Parent Attitudes Towards Childhood Vaccines After the Onset of SARS-CoV-2 in the United States

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Abstract

Objective: To understand the influence of a novel infectious disease epidemic on parent general attitudes about childhood vaccines.

Methods: We conducted a natural experiment utilizing cross-sectional survey data from parents of infants in Washington and Colorado participating in a larger trial that began on September 27, 2019. At enrollment, parents completed the short version of the Parental Attitudes about Childhood Vaccines (PACV-SF), a validated survey scored from 0 to 4, with higher scores representing more negative attitudes. The exposure variable was onset of the SARS-CoV-2 pandemic in the United States, with the before-period defined as September 27, 2019 to February 28, 2020 and the after-period defined as April 1, 2020—December 10, 2020, with the after-period further separated into proximate (April 1, 2020−July 31, 2020) and distant periods (August 1, 2020−December 10, 2020). The outcome variable was parent negative attitudes about childhood vaccines, defined as a score of ≥2 on the PACV-SF. We estimated the probability of the outcome after (vs before) the exposure using log-binomial regression with generalized estimating equations adjusted for demographic confounding variables.

Results: Among 4562 parents, the risk of negative attitudes was lower immediately after (vs before) SARS-CoV-2 onset (adjusted risk ratio [aRR] = 0.58; 95% confidence interval [CI], 0.36, 0.94; P = .027), but by August−December 2020, the average rate of negative attitudes was 35% higher than during April−July 2020 (aRR: 1.35; 95% CI: 1.13, 1.61; P = .0009).

Conclusions: A reduced risk of negative general vaccine attitudes observed immediately after SARS-CoV-2 onset was quickly attenuated.

Keywords: public health; preventive medicine; vaccines; pediatrics

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What's New

The effect of an outbreak of a novel infectious disease on parents' general vaccine attitudes about childhood vaccines is unknown. We found that the onset of the SARS-CoV-2 pandemic had a positive, albeit fleeting, effect on parent general vaccine attitudes.

Perceptions of one's susceptibility to and likelihood of illness from an infectious disease are strongly correlated with the acceptance of an available vaccine to protect against that infectious disease.[1] However, data to support an association between an outbreak of vaccine-preventable disease (VPD), an event that could influence perceived illness likelihood or susceptibility, and increased uptake of its corresponding vaccine has so far been inconclusive.[2−5] Moreover, few studies have examined the effect of an outbreak of a specific VPD on attitudes and beliefs toward vaccines in general[6,7] and no studies have examined the effect of an emerging infectious disease on general vaccine attitudes and beliefs prior to the availability of a vaccine for that infectious disease.

Addressing these gaps in our understanding of how infectious disease incidence influences specific or general

Table 1. The Short Form of the Parent Attitudes About Childhood Vaccines (PACV-SF or PACV-4)

Item	Response Categories*
Have you ever delayed having your child get a shot for reasons other than illness or allergy?	Yes/No/I don't know
How concerned are you that a shot might not prevent the disease?	Not at all concerned, Not too concerned, Not sure, Somewhat concerned, Very concerned
Overall, how hesitant about childhood shots would you consider yourself to be?	Not at all hesitant, Not too hesitant, Not sure, Somewhat hesitant, Very hesitant
I trust the information I receive about shots.	Strongly agree, Agree, Not sure, Disagree, Strongly disagree

*Total scores for the PACV-SF range from 0 to 4.

vaccine attitudes and behavior could help inform public health interventions. For instance, when a vaccine against a specific infectious disease is available, there is a need to increase uptake of this vaccine when the disease reaches epidemic thresholds to curb further transmission and prevent further morbidity and mortality. When there is not a vaccine yet available against a surging novel infectious disease, there is still often a need to maintain or increase uptake of available vaccines against other infectious diseases to prevent dual epidemics. This has been particularly salient during the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) pandemic, during which childhood vaccination rates in the United States have declined and threatened to spur additional outbreaks of VPD.[8−10] Our aim was to evaluate the effect of the SARS-CoV-2 pandemic prior to the availability of a SARS-CoV-2 vaccine on parents' general attitudes about childhood vaccines. We hypothesized that parent negative attitudes about childhood vaccines would be lower after, as compared to before, the start of the pandemic.

