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Knowledge, Attitudes, and Practices Related to Meningitis in Northern Ghana

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Abstract. Meningitis has a significant impact in the Sahel, but the mechanisms for transmission and factors determining a person's vulnerability are not well understood. Our survey examined the knowledge, attitudes, and practices of people in a meningitis-endemic area in the Upper East region of northern Ghana to identify social, economic, and behavioral factors that may contribute to disease transmission and possible interventions that might improve health outcomes. Key results suggest potential interventions in response to the risk posed by migration, especially seasonal migration, a lack of knowledge about early symptoms causing delayed treatment, and a need for further education about the protective benefits of vaccination.

INTRODUCTION

Neisseria meningitidis remains the leading worldwide cause of meningitis and fatal sepsis. In recent years, understanding of the epidemiology has increased and led to progress in the development of the next generation of meningococcal vaccines. However, scarcity of vaccines and challenges in reaching rural populations with these vaccines necessitates a better understanding of the transmission dynamics of meningitis. Therefore, this study is focused on better understanding transmission dynamics of the disease to enhance our knowledge of potentially intervenable factors.

Meningococcal meningitis is endemic to the meningitis belt, a region in sub-Saharan Africa stretching from Ethiopia to Senegal^{1,2} (Figure 1). Outbreaks occur annually during the dry season, during December–May in the Sahel, and large epidemics recur every 8–12 years. The historical incidence rates range from 10–1,000 infections/100,000 persons and a case-fatality rate of approximately 10%.^{3,4} However, during cyclical pandemics, the weekly incidence of suspected meningitis cases can increase to > 1/1000 population in districts in countries in the Sahel.⁵ The levels of endemicity observed regularly in the Sahel region would be considered epidemic in the developed world.⁶

Particularly in the developing world, evidence exists that illness that forces households to pay out of pocket may push a family into a cycle of poverty from which it is difficult to emerge.^{7,8} Meningitis, as a major disease, may be one such illness that can drive a household into severe poverty. In the developing world in the meningitis belt, meningococcal epidemics are devastating and contribute to the cycle of poverty through cost of illness.⁹ In the Upper East region of northern Ghana, for example, the cost of treating a case often equates to two times a farm family's annual income (Akweongo P, and others, unpublished data). Not only is the disease financially disruptive, but long-lasting sequelae also present a burden to the family by disrupting social structure.

Although there are several serogroups of *N. meningitidis*, most epidemics in the Sahel are attributed to the meningo-

cocci of serogroup A. As far back as 2000, however, serogroup W-135 was associated with a worldwide outbreak in pilgrims who were returning from the Hajj,¹⁰ followed by an outbreak in Burkina Faso in 2002¹¹; 2006 saw the emergence of serogroup X meningococci in Niger, a serogroup for which there is currently no vaccine. These epidemics demonstrate that the introduction of new, virulent serogroups into a population can affect the epidemiology of meningococcal disease and underscore the need for continued surveillance.^{12,13}

Until 2010, the primary strategy for managing meningitis outbreaks was reactive vaccination with the bivalent (A,C) or trivalent (A,C,W135) polysaccharide vaccines. These vaccines, although offering protection from serogroups A, C, and W135, only confer protection for two years, do not provoke an immune response in children less than two years of age, and do not prevent the vaccinated person from infecting others. In addition, reactive vaccine campaigns are only partially effective, as shown in Burkina Faso where > 5,000 cases of meningitis/week (> 680 cases/100,000 population) were often reported.¹⁴ A new conjugate vaccine was introduced in 2010, and proactive vaccination across the meningitis belt is underway and scheduled to be completed in 2016. However, the conjugate vaccine is only effective against serogroup A, underscoring the need for continued surveillance and reactive management with the polysaccharide vaccine (Hugonnet S, unpublished data).

