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Evaluating public acceptability of a potential Lyme disease vaccine using a population-based, cross-sectional survey in high incidence areas of the United States

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Abstract

Background: Lyme disease incidence is increasing, despite current prevention options. New Lyme disease vaccine candidates are in development, however, investigation of the acceptability of a Lyme disease vaccine among potential consumers is needed prior to any vaccine coming to market. We conducted a population-based, cross-sectional study to estimate willingness to receive a potential Lyme disease vaccine and factors associated with willingness.

Methods: The web-based survey was administered to a random sample of Connecticut, Maryland, Minnesota, and New York residents June–July 2018. Survey-weighted descriptive statistics were conducted to estimate the proportion willing to receive a potential Lyme disease vaccine. Multivariable multinomial logistic regression models were used to quantify the association of sociodemographic characteristics and Lyme disease vaccine attitudes with willingness to be vaccinated.

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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.

Appendix A. Supplementary material
Supplementary data to this article can be found online at https://doi.org/10.1016/j.vaccine.2021.11.065.

Results: Surveys were completed by 3313 respondents (6% response rate). We estimated that 64% of residents were willing to receive a Lyme disease vaccine, while 30% were uncertain and 7% were unwilling. Compared to those who were willing, those who were uncertain were more likely to be parents, adults 45–65 years old, non-White, have less than a bachelor's degree, or have safety concerns about a potential Lyme disease vaccine. Those who were unwilling were also more likely to be non-White, have less than a bachelor's degree, or have safety concerns about a potential Lyme disease vaccine. In addition, the unwilling had low confidence in vaccines in general, had low perceived risk of contracting Lyme disease, and said they would not be influenced by a positive recommendation from a healthcare provider.

Discussion: Overall, willingness to receive a Lyme disease vaccine was high. Effective communication by clinicians regarding safety and other vaccine parameters to those groups who are uncertain will be critical for increasing vaccine uptake and reducing Lyme disease incidence.

Keywords

Tick; Tickborne; Lyme disease; Vaccine; Acceptability

1. Background

Lyme disease (LD) is a multi-system illness caused by infection with *Borrelia burgdorferi*. These spirochetes are transmitted to humans and animals by the bite of infected *Ixodes* species ticks, primarily in northeastern, mid-Atlantic, and upper-midwestern regions of the United States (US) [1,2]. Incidence has been increasing, with over 30,000 cases reported annually to the Centers for Disease Control and Prevention (CDC) [1]. However, recent studies have estimated that there are nearly 500,000 diagnosed cases annually [3–5]. Early symptoms of LD most often include a characteristic bull's-eye rash known as erythema migrans, as well as flu-like symptoms [6]. If left untreated, the disease can disseminate to cause more severe manifestations, such as arthritis, meningitis, or carditis, the last of which can be fatal in rare cases. Most patients will experience a full recovery after antibiotic treatment, although some may continue to experience symptoms related to disease sequelae [6–10]. Despite the availability of antibiotic treatment, an effective LD vaccine is needed to prevent severe outcomes and long-term symptoms and thereby reduce fiscal burdens on patients and healthcare systems. Further, currently available personal and yard-based prevention methods have not been sufficient to stem rising case numbers, highlighting the need for a population-level prevention modality such as a vaccine [11,12 13].

A safe and efficacious vaccine for LD called LYMErix was available for persons aged 15–70 years from 1998 until 2002 in the US [14,15]. This vaccine conferred protection based on a recombinant outer surface protein A (rOspA) of *B. burgdorferi*. In 2002, it was voluntarily discontinued by the manufacturer, reportedly due to poor sales [16]. However, several factors have been highlighted as reasons contributing to low demand. Most importantly, it was not available for children under 15 years, one of the highest risk age groups. Further, some have cited tepid and cumbersome recommendations by the Advisory Committee on Immunization Practices (ACIP) as a potential reason for low demand by clinicians and the public [17,18]. Vocal opposition by some Lyme disease patient advocacy groups, based on unsubstantiated claims that the vaccine caused Lyme arthritis, is also thought to have played a role in LYMErix's withdrawal [19–22]. The introduction and withdrawal of LYMErix also inauspiciously coincided with the then nascent anti-vaccination movement [22]. Since its withdrawal, the number of LD cases reported annually has nearly doubled.

After nearly two decades without an LD vaccine, new candidates are in development, with initial results showing favorable safety and immunogenicity profiles and potential availability in the next several years [23–25]. While rising LD incidence would ostensibly result in increased demand for a vaccine, the controversial climate surrounding LD [26] and general vaccine hesitancy among some groups [27–30] necessitate further investigation of the acceptability of a LD vaccine among potential consumers. The primary objective of this study was to estimate what proportion of people living in states with a high incidence of LD would be willing to receive a new LD vaccine. The secondary objective was to evaluate factors associated with willingness to receive a LD vaccine.

2. Methods

2.1. Study design and sampling

In the summer of 2018, we conducted a population-based, cross-sectional survey using address-based sampling of persons living in four states with high incidence of LD [31]. The target population included all residents of Connecticut, Maryland, Minnesota, and New York, excluding New York City due to low incidence of LD. The sampling frame included all households with residential addresses listed in the U.S. Postal Service (USPS) database in these areas. We used a stratified, two-stage sampling design where the strata were counties from the above-mentioned states. The primary sampling unit was the household, while the unit of observation was the individual, with a single individual selected within the household. Addresses were purchased from a marketing company that receives updated information on a monthly basis directly from USPS based on change of address submissions. Household addresses were stratified according to county, and the number of addresses selected per county was allocated proportional to county population size. Households were randomly selected within counties. An individual within the household was selected as the one who had the most recent birthday, regardless of age, an established technique to approximate random sampling [32]. For minors selected, parents or guardians ≥18 years of age provided responses; responses from those <18 years were excluded. Subsequently, the term "respondent" will refer to those about whom information was collected.

To estimate the proportion of residents willing to receive a LD vaccine, the sample size calculation parameters included a conservative estimate of 50% of participants responding "Yes" for willingness to receive a LD vaccine; $\alpha = 0.01$; an acceptable margin of error of +/− 5%; and 2 clusters for multi-stage sampling [33]. These parameters resulted in a required sample size of 665 respondents per state (2660 respondents total). Based on a 2016 survey using address-based sampling in Connecticut and Maryland [34], we anticipated a 5% response rate and, therefore, recruited 13,300 individuals per state (53,200 total) to obtain a sample representative of the populations in these states (including responses for both adults and children), in the absence of non-response.