METHODS

We conducted a natural experiment using cross-sectional survey data collected from parents enrolled in an ongoing cluster randomized controlled trial designed to assess the effect of a novel, multifaceted clinician vaccine communication intervention on child immunization status by study completion in 2023.[11] The trial includes 24 primary care pediatric clinics in Washington and Colorado (13 urban, 6 suburban, 1 rural, and 4 with multiple geographic settings given that these clinics had more than one site) and began enrolling parent participants on September 27, 2019. The study activities for this trial were formally reviewed and approved by the Colorado Multiple Institutional Review Board, Washington State Institutional Review Board, and Swedish Health Services Institutional Review Board.

DATA COLLECTION

English- and Spanish-speaking parents ≥18 years old with an infant ≤2 months old receiving health supervision at a clinic enrolled in the trial were eligible to participate. At parent enrollment in the trial and prior to receipt of the study's intervention, all parents completed the self-administered short version of the Parental Attitudes about Childhood Vaccines (PACV), a validated survey based on Health Belief Model concepts, available in multiple languages[12−15] and predictive of vaccine behavior.[16−19] The short version of the PACV (abbreviated as PACV-4 or PACV-SF) included 4 questions and was scored from 0 to 4, with higher scores representing more negative attitudes and beliefs about childhood vaccines (Table 1).[20]

The content and order of questions on the PACV-SF survey did not change over the study period. Given the prioritization of in-person visits for children <2 years old during the pandemic, the mode of implementation of the survey (in-person, self-administered) also did not change during the study period. Parent participants completed the PACV-SF only once. The PACV-SF was embedded in a larger survey of items regarding parent attitudes about non-vaccine-related care, such as breastfeeding and sleep (eg, “It is important to introduce a feeding schedule for my baby as early as possible,” with response categories of strongly agree, agree, not sure, disagree, and strongly disagree).

The PACV-SF also included demographics questions. Race and ethnicity were self-reported by parent participants, with race (American Indian or Alaska Native, Asian, Black or African American, Native Hawaiian or Other Pacific Islander, and White) and ethnicity (Hispanic or Latino) categories defined by investigators based on the US Office of Management and Budget Standards. Reporting race and ethnicity in this study was mandated by the US National Institutes of Health. We chose response categories for other demographic questions based on those we utilized in past immunization studies,[20] including the parents' relationship to the enrolled child (mother, father, or other), whether the enrolled child was the first-born (yes/no), parent age (18−29 years old, ≥30 years old), parents' current marital status (divorced, separated, single, married, living with a partner, or widowed), parents' highest level of education completed (8th grade or less, some high school but not a graduate, high school graduate or GED, some college or 2 year degree, 4-year college degree, more than 4-year college degree), approximate household income ($30,000 or less, $30,001−50,000, $50,001−75,000, or $75,001 or more), and how many children in the household (1, 2, 3, or 4 or more).

The PACV-SF was included in the clinic's standard materials distributed to all parents at check-in for that particular age visit. The survey was distinguished, however, with separate instructions to ensure parents were informed that its completion was voluntary and for research purposes. We considered completed surveys to be documentation of consent. We did not offer incentives to complete the survey, and we did not consistently collect declinations or blank returned surveys to be able to determine response rates.

EXPOSURE VARIABLE

The exposure variable was the United States onset of the SARS-CoV-2 pandemic. We considered the pandemic's onset in the United States to be the entire month of March 2020 to account for the World Health Organization's declaration of the SARS-CoV-2 outbreak as a pandemic on March 11, 2020 and the dynamic nature of SARS-CoV-2 transmission in the United States during March.[21] Therefore, we excluded data obtained during March 2020 from our analyses. We defined the time period before the start of the pandemic as September 27, 2019 (the start of parent enrollment in the larger study) through February 28, 2020. We defined the time-period after the start of the pandemic as April 1, 2020 through December 10, 2020. We excluded parent PACV-SF data after December 10, 2020 to avoid contamination of parent general vaccine attitudes by the availability of a vaccine against SARS-CoV-2 (the first SARS-CoV-2 vaccine was granted an emergency use authorization by the US Food and Drug Administration on December 11, 2020).