The dynamics of the transmission of meningitis in the Sahel are poorly understood and likely the result of several interacting factors, including new strain introduction, population susceptibility to a new serogroup, previous infections that may predispose a person to meningitis, socioeconomic status, migration, behavioral factors, and environmental conditions. Many of these factors, such as dry, dusty conditions, likely act concurrently to place Sahelian residents at risk. Several studies point to the importance of weather-related influences on disease transmission. Early research by Lapeyssonnie¹ noted the occurrence of epidemics during the dry, dusty season, and it is hypothesized that high temperatures coupled with low humidity may favor the conversion of benign meningococcal meningitis bacteria in the nose and throat to a pathogenic bacteria by damaging the mucosa and lowering immune defense.^{2,4,5,15} A statistical analysis of cases and meteorological conditions across the belt during 2009–2011 showed that dry conditions are conducive to meningitis epidemics, and that the epidemics

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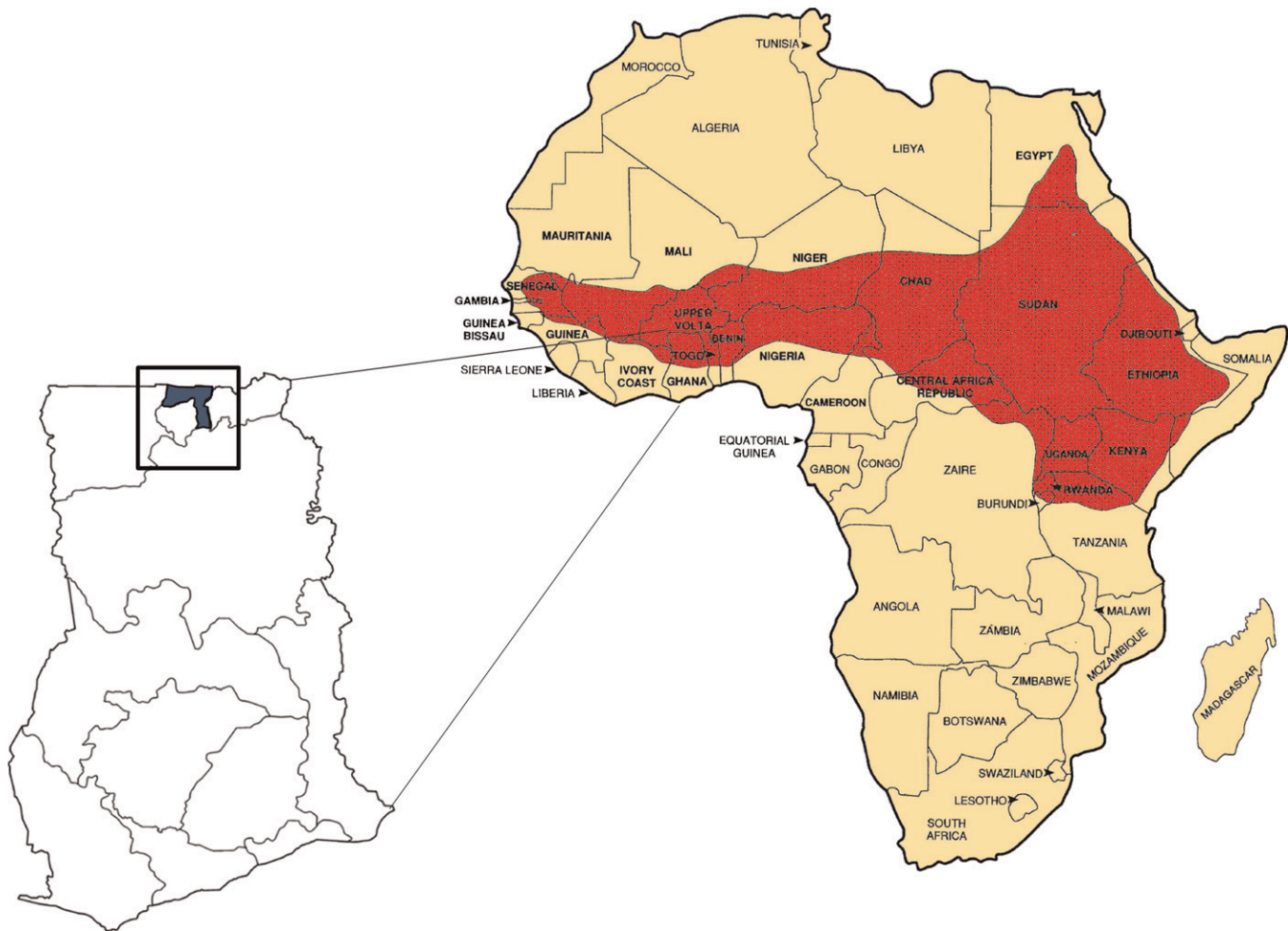