2.2. Data collection

Recruitment, enrollment, and survey completion occurred during June–July 2018, with data collection corresponding with peak tickborne disease activity. An invitation postcard explaining the survey in English was mailed to each randomly selected household. The postcard provided a web link, quick response (QR) barcode, and a unique access code to complete the online survey; alternatively, respondents could choose to complete the survey over the phone with study coordinators. A reminder was mailed two weeks later, and the online surveys were open for approximately four weeks.

Sociodemographic information was collected from respondents (Table 1). An additional variable for metropolitan status (large central metropolitan area vs other) by county was created using the urban–rural classification scheme from the National Center for Health Statistics [35]. The main outcome variable was whether the respondent would be willing to receive a LD vaccine if one were available (or vaccinate the minor, if a parent respondent). The following covariates were also collected from survey responses (Appendix, Table A1): LD vaccine safety concerns; vaccine cost concerns; acceptance of vaccine recommendations from a healthcare provider (HCP); history of LD diagnosis among household members; level of concern about getting LD; time spent in tick habitat; whether vaccines, in general, benefit people; primary source for LD information; and primary location for receiving vaccinations.

2.3. Analysis

The data were weighted to account for the unequal selection probabilities per respondent for the two-stage sampling design [32,36]. We compared the sample distributions of age and gender to known population totals using chi-squared goodness-of-fit tests, and as necessary, conducted post-stratification according to county population distributions of age and gender to reduce sampling error and nonresponse error [36–39]. All analyses were conducted using the weighted, post-stratified dataset, and all analyses incorporated the sampling design into standard error and confidence interval computation and statements of inference. We also evaluated non-random missingness in our outcome variable related to non-response (*i.e.*, selection bias) using Heckman-type selection models [40–42] (Appendix, Section 1 and Table A4).

To estimate the proportion of people in Connecticut, Maryland, Minnesota, and New York willing to receive a LD vaccine, summary statistics were computed for the three-level response for willingness to receive a vaccine. Additionally, descriptive analyses were conducted for the following independent variables: sociodemographic characteristics; LD history, attitudes, and practices; vaccine attitudes; primary sources of LD information; and primary location for receiving vaccines.

To evaluate factors associated with willingness to receive a LD vaccine, we cross-classified the outcome with the above mentioned independent variables, and Pearson chi-squared tests with Rao and Scott design-based adjustments were used to evaluate differences in the outcome across levels of each independent variable [43]. Because our outcome of willingness to vaccinate had three, unordered levels, multivariable multinomial logistic regression models were used to quantify the association between LD vaccination responses and independent variables of interest. For each model, we used "Yes" responses to willingness to be vaccinated as the reference group to which "No" and "Don't know" responses were compared. The independent variables of interest included sociodemographic characteristics (*i.e.*, gender, age category, state, race, and education), LD vaccine safety concerns, LD vaccine cost concerns, and positive recommendation for the LD vaccine from an HCP. The last three independent variables were dichotomized for analysis (Yes = "Some" or "A lot"; No = "Not at all" or "Don't know"). Separate models were built for each independent variable of interest with a specific set of potential confounders identified *a priori* (Appendix, Table A2), and model diagnostics were conducted for each model fit. Multinomial logistic regression model results are presented as unadjusted and adjusted odds ratios (ORs) and 95% confidence intervals (CIs).

Survey development, administration, data collection, and data management were conducted using the Research Electronic Data Capture (REDCap) software hosted at Yale University [44,45]. R version 3.5.2 [46–51] was used for all analyses. This study was conducted through TickNET, a public health network composed of researchers at state health departments, universities, and CDC who collaborate on tickborne disease research and surveillance [52]. Research approval and waiver of documentation of informed consent were obtained from institutional review boards at CDC, Connecticut Department of Public Health, Maryland Department of Health, Minnesota Department of Health, New York State Department of Health, and Yale University. Respondents' participation in the survey indicated consent.

3. Results

The survey response rate was 6% (n = 3313). Fifty-nine records were ineligible due to the following: missing age data (n = 38), the respondent not being the person in the household with the last birthday (n = 15), the adult respondent not being the one to make vaccination decisions for the selected minor (n = 1), or the respondent not answering the main outcome question regarding willingness to be vaccinated (n = 5). An additional 48 records with missing gender information were removed prior to analysis because gender information was necessary for post-stratification. The resulting sample available for analysis was 3206 records. The coefficient of the inverse Mill's ratio resulting from Heckman selection models indicated no evidence of significant selection bias (Appendix, Table A4).

Individuals in the sample were older with a higher proportion female compared to the source population; therefore, we post-stratified the data on age and gender as described above [36–39]. The following proportions of demographic characteristics were fixed by post-stratification: 54% of residents were female, 17% were aged ≥ 65 years, 33% were from New York, and 28% lived in a large central metropolitan area (Table 1). In weighted analysis, we estimated that 15% of residents were parents, 85% were White, and 65% had a bachelor's degree or higher; CIs are reported in Table 1.

For our outcome of interest, we estimated that 64% (n = 2098) of residents were willing to receive a LD vaccine, while 7% (n = 190) were not willing and 30% (n = 918) were uncertain (Table 1). We estimated that 18% of residents experienced a past LD diagnosis in their household, and 86% expressed concern about a future LD diagnosis. An estimated 71% of residents spent time in tick habitat at least weekly. Nearly all residents (92%) used some type of LD prevention measure, while 70% were confident that available measures can prevent LD. The vast majority (94%) were confident that recommended vaccines benefit people. Regarding LD vaccine attitudes, the majority of residents had concerns about vaccine safety (71%) and cost (63%), and the majority (89%) indicated that a positive recommendation from an HCP for the LD vaccine would influence their willingness to be vaccinated. In stratified analyses, differences in willingness to be vaccinated were observed for all characteristics and were significant at $\alpha = 0.05$.

Overall, we estimated that the top sources of LD information for residents were health websites (29%, 95% CI: 28%, 30%), search engines (22%, 95% CI: 21%, 23%), and HCPs (21%, 95% CI: 20%, 22%) (Fig. 1), with similar proportions for those who said “Yes” and “Don’t know” to potential LD vaccination (Appendix, Fig. A1). Among those who said “No” to potential LD vaccination, a lower proportion (22%, 95% CI: 17%, 27%) cited health websites as a primary source of LD information, and a higher proportion cited search engines (25%, 95% CI: 19%, 31%) and social media (6%, 95% CI: 2%, 9%), compared to residents overall and those who said “Yes” and “Don’t know” to LD vaccination (Appendix, Fig. A1).

Overall, the top three locations for receiving vaccinations were HCP offices, clinics, or hospitals (82%, 95% CI: 81%, 83%); pharmacies (12%, 95% CI: 11%, 12%); and workplaces (3%, 95% CI: 2%, 3%) (Fig. 2). Proportions were similar for those who said “Yes” and “Don’t know” to potential LD vaccination, while a higher proportion of those who said “No” said they “do not get vaccines” (14%, 95% CI: 10%, 18%) or that they “Don’t know” their primary location for receiving vaccination (5%, 95% CI: 4%, 6%), compared to residents overall and those who said “Yes” and “Don’t know” to LD vaccination (Appendix, Fig. A2).

