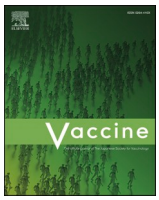
Vaccine 62 (2025) 127495

Contents lists available at ScienceDirect

Vaccine

journal homepage: www.elsevier.com/locate/vaccine



Short communication

# Lyme disease vaccine acceptability among healthcare providers – United States, 2018 and 2022

Taylor D. Bostic [a,b], Sarah A. Hook [a], Grace E. Marx [a,*]

[a] Division of Vector-borne Diseases, Centers for Disease Control and Prevention, Fort Collins, CO, USA
[b] Oak Ridge Institute for Science and Education, Centers for Disease Control and Prevention Fellowship Program, Oak Ridge, TN, USA

ARTICLE INFO

*Keywords:*
Lyme disease
*Borrelia burgdorferi*
Vaccine
Healthcare providers
Vaccination recommendation

ABSTRACT

*Background:* A Lyme disease (LD) vaccine is expected to become available soon. We aimed to understand recent trends in healthcare provider (HCP) willingness to recommend LD vaccination.
*Methods:* Cross-sectional surveys among HCPs were conducted in 2018 and 2022. We compared willingness to recommend LD vaccination by survey year and provider characteristics.
*Results:* Among 3005 HCPs, 70.5 % reported willingness to recommend LD vaccination. This proportion was lower in 2022 than in 2018 (68 % vs 73 %; $p < 0.01$) and did not differ significantly by provider medical specialty. More HCPs in states with high LD incidence were willing to recommend the vaccine compared to HCPs in neighboring or low-incidence states ($p < 0.01$). Vaccine safety was the most frequently reported consideration for recommending LD vaccination (73 %).
*Conclusions:* HCP willingness to recommend LD vaccination decreased from 2018 to 2022. Vaccination education tailored to HCPs that address vaccine safety will be critical for a successful LD vaccination program.

## 1. Introduction

With approximately 476,000 patients diagnosed and treated annually [1], Lyme disease (LD) is the most common vector-borne disease in the United States. Most cases are mild, but if untreated, disease can be severe and very infrequently fatal [2]. Due to the substantial disease burden, LD has significant economic impacts [3]. Over 95 % of reported LD cases occur in 15 high-incidence states in the Northeast, Mid-Atlantic, and Midwest regions where the bacteria, *Borrelia burgdorferi,* is transmitted through the bite of infected *Ixodes scapularis* ticks. Geographic expansion from these areas of hyper-endemicity has been observed [4].

Currently, prevention of LD depends primarily on personal protective behaviors to avoid tick bites, including repellent use and avoidance of tick habitat. However, consistent adoption of these behaviors has proven difficult, and population-level impact on disease reduction has not been demonstrated [5]. For those bitten by a tick, post-exposure prophylaxis (PEP) with a single dose of doxycycline given within 72 h of a tick bite can reduce risk of LD [6]. However, because only about half of people with confirmed LD are aware of being bitten [7], PEP can only help prevent a fraction of cases. Broad uptake of a vaccine by those at risk for LD may be a critical strategy for reducing incidence, once a safe and effective vaccine becomes available.

A vaccine to prevent Lyme disease has not been available since 2002, when the first vaccine, LYMErix, was removed from the market due to low demand amid safety concerns that later proved unfounded [8]. More recently, clinical trials have commenced evaluating new LD vaccine candidates [9,10]. While recent studies have found generally high LD vaccine acceptability among the general public [11,12], recent trends in healthcare provider willingness to recommend a LD vaccine have not been described. The role of healthcare providers (HCPs) in communicating the benefits and safety of vaccines has repeatedly proven to be a significant predictor for patient vaccine acceptance [13]. In this analysis, we evaluate provider willingness to recommend LD vaccination among HCPs surveyed before and after the height of the COVID-19 pandemic to inform effective communication and education strategies for future LD vaccines.

* Corresponding author at: Centers for Disease Control and Prevention, Division of Vector-borne Diseases, 3156 Rampart Rd, Fort Collins, CO 80521, USA.
*E-mail address:* GMarx@cdc.gov (G.E. Marx).

https://doi.org/10.1016/j.vaccine.2025.127495
Received 25 October 2024; Received in revised form 16 June 2025; Accepted 5 July 2025
Available online 17 July 2025
0264-410X/Published by Elsevier Ltd.

