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Risk Factors for Pneumococcal Colonization of the Nasopharynx in Alaska Native Adults and Children

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Abstract

Background.—Alaska Native children have high invasive pneumococcal disease (IPD) rates, and lack of in-home running water has been shown to have a significant association with infection. Pneumococcal conjugate vaccines reduced IPD; however, this population saw substantial replacement disease and colonization with nonvaccine serotypes. We evaluated risk factors for nasopharyngeal pneumococcal colonization in Alaska Native adults and children.

Methods.—We conducted annual surveys from 2008 through 2011 of residents of all ages in 8 rural Alaskan villages. Interviews were conducted, medical charts were reviewed, and nasopharyngeal swabs were cultured for *Streptococcus pneumoniae*. Multivariate logistic regression models were developed for 3 age groups (under 10 years, 10–17 years, and 18 years and older) to determine risk factors for colonization.

Results.—We obtained 12 535 nasopharyngeal swabs from 4980 participants. Our population lived in severely crowded conditions, and 48% of households lacked in-home running water. In children <10 years, colonization was associated with lack of in-home running water, household crowding, and more children in the home. Pneumococcal vaccination status was not associated with colonization. In older children and adults, increased number of persons in the household was associated with pneumococcal colonization.

Conclusions.—Higher colonization prevalence may partially explain increased IPD rates seen in those lacking in-home water services. Improving availability of sanitation services and reducing household crowding may reduce the burden of IPD in this population.

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Keywords

pneumococcal colonization; *Streptococcus pneumoniae*; vaccine; water

Invasive disease caused by *Streptococcus pneumoniae* is a major cause of mortality in children throughout the world, and it is a leading etiology of pneumonia, meningitis, bacteremia, and otitis media. Nasopharyngeal colonization with this pathogen is common, especially in children [1–12]. Colonization is a precursor to invasive disease, and colonized persons can transmit pneumococci to household and community members through respiratory droplets.

Alaska Native (AN) children have a high incidence of invasive pneumococcal disease (IPD) with rates up to 426 cases per 100 000 rural children under 5 per year in 2005–2007 [13–17]. A lack of in-home running water has been associated with increased risk of infection in the rural population [17–19]. Vaccination with heptavalent pneumococcal conjugate vaccine (PCV7) reduced overall rates of invasive disease in AN people [20], with virtual elimination of disease caused by vaccine serotypes. In the years after introduction of the vaccine, however, AN children under age 2 experienced more significant replacement disease with nonvaccine serotypes than other populations, principally due to serotypes 19A and 7F [20]. The same nonvaccine serotypes were increasingly found colonizing the nasopharynx [2, 21, 22], highlighting the role of pneumococcal colonization in transmission of pathogenic serotypes causing invasive disease. The 13-valent PCV (PCV13), which was introduced to Alaska in 2010, includes some of the more common replacement serotypes and may reduce IPD rates further.

To better understand the dynamics of pneumococcal colonization in the AN population, we conducted a study to determine significant socioeconomic and demographic risk factors for pneumococcal colonization.

METHODS

Study Population

As of 2010, there are 138 312 people of at least partial AN descent, comprising 19.4% of Alaska's population [23]. This diverse group includes Aleut, Athabascan, Yup'ik Eskimo, Tlingit, and others. The majority of AN people live in rural villages only accessible by airplane, boat, and snowmobile. Most receive healthcare through the AN health system—a statewide, tribally operated system with village clinics, regional hospitals, and tertiary care facilities in Anchorage. Alaska Native people have access to this system free of charge. Economic opportunity in villages is variable and largely depends on the presence of fishing and other natural resource industries. Uneven distribution of in-home water service is due to technical and engineering factors.

Study Design

We conducted an observational, cross-sectional survey of pneumococcal colonization in 8 rural Alaskan villages in 3 regions: Yukon-Kuskokwim (YK), Norton Sound, and Bristol

Bay. Approval was obtained from village tribal elders, and villages were visited annually from March to April, 2008 to 2011. Approximately 2500 participants of all ages were invited to enroll by a mailing 2 weeks before and a radio announcement on visit days. Participants had to reside in a village for at least 3 weeks. Written informed consent was obtained from each adult and 1 parent of participating children, and written assent was obtained from children age 7–18 years. The study was approved by the Institutional Review Boards of the US Centers for Disease Control and Prevention, the Alaska Area Indian Health Service, and the involved regions' tribal health boards.

Demographic and socioeconomic information was obtained through interviews, medical records were reviewed for recent infection and antibiotic usage, and each participant underwent a nasopharyngeal swab. Nasopharyngeal swabs were immersed in skim-milk tryptone glucose glycerol (STGG) medium and transported on ice packs to the Arctic Investigations Program laboratory in Anchorage, where 50 μL of the STGG specimens were plated onto trypticase soy agar supplemented with 5% sheep blood and 10 μg/mL gentamicin (Remel; Lexana, Kansas). The agar plates were incubated in 5% CO_2 at 35°C–37°C for 18–24 hours. Pneumococci were identified by colony morphology, susceptibility to optochin (>14 mm for 6 mm disk), and bile solubility. The outcome measured was nasopharyngeal colonization with pneumococcus regardless of serotype.