Table 2 shows the estimated unadjusted and adjusted ORs and 95% CIs resulting from survey-weighted, multivariable, multinomial logistic regression analysis. In terms of sociodemographic characteristics, the odds of parents of minors responding “Don’t know” (vs. “Yes”) to LD vaccination was 1.6 times that of the reference group, those 65 years and older (OR: 1.60, 95% CI: 1.06, 2.42). The odds of those aged 45–64 years responding “Don’t know” were also higher compared to those 65 years and older (OR: 1.40, 95% CI: 1.07, 1.85). Females had only slightly higher odds of responding “No” (vs. “Yes”) to LD vaccination compared to males (OR: 1.55, 95% CI: 0.90, 2.68) and did not have higher odds of responding “Don’t know”. Those in Maryland and New York had higher odds of responding “Don’t know” to LD vaccination compared to those in Connecticut (aOR: 1.42, 95% CI: 1.01, 1.99 and aOR: 1.52, 95% CI: 1.05, 2.19, respectively). No differences were found among states for “No” responses. Non-White residents had higher odds of responding “No” to LD vaccination (aOR: 2.29, 95% CI: 1.21, 4.32) and “Don’t know” (aOR: 1.54, 95% CI: 1.10, 2.17) compared to White residents. Those with less than a bachelor’s degree had higher odds of responding “No” (aOR: 2.21, 95% CI: 1.28, 3.83) and “Don’t know” (aOR: 1.47, 95% CI: 1.13, 1.91) to LD vaccination compared to those with more education.

In terms of attitudes toward a LD vaccine, those with safety concerns had higher odds of responding “No” and “Don’t know” to LD vaccination (aOR: 2.62, 95% CI: 1.49, 4.6; aOR: 1.99, 95% CI: 1.42, 2.78, respectively) compared to those without safety concerns. Those who said HCP recommendation would not influence their willingness to be vaccinated had much higher odds of responding “No” (aOR: 5.21, 95% CI: 2.72, 10.00) but only slightly higher odds of responding “Don’t know” (aOR: 1.42, 95% CI: 0.94, 2.15). Finally, those with LD vaccine cost concerns had lower odds of responding “No” to LD vaccination (aOR: 0.36, 95% CI: 0.20, 0.64) compared to those without cost concerns.

4. Discussion

We estimate that over 60% of residents in states with a high incidence of Lyme disease would be willing to receive a LD vaccine if one were available. Approximately 30% of residents were unsure about vaccination, and they were more likely to be parents making decisions for their children, adults 45–65 years of age, non-White, have less than a bachelor’s degree, or have concerns about the safety of a potential LD vaccine. Targeted vaccine communications by HCPs to these groups, especially those in the age groups at highest risk for LD (children aged 5–10 years and adults aged 45–55 years [1]) may increase uptake of a LD vaccine. Less than 10% of residents indicated that they were not willing to be vaccinated. They were also more likely to be non-White, have less than a bachelor’s degree, or have concerns about the safety of a potential LD vaccine, but they also would not be influenced by a positive recommendation from a HCP, have low confidence in vaccines in general, and have low perceived risk of contracting LD. Targeted outreach may be unlikely to change these groups’ willingness to receive a LD vaccine. Alternatively, these groups may have low perceived risk of LD because of truly being at low risk (e.g., those who do not spend time outdoors in tick habitat), and they may not benefit from LD vaccination.

A 2002 study among parents in Nassau County, New York evaluated whether parents would request the LYMErix vaccine for their children, if and when it became available. The vast majority said they would “definitely” (23%) or “likely” (65%) request it, followed by those “unlikely” (9%) to request it and those who would not (3%) [53]. While this response scale differs from that in our study, these results are similar to ours, with the majority willing to be vaccinated and few declining. Another study evaluated a LYMErix vaccination program among New York State Department of Health employees at risk for occupational tick exposure. While only 16% of employees chose to be vaccinated, the majority of non-recipients reported safety as a major concern, as seen in our results [54].

Prior to this study there has been little research on acceptability of a potential new LD vaccine, though a 2016 convenience sample survey conducted in Connecticut and Maryland counties with a high incidence of LD found that the majority of respondents were likely to receive a potential LD vaccine, with 49% “very likely”, 35% “somewhat likely”, 8% “somewhat unlikely”, and 7% “very unlikely” [34]. Similarly, a nationwide population-based survey conducted in 2014 and 2015 found that 65% of respondents in high incidence states would be “likely” to receive a potential LD vaccine [55]. Additionally, a qualitative research study conducted in 2018 using focus groups of those at high risk for LD showed that 57% would be “very likely” to receive a LD vaccine [69]. Again, while the response scales of these studies differ from the present study, our estimates of potential vaccine uptake are concordant.

Demographic disparities in vaccination coverage are common and complex for both compulsory childhood vaccines and for recommended, non-compulsory vaccines for adults and children [27,28,56–59]. Our finding that those who are non-White or those with lower education are more likely to respond “No” and “Don’t know” to LD vaccination contrasts somewhat with studies on childhood vaccines. In Arizona, non-medical exemption rates (*i.e*., vaccine refusals) among kindergarteners were higher in schools with a higher proportion of White children and a lower proportion of free lunches (as a proxy for income) [27]. In a nationwide survey, more White parents reported being unsure about or refusing childhood vaccinations versus other racial groups [28]. However, another nationwide survey found demographic differences when comparing under-vaccinated children with unvaccinated children; under-vaccinated children tended to be Black, have a mother without a college degree, and have lower household income while unvaccinated children tended to be White, have a mother with a college degree, and have higher household income [56]. However, our survey was not parent-specific, and our sample includes only a small proportion of parent respondents. Our results for a voluntary LD vaccine are likely more comparable to annual reports of coverage for recommended, non-compulsory vaccines for adults. Annually, these reports show higher coverage generally for White persons compared with most other racial groups [57,58]. People from racial and ethnic minority groups are at risk for LD, and vaccine communications should focus on these groups in endemic areas.