OUTCOME VARIABLES

The primary outcome variable was the proportion of parents with negative attitudes about childhood vaccines, with negative attitudes about childhood vaccines defined as a score of ≥2 on the PACV-SF, consistent with previous studies.[20] Since an assumption in our natural experiment was that the probability of parents holding negative attitudes about childhood vaccines would have remained unchanged had the pandemic not occurred, we also utilized a secondary outcome variable that was not expected to change with the onset of the pandemic. This secondary outcome variable was the proportion of parents who disagreed (defined as a parent response of strongly disagree or disagree) to a non-vaccine-related attitudinal survey item (“It is important to introduce a feeding schedule for my baby as early as possible”).

ANALYSIS

We used log-binomial regression with generalized estimating equations (GEE) to estimate the probability of parent negative vaccine attitudes before and after the onset of the SARS-CoV-2 pandemic. GEE was used to account for clustering at the clinic level, and because our outcome was collected prospectively and not rare ($\pi > 0.05$), log-binomial regression was used to generate more interpretable risk ratio estimates.[22] We included a linear term for time in our models corresponding to the week in which parent attitudes about childhood vaccines were sampled, a term for onset of the SARS-CoV-2 pandemic, and the interaction term between pandemic onset and time. This parameterization allowed for both a slope and level change in probability of having negative vaccine attitudes with respect to time, with a potential discontinuity point at the onset of the pandemic. The fitted model therefore followed the form

$$\log P(Y_{ij} = 1) = \beta_0 + \beta_1 T_{ij} + \beta_2 X_{ij} + \beta_3 (T_{ij} - T_0) X_{ij}$$

with Y_{ij} the response value for the jth parent in the ith clinic, T_{ij} the time in study weeks that this parent responded to the survey, T_0 the time in study weeks at which the pandemic was assumed to have begun, and X_{ij} equal to 1 if this survey was obtained during the pandemic and 0 if obtained prior to the pandemic. The exponentiated regression coefficient for the binary variable for onset of the pandemic is therefore the estimated risk ratio for negative vaccine attitudes associated with the transition from pre-pandemic to pandemic time periods.

To determine which covariates to adjust for in final models, we used GEE regression as described above to test the association 1) between parent demographic characteristics and negative vaccine attitudes and 2) between these same parent characteristics and the onset of the pandemic. Those characteristics with $P < .2$ in both univariate analyses were retained for the final multivariable GEE model; these covariates were parent relationship to child, marital status, and ethnicity. We used a similar approach to develop a multivariable log-binomial GEE model for parent responses to the comparison non-vaccine related attitudinal survey item before and after the onset of the SARS-CoV-2 pandemic. The final multivariable GEE model used to assess the independent association between the onset of the pandemic and parents disagreeing with the comparison survey item included parent relationship to child and ethnicity as covariates.

We also conducted a secondary analysis of negative vaccine attitudes across 3 pandemic time periods. For this analysis, we characterized the SARS-CoV-2 pandemic using a 3-level variable corresponding to 3 pandemic periods: pre-pandemic (September 27, 2019−February 28, 2020), post-onset proximate period (April 1, 2020−July 31, 2020), and post-onset distant period (August 1, 2020−December 10, 2020). Data from March 2020, considered to be the onset of the SARS-CoV-2 pandemic in the United States, was again excluded. We chose the July 31, 2020 date as the boundary between post-onset proximate and distant periods because it represented the approximate temporal mid-point of the post-onset period. We utilized log-binomial regression with GEE including a three-level variable for pandemic status (pre, post-onset proximate, and post-onset distant). This parameterization allows for the estimation of the average rate of parent negative vaccine attitudes across each pandemic time period. We included demographic variables that were individually associated with both negative vaccine attitudes and the onset of the pandemic at a significance level of <0.2 in a multivariable log-binomial GEE model (parent relationship to child, marital status, and ethnicity). We repeated this analysis using the comparison non-vaccine related attitudinal survey item.