**Table 1**
Willingness to recommend a Lyme disease (LD) vaccine by survey respondent characteristics and Lyme disease state incidence category, United States.

| Characteristic | N (%) | | | N (%) | | | N (%) | | | N (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **High-Incidence** | | | **Neighboring** | | | **Low-Incidence** | | | **Overall** | | |
| | **Would Vaccinate (*n* = 840)** | **Would Not Vaccinate (*n* = 189)** | ***P*-value** | **Would Vaccinate (*n* = 464)** | **Would Not Vaccinate (*n* = 191)** | **P-value** | **Would Vaccinate (*n* = 814)** | **Would Not Vaccinate (*n* = 507)** | **P-value** | **Would Vaccinate (*N* = 2118)** | **Would Not Vaccinate (*N* = 887)** | **P-value** |
| **Survey Year** | | | | | | | | | | | | |
| 2018 | 434 (83) | 87 (17) | 0.1625 | 245 (74) | 87 (26) | 0.0916 | 419 (64) | 231 (36) | 0.0366* | 1098 (73) | 405 (27) | 0.0020* |
| 2022 | 406 (80) | 102 (20) | | 219 (68) | 104 (32) | | 395 (59) | 276 (41) | † | 1020 (68) | 482 (32) | |
| **Sex‡** | | | | | | | | | | | | |
| Male | 462 (83) | 95 (17) | 0.233 | 247 (71) | 103 (29) | 0.8200 | 474 (62) | 288 (38) | 0.5497 | 1183 (71) | 486 (29) | 0.5660 |
| Female | 373 (80) | 93 (20) | | 217 (71) | 87 (29) | | 335 (61) | 218 (39) | | 925 (70) | 398 (30) | |
| **Age, years** | | | | | | | | | | | | |
| 25–44 | 338 (81) | 80 (19) | | 191 (63) | 113 (37) | | 371 (62) | 225 (38) | | 900 (68) | 418 (32) | |
| 45–54 | 227 (81) | 52 (19) | 0.7797 | 133 (73) | 50 (27) | <0.0001* | 225 (59) | 154 (41) | 0.5504 | 585 (70) | 256 (30) | 0.0040* |
| 55+ | 275 (83) | 57 (17) | | 140 (83) | 28 (17) | | 218 (63) | 128 (37) | | 633 (75) | 213 (25) | |
| **Race** | | | | | | | | | | | | |
| White | 586 (82) | 127 (18) | | 328 (70) | 142 (30) | | 525 (61) | 337 (39) | | 1439 (70) | 606 (30) | |
| Black or African American | 34 (85) | 6 (15) | 0.0069* | 15 (68) | 7 (32) | 0.6253 | 31 (78) | 9 (23) | 0.1992 | 80 (78) | 22 (22) | 0.0363* |
| Asian | 175 (84) | 33 (16) | | 88 (76) | 28 (24) | | 191 (62) | 116 (38) | | 454 (72) | 177 (28) | |
| Other | 45 (66) | 23 (34) | | 33 (70) | 14 (30) | | 67 (60) | 45 (40) | | 145 (64) | 82 (36) | |
| **Ethnicity** | | | | | | | | | | | | |
| Hispanic | 35 (90) | 4 (10) | 0.1823 | 23 (79) | 6 (21) | 0.3046 | 58 (67) | 28 (33) | 0.2509 | 116 (75) | 38 (25) | 0.1762 |
| Not Hispanic | 805 (81) | 185 (19) | | 441 (70) | 185 (30) | | 756 (61) | 479 (39) | | 2002 (70) | 849 (30) | |
| **Patient Household Income** | | | | | | | | | | | | |
| Less than $50,000 | 254 (80) | 63 (20) | | 167 (70) | 71 (30) | | 261 (61) | 166 (39) | | 682 (69) | 300 (31) | |
| $50,000 - $99,999 | 354 (82) | 80 (18) | 0.5782 | 174 (70) | 75 (30) | 0.7328 | 335 (63) | 200 (37) | 0.8224 | 863 (71) | 355 (29) | 0.6797 |
| $100,000+ | 232 (83) | 46 (17) | | 123 (73) | 45 (27) | | 218 (61) | 141 (39) | | 573 (71) | 232 (29) | |
| **Medical Specialty** | | | | | | | | | | | | |
| Family Practitioner | 248 (84) | 48 (16) | | 181 (73) | 68 (27) | | 267 (64) | 147 (36) | | 696 (73) | 263 (27) | |
| Internist | 293 (80) | 72 (20) | | 147 (72) | 58 (28) | | 292 (62) | 182 (38) | | 732 (70) | 312 (30) | |
| Pediatrician | 168 (84) | 33 (16) | 0.3908 | 65 (75) | 22 (25) | 0.1603 | 117 (55) | 95 (45) | 0.1567 | 350 (70) | 150 (30) | 0.2644 |
| Nurse Practitioner/ Physician Assistant | 131 (78) | 36 (22) | | 71 (62) | 43 (38) | | 138 (62) | 83 (38) | | 340 (68) | 162 (32) | |
| **LD cases seen in the past 12 months** | | | | | | | | | | | | |
| Range | 0–200 | 0–100 | | 0–110 | 0–30 | | 0–100 | 0–300 | | 0–200 | 0–300 | |
| **With 0 cases N (%)** | 156 (68) | 72 (32) | | 234 (66) | 122 (34) | | 414 (51) | 391 (49) | | 804 (58) | 585 (42) | |
| **With 1+ cases N (%)** | 684 (85) | 117 (15) | | 230 (77) | 69 (23) | | 400 (78) | 116 (22) | | 1314 (81) | 302 (19) | |
| Mean | 14.3 | 12.8 | | 6.6 | 4.0 | | 7.1 | 7.6 | | 10.8 | 8.8 | |
| Median | 5 | 5 | 0.0880 | 3 | 2 | 0.0975 | 3 | 2 | .0033† | 3 | 2 | <.0001† |