Vaccine safety concerns are often cited as reasons for delaying or refusing vaccinations generally among both parents and adults, and these concerns were also an important factor in LYMErix vaccination decisions, despite it being proven to be safe [28–30,53,54,56,60,61]. Our results show that safety will also be an important consideration in future LD vaccination decisions. A new LD vaccine may spawn additional safety concerns given that the waning demand for LYMErix was due, in part, to safety concerns, albeit unfounded. However, current vaccine candidates do not include the alleged, arthritis-causing epitope present in the LYMErix vaccine, which may assuage concerns for some [62]. Further, many studies, including this one, have shown that a positive recommendation for vaccination from an HCP has a significant influence on the vaccination decision and can increase uptake [61,63,64]. While other factors such as efficacy, convenience, and LD risk, among others, will undoubtedly play a role in uptake of a potential LD vaccine, effectively communicating its safety profile will be critical, and HCPs should be primary communicators of this information to the public [65]. As such, it will be important for public health practitioners to work with HCPs to develop messaging and other tools for discussing LD vaccines with patients.

These results must be interpreted in the context of several potential limitations. While we anticipated and accounted for a low response rate in our sample size calculations, such large non-response may affect the validity of our estimate of vaccine uptake due to non-response error. For example, it is possible that those who do not perceive themselves to be at risk for LD had low interest in the survey and chose not to respond. These non-respondents may be likely to decline LD vaccination due to their perceived low risk, thereby causing an overestimate of the proportion willing to be vaccinated in our sample, compared to the target population. Similarly, those who perceive themselves to be at high risk for LD may have had keen interest in participating in the survey, and their perceived risk may lead to higher willingness to be vaccinated, again leading to an overestimate of vaccine acceptance. However, post-stratification was intended to mitigate this non-response error, and Heckman selection model results did not reveal significant selection bias. Further, our results are very similar to other LD vaccine acceptability studies with different sampling methods, as noted above. In terms of information bias, most survey questions, including the willingness to vaccinate outcome and independent variables of interest, concerned respondents' opinions, making recall or misclassification error unlikely. However, given the hypothetical nature of the survey questions, the estimate of intention to receive a LD vaccine may change as more information on vaccine parameters becomes available or may differ from actual vaccine uptake. For example, results were mixed for studies evaluating the correlation between intention to receive a vaccine and actual uptake during the 2009–2010 influenza A/H1N1 pandemic in the United States [66–68]. Lastly, while our results are generalizable to the populations of participating states, excluding residents of New York City, these results may or may not be generalizable to other states with a high incidence of LD. However, the states in this study represent a range of endemicity, from fully endemic in Connecticut to focally endemic in parts of Minnesota and New York; therefore, results are likely applicable to other endemic states, such as Massachusetts and Wisconsin, but may not apply to states where LD is emerging, such as Michigan and West Virginia.

In anticipation of a new LD vaccine coming to market, future studies should further evaluate parent-specific vaccine concerns, given that children are at high risk for LD and may benefit most from the vaccine. Additional evaluations of vaccine acceptability will also be needed once safety, efficacy, dosing, and immunogenicity data is available for a new vaccine. Our estimate of potential vaccine uptake provides important information for ACIP recommendations and may be used in economic evaluations of a potential vaccine. Lastly, our characterization of the factors affecting willingness to receive a potential LD vaccine can inform future communication and education efforts with clinicians and the public to increase awareness and uptake of a vaccine.

5. Conclusions

LD incidence is increasing, despite current prevention options. A new LD vaccine could substantially reduce disease incidence if vaccine uptake is high. The majority of residents in four high incidence states would be willing to receive a LD vaccine if one were available. Effective communication by clinicians regarding safety, efficacy, and other vaccine parameters to those demographic groups who are uncertain about LD vaccination will be critical for increasing vaccine uptake and reducing LD incidence.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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References

[1]. Schwartz AM, Hinckley AF, Mead PS, Hook SA, Kugeler KJ. Surveillance for Lyme disease – United States, 2008–2015. MMWR Surveill Summ 2017;66 (22):1–12.

[2]. Rosenberg R, Lindsey NP, Fischer M, Gregory CJ, Hinckley AF, Mead PS, et al. Vital signs: trends in reported vectorborne disease cases – United States and Territories, 2004–2016. MMWR Morb Mortal Wkly Rep 2018;67(17):496–501. [PubMed: 29723166]

[3]. Nelson CA, Saha S, Kugeler KJ, Delorey MJ, Shankar MB, Hinckley AF, et al. Incidence of clinician-diagnosed lyme disease, United States, 2005–2010. Emerg Infect Dis 2015;21(9):1625–31. [PubMed: 26291194]

[4]. Hinckley AF, Connally NP, Meek JI, Johnson BJ, Kemperman MM, Feldman KA, et al. Lyme disease testing by large commercial laboratories in the United States. Clin Infect Dis 2014;59:676–81. [PubMed: 24879782]

[5]. Kugeler KJ, Schwartz AM, Delorey MJ, Mead PS, Hinckley AF. Estimating the frequency of Lyme disease diagnoses, United States, 2010–2018. Emerg Infect Dis 2021;27(2):616–9. [PubMed: 33496229]

[6]. Wormser GP, Dattwyler RJ, Shapiro ED, Halperin JJ, Steere AC, Klempner MS, et al. The clinical assessment, treatment, and prevention of Lyme disease, human granulocytic anaplasmosis, and babesiosis: clinical practice guidelines by the Infectious Diseases Society of America. Clin Infect Dis 2006;43:1089–134. [PubMed: 17029130]

[7]. Magid D, Schwartz B, Craft J, Schwartz JS. Prevention of Lyme disease after tick bites. A cost-effectiveness analysis. N Engl J Med 1992;327(8):534–41. [PubMed: 1298217]

[8]. Nichol G, Dennis DT, Steere AC, Lightfoot R, Wells G, Shea B, et al. Test-treatment strategies for patients suspected of having Lyme disease: a cost-effectiveness analysis. Ann Intern Med 1998;128:37–48. [PubMed: 9424980]

[9]. Meltzer MI, Dennis DT, Orloski KA. The cost effectiveness of vaccinating against Lyme disease. Emerg Infect Dis 1999;5(3):321–8. [PubMed: 10341168]

[10]. Weitzner E, McKenna D, Nowakowski J, Scavarda C, Dornbush R, Bittker S, et al. Long-term assessment of post-treatment symptoms in patients with culture-confirmed early Lyme disease. Clin Infect Dis 2015;61(12):1800–6. [PubMed: 26385994]

[11]. CDC. Lyme disease charts and figures: historical data; 2019.

[12]. Hayes EB, Piesman J. How can we prevent Lyme disease? N Engl J Med 2003;348(24):2424–30. [PubMed: 12802029]

[13]. Gomes-Solecki M, Arnaboldi PM, Backenson PB, Benach JL, Cooper CL, Dattwyler RJ, et al. Protective immunity and new vaccines for Lyme disease. Clin Infect Dis 2020;70(8):1768–73. [PubMed: 31620776]

[14]. Poland GA, Jacobson RM. The prevention of Lyme disease with vaccine. Vaccine 2001;19(17–19):2303–8. [PubMed: 11257352]

[15]. ACIP. Recommendations for the use of Lyme disease vaccine recommendations of the Advisory Committee on Immunization Practices (ACIP). Morb Mortal Wkly Rep 1999;48:1–17.