FIGURE 1. African Meningitis Belt (modified from Moore⁴ and Dukic and others¹⁶) and the Kassena-Nankana District of northern Ghana (inset).

end with the high humidity associated with the onset of the rainy season.^{16,17}

Although meningitis is a vaccine-preventable disease, vaccine dissemination strategies are often less than 100% effective at reaching populations at risk, particularly in rural areas in the developing world. There is also limited knowledge of the co-factors influencing spread and severity of meningococcal disease. A previous clinic-based study conducted during 2006–2007 in Burkina Faso addressed issues concerning beliefs surrounding disease etiology and found these beliefs had an important influence on health care seeking behavior.⁹ A search of the literature indicates this is the first case-control knowledge, attitudes, and practices survey to be undertaken in the meningitis belt of Africa. The Upper East region of northern Ghana, where the survey was conducted, is a region with seasonal hyperendemicity and epidemic occurrence of meningitis. This study focused on the socioeconomic determinants of meningitis, impacts on morbidity and mortality, and potentially intervenable factors.

MATERIALS AND METHODS

Questionnaires were developed by a U.S. and Navrongo Health Research Center team of public health practitioners and behavioral scientists and pre-tested in the field to ensure

content validity in early 2010. The key elements of the survey reflected the interests and concerns of local health officials. Information was obtained regarding participants' knowledge of symptoms of meningitis, health care-seeking behaviors, perception of risk of meningitis and factors associated with elevated risk, as well as understanding of seasonality of disease transmission. Formal consent to conduct the study was obtained from the chief in each of the sub-areas within the district. Further consent from the participants was acquired through the translator who signed consent on the questionnaire. Interviews were conducted by trained researchers from the Navrongo Health Research Center in the preferred language of the interviewee. Institutional Review Board approval was obtained from the Navrongo Health Research Center, Navrongo, Ghana and the National Center for Atmospheric Research, Boulder, Colorado.

Study area and population. The participants in this study were inhabitants of the Upper East region of northern Ghana in the rural Kassena-Nankana (K-N) district (Figure 1). The K-N district is situated in the savannah region of Sahelian Africa and experiences two main weather seasons: a wet season during June–October and a dry season for the rest of the year. The population size is approximately 140,000, and most inhabitants live in rural areas, with the exception of approximately 20,000 residents who live in the town of Navrongo.¹⁵

Inhabitants of the Upper East region of northern Ghana are either Kassem-speaking or Nankani-speaking agriculturalists. Most inhabitants live within compounds consisting of 1–5 mud-walled, thatched-roof households housing an average of 10 inhabitants per compound. Access to electricity and piped water is limited throughout the rural region, and underground water is accessed through centrally located boreholes. Farming is the main source of income in this rural region.

Data collection. A structured interview questionnaire was used for the case–control study conducted in the dry season of 2010. All confirmed cerebrospinal meningitis–positive cases spanning 2008–2011 from the K-N district were obtained from the District Health Management Team for the interviews. Cases before 2008 were not accessed because of the potential for participant recall bias. Of 178 persons with cases identified during the aforementioned time period, 52 were dead, 31 had migrated from the district, 16 were untraceable, and 5 denied having contracted cerebrospinal meningitis. Seventy-four persons were interviewed and matched with 148 controls for a total of 222 interviews. Controls were matched by age, sex, and geographic location.