(*continued on next page*)

**Table 1** (*continued*)

| Characteristic | N (%) | | | N (%) | | | N (%) | | | N (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | High-Incidence | | | Neighboring | | | Low-Incidence | | | Overall | | |
| | Would Vaccinate (*n* = 840) | Would Not Vaccinate (*n* = 189) | *P*-value | Would Vaccinate (*n* = 464) | Would Not Vaccinate (*n* = 191) | P-value | Would Vaccinate (*n* = 814) | Would Not Vaccinate (*n* = 507) | P-value | Would Vaccinate (*N* = 2118) | Would Not Vaccinate (*N* = 887) | P-value |
| **Years in clinical practice** | | | | | | | | | | | | |
| Mean | 17.8 | 17.7 | | 17.5 | 13.9 | | 16.5 | 16.3 | | 17.2 | 16.1 | |
| Median | 17.0 | 16.0 | 0.7380 | 17.0 | 11.0 | <.0001† | 15.0 | 15.0 | 0.6871 | 16 | 15 | 0.0009† |
| Range | 3–42 | 3–47 | | 3–43 | 3–38 | | 3–48 | 3–53 | | 3–48 | 3–53 | |

Other race includes 'Native Hawaiian or other Pacific Islander', 'American Indian or Alaskan Native', and 'Two or more races'.
"Would vaccinate" = "very likely" and "somewhat likely" responses. "Would not vaccinate" = "very unlikely", "somewhat unlikely", and "don't know/not sure".
High-incidence states include Connecticut, Delaware, Maine, Maryland, Massachusetts, Minnesota, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, Virginia, West Virginia, Wisconsin, and the District of Columbia. Any state sharing a border with or located between high-incidence states was classified as "neighboring". Neighboring states include Illinois, Indiana, Iowa, Kentucky, Michigan, North Carolina, North Dakota, Ohio, South Dakota, and Tennessee. All other states were categorized as having a low incidence of Lyme disease (Alabama, Alaska, Arizona, Arkansas, California, Colorado, Florida, Georgia, Hawaii, Idaho, Kansas, Louisiana, Mississippi, Missouri, Montana, Nebraska, Nevada, New Mexico, Oklahoma, Oregon, South Carolina, Texas, Utah, Washington, and Wyoming).
‡ Totals include only those who responded "male" or "female."
* Chi-square test of significance.
† Wilcoxon test of significance.

## 2. Methods

### 2.1. Data source

DocStyles is an annual, cross-sectional survey of an online panel of HCPs.[1] The Centers for Disease Control and Prevention (CDC) licensed the survey results from Porter Novelli Public Services, a public relations firm that specializes in health and social marketing. The 2018 and 2022 DocStyles surveys were administered to a quota-based sample of panelists consisting of 1000 primary care physicians (including family practitioners and internists), 250 obstetricians/gynecologists (OB/GYNs), 250 pediatricians, 250 nurse practitioners/physician assistants, 250 oncologists, and 250 pharmacists.[2]

Survey participation was voluntary and could end at any time. Monetary honorariums ($40–90) were paid to each respondent, depending on the number of questions they were asked to complete.[3] The survey included core questions regarding the healthcare providers' clinical practice and geographic location, demographics of the respondent and their patients, and questions regarding specific diseases.

CDC licensed questions related to LD and potential LD vaccine acceptability on the 2018 and 2022 surveys (Appendix A). The primary outcome of interest, willingness to recommend a potential LD vaccine, was evaluated using the question, "Scientists are currently working on vaccines to protect people from Lyme disease. A Lyme disease vaccine may become FDA-approved and available for people of all ages in the next several years. When there is a new vaccine, how likely would you be to recommend it to your patients?" Survey participants were also asked about what factors would be most important for them in deciding whether they would offer the new LD vaccine to their patients.

### 2.2. Analysis

Included in this analysis were providers who reported they 1) worked in an individual, group, or hospital practice, 2) lived in the United States, and 3) practiced medicine for ≥3 years. We excluded data from OB/GYNs and oncologists to generate a sample of providers most likely to treat patients with LD; we excluded data from pharmacists because they were only included in the 2018 survey. States where respondents resided and worked at the time of the survey were classified into LD incidence categories: high, neighboring, and low[4][5].