[16]. Shen AK, Mead PS, Beard CB. The Lyme disease vaccine–a public health perspective. Clin Infect Dis 2011;52(Suppl 3):s247–52. [PubMed: 21217171]

[17]. Plotkin SA. Correcting a public health fiasco: the need for a new vaccine against Lyme disease. Clin Infect Dis 2011;52(Suppl 3):s271–5. [PubMed: 21217175]

[18]. Plotkin SA. Need for a new Lyme disease vaccine. N Engl J Med 2016;375 (10):911–3. [PubMed: 27602662]

[19]. Aronowitz RA. The rise and fall of the lyme disease vaccines: a cautionary tale for risk interventions in American medicine and public health. Milbank Q 2012;90:250–77. [PubMed: 22709388]

[20]. Lathrop SL, Ball R, Haber P, Mootrey GT, Braun MM, Shadomy SV, et al. Adverse event reports following vaccination for Lyme disease: December 1998-July 2000. Vaccine 2002;20(11–12):1603–8. [PubMed: 11858868]

[21]. Ball R, Shadomy SV, Meyer A, Huber BT, Leffell MS, Zachary A, et al. HLA type and immune response to Borrelia burgdorferi outer surface protein a in people in whom arthritis developed after Lyme disease vaccination. Arthritis Rheum 2009;60(4):1179–86. [PubMed: 19333928]

[22]. Nigrovic LE, Thompson KM. The Lyme vaccine: a cautionary tale. Epidemiol Infect 2007;135(1):1–8. [PubMed: 16893489]

[23]. Flaherty B Can a new Lyme disease vaccine overcome a history of distrust and failure? STAT; 2019.

[24]. Wang Y, Esquivel R, Flingai S, Schiller ZA, Kern A, Agarwal S, et al. Anti-OspA DNA-encoded monoclonal antibody prevents transmission of spirochetes in tick challenge providing sterilizing immunity in mice. J Infect Dis. 2019;219:1146–50. [PubMed: 30476132]

[25]. Wang Y, Kern A, Boatright NK, Schiller ZA, Sadowski A, Ejemel M, et al. Pre-exposure prophylaxis with OspA-specific human monoclonal antibodies protects mice against tick transmission of Lyme disease spirochetes. J Infect Dis 2016;214(2):205–11. [PubMed: 27338767]

[26]. Lantos PM. Chronic Lyme disease: the controversies and the science. Expert Rev Anti Infect Ther 2011;9(7):787–97.

[27]. Birnbaum MS, Jacobs ET, Ralston-King J, Ernst KC. Correlates of high vaccination exemption rates among kindergartens. Vaccine 2013;31(5):750–6. [PubMed: 23246263]

[28]. Gust DA, Darling N, Kennedy A, Schwartz B. Parents with doubts about vaccines: which vaccines and reasons why. Pediatrics 2008;122(4):718–25. [PubMed: 18829793]

[29]. Lutz CS, Fink RV, Cloud AJ, Stevenson J, Kim D, Fiebelkorn AP. Factors associated with perceptions of influenza vaccine safety and effectiveness among adults, United States, 2017–2018. Vaccine 2020;38(6):1393–401. [PubMed: 31883808]

[30]. Salmon DA, Dudley MZ, Glanz JM, Omer SB. Vaccine hesitancy: causes, consequences, and a call to action. Am J Prev Med 2015;49(6):S391–8. [PubMed: 26337116]

[31]. Link MW, Battaglia MP, Frankel MR, Osborn L, Mokdad AH. A Comparison of address-based sampling (ABS) versus random-digit dialing (RDD) for general population surveys. Publ Opin Quart 2008;72(1):6–27.

[32]. Fowler FJ. Survey research methods. 5th ed. Los Angeles: SAGE; 2014.

[33]. CDC. Epi Info. In: CDC, editor. 7.2.2.2 ed2017.

[34]. Niesobecki S, Hansen AJ, Rutz H, Mehta S, Feldman K, Meek J, et al. Knowledge, attitudes, and behaviors regarding tick-borne disease prevention in endemic areas. Ticks Tick Borne Dis 2019;10(6).

[35]. Ingram DD, Franco SJ. NCHS urban-rural classification scheme for counties. Vital Health Stat 2013;2(2014):1–73.

[36]. Lumley T Analysis of complex survey samples. J Stat Softw 2004;9:1–19.

[37]. Lumley T Complex surveys: a guide to analysis using R. Hoboken, New Jersey: John Wiley & Sons, Inc.; 2010.

[38]. Sampling LSL. Design and analysis (advanced series). 2nd ed. Boston, MA: Brooks/Cole; 2010.

[39]. Sarndal C-E, Lundstrom S Estimation in surveys with nonresponse. West Sussex PO19 8SQ, England: John Wiley & Sons, Ltd; 2005.

[40]. Heckman JJ. Sample selection bias as a specification error. Econometrica 1979;47(1):153. 10.2307/1912352.

[41]. Amemiya T Tobit models: a survey. J Econ 1984;24(1–2):3–61.

[42]. Toomet O, Henningsen A. Sample selection models in R: package sampleselection.

[43]. Rao J, Scott J. On Chi-squared tests for multiway contingency tables with cell proportions estimated from survey data. Ann Stat 1984;12:46–60.

[44]. Harris PA, Taylor R, Minor BL, Elliott V, Fernandez M, O'Neal L, et al. The REDCap consortium: building an international community of software platform partners. J Biomed Inform 2019;95:103208. 10.1016/j.jbi.2019.103208. [PubMed: 31078660]

[45]. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)–a metadata-driven methodology and workflow process for providing translational research informatics support. J Biomed Inform 2009;42(2):377–81. [PubMed: 18929686]

[46]. Wickham H tidyverse: easily install and load the 'Tidyverse'. R package version 1.2.1 ed; 2017.

[47]. Freedman GE. srvyr: 'dplyr'-like syntax for summary statistics of survey data. R package version 0.3.4 ed; 2019.

[48]. Lumley T Survey: analysis of complex survey samples R package version 3.35–1 ed; 2019.

[49]. Long J _jtools: analysis and presentation of social scientific data_. R package version 2.0.1 ed; 2019.

[50]. Wei T, Simko V. R package "corrplot": visualization of a correlation matrix (Version 0.84) Version 0.84 ed; 2017.

[51]. Fox J, Weisberg S. An R companion to applied regression. 2nd ed. Thousand Oaks CA: Sage; 2011.