Statistical Analysis

Data for this study were double-entered into Paradox for Windows (Borland International, Scotts Valley, CA), and analyses were performed using Epi-Info and SAS version 9.3 (SAS Institute, Cary, NC). Because age was a strong modifier of pneumococcal colonization and IPD, we divided the population into 3 age groups for analysis: under 10 years, 10–17 years, and ≥18 years. For univariate analyses, the likelihood-ratio χ^2 test was used to test categorical covariates, and the Cochran-Armitage trend test was used for ordinal covariates. Logistic regression was used for development of multivariate models. We tested for an association between pneumococcal colonization and household size (number of persons living in the home), the number of rooms in a home, and household crowding (number of persons per room in a home) in univariate analyses. Because of the induced collinearity, only household size and household crowding were considered in the multivariate models. Age was treated as a categorical covariate in all statistical models. Because sample sizes allowed, the initial multivariate model included all covariates. The best-fit regression model was determined by non-automatic backward selection using the strategy described by Hosmer and Lemeshow [24]. Study year was included in all models. The 95% confidence intervals (CIs) were used for all odds ratios (ORs). For the analysis of prevalence by village and region, village A and Bristol Bay were chosen as references because colonization prevalence in each was respectively close to the median of prevalence ranges.

RESULTS

Demographics

Between 2008 and 2011, we collected 12 669 nasopharyngeal swabs; 70% of village residents participated. We excluded 134 swabs due to incomplete culture or demographic

data. A total of 12 535 swabs from 4980 participants between age 4 days and 92 years were included in the analysis. Overall, 49% of participants were female and 99.3% were of AN heritage (Table 1). Children from 3 to 59 months of age had an up-to-date vaccination rate of 83.9% with a PCV [25]. In this population, 52% of participants had in-home running water, and the median crowding index was 1.5 persons per room. On average, households had 5 persons living in them with a mean of 2.1 adults ≥18 years of age. Within the previous 90 days, 25.4% of participants received antibiotics and 35.5% of participants had a respiratory infection.

Risk Factors for Pneumococcal Colonization

Overall, 4155 of 12 535 (33.2%) swabs grew pneumococcus. Colonization prevalence peaked at age 4 years (71.8%) and then declined progressively, reaching 9.5% in adults over age 65 years (Figure 1). In children <10 years of age (Table 2), colonization over all 4 years and all 8 villages was 62.5%, ranging from a low of 37.1% (village D, 2009) to a high of 77.4% (village C, 2011). In children age 10–17 years (Table 3), 40.1% were colonized, ranging from a low of 23.5% (village A, 2010) to a high of 61.7% (village E, 2010). In adults (Table 4), 14.3% were colonized, ranging from a low of 7.2% (village E, 2008) to a high of 29.2% (village E, 2010). On multivariate analysis, increased age was associated with lower colonization prevalence in all 3 age groups ($P < .0001$ for each age group), whereas no association was found with sex in any of the age groups ($P > .37$ for all) or with vaccination status in children under age 5 years ($P = .14$). In children under 5 years of age in all villages, 65% of those who were adequately vaccinated with PCV carried pneumococcus, similar to 65% among children who were not adequately vaccinated.

Colonization prevalence varied by region and by village in all ages. On univariate analysis, children under age 18 years living in the YK region had 50% higher colonization odds than those living in Bristol Bay. Living in village F in the YK delta was associated with increased colonization prevalence in this same age group on univariate analysis, but not in adults. On multivariate analysis, this significant association with village F persisted only in those age 10–17 years. In village D in Norton Sound, children under age 10 years had half the odds ($P < .0001$) and adults had two-thirds the odds of colonization ($P = .005$) when compared to similar-age participants in reference village A in Bristol Bay. Multivariate analysis also showed a significant association between living in village H in the YK delta and increased prevalence in children aged 10–17 years (OR, 1.43; 95% CI, 1.03–1.99), but an association was not found in children under 10 years or adults.

Lack of in-home running water was associated with significantly increased colonization prevalence in children <10 years of age on multivariate analyses (OR, 1.35; 95% CI, 1.08–1.69). This association was stronger when analysis was restricted to children age under 5 years (OR, 1.42) (data not shown). There was no association on univariate or multivariate analyses between colonization and in-home running water in children aged 10–17 years or adults.