We defined willingness to recommend vaccination as a binary variable: willing participants indicated they would be "very likely" or "somewhat likely" to recommend vaccination; unwilling participants indicated they would be "very unlikely", "somewhat unlikely" or "don't

[1] SERMO is a global market research company. http://www.sermo.com

[2] Oncologists and pharmacists were only recruited for the 2018 survey year.

[3] All panelists are verified prior to taking the survey via a double opt-in sign in process with telephone confirmation at their place of work. Invitation to take the survey was also staggered based on activity level with high responders (panelists who answer >75 % of surveys sent) invited first, followed by medium responders (answered 25–75 % of surveys), and low responders (answered <25 %). Priority was made for panelists who did not participate in the previous year's DocStyles survey over other respondents.

[4] High-incidence states include Connecticut, Delaware, Maine, Maryland, Massachusetts, Minnesota, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, Virginia, West Virginia, Wisconsin, and the District of Columbia. Any state sharing a border with or located between high-incidence states was classified as "neighboring". Neighboring states (i.e., those that share a border with high-incidence states) include Illinois, Indiana, Iowa, Kentucky, Michigan, North Carolina, North Dakota, Ohio, South Dakota, and Tennessee. All other states were categorized as having a low incidence of Lyme disease (Alabama, Alaska, Arizona, Arkansas, California, Colorado, Florida, Georgia, Hawaii, Idaho, Kansas, Louisiana, Mississippi, Missouri, Montana, Nebraska, Nevada, New Mexico, Oklahoma, Oregon, South Carolina, Texas, Utah, Washington, and Wyoming).