Statistical analyses. The survey data were double entered and verified using EpiData Software, version 3.02 (www.epidata.dk). Odds ratios (ORs) of meningitis status and predictor variables were determined using conditional logistic regression. Significant results are depicted by *P* values < 0.05. Data analyses were conducted using SPSS version 20 (IBM, Armonk, NY).

RESULTS

Study population. Of the 222 survey respondents from the K-N district, most were female (52.3%), less than 18 years old (57.2%), and of Nankani descent (59.9%). These percentages were consistent across both cases and controls. More than half (60.8%) of respondents from both groups reported that they had received no formal education. Although schooling was not statistically different across groups, significantly more controls reported being farmers (49.3% of controls compared with 36.5% of cases; OR = 0.414, 95% confidence interval [CI] = 0.194–0.882, *P* = 0.022). The socioeconomic data collected in the survey were not sufficient to estimate household wealth; instead, the wealth index from the Demographic Social Survey was used from data last collected in 2009. These wealth calculations are derived from extensive, regular surveys of households. Based on the Demographic Social Surveys, five quintiles were deduced (least poor, less poor, poor, very poor, and poorest households). Analysis of this sample showed a higher percentage of cases in the least poor category, and a lower percentage of cases in the poorest category. A complete list of demographics is shown in Table 1.

Symptoms of meningitis. Survey responses indicate that cases and controls refer to meningitis using the same terms (neck disease, 43.2%; meningitis, 28.8%; waist disease, 24.8%). Although both groups were equally aware of stiff neck as a symptom of meningitis (68.9%), cases were more likely than controls to mention early symptoms such as loss of appetite (OR = 5.08, 95% CI = 2.37–10.88, *P* < 0.001), vomiting (OR = 2.87, 95% CI = 1.35–6.14, *P* = 0.006), stiffness in the waist (OR = 5.26, 95% CI = 2.1–13.19, *P* < 0.001), high body temperature (OR = 2.26, 95% CI = 1.17–4.36, *P* = 0.015), and severe headache (OR = 1.94, 95% CI = 1.04–3.63, *P* =

TABLE 1
Sociodemographic characteristics of survey respondents for knowledge, attitudes, and practices regarding meningitis, northern Ghana

Characteristic	Case, n = 74 (%)	Control, n = 148 (%)	Total, n = 222 (%)
Sex	35 (47.3)	71 (49.97)	106 (47.75)
M	35 (47.3)	71 (49.97)	106 (47.75)
F	39 (52.7)	77 (52.03)	116 (52.25)
Age, years			
< 18	42 (56.76)	85 (57.43)	127 (57.21)
≥ 18	32 (43.24)	63 (42.57)	95 (42.79)
Education			
None	45 (60.81)	90 (60.81)	135 (60.81)
Primary/junior high	20 (27.03)	46 (31.08)	66 (29.73)
Senior high	5 (6.76)	5 (3.38)	10 (4.5)
Tertiary	4 (5.41)	7 (4.73)	11 (4.95)
Primary occupation			
Unemployed	4 (5.41)	6 (4.05)	10 (4.5)
Farmer	8 (10.81)	27 (18.24)	35 (15.77)
Casual	1 (1.35)	1 (0.68)	2 (0.9)
Self-employed	9 (12.16)	19 (12.84)	28 (12.61)
Student	6 (8.11)	7 (4.73)	13 (5.86)
Government worker	4 (5.41)	3 (2.03)	7 (3.15)
Wealth quintiles			
Least poor	24 (32.0)	28 (20.59)	53 (23.42)
Less poor	11 (14.67)	28 (20.59)	39 (17.57)
Poor	12 (16.0)	24 (17.65)	36 (16.22)
Very poor	22 (29.33)	34 (25.0)	56 (25.23)
Poorest	6 (8.0)	22 (16.18)	28 (12.61)
Ethnicity			
Nankani	44 (59.46)	89 (60.14)	133 (59.91)
Kassem	30 (40.54)	59 (39.86)	89 (40.09)