[52]. Mead P, Hinckley A, Hook S, Beard CB. TickNET–A collaborative public health approach to tickborne disease surveillance and research. Emerg Infect Dis 2015;21(9):1574–7. [PubMed: 26291549]

[53]. Barone SR, Bohrer SS, Erhardt WA. Parental knowledge of and attitudes toward LYMErix (recombinant Osp–a lyme vaccine). Clin Pediatr (Phila) 2002;41 (1):33–6. [PubMed: 11866363]

[54]. Nolan K, Mauer MP. An evaluation of a Lyme disease prevention program in a working population. Am J Health Promot 2006;20(6):379–82. [PubMed: 16871815]

[55]. Nawrocki CC, Hinckley AF. Experiences with tick exposure, Lyme disease, and use of personal prevention methods for tick bites among members of the U.S. population, 2013–2015. Ticks Tick-borne Dis 2021;12(1).

[56]. Smith PJ, Chu SY, Barker LE. Children who have received no vaccines: who are they and where do they live? Pediatrics 2004;114(1):187–95. [PubMed: 15231927]

[57]. Williams WW, Lu P-J, O'Halloran A, Kim DK, Grohskopf LA, Pilishvili T, et al. Surveillance of vaccination coverage among adult populations – United States, 2015. MMWR Surveill Summ 2017;66(11):1–28.

[58]. Williams WW, Lu PJ, O'Halloran A, Bridges CB, Kim DK, Pilishvili T, et al. Vaccination coverage among adults, excluding influenza vaccination – United States, 2013. MMWR Morb Mortal Wkly Rep 2015;64:95–102. [PubMed: 25654611]

[59]. Smith PJ, Humiston SG, Parnell T, Vannice KS, Salmon DA. The association between intentional delay of vaccine administration and timely childhood vaccination coverage. Public Health Rep 2010;125(4):534–41. [PubMed: 20597453]

[60]. Salmon DA, Moulton LH, Omer SB, deHart MP, Stokley S, Halsey NA. Factors associated with refusal of childhood vaccines among parents of school-aged children: a case-control study. Arch Pediatr Adolesc Med 2005;159(5):470. 10.1001/archpedi.159.5.470. [PubMed: 15867122]

[61]. Jacobson RM, St. Sauver JL, Griffin JM, MacLaughlin KL, Finney Rutten LJ. How health care providers should address vaccine hesitancy in the clinical setting: evidence for presumptive language in making a strong recommendation. Hum Vaccin Immunother 2020;16(9):2131–5. [PubMed: 32242766]

[62]. Shaffer L Inner workings: Lyme disease vaccines face familiar challenges, both societal and scientific. Proc Natl Acad Sci U S A 2019;116(39):19214–7. [PubMed: 31554734]

[63]. Lu P-J, Yankey D, Fredua B, O'Halloran AC, Williams C, Markowitz LE, et al. Association of provider recommendation and human papillomavirus vaccination initiation among male adolescents aged 13–17 Years-United States. J Pediatr 2019;206:33–41.e1. [PubMed: 30448270]

[64]. Gargano LM, Herbert NL, Painter JE, Sales JM, Morfaw C, Rask K, et al. Impact of a physician recommendation and parental immunization attitudes on receipt or intention to receive adolescent vaccines. Hum Vaccin Immunother 2013;9 (12):2627–33. [PubMed: 23883781]

[65]. Salmon DA, Dudley MZ, Glanz JM, Omer SB. Vaccine hesitancy: causes, consequences, and a call to action. Vaccine 2015;33(Suppl 4):D66–71. [PubMed: 26615171]

[66]. Liao Q, Cowling BJ, Lam WW, Fielding R. Factors affecting intention to receive and self-reported receipt of 2009 pandemic (H1N1) vaccine in Hong Kong: a longitudinal study. PLoS One 2011;6(3).

[67]. Gidengil CA, Parker AM, Zikmund-Fisher BJ. Trends in risk perceptions and vaccination intentions: a longitudinal study of the first year of the H1N1 pandemic. Am J Public Health 2012;102(4):672–9. [PubMed: 22397349]

[68]. Maurer J Inspecting the mechanism: a longitudinal analysis of socioeconomic status differences in perceived influenza risks, vaccination intentions, and vaccination behaviors during the 2009–2010 influenza pandemic. Med Decis Making 2016;36(7):887–99. [PubMed: 26416814]

[69]. Roshni Devchand, Laura Koehler, Sarah Hook, Grace Marx, Holley Hooks, Amy Schwartz, et al. Understanding consumer and clinician perceptions of a potential Lyme disease vaccine. Health Education Research 2021.