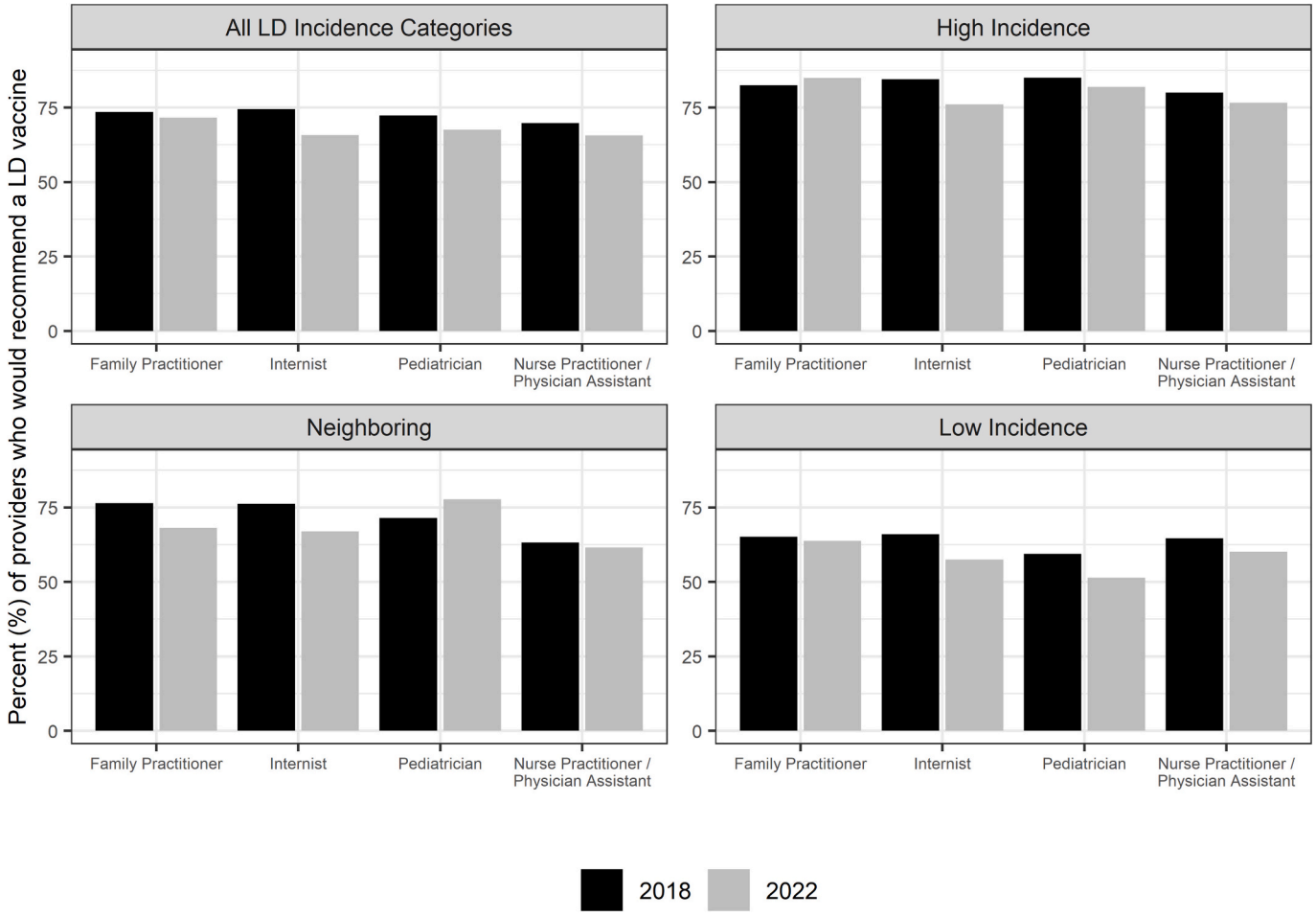



**Fig. 1.** Percent of healthcare providers willing to recommend the Lyme disease (LD) vaccine to their patients by survey year, medical specialty, and LD incidence category.

know/not sure". We compared data by survey year, provider characteristics, and LD incidence category using descriptive analyses. To compare willingness across variables of interest, we used chi-square tests for categorical variables and Wilcoxon rank sum tests for numerical variables. Odds ratios (OR) and 95 % confidence intervals (CIs) were calculated for univariate (unadjusted) and multivariable (adjusted for all other variables of interest) logistic regression models. Statistical significance was determined using an alpha level of 0.05. All analyses were performed using SAS version 9.4 (SAS Institute Inc., Cary, North Carolina).

## 3. Results

In 2018, Porter Novelli invited 3465 HCPs to participate in the survey; 2256 (65 %) participated. In 2022, 2587 HCPs were invited to complete the survey; 1752 (68 %) participated. Of the completed surveys, 1503 (67 %) and 1502 (86 %) met the inclusion criteria in 2018 and 2022, respectively. In both survey years, about 1/3 of participants were family practitioners, 1/3 were internists, 1/6 were pediatricians, and 1/6 were nurse practitioners or physician assistants.

### 3.1. Clinician demographics

Among the combined 3005 survey respondents from both years, 1029 (34 %) resided in states with high LD incidence, 655 (22 %) in neighboring states, and 1321 (44 %) in low-incidence states. Respondents were most often White (68 %), non-Hispanic (95 %), and between 25 and 44 years old (44 %).

### 3.2. Willingness to recommend a LD vaccine

Overall, 2118 (71 %) respondents reported that they would be willing to recommend the LD vaccine (Table 1). In 2018, 73 % of respondents reported that they would be willing to recommend the vaccine, compared to 68 % in 2022 ($p < 0.005$); this decrease was consistent across specialty types (**Fig. 1**).

A greater proportion of respondents in high-incidence states (82 %) reported they would be willing to recommend the LD vaccine compared to respondents in neighboring (71 %) and low-incidence (62 %) states ($p < 0.0001$). In the multivariable analysis adjusting for other variables, HCPs in neighboring and low-incidence states were less likely to recommend the LD vaccine, compared with HCPs in high-incidence states (OR: 0.631, 95 % CI: 0.496–0.802; OR: 0.409, 95 % CI: 0.334–0.502, respectively) (Table 2). Additionally, respondents in high-incidence states were most supportive of a LD vaccine recommendation, with 41 % "very likely" to recommend the vaccine, compared to 27 % and 23 % in neighboring and low-incidence states, respectively (Table 3). Among respondents from high-incidence states, family practitioners and pediatricians were most willing to recommend LD vaccination (both 84 %), followed by internists (80 %) and nurse practitioners/physician assistants (78 %), although these differences were not statistically significant (Table 1). Respondents who reported treating more LD cases within the 12 months prior to taking the survey were more likely to recommend the LD vaccine (adjusted OR:1.02, 95 % CI: 1.010–1.031) (Table 2).

Survey respondents indicated which factors would be most important in deciding whether they would offer the vaccine to their patients