Table 2. Demographic and Other Characteristics of Study Population

	No. (%)			
	Total (n = 4562)	Before Onset of SARS-CoV-2 Pandemic (n = 1418)	After Onset of SARS-CoV-2 Pandemic (n = 3144)	P*
Relationship to child				
Mother	3933 (86.2)	1241 (87.5)	2692 (85.6)	.05
Parent age (years)†				
≥30	3206 (72.2)	1000 (71.7)	2206 (72.5)	.30
Parent's marital status†				
Single, separated, widowed, or divorced	230 (5.2)	57 (4.1)	173 (5.7)	.01
Married or living with a partner	4204 (94.8)	1335 (95.9)	2869 (94.3)	
Parent education†				
High school graduate/GED or less	503 (11.4)	146 (10.5)	357 (11.8)	.24
Some college/2 year degree or more	3921 (88.6)	1242 (89.5)	2679 (88.2)	
Household income†				
≤$50,000	693 (16.0)	204 (15.0)	489 (16.4)	.70
>$50,000	3643 (84.0)	1157 (85.0)	2486 (83.6)	
Parent ethnicity†				
Hispanic/Latino	499 (11.3)	140 (10.1)	359 (11.9)	.06
Completed survey in Spanish	16 (0.4)	7 (0.5)	9 (0.3)	.22
Parent race†				
White	3664 (85.3)	1152 (85.3)	2512 (85.4)	.59‡
Black/African American	87 (2.0)	22 (1.6)	65 (2.2)	
American Indian/Alaska Native	43 (1.0)	14 (1.0)	29 (1.0)	
Asian	320 (7.5)	108 (8.0)	212 (7.2)	
Native Hawaiian/Pacific Islander	15 (0.3)	7 (0.5)	8 (0.3)	
Multiracial	163 (3.8)	47 (3.5)	116 (3.9)	
Number of children in household†				
≤3	4201 (94.7)	1323 (94.8)	2878 (94.7)	.90
>3	234 (5.3)	73 (5.2)	161 (5.3)	
Child eligible for survey is first-born†	2055 (46.4)	649 (46.8)	1406 (46.2)	.34

*Comparison of populations before and after the onset of the pandemic using generalized estimating equations (GEE) with binomial distribution, log link function and accounting for clustering at the clinic level.

†Numbers do not equal total N because of missing data.

‡Reflects comparison of white vs. non-white populations before and after the onset of the pandemic.

Lastly, we conducted a sensitivity analysis in which we utilized a more restrictive definition for our primary outcome variable of negative parental attitudes about childhood vaccines (a PACV-SF score of ≥3). A score of ≥2 out of 4 on the PACV-SF had high specificity (79%−81%) for identifying parents who scored ≥50 (out of 100) on the full 15-item PACV—the score threshold significantly associated with an increase in under-immunization of their child—when using previous PACV validation datasets.[16,17] However, this PACV-SF score threshold could result in up to 21% of parents being false positives (ie, would not score ≥50 on the full PACV). At the more restrictive PACV-SF score threshold of ≥3 for negative vaccine attitudes, the lower-limit specificity of the PACV-SF improved to 95%, making misclassification of parents on the full PACV less likely. Using this more restrictive definition, we performed log-binomial regression with GEE that included a linear term for time, a term for onset of the SARS-CoV-2 pandemic, and the interaction between pandemic onset and time. Second, we performed multivariable log-binomial regression with GEE that included demographic variables associated with both negative vaccine attitudes and beliefs and the onset of the pandemic at a significance level of <0.2 in univariate analyses (parent marital status).

RESULTS

There were 4562 parent participants included in analysis (Table 2). Most were mothers, married, ≥30 years old, and white. Parent participants who completed the PACV-SF after the onset of the SARS-CoV-2 pandemic differed significantly by marital status, ethnicity, and their relationship to the child compared to those who completed the PACV-SF before pandemic onset.