0.038). Cases reported first learning of the symptoms of meningitis by getting the disease or being told by their doctor (OR = 11.52, 95% CI = 3.39–39.21, *P* < 0.001 and OR = 23.06, 95% CI = 3.00–177.45, *P* < 0.003, respectively). Alternatively, controls were most likely to know about the symptoms because a friend had the disease (OR = 0.37, 95% CI = 0.15–0.95, *P* = 0.038) (Table 2).

Health care-seeking behavior. Respondents reported that they first went to the clinic when they were very sick (42.8%); other places where care was sought included the hospital (21.2%), or receiving treatment at home (18.0%). When a person within the compound was suspected of having meningitis, interviewees also reported taking the person first to the clinic (56.3%), then the hospital (28.8%). Interestingly, cases were significantly more likely to be treated at a hospital (OR = 2.44, 95% CI = 1.01–5.94, *P* = 0.049) or at home (OR = 5.30, 95% CI = 1.42–19.7, *P* = 0.013). Alternatively, controls were more likely to feel that there were certain circumstances in which they would first go to a drug shop when they or a family member were ill (OR = 0.3, 95% CI = 0.11–0.81, *P* = 0.017). Forty-two percent of the sample reported that they would use eastern and western medicine at the same time. When deciding to take a sick person for treatment, severity of illness (84.2%) was the driving motivator, followed by cost of treatment (26.6%). Symptoms regarded as severe included body weakness (74.3%), high body temperature (64.4%), and the inability to eat/drink (60.4%). When asked who in the household typically makes decisions regarding seeking treatment, 41.0% of interviewees indicated that it was the sick person's father (Table 3).

Causes of meningitis. Cases and controls indicated that heat (83.3%) is the most likely cause of developing meningitis, with lack of ventilation (54.5%) and sleeping in crowded

TABLE 2
Survey results, by question, for knowledge related to about meningitis, northern Ghana*