A higher number of household occupants was associated with increased colonization odds in all ages on univariate analysis. Having more than 3 children under 10 years old in a household also increased colonization odds for all ages on univariate analysis. On

multivariate analysis, a significant association with number of household occupants persisted only in children age 10–17 years and adults (OR = 1.06 and 1.05, respectively). A significant association with having more than 3 young children in a household persisted only for children under age 10 years (OR, 1.47; 95% CI, 1.22–1.77). This result means that in this youngest age group, those living in a household with 3 or more other small children had 47% higher colonization odds than those living with less than 3 other young children.

On univariate analysis, increased household crowding was associated with increased colonization prevalence in all ages, whereas the number of rooms in a household had a negative association with colonization prevalence for children under 10 years and children 10–17 years. On multivariate analysis, a significant association between colonization and household crowding persisted only for children under 10 years (OR = 1.11 per each additional person/room; 95% CI, 1.03–1.20). The number of rooms was not included in the multivariate model.

Antibiotic therapy within the previous 90 days was associated with reduced colonization prevalence in all ages on univariate and multivariate analyses. For children under age 10, having had otitis media, streptococcal pharyngitis, or pneumonia within the previous 90 days was associated with decreased colonization prevalence on univariate analysis. On multivariate analysis, a negative association remained only with otitis media (OR, .79; 95% CI, .64–.97). Also on multivariate analysis, increased colonization in adults was associated with having had bronchitis or a skin infection.

DISCUSSION

Alaska Native people living in rural communities have high rates of IPD and a high prevalence of pneumococcal nasopharyngeal colonization. We evaluated risk factors for colonization and found that increased prevalence in children under 10 years of age is independently associated with younger age, lack of in-home running water, increased household crowding, and a higher number of young children in the household. Factors associated with reduced colonization prevalence in this age group are recent antibiotic therapy, recent otitis media, and a higher number of rooms in the household. Among persons 10–17 years of age and adults, colonization was associated with living with a larger number of people, whereas reduced colonization was associated with recent antibiotic therapy.

This population is colonized early in life, with 54% of children under 6 months old carrying pneumococcus. This finding is similar to what has been seen in other populations [1, 3, 4, 7, 8, 26]. In this population, prevalence peaked at age 4 years, whereas other populations showed prevalence peaks at younger ages (generally from 6 months to 2 years) [1, 6, 8, 10, 11]. The peak colonization prevalence in our study was also later than the peak rates of IPD, which are highest in AN children at 12 months of age (Arctic Investigations Program, unpublished data). The reason for this discrepancy is not known, and the mechanism by which nasopharyngeal pneumococcal colonization leads to invasive disease is incompletely understood. It is possible that colonized younger children are more at risk of invasive disease than colonized older children.

Colonization prevalence was 14% in adults in this study, which is higher than in a Swedish adult population (0.8%) [27] and lower than in Australian Aboriginal adults (26%) [12]. Mackenzie et al. [12] showed an increase in colonization prevalence with age in Australian Aboriginal people older than 35 years; however, our study showed a steady decline in colonization with age (Figure 1).

In a previous study in this population, we showed that IPD risk among children under 5 years of age is more than twice as high in villages where <10% of households have in-home water service compared to villages where ≥80% households have running water, after adjusting for household crowding and income [17]. In houses without in-home water service, water must be hauled by hand and is conserved for use in cooking and dish washing [28]. We postulated that water rationing in these households decreases opportunities for handwashing, especially in smaller children who need assistance, and leads to increased transmission of pneumococci among household members. Higher rates of other infections where hand or body hygiene can reduce risk (Staphylococcus aureus skin infections, viral infections of the lower respiratory tract) have been demonstrated in rural Alaska populations that lack adequate in-home water supplies [17–19, 29]. This is the first study, to our knowledge, to assess the relationship between in-home running water and pneumococcal colonization. The finding of 35% higher odds of colonization among children without in-home running water supports the hypothesis that access to in-home running water could reduce IPD in this population.

We hypothesize that lack of in-home running water had no association with colonization in adolescents and adults because of age-related differences in hygiene practices. As children grow, they may initiate handwashing more frequently due to fewer physical barriers, access to water at school, and hygiene education. Younger children are most vulnerable to colonization and infection, and they are the least likely to wash their hands, making them ideal disseminators of pneumococci within households and communities. This tendency of children to disseminate the bacterium once colonized also likely explains a reduction in adult IPD following routine vaccination of children with PCVs [30]. Our data suggest that a protective effect of in-home running water may be strongest in the youngest age group. These data help reinforce the need to achieve universal access to in-home running water to reduce health disparities in this population. Still, the colonization prevalence of 61% in children in homes with running water is very high for a developed country, and we consider other factors as well to explain the high rates of IPD in rural Alaska.