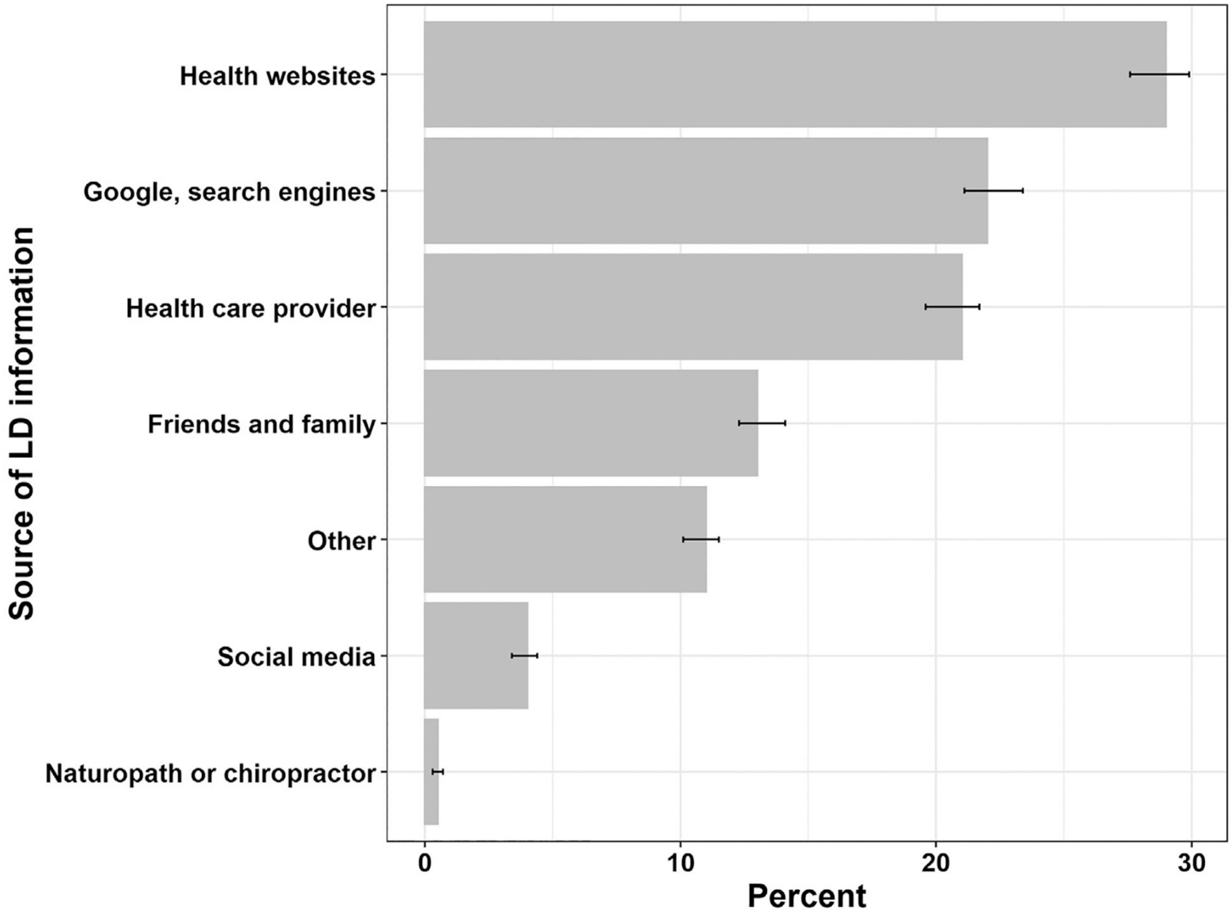

Fig. 1.

Residents' primary source for LD information. The gray bars represent the weighted percent. The black lines represent 95% confidence intervals.

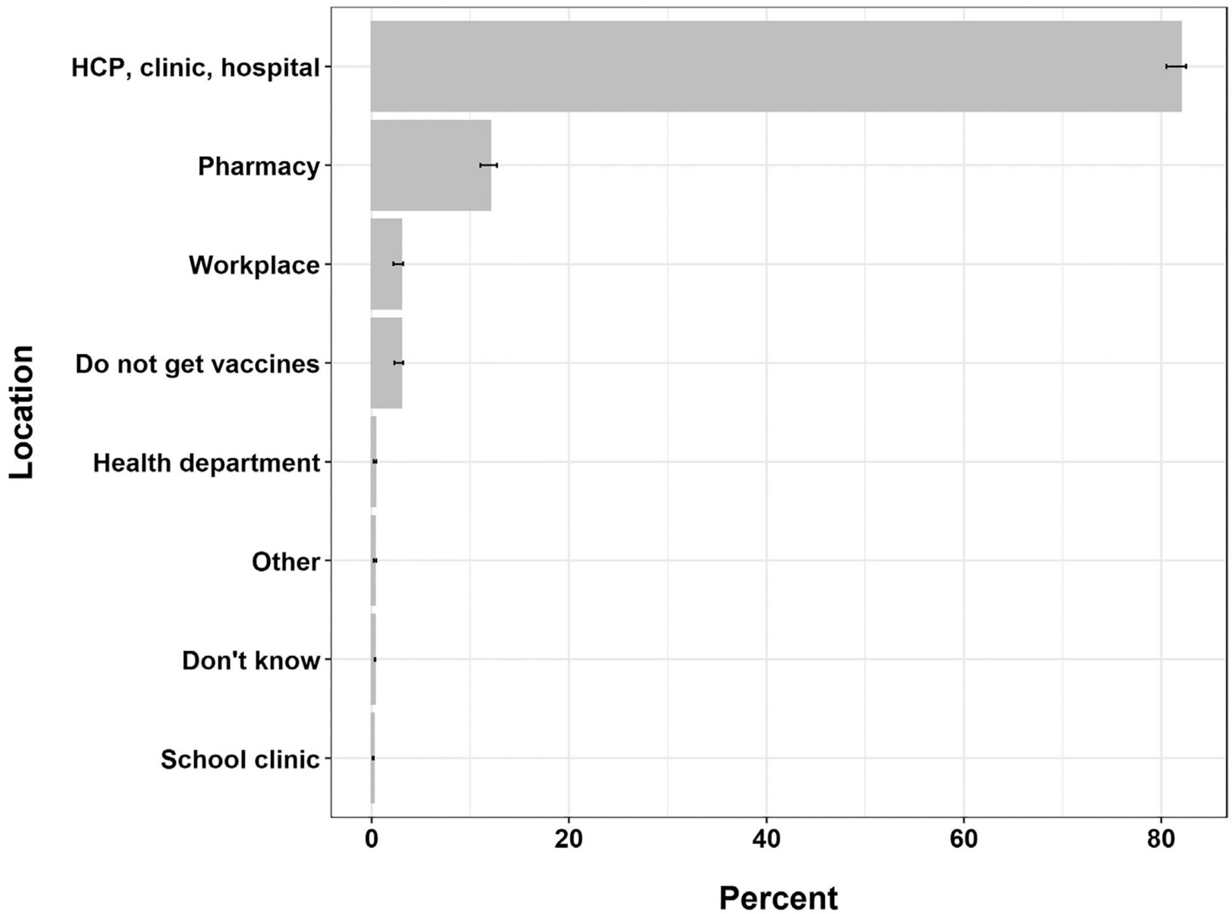

Fig. 2.

Residents' primary location for receiving vaccination. The gray bars represent the weighted percent. The black lines represent 95% confidence intervals. "HCP" denotes healthcare provider.

Table 1

Respondent characteristics and willingness to receive a Lyme disease (LD) vaccine, weighted % (95% CI).

		Willingness to receive a LD vaccine*		
Characteristic	**All****	**Yes**	**No**	**Don't Know**
Total, N = 3206		**64 (62, 65), n = 2098**	**7 (6, 8), n = 190**	**30 (29, 31), n = 918**
Demographics				
Gender* **				
Female	54	54 (53, 54)	64 (59, 70)	54 (52, 56)
Male	46	46 (46, 47)	36 (30, 41)	46 (44, 48)
Age category* (years)**				
<18	15	14 (13, 15)	13 (10, 16)	19 (17, 20)
18–44	33	36 (35, 37)	34 (29, 40)	28 (26, 30)
45–64	34	32 (31, 33)	39 (33, 45)	38 (36, 40)
65+	17	18 (18, 19)	14 (11, 17)	16 (14, 17)
State				
CT	20	21 (21, 22)	17 (12, 21)	16 (15, 18)
MD	27	27 (26, 28)	24 (19, 29)	29 (27, 31)
MN	20	20 (19, 21)	24 (20, 28)	18 (17, 20)
NY	33	32 (31, 33)	35 (29, 41)	37 (35, 39)
Race				
White	85 (84, 86)	87 (86, 88)	75 (69, 81)	81 (79, 83)
Non-White	15 (14, 16)	13 (12, 14)	25 (19, 31)	19 (17, 21)
Education				
Some college or less	35 (33, 36)	31 (29, 32)	50 (44, 56)	39 (37, 41)
Bachelor's degree or higher	65 (64, 67)	69 (68, 71)	50 (44, 56)	61 (59, 63)
Metropolitan status				
Large central metro area	28	28 (27, 29)	38 (33, 44)	26 (24, 28)
Other	72	72 (71, 73)	62 (56, 67)	74 (72, 76)
LD history, attitudes, and practices				
Past LD diagnosis in household				