Variable	Case, n = 74 (%)	Control, n = 148 (%)	Total, n = 122 (%)	OR (P)
Q1. "What is the disease that normally occurs during the very hot season called?"				
Meningitis	24 (32.43)	40 (27.03)	64 (28.83)	1.33 (0.378)
Neck disease	31 (41.89)	65 (43.92)	96 (43.24)	0.88 (0.724)
Waist disease	17 (22.97)	38 (25.68)	55 (24.77)	0.75 (0.597)
Q2. "What are the symptoms of meningitis?"				
High body temperature	52 (70.27)	80 (54.05)	132 (59.46)	2.21 (0.017)
Stiff neck	52 (70.27)	101 (68.24)	153 (68.92)	1.09 (0.764)
Vomiting	20 (27.03)	18 (12.16)	38 (17.12)	2.92 (0.005)
Severe headache	51 (68.92)	81 (54.73)	132 (59.46)	1.94 (0.038)
Stiffness in the waist	34 (45.95)	38 (25.68)	72 (32.43)	5.26 (< 0.001)
Loss of appetite	29 (39.19)	18 (12.16)	47 (21.17)	5.08 (< 0.001)
Q3. "How did you first learn about the symptoms of meningitis?"				
Got meningitis	18 (24.32)	4 (2.72)	22 (9.91)	11.52 (< 0.001)
Doctor told them	14 (18.92)	5 (3.38)	19 (8.56)	23.06 (0.003)
Friend had it	6 (8.11)	28 (18.92)	34 (15.32)	0.37 (0.038)
Q4. "How does someone contract meningitis?"				
Crowded sleeping	30 (40.54)	73 (49.32)	103 (46.4)	0.70 (0.217)
Lack of ventilation	36 (48.65)	85 (57.43)	121 (54.5)	0.64 (0.173)
Heat	61 (82.43)	124 (83.78)	185 (83.33)	0.95 (0.896)
From dirty surroundings	10 (13.51)	8 (5.41)	18 (8.11)	2.91 (0.042)
Q5. "Where do people contract meningitis?"				
Everywhere	51 (68.92)	111 (75.0)	162 (72.97)	1.37 (0.344)
Q8. "Is there a time of year when meningitis usually ends?"				
When the rains start	46 (62.16)	105 (70.95)	151 (68.02)	0.65 (0.0188)
Q9. "Are there certain areas in the K-N district that are more at risk to meningitis?"				
Rural areas	16 (21.62)	37 (25.0)	53 (23.87)	0.85 (0.655)
Everywhere	50 (67.57)	95 (64.19)	145 (65.32)	1.7 (0.606)
Q11. "At what age is a person most at risk for meningitis?"				
Children 2–11 years of age	13 (17.57)	41 (27.7)	54 (24.32)	0.56 (0.097)
Everyone	42 (56.75)	73 (49.32)	115 (51.8)	1.40 (0.250)
Q17. "Are there ways to protect you and your family from meningitis?"				
Vaccinations	24 (32.43)	50 (33.78)	74 (33.33)	0.94 (0.885)
Do not sleep crowded	31 (41.89)	72 (48.65)	103 (46.4)	0.74 (0.339)
Do not sleep in hot rooms	33 (44.59)	74 (50.0)	107 (48.2)	0.73 (0.339)
Q18. "If someone in your family becomes ill, are there ways not to get sick?"				
Isolate the person	18 (24.32)	51 (34.46)	69 (31.08)	0.51 (0.077)
Vaccinate the family	19 (25.68)	26 (17.57)	45 (20.27)	1.97 (0.087)
Do not sleep in hot rooms	23 (31.08)	54 (36.49)	77 (34.68)	0.74 (0.378)
Q19. Have you or anyone in your family been vaccinated in the past three years?				
Yes	46 (62.16)	97 (65.54)	143 (64.41)	0.84 (0.594)

*OR = odds ratio obtained from conditional logistic regression. Values in **bold** indicate significance at $P < 0.05$.

rooms (46.4%) also cited as causes of the disease. Although only 8.1% of respondents indicated that one could contract meningitis from dirty surroundings, cases were significantly more likely to mention this option (OR = 2.91, 95% CI = 1.04–8.13, $P = 0.042$). Surprisingly, only 33.3% of respondents reported vaccination as a way to protect themselves or their family from getting meningitis. Other responses included not sleeping in hot (48.2%) or crowded (46.4%) places. When asked about ways to protect themselves or others if someone in their family contracted meningitis, 34.7% of respondents said they would avoid sleeping in hot rooms, or isolate the sick person (31.1%). Interestingly, only 20.3% of the sample indicated vaccination as a way to reduce risk to the rest of the family once someone in the household had contracted meningitis, yet 64.4% of cases and controls reported that either they or someone in their family had been vaccinated against meningitis in the past three years (Table 2).

Seasonality of transmission. All respondents reported that the time of year when meningitis is most frequent is during the hot, dry season (97.9%) and that it ends when the rains come (68.0%). Furthermore, 95.0% of all respondents reported that they sleep outside during the hot, dry season. Approximately half (51.8%) of the sample stated that everyone, at any age, is at risk for meningitis; 24.3% noted that children 2–11 years

of age were at highest risk. When asked where people contract meningitis, the most common answer was everywhere (73%). Similarly, 65.3% of respondents indicated that the risk for meningitis is everywhere in the K-N district. However, 23.9% cited rural areas as the place where people are more likely to contract the disease (Table 2).

Migration. Cases were more likely than controls to have lived outside of the K-N district at some point since 2006 (OR = 2.34, 95% CI = 1.21–4.56, $P = 0.012$) (Table 3).

