs.<sup>14-16</sup> Similar efforts in Colorado and Oregon both failed to pass.<sup>17,18</sup> Additionally, California is in the process of enacting SB-276, a bill designed to tighten requirements to obtain medical vaccine exemptions.<sup>19</sup>

### Impact of exemptions

Vaccine exemptions remains rare, but the number of parents obtaining exemptions is on the rise.<sup>20</sup> Reports from the CDC indicate that across the total population, less than <1% of parents have opted their child out of all required vaccinations.<sup>21</sup> However, these numbers have been rising steadily since the early 1990's.<sup>9</sup> In one study, among the 18 states that permitted nonmedical exemptions, rates of exemption seeking rose in 12 states, with the greatest increases occurring between 2009 and 2014.<sup>22</sup> The rate of NMEs also reflects the ease with which parents can obtain them. Multiple studies have confirmed that the ease of obtaining a nonmedical exemption is inversely correlated with exemption rates.<sup>23,24</sup> In 2012, Omer and colleagues found that states with easy access to exemptions had NME rates nearly twice that of the states with more difficult process.<sup>24</sup> The rise in NMEs is further compounded by clustering effects, as parents of unvaccinated children tend to be in close proximity, concentrating areas of vulnerability and increasing the likelihood of disease outbreaks.<sup>25,26</sup> A study in California found that prior to SB277, 2.5% of students entering kindergarten received NMEs, but clustering effects led to some school districts where MMR vaccination rates dropped below 50%.<sup>27</sup>

In terms of infectious disease outbreaks, evidence suggests that rising rates of NME and clustering both contribute to outbreaks of vaccine-preventable illnesses. The highly infectious nature of many of these diseases, and particularly measles, can only be suppressed through regular immunization and herd immunity. For instance, a child that forgoes MMR vaccine is up to 35 times more likely to contract measles than a vaccinated child.<sup>28</sup> In 2010, NMEs (coupled with declining vaccine efficacy) were attributed to reasons rising pertussis rates in California.<sup>29</sup> In 2015, a major multi-state measles outbreak centered in Disneyland theme park in California was at least partially fuelled by unvaccinated children.<sup>30</sup>

Current measles outbreaks are spreading through under-vaccinated religious communities and in communities with high rates of unvaccinated children. The latest updates from the Rockland County, New York outbreak indicate that of 275 confirmed cases, 81% were unvaccinated or under vaccinated for MMR, 15% were of unknown vaccination status, and only 3% had received the recommended 2 doses of MMR.<sup>31</sup> Similarly, among the 81 cases documented in

Washington State as of June 17, 2019, 63 were unvaccinated, 4 were under-vaccinated, 12 were of unknown vaccination status, and only 2 cases was reported among fully immunized individuals.<sup>32</sup>

### Vaccine exemptions and public attitudes

In March 2015, we contracted with the GfK Group, an international research firm, to conduct a nationally representative sample of non-Hispanic White and non-Hispanic Black American adults, administered through GfK's KnowledgePanel.<sup>33</sup> Our survey was administered at the peak of the 2015 Disneyland measles outbreak and we asked respondents a suite of items asking them to rate how the media coverage of the outbreak impacted their views towards both nonmedical vaccine exemptions and mandatory vaccination. Response rates were high, at 57%. These responses, combined with demographic information, gave us a unique, and data-driven perspective of how media coverage of the outbreak was influencing vaccine attitudes in virtually real time.

In our representative sample of African American and White adults ( $n = 1,657$ ), we found that nearly 70% of adults followed news coverage of the outbreak, with 35.2% watching at least "somewhat closely" (See Table 1). Of the 364 adults with children under 18, 92% indicated that all their children were up-to-date on measles vaccination, mirroring the 2015 national average of 91.9%. We asked two opinion items: "How has news of the current measles outbreak affected your attitudes towards required childhood vaccinations?" and "In some states, children can go to school without being vaccinated if their parents oppose vaccination for religious or philosophical reasons. How has the news of the measles outbreak affected your attitude towards these non-medical exemptions for required vaccinations?". Responses to these two items were significantly correlated ( $p = .01$ ) and reflected an inverse relationship between attitudes toward required vaccination and attitudes toward vaccine exemptions. In Table 1, slightly over half (51%) of respondents reported that the measles outbreak had "no effect" on their attitudes towards required vaccination. Similarly, slightly less than half (47%) reported "no effect" on their attitudes towards vaccine exemptions. However, among those who reported a change of opinions, the majority felt more favorably towards required vaccination (46% more, 3% less) and less favorable towards nonmedical vaccine exemptions (7% more, 46% less).