The risk that a parent had negative vaccine attitudes was lower immediately after (vs before) the onset of the pandemic (risk ratio [RR] associated with the pandemic onset term: 0.57; 95% confidence interval [CI]: 0.36, 0.91; P = .019). There was no significant difference observed in the probability of parents disagreeing with the non−vaccine-related attitudinal item immediately after (vs before) the onset of the SARS-CoV-2 pandemic (RR = 1.03; 95% CI, 0.92, 1.15; P = .591). In multivariable models adjusted for confounding by demographic characteristics, we found no change in either the magnitude or significance of the effect estimated in our unadjusted models: the risk that a parent participant had negative vaccine attitudes remained lower immediately after (vs before) the onset of the pandemic (adjusted risk ratio [aRR] = 0.58; 95% CI, 0.36, 0.94; P = .027), and the estimated risk that a parent participant disagreed with the

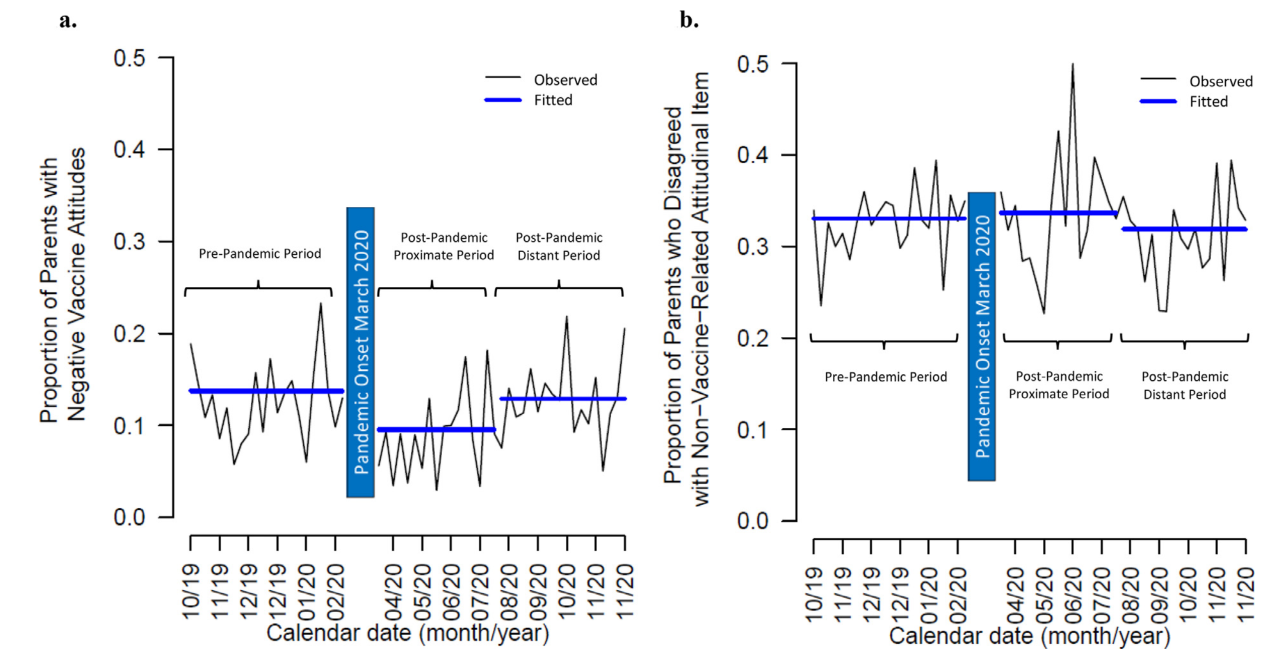

Figure. *Average rates of parent negative vaccine attitudes (a) and parent disagreement with non-vaccine related attitudinal item (b) across pandemic time periods.*

non−vaccine-related attitudinal item remained was not significantly different immediately after (vs before) the onset of the pandemic (aRR = 1.04; 95% CI, 0.93, 1.16; *P* = .519).