Cooking behavior. Information regarding where persons cooked (inside versus outside) was obtained from participants, as well as the type of fuel that was used for cooking, specifically during the dry season. The main fuel source used by study participants in this region was firewood (60.6%), followed by charcoal and millet stalks (each 18.1%). Although the data were not significant, cooking inside using either firewood or millet stalks as fuel was associated with meningitis risk (OR = 2.21, 95% CI = 0.87–5.61, $P = 0.097$). Cooking outside occurs frequently during the hot, dry season when high temperatures in February, March, and April (the hottest months) have averaged 103°F (39°C), 102°F (38.8°C), and 103°F (39°C), respectively, over the past two years.¹⁸

Perception of disease severity. When asked what health issues are worrisome, cases and controls mentioned malaria

TABLE 3
Survey results, by question, for practices related to about meningitis, northern Ghana*

Variable	Case, n = 74 (%)	Control, n = 148 (%)	Total, n = 122 (%)	OR (P)
Q21. "Have you lived outside the K-N district since 2006?"				
Yes	29 (39.19)	35 (23.65)	64 (28.83)	2.34 (0.012)
Q25. "When do you and your family sleep outdoors?"				
Hot, dry season	71 (95.95)	140 (94.59)	211 (95.05)	1.61 (0.505)
Q26. "Who makes the decision to seek treatment for meningitis?"				
Patient's father	26 (35.14)	65 (43.92)	91 (40.99)	0.57 (0.129)
Q27. "Where do you first go if someone in your family becomes very sick?"				
Clinic	29 (39.19)	66 (44.59)	95 (42.79)	0.66 (0.296)
Hospital	17 (22.97)	13 (8.78)	47 (21.17)	1.39 (0.506)
Treat at home	15 (20.27)	25 (16.89)	40 (18.02)	1.36 (0.472)
Q30. "Where do you first go if someone in your family has meningitis?"				
Clinic	35 (47.3)	90 (60.81)	125 (56.31)	0.37 (0.017)
Hospital	26 (35.14)	38 (25.68)	64 (28.83)	2.44 (0.049)
Treat at home	10 (13.51)	6 (4.05)	16 (7.21)	5.30 (0.013)
Q31. "What symptoms mean a person is sick enough for treatment?"				
Body weakness	55 (74.32)	110 (74.32)	165 (74.32)	1.00 (1.00)
Unable to eat/drink	46 (62.16)	88 (59.46)	134 (60.36)	1.16 (0.624)
Q32. "What factors do you consider when taking someone for treatment?"				
Severity of illness	67 (90.54)	120 (81.08)	187 (84.23)	2.53 (0.051)
Cost of treatment	20 (27.03)	39 (26.35)	59 (26.58)	1.11 (0.789)
Q33. "Are there times when you would use both eastern and western medicine?"				
Yes	31 (41.89)	63 (42.57)	94 (42.34)	0.86 (0.567)
Q35. "Are there times when you would first go to a drug shop when sick?"				
Yes	65 (87.84)	110 (74.83)	175 (79.19)	3.34 (0.017)

*OR = odds ratio obtained from conditional logistic regression. Values in **bold** indicate significance at $P < 0.05$.

(90.5%) and meningitis (41.9%). When asked what was most worrisome, 57.7% of the sample mentioned malaria. However, when asked whether meningitis was a serious disease, 100% of cases reported that meningitis was serious compared with 93.2% of controls ($P = 0.02$), and cases were also more likely to report that it is the responsibility of health care workers to prevent meningitis (OR = 2.89, 95% CI = 1.18–7.08, $P = 0.02$). Other responses that were endorsed equally included doctors (64.4%) and the government (32.4%) (Table 4).

DISCUSSION

The results of the survey suggest several strategies for mitigating meningitis risk in northern Ghana. Most importantly, the fact that 100% of the cases and 93.2% of controls identified meningitis as a serious disease suggests that the population in the K-N district would be interested in knowing about new approaches to minimize their risk. Surprisingly, only 33% of the people surveyed identified vaccination as an effective way to protect themselves or their family from meningitis, in spite of the fact that more than 64% of participants reported

they or their family members had been vaccinated. This result implies that greater education and more effective communication about the protective effect of vaccination might be beneficial in increasing vaccination coverage.