Using chi-square analysis, we also observed significant differences in attitudes by demographics. After the outbreak, a significantly higher proportion of Whites (48%) viewed required vaccinations favorably than African Americans (33%). The reverse was also true: a significantly lower proportion of Whites (6%) viewed vaccine exemptions favorably than African Americans (11%). The relationship between education levels and attitudes showed a graded relationship. As education level increased, the proportion of adults favoring required vaccination increased, and the proportion of adults with favorable attitudes towards NMEs declined. Additionally, adults with higher income (>\$40K) felt more favorable towards required vaccination, and less favorable towards exemptions

**Table 1.** Attitudes toward vaccination by demographic, political and ideological variables.

	Required Childhood Vaccines			Nonmedical Vaccine Exemptions		
	More Favorable	No Effect	Less Favorable	More Favorable	No Effect	Less Favorable
<b>Race</b>		<i>p</i> = .000			<i>p</i> = .000	
White ( <i>n</i> = 827)	47.9%	49.5%	2.7%	5.8%	44.5%	49.7%
African American ( <i>n</i> = 793)	32.8%	62.2%	5.0%	11.4%	62.4%	26.2%
<b>Education</b>		<i>p</i> = .000			<i>p</i> = .000	
Less than H.S. ( <i>n</i> = 116)	30.7%	62.8%	6.6%	9.5%	54.0%	36.5%
High School ( <i>n</i> = 504)	44.2%	51.6%	4.1%	7.0%	57.7%	35.3%
Some College ( <i>n</i> = 481)	44.4%	53.0%	2.6%	7.4%	47.4%	45.2%
College or higher ( <i>n</i> = 519)	52.1%	46.5%	1.4%	4.5%	34.6%	60.8%
<b>Household Income</b>		<i>p</i> = .007			<i>p</i> = .000	
< \$20,000 ( <i>n</i> = 318)	38.2%	57.5%	4.2%	14.4%	55.3%	30.2%
\$20,000- \$40,000 ( <i>n</i> = 331)	37.6%	58.8%	3.6%	4.3%	60.2%	35.5%
\$40,000-\$85,000 ( <i>n</i> = 527)	49.5%	48.0%	2.6%	5.5%	47.7%	46.8%
>\$85,000 ( <i>n</i> = 443)	48.6%	48.5%	2.9%	5.5%	37.3%	57.2%
<b>Political Ideology</b>		<i>p</i> = .000			<i>p</i> = .000	
Extremely Liberal ( <i>n</i> = 76)	37.1%	59.7%	3.2%	12.9%	25.8%	61.3%
Liberal ( <i>n</i> = 266)	52.1%	42.3%	5.6%	6.8%	35.5%	57.7%
Slightly Liberal ( <i>n</i> = 153)	52.3%	46.1%	1.6%	3.1%	38.0%	58.9%
Moderate ( <i>n</i> = 596)	42.1%	56.1%	1.8%	6.0%	51.5%	42.4%
Slightly Conservative ( <i>n</i> = 188)	49.8%	47.9%	2.3%	1.4%	51.1%	47.5%
Conservative ( <i>n</i> = 243)	49.2%	46.9%	3.9%	10.6%	47.4%	41.9%
Extremely Conservative ( <i>n</i> = 58)	32.5%	67.5%	0.0%	10.1%	64.6%	25.3%
<b>Political Affiliation</b>		<i>p</i> = .000			<i>p</i> = .000	
Strong Democrat ( <i>n</i> = 520)	55.0%	42.1%	3.0%	8.2%	35.2%	56.6%
Moderate Democrat ( <i>n</i> = 227)	41.3%	56.4%	2.2%	7.3%	50.0%	42.7%
Leans Democrat ( <i>n</i> = 313)	42.3%	53.9%	3.8%	5.0%	44.8%	50.2%
Independent/Undecided ( <i>n</i> = 47)	24.0%	66.0%	10.0%	2.1%	61.7%	36.2%
Leans Republican ( <i>n</i> = 222)	43.6%	52.1%	4.3%	5.2%	56.4%	38.4%
Moderate Republican ( <i>n</i> = 134)	49.8%	48.8%	1.4%	8.3%	46.8%	44.9%
Strong Republican ( <i>n</i> = 154)	45.4%	53.3%	1.3%	7.6%	47.5%	45.0%

when compared to lower income adults. What is notable about many of these demographic trends, is that they go against the prevailing trends in vaccine exemptions – studies have shown that the parents seeking vaccine exemptions tend to be wealthier, whiter, and more educated than the general population.<sup>34-36</sup>