In our secondary analysis, we found that the average rate of parent negative attitudes about childhood vaccines was significantly higher pre-pandemic than during the post-onset proximate period (aRR = 1.46; 95% CI, 1.23, 1.74; *P* < .0001). However, we also found that the reduced rate of negative vaccine attitudes in the post-onset proximate period was quickly attenuated: the rate of negative vaccine attitudes was significantly higher in the post-onset distant (vs proximate) period (aRR = 1.35; 95% CI, 1.13, 1.61; *P* = .0009) and there was no significant difference in the average rate of negative vaccine attitudes between the post-onset distant period and the pre-pandemic period (aRR = 1.09; 95% CI, 0.93, 1.27; *P* = .30; Figure). By contrast, there were no significant difference observed in the average rate of parents disagreeing with the non-vaccine attitudinal item across these 3 time periods (Figure).

In our sensitivity analyses, we found results similar to our main analyses. The risk that a parent had negative vaccine attitudes, defined as a PACV-SF score of ≥3, was significantly lower immediately after (vs before) the onset of the pandemic (RR = 0.45; 95% CI, 0.23, 0.88; *P* = .019). We observed the same effect in multivariable GEE log-binomial modeling (aRR = 0.43; 95% CI, 0.21, 0.88; *P* = .020).

DISCUSSION

We found the risk that parents had negative general attitudes about childhood vaccines was significantly lower immediately after (vs. before) the onset of the SARS-CoV-2 pandemic, but this effect dissipated by December 2020. Our study therefore provides evidence for two important phenomena. First, our findings support the hypothesis that a highly visible increase in the incidence of an infectious disease at a time when a vaccine to prevent illness caused by that infectious disease is not yet available may positively influence parents' general attitudes about childhood vaccines. To our knowledge, this is the first evidence of this effect, though others have shown that parents' general attitudes about childhood vaccines can improve after an increase in the incidence of an infectious disease in which a vaccine is already available.[6,7] Our results, therefore, suggest that the rise in the incidence of an infectious disease itself, regardless of the availability of a vaccine to prevent illness caused by that infectious disease, has the potential to positively influence parent's attitudes and beliefs about other childhood vaccines.

The mechanism for this observed effect is unknown. However, given the strong correlations between perceived likelihood of illness from or susceptibility to an infectious disease and uptake of an available vaccine to protect against illness from that infectious disease,[1] it is possible that the SARS-CoV-2 pandemic increased parent perceptions of their child's susceptibility to other infections for which there are available vaccines. Parents' increased perceptions of the value of vaccines in preventing infectious disease could have positively influenced parent attitudes toward those vaccines. Given vaccine attitudes are a strong predictor of intention to vaccinate,[23] this explanation is aligned with the results of a recent study in which investigators found, among parents surveyed at the start of the SARS-CoV-2 pandemic, an increased intention to vaccinate their child against influenza.[24]

Second, our findings support the conclusion that any positive influence on parent general attitudes about childhood vaccines from a rise in the incidence of an infectious disease may be short-lived. Though attitudes about vaccines, like any attitude, are prone to change over time,[25] our findings are notable because the observed change occurred despite the continued presence of SARS-CoV-2 and before the availability of a vaccine. Yet, there are numerous social, personal, political, and cultural factors that influence vaccine attitudes,[26] and our findings suggest these other factors can overcome the relative influence of the infectious disease environment on those same attitudes. Indeed, it is possible that parents' general vaccine attitudes were influenced in the lead up to the authorization of the first SARS-CoV-2 vaccine by concerns that the authorization process was being politicized and rushed.[27]

Our findings could be integrated into future public health campaigns in response to outbreaks of emerging infectious diseases that have no available vaccine. For instance, vaccination rates may decline during these outbreaks due to physical distancing recommendations or parental concerns about exposure to the emerging infectious disease during routine vaccination visits for their child, as occurred during the 2014−2016 Ebola outbreak in Sierra Leone[28] and in the SARS-CoV-2 pandemic in the United States.[29] A future public health campaign could proactively harness the observed, albeit possibly short-lived, effect of a reduction in negative parental attitudes about routine childhood vaccines after the onset of an epidemic to blunt immediate declines in parent attendance at routine vaccination visits for their child.