**Table 2**
Characteristics associated with healthcare providers' willingness to recommend a Lyme disease (LD) vaccine.

| Variable | Unadjusted | | Adjusted | |
|---|---|---|---|---|
| | Odds Ratio | 95 % CI | Odds Ratio | 95 % CI |
| **Survey year** | | | | |
| 2018 (ref) | | | | |
| 2022 | 0.781 | 0.667, 0.913* | 0.783 | 0.665, 0.922* |
| **Sex** | | | | |
| Male (ref) | | | | |
| Female | 0.955 | 0.815, 1.118 | 0.976 | 0.817, 1.165 |
| **Age (years[a])** | | | | |
| 25–44 (ref) | | | | |
| 45–54 | 1.061 | 0.880, 1.280 | 1.016 | 0.836, 1.235 |
| 55+ | 1.380 | 1.137, 1.675* | 1.279 | 1.039, 1.573* |
| **Race** | | | | |
| White (ref) | | | | |
| Black or African-American | 1.531 | 0.946, 2.477 | 1.599 | 0.976, 2.622 |
| Asian | 1.080 | 0.886, 1.317 | 1.196 | 0.966, 1.481 |
| Other race | 0.745 | 0.559, 0.992* | 0.762 | 0.562, 1.033 |
| **Ethnicity** | | | | |
| Not Hispanic (ref) | | | | |
| Hispanic | 1.294 | 0.890, 1.884 | 1.592 | 1.076, 2.356* |
| **Patient household income** | | | | |
| Less than $50,000 (ref) | | | | |
| $50,000 - $99,999 | 1.069 | 0.890, 1.285 | 1.052 | 0.869, 1.272 |
| $100,000+ | 1.086 | 0.886, 1.333 | 1.0060 | 0.858, 1.311 |
| **Medical specialty** | | | | |
| Family Practitioner (ref) | | | | |
| Internist | 0.887 | 0.730, 1.076 | 0.870 | 0.710, 1.066 |
| Pediatrician | 0.882 | 0.695, 1.119 | 0.865 | 0.674, 1.108 |
| Nurse Practitioner/ Physician Assistant | 0.793 | 0.627, 1.003 | 0.854 | 0.659, 1.107 |
| **State incidence category** | | | | |
| High (ref) | | | | |
| Neighboring | 0.547 | 0.434, 0.689* | 0.631 | 0.496, 0.802* |
| Low | 0.361 | 0.298, 0.438* | 0.409 | 0.334, 0.502* |
| **Number of LD cases treated in the past 12 months** | 1.034 | 1.023, 1.045* | 1.021 | 1.010, 1.031* |
| **Years practicing medicine[b]** | 1.014 | 1.005, 1.022* | 1.010 | 1.00, 1.019* |

Ref: reference category.
Other race includes 'Native Hawaiian or other Pacific Islander', 'American Indian or Alaskan Native', and 'Two or more races'.
High-incidence states include Connecticut, Delaware, Maine, Maryland, Massachusetts, Minnesota, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, Virginia, West Virginia, Wisconsin, and the District of Columbia. Any state sharing a border with or located between high-incidence states was classified as "neighboring". Neighboring states include Illinois, Indiana, Iowa, Kentucky, Michigan, North Carolina, North Dakota, Ohio, South Dakota, and Tennessee. All other states were categorized as having a low incidence of Lyme disease (Alabama, Alaska, Arizona, Arkansas, California, Colorado, Florida, Georgia, Hawaii, Idaho, Kansas, Louisiana, Mississippi, Missouri, Montana, Nebraska, Nevada, New Mexico, Oklahoma, Oregon, South Carolina, Texas, Utah, Washington, and Wyoming).
Adjusted for all other variables except age[a] and years practicing medicine[b] due to high correlation between these two variables.
* Significant ($p < 0.05$).

**Table 3**
Healthcare provider attitudes and considerations towards recommending a Lyme disease vaccine, by Lyme disease incidence category of the state of residence, 2018 and 2022.

| Lyme disease vaccine attitudes and practices | High-Incidence | Neighboring | Low-Incidence | Overall |
|---|---|---|---|---|
| | N (%) | | | |
| **A. Likelihood of recommending a Lyme disease vaccine** | **(*n* = 1029)** | **(*n* = 655)** | **(*n* = 1321)** | **(*N* = 3005)** |
| Very Likely | 419 (41) | 180 (27) | 305 (23) | 904 (30) |
| Somewhat Likely | 421 (41) | 284 (43) | 509 (39) | 1214 (40) |
| Somewhat Unlikely | 86 (8) | 69 (11) | 162 (12) | 317 (11) |
| Very Unlikely | 28 (3) | 46 (7) | 134 (10) | 208 (7) |
| Don't Know/Not Sure | 75 (7) | 76 (12) | 211 (16) | 362 (12) |
| **B. Most important factor(s) in deciding to offer a Lyme disease vaccine. *Select all that apply.*** * | **(*n* = 986)** | **(*n* = 633)** | **(*n* = 1253)** | **(*N* = 2872)** |
| Safety of the vaccine | 815 (83) | 449 (71) | 837 (67) | 2101 (73) |
| Possible side effects of the vaccine | 697 (71) | 376 (59) | 688 (55) | 1761 (63) |
| Patients' risk of getting Lyme disease | 641 (65) | 433 (68) | 845 (67) | 1919 (67) |
| Cost of the vaccine | 544 (55) | 353 (56) | 610 (49) | 1507 (52) |
| Dosing schedule of the vaccine | 307 (31) | 180 (28) | 289 (23) | 776 (27) |
| Severity of Lyme disease | 215 (22) | 129 (20) | 244 (19) | 588 (20) |
| Other reasons not listed | 36 (4) | 26 (4) | 73 (6) | 135 (5) |
| I do not counsel patients on Lyme disease | 20 (2) | 24 (4) | 75 (6) | 119 (4) |