The AN population in this study lived in severely crowded conditions, defined as 1.5 or more persons per room. This study adds to the literature showing a link between household crowding and pneumococcal colonization [26, 31, 32]. Outbreaks of pneumococcus are uncommon but typically occur in facilities with close living conditions, such as medical wards, prisons, and military barracks. Crowding results in more physical contact that enhances pneumococcal transmission. In our population, increased household crowding was found to be associated with (1) increased colonization in all ages on univariate analysis and (2) in children under age 10 years on multivariate analysis. Likewise, colonization prevalence increases with increasing number of household occupants and decreases with increasing number of rooms in a household. Having more children in a household is

associated with increased colonization prevalence for all ages, which reflects the importance of young children as potential transmitters of pneumococcus.

Our data showed no association between vaccination and overall colonization prevalence, which is consistent with previous data [2, 21, 22]. We saw a negative association between recent antibiotics and pneumococcal colonization, which has been demonstrated in many other studies [1, 2, 21, 33, 34]. Children <10 years of age who recently had otitis media, streptococcal pharyngitis, or pneumonia had lower odds of colonization. This reduction is likely the effect of antibiotic therapy prescribed for these infections. It is interesting to note that recent respiratory tract infections of typically viral etiology (viral pharyngitis, upper respiratory tract infection, bronchitis, and bronchiolitis) had no association with decreased colonization prevalence, perhaps suggesting that antibiotic therapy was appropriately limited to infections only of likely bacterial origin.

We found overall higher prevalence of colonization in the YK delta compared to other regions, which correlates with the higher IPD rates in this region. Children under age 2 living in this region have higher IPD rates than AN children in other regions and experienced more replacement disease after vaccination than elsewhere in Alaska [17]. We were unable to explain the differences in colonization prevalence between villages in our study; however, the data suggest that these differences are real rather than temporary fluctuations in colonization. For children and adolescents living in village F, colonization prevalence was among the highest of all villages in most years, whereas for the same age groups living in village D, colonization prevalence was among the lowest of all villages in most years. A significant proportion of households in both villages F and D lacked access to in-home running water, suggesting that the cause of this persistent disparity in prevalence was not measured in our study. These differences may also reflect introduction of new pneumococcal types, variability in nasopharyngeal swabbing technique, or issues related to the transportation of samples from villages to the laboratory in Anchorage.

The generalizability of our results may be limited by the study population of rural AN persons, who have significant differences in lifestyle, household crowding, and living conditions from the general US population. This was also a convenience sample that tended to draw households with more people overall, more children, and less in-home running water. When proportions of in-home running water in our sample were compared with unpublished data for each village, our participants tended to be less likely to have in-home running water than the village averages. Thus, the overall prevalence of colonization from this study may be somewhat higher than the actual prevalence in these regions. This result is consistent with an analysis of this surveillance population in the past [35], which showed bias toward households with more children and more frequent clinic visits. The large sample sizes in this analysis provided high power to detect relatively small effect sizes. The epidemiological significance of a 5% difference in pneumococcal colonization prevalence is not completely understood. Furthermore, income and education levels of parents may play a role in village of residence, hygiene habits, and household crowding; however, these socioeconomic risk factors were not assessed in this study.

The main findings of this study highlight the importance of improving living standards for AN populations. Providing universal in-home water service may be a way to improve hygiene and reduce pneumococcal colonization and infection, especially in younger children. For villages with water services limited by technical geographic difficulties, this process may require experimentation with individual household water purifiers that allow recycling of waste water. Reducing crowding through education and housing innovations may also reduce colonization and disease rates.