This study is limited by its design. Natural experiments preclude randomization that would ensure unmeasured confounders are equally distributed across populations. We did, however, adjust for observed confounders and found no change in the significance of our results. In addition, natural experiments are inherently confounded by secular trends. However, finding no change in the proportion of parents responding negatively to a concurrently assessed non−vaccine-related attitudinal item corroborates the interpretation that the observed change in vaccine attitudes may be attributable to the onset of the pandemic. Nonetheless, our results may be confounded by fewer parents with negative vaccine attitudes completing the PACV-SF postpandemic, fewer parents attending health supervision visits postpandemic, or other unobserved factors.

We also measured parent vaccine attitudes rather than actual vaccine behavior. However, the instrument we used to measure parent vaccine attitudes is predictive of vaccine behavior,[16−19] though it is unclear whether this correlation persists post-pandemic. We also found no difference in the significance of our results when using the more restrictive PACV-SF score threshold of ≥3 for negative vaccine attitudes that made misclassification of parents as scoring ≥50 (out of 100) on the full PACV, the score threshold significantly associated with vaccine behavior, less likely. Additional studies are needed to understand how, or whether, the observed reduction in parent negative attitudes affected parent's vaccine behavior.

Additional limitations include measurement of general vaccine attitudes in a cross-sectional cohort which did not enable assessment of within-parent changes, as well as the lack of measurement of potential mechanisms for the observed effect, such as changes in risk perception. Our study sample was large and demographically representative of the populations in Colorado and Washington State,[30] enhancing the generalizability of our results; however, our results may not be applicable to populations in other US states or other countries with demographics distinct from our study population. Similarly, the PACV was initially validated in an English-speaking population from a specific US geographic location, potentially limiting its validity for assessing parent attitudes about childhood vaccines in other populations and geographic locations. However, more recent studies affirming the validity of the PACV in other US geographic locations,[19] among US Spanish-speaking parents,[14,31] and in other countries[12,13,15] lessen this concern.

Conclusion

We observed a significant, though fleeting, effect of the SARS-CoV-2 pandemic on parents' general attitudes about childhood vaccines. This effect could be proactively harnessed to sustain or increase routine childhood vaccination during future outbreaks of novel infectious diseases.

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References

1. Brewer NT, Chapman GB, Gibbons FX, et al. Meta-analysis of the relationship between risk perception and health behavior: the example of vaccination. *Health Psychol*. 2007;26:136–145.
2. Oster E. Does disease cause vaccination? Disease outbreaks and vaccination response. *J Health Econ*. 2018;57:90–101.
3. Wolf ER, Opel D, DeHart MP, et al. Impact of a pertussis epidemic on infant vaccination in Washington state. *Pediatrics*. 2014;134:456–464.
4. Cataldi JR, Dempsey AF, O'Leary ST. Measles, the media, and MMR: impact of the 2014-15 measles outbreak. *Vaccine*. 2016;34:6375–6380.
5. Schober T. Effects of a measles outbreak on vaccination uptake. *Econ Hum Biol*. 2020;38: 100871.
6. Cacciatore MA, Nowak G, Evans NJ. Exploring the impact of the US measles outbreak on parental awareness of and support for vaccination. *Health Aff (Project Hope)*. 2016;35:334–340.
7. Cacciatore MA, Nowak GJ, Evans NJ. It's complicated: the 2014-2015 U.S. measles outbreak and parents' vaccination beliefs, confidence, and intentions. *Risk Analysis*. 2018;38:2178–2192.
8. Bramer CA, Kimmins LM, Swanson R, et al. Decline in Child Vaccination coverage during the COVID-19 pandemic - Michigan Care Improvement Registry, May 2016-May 2020. *Mmwr*. 2020;69:630–631.