High-incidence states include Connecticut, Delaware, Maine, Maryland, Massachusetts, Minnesota, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, Virginia, West Virginia, Wisconsin, and the District of Columbia. Any state sharing a border with or located between high-incidence states was classified as "neighboring". Neighboring states include Illinois, Indiana, Iowa, Kentucky, Michigan, North Carolina, North Dakota, Ohio, South Dakota, and Tennessee. All other states were categorized as having a low incidence of Lyme disease (Alabama, Alaska, Arizona, Arkansas, California, Colorado, Florida, Georgia, Hawaii, Idaho, Kansas, Louisiana, Mississippi, Missouri, Montana, Nebraska, Nevada, New Mexico, Oklahoma, Oregon, South Carolina, Texas, Utah, Washington, and Wyoming).
* Respondents who selected "I do not offer/provide vaccinations" ($n = 133$) were excluded.

(Table 3). Across incidence categories, vaccine safety was the most frequently reported consideration (73 %), followed by the patient's risk of getting LD (67 %), possible side effects of the vaccine (63 %), and the cost of the vaccine (52 %).

## 4. Discussion

In this large sample of U.S. HCPs, we found that willingness to recommend a LD vaccine decreased from 2018 to 2022 but was highest

overall among those who lived and worked in states with a high incidence of LD. The proportion of HCPs willing to recommend a LD vaccine in this study (71 %) was slightly higher than the 64 % - 68 % acceptability rates reported among the general public [11,12]. The greater willingness to recommend LD vaccination among HCPs in states with high LD incidence is likely due to awareness of disease risk in their area and the fact that their patients are most likely to benefit from LD vaccination [14]. Across all LD incidence categories, providers who treated more LD cases during the survey year were also more willing to recommend vaccination.

Since the onset of the COVID-19 pandemic, trust in governmental organizations like CDC and FDA has decreased among HCPs, which can influence decisions to both receive and recommend vaccines 15. Additional post-pandemic factors which may be contributing to lower rates of routine pediatric vaccinations [16] include decreased physical access to patients due to higher frequency of telehealth visits, clinical staffing shortages, and lenient enforcement of immunization requirements in schools [15,17].

HCP participants reported vaccine safety as the most important consideration when recommending LD vaccination, regardless of LD incidence category. Concerns of safety for newer vaccines among HCPs and the general public have been consistently identified as a limiting factor in successful uptake, as seen with the COVID-19 vaccines and more recently the new respiratory syncytial virus (RSV) vaccine [14,18,19]. Maintaining and improving Immunization Information Systems (IIS)[5] and safety monitoring systems, such as VAERS and V-safe [20], to monitor uptake and safety once the vaccine is available will be critical in ensuring vaccine safety and informing communications to HCPs and the public.

This analysis is subject to several limitations. First, this cross-sectional survey administered at two time points among different samples of HCPs may not be representative of the perspectives of individual HCPs over time. Second, the survey questions pertained to a potential new vaccine for which efficacy and safety information are not yet available. Specific vaccine characteristics such as side effects, dosing schedule, cost, and patient-level characteristics such as age may be additional factors influencing providers' willingness to recommend LD vaccination to patients. Third, combining responses by participants who reported being unsure with those who reported being unlikely or very unlikely to recommend LD vaccination might inadvertently overestimate provider LD vaccine hesitancy. Lastly, we did not include questions about general vaccination perspectives or acceptance of non-LD vaccines in the survey, thus limiting our ability to contextualize changes in LD vaccine acceptability over time with general vaccination recommendation trends or the effect of the COVID-19 pandemic.

In conclusion, most providers were willing to recommend LD vaccination to their patients, particularly providers who work and reside in states where LD is common. After a LD vaccine becomes available, tailored vaccination education that addresses vaccine safety and targets clinicians in areas with highest LD risk will be key for a successful LD vaccination program.

## Disclaimer.

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

## CRediT authorship contribution statement

**Taylor D. Bostic:** Writing – original draft, Writing – review & editing. **Sarah A. Hook:** Validation, Conceptualization, Writing – review & editing, Methodology. **Grace E. Marx:** Writing – original draft, Conceptualization, Writing – review & editing, Supervision.

## Funding

This work was supported by the US Centers for Disease Control and Prevention.

## 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.

## Acknowledgments

We thank Kalanthe Horiuchi (CDC) for her help with the data analysis and statistical review. We also wish to thank the healthcare providers who participate in the DocStyles surveys.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.vaccine.2025.127495.

## Data availability

The data are licensed to the Centers for Disease Control and Prevention. The data are not publicly available due to privacy or ethical restrictions.