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References

1. Abdullahi O, Karani A, Tigoi CC, et al. The prevalence and risk factors for pneumococcal colonization of the nasopharynx among children in Kilifi District, Kenya. PLoS One 2012; 7:e30787. [PubMed: 22363489]
2. Park SY, Moore MR, Bruden DL, et al. Impact of conjugate vaccine on transmission of antimicrobial-resistant *Streptococcus pneumoniae* among Alaskan children. Pediatr Infect Dis J 2008; 27:335–40. [PubMed: 18316986]
3. Faden H, Stanievich J, Brodsky L, et al. Changes in nasopharyngeal flora during otitis media of childhood. Pediatr Infect Dis J 1990; 9:623–6. [PubMed: 2122410]
4. Syrjänen RK, Kilpi TM, Kaijalainen TH, et al. Nasopharyngeal carriage of *Streptococcus pneumoniae* in Finnish children younger than 2 years old. J Infect Dis 2001; 184:451–9. [PubMed: 11471103]
5. García-Rodriguez JA, Fresnadillo Martínez MJ. Dynamics of nasopharyngeal colonization by potential respiratory pathogens. J Antimicrob Chemother 2002; 50(Suppl S2):59–73.
6. Yagupsky P, Porat N, Fraser D, et al. Acquisition, carriage, and transmission of pneumococci with decreased antibiotic susceptibility in young children attending a day care facility in southern Israel. J Infect Dis 1998; 177:1003–12. [PubMed: 9534975]
7. Steele RW, Warrier R, Unkel PJ, et al. Colonization with antibiotic-resistant *Streptococcus pneumoniae* in children with sickle cell disease. J Pediatr 1996; 128:531–5. [PubMed: 8618188]
8. De Lencastre H, Kristinsson KG, Brito-Avó A, et al. Colonization of respiratory tract pathogens and molecular epidemiology of *Streptococcus pneumoniae* colonization in healthy children attending day care centers in Lisbon, Portugal. Microb Drug Resist 1999; 5:19–29. [PubMed: 10332718]
9. Dagan R, Melamed R, Muallem M, et al. Nasopharyngeal colonization in southern Israel with antibiotic-resistant pneumococci during the first two years of life: relation to serotypes likely to be included in pneumococcal conjugate vaccines. J Infect Dis 1996; 174:1352–5. [PubMed: 8940233]
10. Zenni MK, Cheatham SH, Thompson JM, et al. *Streptococcus pneumoniae* colonization in the young child:association with otitis media and resistance to penicillin. J Pediatr 1995; 127:533–7. [PubMed: 7562272]
11. Gray BM, Turner ME, Dillon HC. Epidemiologic studies of streptococcus pneumoniae in infants. The effects of season and age on pneumococcal acquisition and colonization in the first 24 months of life. Am J Epidemiol 1982; 116:692–703. [PubMed: 7137156]
12. Mackenzie GA, Leach AJ, Carapetis JR, et al. Epidemiology of nasopharyngeal colonization of respiratory bacterial pathogens in childrenandadults:cross-sectionalsurveysinapopulationwithhigh rates of pneumococcal disease. BMC Infect Dis 2010; 10:304. [PubMed: 20969800]
13. Davidson M, Schraer CD, Parkinson AJ, et al. Invasive pneumococcal disease in an Alaska Native Population, 1980 through 1986. JAMA 1989; 261:715–8. [PubMed: 2911166]

14. Davidson M, Parkinson A, Bulkow LR, et al. The epidemiology of invasive pneumococcal disease in Alaska, 1986–1990–ethnic differences and opportunities for prevention. J Infect Dis 1994; 170:p368–76.
15. Rudolph KM, Parkinson AJ, Reasonover AL, et al. Serotype distribution and antimicrobial resistance patterns of invasive isolates of Streptococcus pneumoniae: Alaska, 1991–1998. J Infect Dis 2000; 182:490–6. [PubMed: 10915080]
16. Gilsdorf JR. Bacterial meningitis in southwestern Alaska. Am J Epidemiol 1977; 106:388–91. [PubMed: 920727]
17. Wenger JD, Zulz T, Bruden D, et al. Invasive pneumococcal disease in Alaskan children: impact of the seven-valent pneumococcal conjugate vaccine and the role of water supply. Pediatr Infect Dis J 2010; 29:251–6. [PubMed: 19952861]
18. Gessner BD. Lack of piped water and sewage services is associated with pediatric lower respiratory tract infection in Alaska. J Pediatr 2008; 152:666–70. [PubMed: 18410771]
19. Hennessy TW, Ritter T, Holman RC, et al. The relationship between inhome water service and the risk of respiratory tract, skin and gastrointestinal tract infections among rural Alaska Natives. Am J Public Health 2008; 98:2072–8. [PubMed: 18382002]
20. Singleton RJ, Hennessy TW, Bulkow LR, et al. Invasive pneumococcal disease caused by nonvaccine serotypes among Alaska native children with high levels of 7-valent pneumococcal conjugate vaccine coverage. JAMA 2007; 297:1784–92. [PubMed: 17456820]
21. Moore MR, Hyde TB, Hennessy TW, et al. Impact of a conjugate vaccine on community-wide carriage of nonsusceptible Streptococcus pneumoniae in Alaska. J Infect Dis 2004; 190:2031–8. [PubMed: 15529269]
22. Hennessy TW, Singleton RJ, Bulkow LR, et al. Impact of heptavalent pneumococcal conjugate vaccine on invasive disease, antimicrobial resistance and colonization in Alaska Natives: progress towards elimination of a health disparity. Vaccine 2005; 23: 5464–73. [PubMed: 16188350]
23. U.S. Census of Population and Housing, 2010: Summary Population and Housing Characteristics: Alaska. Washington: Government Printing Office, 2012.
24. Hosmer DW, Lemeshow S. Applied Logistic Regression. 2nd ed. New York: John Wiley & Sons, 2000.
25. Advisory Committee on Immunization Practices. Preventing pneumococcal disease among infants and young children. Recommendations of the Advisory Committee on Immunization Practices (ACIP). MMWR Recomm Rep 2000; 49:1–35.
26. Sung RY, Ling JM, Fung SM, et al. Carriage of *Haemophilus influenza* and *Streptococcus pneumoniae* in healthy Chinese and Vietnamese children in Hong Kong. Acta Paediatr 1995; 84: 1262–7. [PubMed: 8580623]
27. Gunnarsson RK, Holm SE, Soderstrom M. The prevalence of potentialpathogenicbacteriainnasopharyngeal samplesfromhealthy children and adults. Scand J Prim Health Care 1998; 16:13–17. [PubMed: 9612873]
28. Eichelberger LP. Living in utility scarcity: energy and water insecurity in Northwest Alaska. Am J Public Health 2010; 100: 1010–8. [PubMed: 20403886]
29. Bulkow LR, Singleton RJ, DeByle C, et al. Risk factors for hospitalization with lower respiratory tract infections in children in rural Alaska. Pediatrics 2012; 129:e1220–7. [PubMed: 22508919]
30. Lexau CA, Lynfield R, Danila R, et al. Changing epidemiology of invasive pneumococcal disease among older adults in the era of pediatric pneumococcal conjugate vaccine. JAMA 2005; 294: 2043–51. [PubMed: 16249418]
31. Petrosillo N, Pantosti A, Bordi E, et al. Prevalence, determinants, and molecular epidemiology of Streptococcus pneumoniae isolates colonizing the nasopharynx of healthy children in Rome. Eur J Clin Microbiol Infect Dis 2002; 21:181–8. [PubMed: 11957019]
32. Jacoby P, Carville KS, Hall G, et al. Crowding and other strong predictors of upper respiratory tract carriage of otitis media-related bacteria in Australian Aboriginal and non-Aboriginal children. Pediatr Infect Dis J 2011; 30:480–5. [PubMed: 21593705]
33. Raymond J, Le Thomas I, Moulin F, et al. Sequential colonization by *Streptococcus pneumoniae* of healthy children living in an orphanage. J Infect Dis 2000; 181:1983–8. [PubMed: 10837179]