Our results regarding shifting attitudes and political ideology were also illustrative. Recent headlines have highlighted a growing ideological divide over “vaccine rights” between Republicans and Democrats.<sup>37</sup> At the time our survey was conducted in 2015, we found that individuals who felt more favorably towards NMEs fell to both ends of the political spectrum, with 12.9% of self-identified “extremely liberal” adults and 10.1% of “extremely conservative” adults, compared to 6.0% of political “moderates”. On a separate measure of party affiliation, we observed similar rates and patterns between both Republicans and Democrats. The evidence of a growing ideological divide, hinted at in 2015, is increasingly clear in 2019, as state legislatures and news reports highlight Republican resistance to mandatory vaccination policies.<sup>37</sup> This may be evidence of the broader party beginning to incorporate attitudes from a more extreme ideological base.

It is important to note that our survey is not limited to parents, nor are attitudes in any way indicative of actual vaccine related behaviors. However, polling data conducted by Pew in 2016 supports many of our findings. Pew found 82% of US adults believed MMR vaccination should be required for children to attend public schools.<sup>38</sup> However, that same survey found 17% of adults felt that parents should have “the ability to decide not to vaccinate their children”, with more conservatives (25%) expressing this attitude than either independents (15%) or liberals (9%).<sup>38</sup>

## Impact on public health

Public health practitioners, health care providers and policy makers continue to grapple with policy decisions about NMEs. There is evidence that public support is shifting, these results suggest, that for those who reported change in their attitudes based on media coverage of the 2015 outbreak, there was greater support for required vaccination and reduced support for NMEs. We also know from the 2019 outbreaks that the outbreaks themselves, coupled with intensive news coverage, substantial public health activities, and school engagement have led to increased demand for vaccination in California, Oregon, and beyond.<sup>39,40</sup> However, policies eliminating NMEs alone may not be enough. Even with the initial success of SB277 in California, the rate of medical exemptions increased by 250% immediately following SB277, suggesting abuse of the medical exemption system.<sup>41</sup> Similarly, Ostrov (2019) reported that medical exemptions have soared in some California schools that previously had the highest rates of NMEs, and across the state, medical exemptions have more than tripled.<sup>42</sup>

From a public health perspective, we cannot wait for an outbreak to occur in order to see vaccination rates move toward those needed for herd immunity. With the global challenge of vaccine hesitancy, we increasingly need to acknowledge the complex set of factors that influence parents and policy makers in vaccine decisions. Those factors, from perceived risk of vaccine side effects, trust in institutions, and an increased societal shift away from expert opinion and evidence, interact with individual family needs, parental perceptions of their child's health, and increasingly, the family's social networks and norms.

Today, the great danger is that the increasing politicization of vaccination, will exacerbate polarization of the vaccine discussion. Although some frame the discussion as a debate, the scientific

evidence for the safety and value of childhood vaccines is sound. However, today's rapidly evolving social media world and overt questioning of science at the highest levels of US government undermine scientific credibility in ways that are dangerous to the public's health. Malicious actors on social media,<sup>43,44</sup> politicians from ideological extremes, and the growing, uncurated world of online information, all contribute to this troubling phenomenon.

In Oregon, California and Washington, organized anti-vaccine groups rallied opponents to bills in such numbers that they overwhelmed legislative offices, often drowning out the voices of other constituents. Furthermore, the language of some opponents has harkened back to painful periods of US and world history as illustrated by this description of the Oregon hearings: "... the most passionate pleas came from those who compared their plight to Brown v. Board of Education and Nazi concentration camps, saying that those who choose not to vaccinate their children would be segregated unfairly" (p.5).<sup>45</sup> In Colorado, a state legislator's support of a bill to reduce NMEs led to death threats against his children's lives.<sup>42</sup>

Clearly, policy makers will continue to face increasing pressure from citizens advocating for NMEs. It is critical that they work with public health and health care organizations to understand the importance of strong vaccine laws and the need to minimize unnecessary exemptions. With an obligation to serve the public, it is essential that policy makers approach this as a public health issue and restrain themselves from politicizing vaccine law for political gain. As policy makers, it is their obligation to share the best evidence available, and avoid spreading misinformation. Ultimately, this is about protecting our children and adults from measles, a serious disease, and increasingly, it is about educating the public about the overall importance of vaccination of all vaccine preventable diseases.