9. Santoli JM, Lindley MC, DeSilva MB, et al. Effects of the COVID-19 pandemic on routine pediatric vaccine ordering and administration - United States, 2020. *MMWR*. 2020;69:591–593.
10. O'Leary ST, Trefren L, Roth H, et al. Number of childhood and adolescent vaccinations administered before and after the COVID-19 outbreak in Colorado. *JAMA Pediatr*. 2021;175:305–307.
11. Opel DJ, Robinson JD, Spielvogle H, et al. Presumptively Initiating Vaccines and Optimizing Talk with Motivational Interviewing' (PIVOT with MI) trial: a protocol for a cluster randomised controlled trial of a clinician vaccine communication intervention. *BMJ Open*. 2020;10: e039299.
12. Alsuwaidi AR, Elbarazi I, Al-Hamad S, et al. Vaccine hesitancy and its determinants among Arab parents: a cross-sectional survey in the United Arab Emirates. *Hum Vaccines Immunotherap*. 2020;16:3163–3169.
13. Mohd Azizi FS, Kew Y, Moy FM. Vaccine hesitancy among parents in a multi-ethnic country, Malaysia. *Vaccine*.2017;35:2955-2961.
14. Cunningham RM, Kerr GB, Orobio J, et al. Development of a Spanish version of the parent attitudes about childhood vaccines survey. *Hum Vaccines Immunotherap*. 2019;15:1106–1110.
15. Napolitano F, D'Alessandro A, Angelillo IF. Investigating Italian parents' vaccine hesitancy: a cross-sectional survey. *Hum Vaccines Immunotherap*. 2018;14:1558–1565.
16. Opel DJ, Taylor JA, Mangione-Smith R, et al. Validity and reliability of a survey to identify vaccine-hesitant parents. *Vaccine*. 2011;29:6598–6605.
17. Opel DJ, Taylor JA, Zhou C, et al. The relationship between parent attitudes about childhood vaccines survey scores and future child immunization status: a validation study. *JAMA Pediatr*. 2013;167:1065–1071.
18. Opel DJ, Mangione-Smith R, Taylor JA, et al. Development of a survey to identify vaccine-hesitant parents: the parent attitudes about childhood vaccines survey. *Hum Vaccin*. 2011;7:419–425.
19. Williams SE, Morgan A, Opel D, et al. Screening tool predicts future underimmunization among a pediatric practice in Tennessee. *Clin Pediatr*. 2016;55:537–542.
20. Opel DJ, Henrikson N, Lepere K, et al. Previsit screening for parental vaccine hesitancy: a cluster randomized trial. *Pediatrics*. 2019;144: e20190802. https://doi.org/10.1542/peds.2019-0802.
21. Schuchat A. CDC Covid Response Team. Public health response to the initiation and spread of pandemic COVID-19 in the United States, February 24-April 21, 2020. *MMWR*. 2020;69:551–556.
22. McNutt LA, Wu C, Xue X, et al. Estimating the relative risk in cohort studies and clinical trials of common outcomes. *Am J Epidemiol*. 2003;157:940–943.
23. Brewer NT, Chapman GB, Rothman AJ, et al. Increasing vaccination: putting psychological science into action. *Psychol Sci Public Interest*. 2017;18:149–207.
24. Goldman RD, McGregor S, Marneni SR, et al. Willingness to vaccinate children against Influenza after the Coronavirus Disease 2019 pandemic. *J Pediatr*. 2021;228:87–93. e82.
25. Rossi P, Wright JD, Anderson AB. *Handbook of Survey Research*. New York, NY: Academic Press, Inc.; 1983.
26. Handy LK, Maroudi S, Powell M, et al. The impact of access to immunization information on vaccine acceptance in three countries. *PloS one*. 2017;12:e0180759.
27. Kaiser Family Foundation. *KFF health tracking poll − October 2020.*2020.
28. Sun X, Samba TT, Yao J, et al. Impact of the Ebola outbreak on routine immunization in western area, Sierra Leone - a field survey from an Ebola epidemic area. *BMC Public Health*. 2017;17:363.
29. Vaccine rates drop dangerously as parents avoid doctor's visits. 2020. Available at: https://www.nytimes.com/2020/04/23/health/coronavirus-measles-vaccines.html. Accessed July 25, 2022.
30. US Census Bureau. QuickFacts: Colorado, Washington, United States. 2021; Available at: https://www.census.gov/quickfacts/fact/table/CO,WA,US/RHI125219. Accessed July 23, 2021.
31. Cunningham RM, Minard CG, Guffey D, et al. Prevalence of vaccine hesitancy among expectant mothers in Houston, Texas. *Acad Pediatr*. 2018;18:154–160.