34. Dabernat H, Geslin P, Megraud F, et al. Effects of cefixime and co-amoxiclav treatment on nasopharyngeal colonization of *Streptococcus pneumoniae* and *Haemophilus influenzae* in children with acute otitis media. J Antimicrob Chemother 1998; 41:253–8. [PubMed: 9533468]

35. Bruden D, Hennessy TW, Butler JC, et al. Evaluation of a volunteer sample in nasopharyngeal colonization surveys for *Streptococcus pneumoniae* in rural Alaska. Int J Circumpolar Health 2005; 64: 16–25. [PubMed: 15776989]

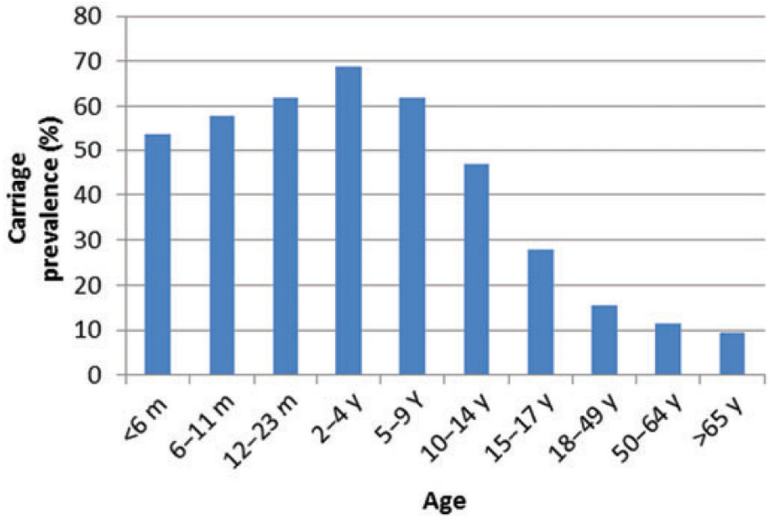

Figure 1.
Overall prevalence of nasopharyngeal pneumococcal carriage by age group, rural Alaska villages, 2008–2011.

Table 1.

Demographics and Carriage Rates of the Population Studied

	Number (% of Total)
Total swabs	12 535 (100%)
Colonized	4155 (33.2%)
Female	6133 (49%)
Alaska Native	12 421 (99.3%)
Age	
<6 mo	126 (1.0%)
6–11 mo	187 (1.5%)
12–23 mo	358 (2.9%)
2–4 years	1032 (8.2%)
5–9 years	1714 (13.7%)
10–14 years	1721 (13.7%)
15–17 years	942 (7.5%)
18–49 years	4839 (38.6%)
50–64 years	1136 (9.1%)
>65 years	480 (3.8%)
In-home running water	
No	6023 (48%)
Household crowding (no. of people/no. of rooms in the house)	
Mean	1.5
Percentage of children age 3–59 months up-to-date on pneumococcal vaccination	
	1389 (83.9%)
Region	
Bristol Bay	1649 (13.2%)
YK Delta	7724 (61.7%)
Norton Sound	3162 (25.2%)
Recent Infection (previous 90 d)	
Respiratory[a]	4454 (35.5%)
Skin	438 (3.5%)
Urinary tract	249 (2.0%)
Recent systemic antibiotic use	3188 (25.4%)

[a]Includes otitis media, viral pharyngitis, upper respiratory tract infection, strep throat, pneumonia, bronchitis, and bronchiolitis.