## Disclosure of potential conflicts of interest

No potential conflicts of interest were disclosed.

## Funding

This research was supported by the Center of Excellence in Race, Ethnicity and Health Disparities Research (NIH-NIMHD: P20MD006737; PIs, Sandra Quinn and Stephen Thomas). Additionally, this research was supported by Supplementing Survey-Based Analyses of Group Vaccination Narratives and Behaviors Using Social Media, (David Broniatowski & Sandra Quinn, PI, Grant 5R01GM114771), funded by the National Institute of General Medical Sciences, NIH.

## ORCID

Sandra Crouse Quinn  <http://orcid.org/0000-0002-3258-4595>

A. M. Jamison  <http://orcid.org/0000-0002-3954-9581>

## References

- Centers for Disease Control and Prevention. Measles outbreaks; 2019 [accessed 2019 Jun 8]. <https://www.cdc.gov/measles/cases-outbreaks.html>.
- World Health Organization. Measles fact sheet. Measles key facts; 2018 Nov 11 [accessed 2019 Apr 15]. <https://www.who.int/en/news-room/fact-sheets/detail/measles>.
- Phadke VK, Bednarczyk RA, Salmon DA, Omer SB. Association between vaccine refusal and vaccine-preventable diseases in the United States: a review of measles and pertussis. *Jama*. 2016;315:1149–58.
- Lo NC, Hotez PJ. Public health and economic consequences of vaccine hesitancy for measles in the United States. *JAMA Pediatr*. 2017;171:887–92.
- Gostin LO. Law, ethics, and public health in the vaccination debates: politics of the measles outbreak law, ethics, and public health in the vaccination debates law, ethics, and public health in the vaccination debates. *JAMA*. 2015;313(11):1099–100. doi:10.1001/jama.2015.1518.
- National Conference of State Legislatures. States with religious and philosophical exemptions from school immunization requirements; 2019 Jun 14 [accessed 2019 Jun 24]. <http://www.ncsl.org/research/health/school-immunization-exemption-state-laws.aspx>.
- Centers for Disease Control and Prevention. School vaccination requirements and exemptions. Schoolvaxview; 2017 Oct 17 [accessed Jun 24 2019]. <https://www.cdc.gov/vaccines/imz-managers/coverage/schoolvaxview/requirements/index.html>.
- Najera RF. The history of vaccines. Very few religions expressly prohibit vaccination, yet confusion remains; 2018 Nov 9 [accessed 2019 Jun 25]. <https://www.historyofvaccines.org/content/blog/religion-vaccination-confusion>.
- Omer SB, Salmon DA, Orenstein WA, deHart MP, Halsey N. Vaccine refusal, mandatory immunization, and the risks of vaccine-preventable diseases. *N Engl J Med*. 2009;360(19):1981–88. doi:10.1056/NEJMsa0806477.
- Diekema DS. Personal belief exemptions from school vaccination requirements. *Annu Rev Public Health*. 2014;35:275–92.
- The College of Physicians of Philadelphia. Timeline: history of vaccines. History of vaccines. [accessed 2019 Jun 25]. [https://www.historyofvaccines.org/timeline#EVT\\_69](https://www.historyofvaccines.org/timeline#EVT_69).
- Novak A. The religious and philosophical exemptions to state-compelled vaccination: constitutional and other challenges. *Univ Pa J Const Law*. 2005;7:1101.
- Pan R Senate Bill No. 277 public health: vaccinations; 2015 [accessed 2019 Jun 25]. [https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill\\_id=201520160SB277](https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB277).
- Harris, Stonier, Robinson, Macri, Jinkins, Cody, Thai, Davis, Appleton, Doglio, et al. Washington state bill HB1638, 2019–20 promoting immunity against vaccine preventable diseases; 2019 [accessed 2019 Jun 25]. <https://app.leg.wa.gov/bills/summary?BillNumber=1638&Year=2019&Initiative=false>.
- McKinley J. Measles outbreak: N.Y. Eliminates religious exemptions for vaccinations. *New York Times*; 2019 Jun 13:A1.
- Tipping R An act to protect maine children and students from preventable diseases by repealing certain exemptions from the laws governing immunization requirements; 2019 [accessed 2019 Jun 25]. <http://legislature.maine.gov/LawMakerWeb/summary.asp?LD=798&SessionID=13>.
- Greenlick, Thomsen, Helt, Mitchell, Schouten, Wilde, Doherty, McKeown, Power, Prusak, et al. Oregon state bill HB3063; 2019 [accessed 2019 Jun 25]. <https://olis.leg.state.or.us/liz/2019R1/Measures/Overview/HB3063>.
- Staver A, Garcia N. Vaccination bill dead in colorado senate, sparking accusations of putting politics before kids' health. *The Denver Post*; 2019 May 2 [accessed 2019 Jun 25]. <https://www.denverpost.com/2019/05/02/vaccine-vaccination-bill-colorado-senate/>.
- Gutierrez M. California vaccine bill clears Assembly panel despite emotional backlash from parents. *Los Angeles Times*; 2019 Jun 20 [accessed 2019 Jun 25]. <https://www.latimes.com/politics/la-pol-ca-vaccine-exemption-bill-hearing-20190620-story.html>.
- Mellerson JL, Maxwell CB, Knighton CL, Kriss JL, Seither R, Black CL. Vaccination coverage for selected vaccines and exemption rates among children in kindergarten—United States, 2017–18 school year. *Morb Mortal Wkly Rep*. 2018;67(40):1115. doi:10.15585/mmwr.mm6740a3.
- Centers for Disease Control and Prevention (CDC). Estimated number and percentage of children enrolled in kindergarten with an