More than 85% of all survey participants indicated they would seek medical attention from either a clinic or hospital once they concluded that they or their family member had contracted meningitis. However, cases were much more likely to identify early symptoms of meningitis such as loss of appetite, vomiting, stiffness in the waist, high body temperature, and severe headache. Given the efficacy of early intervention in meningitis treatment, these survey results suggest that education about the early symptoms of meningitis would serve as a trigger for persons in the K-N district to seek medical help from clinics sooner, improving health outcomes. Similarly, because 42.3% of persons reported going simultaneously to traditional healers and western clinicians, working with both groups to identify meningitis earlier and refer patients appropriately could also improve outcomes.

Our survey also identified migration as a significant risk factor for meningitis; cases were nearly twice as likely to have

TABLE 4
Survey results, by question, for attitudes related to about meningitis, northern Ghana*

Variable	Case, n = 74 (%)	Control, n = 148 (%)	Total, n = 122 (%)	OR (P)
Q37. "Which health issues are worrisome?"				
Meningitis	34 (45.95)	59 (39.86)	93 (41.89)	1.39 (0.302)
Malaria	66 (89.19)	135 (91.22)	201 (90.54)	0.77 (0.608)
Diarrhea	38 (51.35)	77 (52.38)	115 (52.04)	0.94 (0.845)
Q38. "Which health issue is most worrisome?"				
Malaria	37 (50.0)	91 (61.49)	128 (57.66)	0.59 (0.088)
Q39. "Do you think meningitis is a serious disease?"				
Yes	74 (100)	138 (93.24)	212 (95.5)	0.52 (0.202)
Q40. "Whose responsibility is it to prevent meningitis?"				
Government	22 (29.73)	50 (33.78)	72 (32.43)	0.77 (0.480)
Healthcare workers	60 (81.08)	102 (68.92)	162 (72.97)	2.80 (0.024)
Doctors	45 (60.81)	98 (66.22)	143 (64.41)	0.76 (0.409)

*OR = odds ratio obtained from conditional logistic regression. Value in **bold** indicates significance at $P < 0.05$.

lived outside of the K-N district as controls. Discussions with survey participants and public health workers suggest that migration may pose a risk because persons miss vaccination campaigns or let their vaccinations lapse and return unprotected. Two scenarios were considered common: a farmer who travels during the dry season to work the harvest in southern Ghana because lack of local opportunity, and persons who permanently relocate to southern Ghana. In either case, an unanticipated return during the dry season (for example, to attend a funeral) exposes them to meningitis. Because the meningitis vaccine takes 10 days to provide any protective benefit, vaccinating before these sudden trips is not practical. Possible interventions include education for persons with family members in the north to encourage them to keep their vaccinations up to date, or targeted vaccination for areas with large populations of migrant workers, even if those locations themselves are outside the meningitis belt.

Although the sample size was too small to detect statistically significant differences between cases and controls in cooking location or fuel type, a higher percentage of cases reported using firewood and cooking indoors during the dry season. Anecdotal information suggests that persons purposefully avoid exposure to smoke from millet stalks, but are less likely to avoid exposure to smoke from firewood because people do not consider firewood as smoky as millet. In both cases, the data suggest that smoke exposure is linked to meningitis.¹⁹ Interventions that reduce exposure to smoke, such as cooking outside or in well-ventilated rooms, or using clean cook stoves, may therefore decrease meningitis risk.

As the wealth quintile moved from least poor to poorest, vaccination coverage decreased from 74.0% to 53.0%. Although this result was not statistically significant given the small sample size, it suggests that interventions that target the poorest members of society will yield the most impact and adds to moral and economic arguments for prioritizing services and interventions for the poorest and most vulnerable members of society.

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