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Table 2.

Risk Factors for Nasopharyngeal Colonization With *Streptococcus pneumoniae* Among Rural Alaskans 10 Years and Younger, 2008–2011

Risk Factor		Colonized	Total	Univ. OR	Univ. *P* Value	Mult. OR (95% CI)	Mult. *P* Value
Age	<6 mo	54%	126	ref	.0003	ref	<.0001
	6–11 mo	58%	187	1.17		1.63 (1.01, 2.62)	
	1 y	62%	358	1.38		1.79 (1.17, 2.75)	
	2–4 y	69%	1032	1.86		2.03 (1.38, 2.99)	
	5–9 y	62%	1714	1.38		1.30 (.89, 1.89)	
Region	Bristol Bay	57%	345	ref	<.0001	N/A	N/A
	Norton Sound	56%	871	.95			
	YK Delta	67%	2201	1.54			
Village (region)	A (BB)	58%	213	ref	<.0001	ref	<.0001
	B (BB)	56%	132	.93		.76 (.48, 1.20)	
	C (NS)	61%	445	1.16		.93 (.66, 1.31)	
	D (NS)	50%	426	.73		.50 (.33, 0. 76)	
	E (YK)	63%	574	1.26		1.01 (.73, 1. 42)	
	F (YK)	75%	616	2.18		1.43 (.96, 2. 15)	
	G (YK)	64%	605	1.33		1.03 (.72, 1. 47)	
	H (YK)	66%	406	1.39		1.02 (.71, 1. 46)	
In-home	Yes	61%	1717	ref	.001	ref	.01
running water	No	66%	1700	1.25		1.35 (1.08, 1.69)	
No. persons	2–3	57%	148	1.07[b]	<.0001		.30
per	4–6	61%	1435				
household	>7	66%	1834				
>3 children	No	61%	2552	ref	<.000l	ref	<.0001
<10 y old	Yes	71%	865	1.57		1.47 (1.22, 1.77)	
No. rooms	1–2	68%	535	.93[c]	.002	N/A	N/A
per	3–4	64%	1409				
household	>5	61%	1474				
No. persons	<1	55%	248	1.14[d]	<.0001	1.11 (1.03, 1.20)	.009
per room	1–< 1.5	59%	1022				

Risk Factor		Colonized	Total	Univ. OR	Univ. *P* Value	Mult. OR (95% CI)	Mult. *P* Value
	1.5–< 2.0	61%	717				
	>2.0	69%	1430				
Antibiotics	No	68%	2096	ref	<.0001	ref	<.0001
in prev. 90 d	Yes	55%	1321	.57		.57 (.47, .68)	
Respiratory infection[a]		61%	1991	.81	.003		N/A
Otitus media		57%	970	.68	<.0001	.79 (.64, .97)	.02
Strep throat		57%	347	.76	.02		.98
Pneumonia		56%	215	.72	.02		.12

Abbreviations: CI, confidence interval; Mult., multivariate; N/A, not applicable; OR, odds ratio; prev., previous; ref., reference; Univ., univariate.

[a]"Respiratory infection" includes the following diagnoses: otitis media, viral pharyngitis, upper respiratory tract infection, strep throat, pneumonia, bronchitis, and bronchiolitis.

[b]Odds increase in colonization with each additional person per household.

[c]Odds decrease in colonization with each additional room per household.

[d]Odds increase in colonization with each additional person per room.

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Table 3.

Risk Factors for Nasopharyngeal Colonization With *Streptococcus pneumoniae* Among Rural Alaskans 10–17 Years of Age, 2008–2011

Risk Factor		% Colonized	Total #	Univ. OR	Univ. *P* Value	Mult. OR (95% CI)	Mult. *P* Value
Age	10–14y	47%	1721	ref	<.0001	ref	<.0001
	15–17y	28%	942	.44		.43 (.36, .51)	
Region	Bristol Bay	35%	383	ref	<.0001	N/A	N/A
	Norton Sound	32%	613	.89			
	YK Delta	44%	1667	1.47			
Village (region)	A (BB)	38%	258	ref	<.0001	ref	<.0001
	B (BB)	30%	125	.70		.73 (.46, 1.17)	
	C (NS)	34%	320	.85		.80 (.56, 1.15)	
	D (NS)	31%	293	.74		.71 (.49, 1.03)	
	E (YK)	45%	425	1.37		1.36 (.99, 1.88)	
	F (YK)	46%	49 I	1.43		1.39 (1.01, 1.91)	
	G (YK)	37%	367	.99		.97 (.70, 1.36)	
	H (YK)	47%	384	1.45		1.43 (1.03, 1.99)	
In-home	Yes	39%	1391	ref	.26		.31
running water	No	41%	1272	1.09			
No. persons	2–3	27%	147	1.06[b]	.0005	1.06 (1.02, 1.10)	.001
per	4–6	40%	1101				
household	≥7	41%	1415				
≥3 children	No	39%	2034	ref	.02		.63
<10yold	Yes	44%	628	1.24			
≥3 adolescents	No	40%	360	ref	.94		.38
10–17 y old	Yes	40%	2302	1.01			
No. rooms	1–2	45%	264	.94[c]	.03	N/A	N/A
Per	3–4	41%	1099				
household	>5	38%	1300				
No. persons	<1	31%	250	1.12[d]	.002		.37
per room	1–< 1.5	38%	978				
	1.5–<2.0	43%	539				