## References

[1] 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. https://doi.org/10.3201/eid2702.202731.
[2] Marx GE, Leikauskas J, Lindstrom K, et al. Fatal Lyme carditis in New England: two case reports. Ann Intern Med 2020;172(3):222–4. https://doi.org/10.7326/L19-0483.
[3] Hook SA, Jeon S, Niesobecki SA, et al. Economic burden of reported Lyme disease in high-incidence areas, United States, 2014-2016. Emerg Infect Dis 2022;28(6):1170–9. https://doi.org/10.3201/eid2806.211335.
[4] Kugeler KJ, Farley GM, Forrester JD, Mead PS. Geographic distribution and expansion of human Lyme disease, United States. Emerg Infect Dis 2015;21(8):1455–7. https://doi.org/10.3201/eid2108.141878.
[5] Schwartz AM, Mackeprang JM, Mead PS, Hinckley AF. Effectiveness of personal protection measures against Lyme disease: a review of epidemiologic studies from the United States. Zoonoses Public Health 2022;69(7):777–91. https://doi.org/10.1111/zph.12984.
[6] Zhou G, Xu X, Zhang Y, et al. Antibiotic prophylaxis for prevention against Lyme disease following tick bite: an updated systematic review and meta-analysis. BMC Infect Dis 2021;21(1):1141. https://doi.org/10.1186/s12879-021-06837-7.
[7] Thompson A, Mannix R, Bachur R. Acute pediatric monoarticular arthritis: distinguishing Lyme arthritis from other etiologies. Pediatrics 2009;123(3):959–65. https://doi.org/10.1542/peds.2008-1511.
[8] Nigrovic LE, Thompson KM. The Lyme vaccine: a cautionary tale. Epidemiol Infect 2007;135(1):1–8. https://doi.org/10.1017/S0950268806007096.
[9] Bézay N, Wagner L, Kadlecek V, et al. Optimisation of dose level and vaccination schedule for the VLA15 Lyme borreliosis vaccine candidate among healthy adults: two randomised, observer-blind, placebo-controlled, multicentre, phase 2 studies. Lancet Infect Dis 2024;24(9):1045–58. https://doi.org/10.1016/S1473-3099(24)00175-0.
[10] Pine M, Arora G, Hart TM, et al. Development of an mRNA-lipid nanoparticle vaccine against Lyme disease. Mol Ther 2023;31(9):2702–14. https://doi.org/10.1016/j.ymthe.2023.07.022.
[11] Gidengil C, Scherer AM, Parker AM, et al. Lyme disease vaccine attitudes and intentions among parents of children aged 5-18 years in the United States. Vaccine 2024;42(8):1899–905. https://doi.org/10.1016/j.vaccine.2024.01.081.
[12] Hook SA, Hansen AP, Niesobecki SA, et al. Evaluating public acceptability of a potential Lyme disease vaccine using a population-based, cross-sectional survey in high incidence areas of the United States. Vaccine 2022;40(2):298–305. https://doi.org/10.1016/j.vaccine.2021.11.065.
[13] Gilkey MB, McRee AL. Provider communication about HPV vaccination: a systematic review. Hum Vaccin Immunother 2016;12(6):1454–68. https://doi.org/10.1080/21645515.2015.1129090.

[5] Immunization Information Systems (IIS) are computerized databases that record immunization doses administered by participating providers to persons residing within a given geopolitical area.

[14] Devchand R, Koehler L, Hook S, et al. Understanding consumer and clinician perceptions of a potential Lyme disease vaccine. Health Educ Res 2022;36(5):494–504. https://doi.org/10.1093/her/cyab032.
[15] Dudley MZ, Schuh HB, Forr A, Shaw J, Salmon DA. Changes in vaccine attitudes and recommendations among US healthcare personnel during the COVID-19 pandemic. NPJ Vaccines 2024;9(1):49. https://doi.org/10.1038/s41541-024-00826-y.
[16] Treharne A, Patel Murthy B, Zell ER, et al. Impact of the COVID-19 pandemic on routine childhood vaccination in 9 U.S. jurisdictions. Vaccine 2024;42(22):125997. https://doi.org/10.1016/j.vaccine.2024.05.045.
[17] 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 Morb Mortal Wkly Rep 2020;69(19):591–3. https://doi.org/10.15585/mmwr.mm6919e2.
[18] Langer S, Holzapfel S, August L, Badura A, Wellmann S, Mack I. Parental knowledge and attitudes to infant immunization in the context of RSV: all about confidence? Vaccine 2024;42(23):126050. https://doi.org/10.1016/j.vaccine.2024.06.018.
[19] Paterson P, Meurice F, Stanberry LR, Glismann S, Rosenthal SL, Larson HJ. Vaccine hesitancy and healthcare providers. Vaccine 2016;34(52):6700–6. https://doi.org/10.1016/j.vaccine.2016.10.042.
[20] Duffy J, Myers TR, Marquez P, et al. JYNNEOS vaccine safety surveillance during the 2022 Mpox outbreak using the vaccine adverse event reporting system and V-safe, United States, 2022 to 2023. Sex Transm Dis 2024;51(8):509–15. https://doi.org/10.1097/OLQ.0000000000001978.