		Willingness to receive a LD vaccine*		
Characteristic	**All****	**Yes**	**No**	**Don't Know**
Total, N = 3206		**64 (62, 65), n = 2098**	**7 (6, 8), n = 190**	**30 (29, 31), n = 918**
Yes	18 (17, 19)	21 (20, 22)	14 (9, 19)	13 (12, 15)
No	82 (81, 83)	79 (78, 80)	86 (81, 91)	87 (85, 88)
Concern about future LD diagnosis				
Yes	86 (85, 86)	94 (93, 95)	56 (50, 62)	74 (72, 76)
No	14 (14, 15)	6 (5, 7)	44 (38, 50)	26 (24, 28)
Time spent in tick habitat				
At least weekly	71 (70, 73)	82 (80, 83)	51 (45, 57)	54 (52, 56)
Monthly or less	29 (27, 30)	18 (17, 20)	49 (43, 55)	46 (44, 48)
Current use of LD prevention measures				
Yes	92 (91, 93)	94 (93, 95)	87 (83, 91)	90 (88, 91)
No	8 (7, 9)	6 (5, 7)	13 (9, 17)	10 (9, 12)
Confidence in LD prevention measures				
Yes	70 (68, 71)	67 (65, 68)	81 (76, 85)	74 (71, 76)
No	30 (29, 32)	33 (32, 35)	19 (15, 24)	26 (24, 29)
Confidence in general vaccines				
Yes	94 (93, 95)	98 (97, 98)	69 (64, 74)	91 (89, 93)
No	6 (5, 7)	2 (2, 3)	31 (26, 36)	9 (7, 11)
LD vaccine attitudes				
LD vaccine safety concerns				
Yes	71 (70, 72)	68 (66, 69)	80 (75, 84)	75 (74, 77)
No	29 (28, 30)	32 (31, 34)	20 (16, 25)	25 (23, 26)
Healthcare provider **influence on LD vaccination**				
Yes	89 (88, 89)	93 (92, 94)	57 (52, 63)	87 (85, 89)
No	11 (11, 12)	7 (6, 8)	43 (37, 48)	13 (11, 15)
LD vaccine cost concerns				
Yes	63 (62, 65)	66 (65, 68)	34 (28, 40)	64 (62, 67)
No	37 (35, 38)	34 (32, 35)	66 (60, 72)	36 (33, 38)

* All comparisons made in stratified analyses using Pearson chi-squared tests with Rao and Scott design-based adjustments had resultant p values ≤0.001.

** County distributions of gender and age were used for post-stratification; as such, these point estimates for the overall sample are fixed at the population values and have no associated interval estimate. Because state and metropolitan status are based on county population totals, these point estimates are also fixed.

*** Gender and age categories represent the potential vaccinee, *i.e.*, adult respondents and the children for whom parents responded.

Table 2

Unadjusted and adjusted odds ratios for Lyme disease (LD) vaccination responses using multinomial logistic regression.

	LD vaccination responses (ref. = Yes)			
	No		Don't Know	
Variable	**OR (95% Cl)**	**aOR (95% Cl)**	**OR (95% Cl)**	**aOR (95% Cl)**
Vaccinee age category*(ref. = 65 + years)				
<18	1.19 (0.38, 3.68)	NA	1.60 (1.06, 2.42)	NA
18–44	1.23 (0.69, 2.19)	NA	0.91 (0.66, 1.26)	NA
45–64	1.59 (0.88, 2.85)	NA	1.40 (1.07, 1.85)	NA
Gender*(ref. = Male)				
Female	1.55 (0.90, 2.68)	NA	1.00 (0.77, 1.31)	NA
State[1](ref. = Connecticut)				
Maryland	1.13 (0.60, 2.13)	1.16 (0.61, 2.19)	1.40 (0.99, 1.98)	1.42 (1.01, 1.99)
Minnesota	1.54 (0.77, 3.07)	1.51 (0.76, 3.00)	1.20 (0.83, 1.73)	1.19 (0.82, 1.73)
New York	1.41 (0.79, 2.50)	1.41 (0.80, 2.48)	1.52 (1.05, 2.20)	1.52 (1.05, 2.19)
Race[2](ref. = White)				
Non-White	2.24 (1.18, 4.26)	2.29 (1.21, 4.32)	1.55 (1.10, 2.18)	1.54 (1.10, 2.17)
Education[3](ref. = > Bachelor's degree)				
<Bachelor's degree	2.29 (1.35, 3.88)	2.21 (1.28, 3.83)	1.45 (1.12, 1.87)	1.47 (1.13, 1.91)
LD vaccine safety concerns[4](ref. = No)				
Yes	1.86 (1.12, 3.1)	2.62 (1.49, 4.60)	1.48 (1.07, 2.03)	1.99 (1.42, 2.78)
HCP influence on LD vaccination[5](ref. = Yes)				
No	9.32 (5.43, 16.01)	5.21 (2.72, 10.00)	1.92 (1.30, 2.84)	1.42 (0.94, 2.15)
LD vaccine cost concerns[6](ref. = No)				
Yes	0.26 (0.16, 0.43)	0.36 (0.20, 0.64)	0.92 (0.74, 1.16)	1.07 (0.82, 1.39)

* Unadjusted models only; no potential confounders were included in these models.

[1] State model adjusted for age category and education.

[2] Race model adjusted for metro status.

[3] Education model adjusted for age category, gender, state, race, and metro status.

[4] LD vaccine safety concerns model adjusted for age category, gender, education, HCP recommendation, past LD diagnosis in household, concern about future LD diagnosis, time spent in tick habitat, current use of LD prevention measures, general confidence in vaccines.

[5] HCP (healthcare provider) influence on LD vaccination model adjusted for age category, gender, education, past LD diagnosis in household, concern about future LD diagnosis, time spent in tick habitat, general confidence in vaccines.

[6] LD vaccine cost concerns model adjusted for age category, gender, state, education, HCP recommendation, concern about future LD diagnosis, time spent in tick habitat, current use of LD prevention measures, general confidence in vaccines.