Risk Factor		% Colonized	Total #	Univ. OR	Univ. *P* Value	Mult. OR (95% CI)	Mult. *P* Value
	>2.0	43%	896				
Antibiotics	No	41%	2143	ref	.03	ref	.005
in prev. 90 d	Yes	36%	520	.81		.74 (.61, .91)	
Respiratory infection[a]		39%	914	.93	.39		N/A

Abbreviations: CI, confidence interval; Mult., multivariate; N/A, not applicable; OR, odds ratio; prev., previous; ref, reference; Univ., univariate.

[a]"Respiratory infection" includes the following diagnoses: otitis media, viral pharyngitis, upper respiratory tract infection, strep throat, pneumonia, bronchitis, and bronchiolitis.

[b]Odds increase in colonization with each additional person per household.

[c]Odds decrease in colonization with each additional room of per household.

[d]Odds increase in colonization with each additional person per room.

Table 4.

Risk Factors for Nasopharyngeal Colonization With *Streptococcus pneumoniae* Among Rural Alaskans 18 Years and Older, 2008–2011

Risk Factor		% Colonized	Total #	Univ. OR	Univ. *P* Value	Mult. OR (95% CI)	Mult. *P* Value
Age	18–9 y	16%	4839	ref	<.0001	ref	<.0001
	>50 y	11%	1616	.66		.70 (.58, .83)	
Region	Bristol Bay	14%	921	ref	.005	N/A	N/A
	Norton Sound	12%	1678	.81			
	YK Delta	15%	3856	1.07			
Village (region)	A (BB)	15%	644	ref	.001	ref	.005
	B (BB)	14%	277	.96		.96 (.64, 1.43)	
	C (NS)	13%	948	.89		.85 (.63, 1.15)	
	D (NS)	10%	730	.68		.66 (.47, .91)	
	E (YK)	17%	844	1.21		1.17 (.88, 1.55)	
	F (YK)	15%	1058	1.04		1.00 (.76, 1.32)	
	G (YK)	13%	1147	.86		.86 (.65, 1.13)	
	H (YK)	17%	807	1.22		1.14 (.85, 1.52)	
In-home	Yes	15%	3404	ref	.31		.44
running water	No	14%	3051	.93			
No. persons	2–3	12%	1276	1.06[b]	<.0001	1.05 (1.02, 1.07)	.0006
per	4–6	14%	2705				
household	>7	16%	2474				
>3 children	No	14%	4971	ref	.03		.90
<10yold	Yes	16%	1483	1.19			
>3 adolescents	No	14%	6235	ref	.10		.73
10–17 y old	Yes	18%	219	1.35			
No. rooms	1–2	14%	877	1.02[c]	.38	N/A	N/A
per	3–4	14%	2627				
household	>5	14%	2951				
No. persons	<1	13%	1339	1.08[d]	.008		.82
per room	1–< 1.5	13%	2221				
	1.5–<2.0	14%	1121				

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Risk Factor		% Colonized	Total #	Univ. OR	Univ. *P* Value	Mult. OR (95% CI)	Mult. *P* Value
	>2.0	17%	1774				
Antibiotics	No	15%	5108	ref	.01	ref	.0003
In prev. 90 d	Yes	12%	1347	.79		.68 (.55, .84)	
Respiratory infection[a]		14%	1549	.95	.51		N/A
Bronchitis		15%	342	1.08	.64	1.41 (1.02, 1.96)	.04
Skin infection		17%	218	1.23	.26	1.54 (1.03, 2.31)	.04

Abbreviations: CI, confidence interval; Mult., multivariate; N/A, not applicable; OR, odds ratio; prev., previous; ref, reference; Univ., univariate.

[a]"Respiratory infection" includes the following diagnoses: otitis media, viral pharyngitis, upper respiratory tract infection, strep throat, pneumonia, bronchitis, and bronchiolitis.

[b]Odds increase in colonization with each additional person per household.

[c]Odds decrease in colonization with each additional room per household.

[d]Odds increase in colonization with each additional person per room.