- exemption from one or more vaccines by state and the United States, school vaccination assessment program 2009–10 through 2017–18 school years. *SchoolVaxView*; 2018 Oct 11 [accessed 2019 Jun 25]. <https://www.cdc.gov/vaccines/imz-managers/coverage/schoolvaxview/data-reports/exemptions-trend/index.html>.
22. Olive JK, Hotez PJ, Damania A, Nolan MS. The state of the antivaccine movement in the United States: a focused examination of nonmedical exemptions in states and counties. *PLoS Med*. 2018;15(6):e1002578. doi:10.1371/journal.pmed.1002578.
  23. Rota JS, Salmon DA, Rodewald LE, Chen RT, Hibbs BF, Gangarosa EJ. Processes for obtaining nonmedical exemptions to state immunization laws. *Am J Public Health*. 2001;91(4):645. doi:10.2105/ajph.91.1.129.
  24. Omer SB, Richards JL, Ward M, Bednarczyk RA. Vaccination policies and rates of exemption from immunization, 2005–2011. *N Engl J Med*. 2012;367(12):1170–71. doi:10.1056/NEJMc1209037.
  25. Aloe C, Kulldorff M, Bloom BR. Geospatial analysis of nonmedical vaccine exemptions and pertussis outbreaks in the United States. *Proc Natl Acad Sci*. 2017;114(27):7101–05. doi:10.1073/pnas.1700240114.
  26. Omer SB, Enger KS, Moulton LH, Halsey NA, Stokley S, Salmon DA. Geographic clustering of nonmedical exemptions to school immunization requirements and associations with geographic clustering of pertussis. *Am J Epidemiol*. 2008;168(12):1389–96. doi:10.1093/aje/kwn263.
  27. Carrel M, Bitterman P. Personal belief exemptions to vaccination in California: a spatial analysis. *Pediatrics*. 2015;136(1):80–88. doi:10.1542/peds.2015-0831.
  28. Salmon DA, Haber M, Gangarosa EJ, Phillips L, Smith NJ, Chen RT. Health consequences of religious and philosophical exemptions from immunization laws: individual and societal risk of measles. *JAMA*. 1999;282(1):47–53. doi:10.1001/jama.282.1.47.
  29. Atwell JE, Van Otterloo J, Zipprich J, Winter K, Harriman K, Salmon DA, Halsey NA, Omer SB. Nonmedical vaccine exemptions and pertussis in California, 2010. *Pediatrics*. 2013;132(4):624–30. doi:10.1542/peds.2013-0878.
  30. Zipprich J, Winter K, Hacker J, Xia D, Watt J, Harriman K. Measles outbreak—California, December 2014–february 2015. *MMWR Morb Mortal Wkly Rep*. 2015;64:153.
  31. Rockland County Department of Health. 2018–2019 Measles outbreak in Rockland county; 2019 Jun 19 [accessed 2019 Jun 25]. <http://rocklandgov.com/departments/health/measles-information/>.
  32. Washington State Department of Health. Measles 2019; 2019 May [accessed 2019 Jun 25]. <https://www.doh.wa.gov/YouandYourFamily/IllnessandDisease/Measles/Measles2019>.
  33. GfK Group. Knowledge panel a methodological overview; 2015 [accessed 2019 Jun 25]. [https://www.gfk.com/fileadmin/user\\_upload/dyna\\_content/US/documents/KnowledgePanel\\_-\\_A\\_Methodological\\_Overview.pdf](https://www.gfk.com/fileadmin/user_upload/dyna_content/US/documents/KnowledgePanel_-_A_Methodological_Overview.pdf).
  34. Birnbaum MS, Jacobs ET, Ralston-King J, Ernst KC. Correlates of high vaccination exemption rates among kindergartens. *Vaccine*. 2013;31(5):750–56. doi:10.1016/j.vaccine.2012.11.092.
  35. Yang YT, Silverman RD. Legislative prescriptions for controlling nonmedical vaccine exemptions. *JAMA*. 2015;313(3):247–48. doi:10.1001/jama.2014.16286.
  36. McNutt L-A, Desemone C, DeNicola E, El Chebib H, Nadeau JA, Bednarczyk RA, Shaw J. Affluence as a predictor of vaccine refusal and underimmunization in California private kindergartens. *Vaccine*. 2016;34(14):1733–38. doi:10.1016/j.vaccine.2015.11.063.
  37. Allen A. How the anti-vaccine movement crept into the GOP mainstream. *Politico*; 2019 May 27 [accessed 2019 Jun 25]. <https://www.politico.com/story/2019/05/27/anti-vaccine-republican-mainstream-1344955>.
  38. Pew Research Center. *Vast Majority of Americans Say Benefits of Childhood Vaccines Outweigh Risks*. Pew Research Center; 2017 [accessed 2019 Jun 25]. <https://www.pewresearch.org/science/2017/02/02/vast-majority-of-americans-say-benefits-of-childhood-vaccines-outweigh-risks/>.
  39. Aleccia J. Measles outbreak sends vaccine demand soaring, even among the hesitant. *The Seattle Times*; 2019 Feb 6 [accessed 2019 Jun 25]. <https://khn.org/news/measles-outbreak-sends-vaccine-demand-soaring-even-among-the-hesitant/>.
  40. Crawford T, Stephanie I. Immunization rates go up at two Vancouver schools where measles outbreak began. *Vancouver Sun*; 2019 Feb 25 [accessed 2019 Jun 25]. <https://vancouver.sun.com/news/local-news/teens-defy-parents-to-get-measles-vaccine-during-vancouver-outbreak>.
  41. Mohanty S, Buttenheim AM, Joyce CM, Howa AC, Salmon D, Omer SB. Experiences with medical exemptions after a change in vaccine exemption policy in California. *Pediatrics*. 2018;142(5):e20181051. doi:10.1542/peds.2018-1051.
  42. Ostrov BF. Exemptions surge as parents and doctors do “Hail Mary” around vaccine laws; 2019 Apr 5 [accessed 2019 Jun 25]. <https://khn.org/news/medical-exemptions-surge-parents-doctors-bypass-vaccine-laws/>.
  43. Broniatowski DA, Jamison AM, Qi S, AlKulaib L, Chen T, Benton A, Quinn SC, Dredze M. Weaponized health communication: twitter bots and Russian trolls amplify the vaccine debate. *Am J Public Health*. 2018;108(10):1378–84. doi:10.2105/AJPH.2018.304567.
  44. Jamison AM, Broniatowski DA, Quinn SC. Malicious actors on twitter: a guide for public health researchers. *Am J Public Health*. 2019;109:688–92. doi:10.2105/AJPH.2019.304969.
  45. Harbarger M. Hundreds pack Oregon hearing to oppose bill to end vaccine exemptions. *The Oregonian*; 2019 Mar 5 [accessed 2019 Jun 25]. <https://www.oregonlive.com/education/2019/03/hundreds-pack-oregon-hearing-to-oppose-vaccination-bill.html>.