UK Health Security Agency

Infectious period, incubation period and transmission measures of meningococcal disease in outbreak contexts

A systematic evidence summary

Contents

Main messages

1. This systematic evidence summary (search from 1 January 2010 to 2 April 2026, to capture evidence published after the rollout of the meningococcal A vaccine in West Africa in 2010) identified and summarised evidence relating to the infectious period, incubation period and transmission measures of meningococcal disease in outbreak contexts.

2. Thirteen studies were included, of which 3 were outbreak reports (1 to 3) and 10 were cross-sectional studies (4 to 13). Three studies were conducted in the USA (1, 8, 12), 2 in the UK (3, 4), and one each in Brazil (11), Burkina Faso (10), China (13), France (5), Italy (9), Liberia (2), Peru (7) and Sweden (6).

3. Evidence from a small cluster following occupational exposure to meningococcal disease serogroup C suggested that the incubation period was 2 days in one person and 5 days in another, with a mean of 3.5 days. Neither of the secondary cases had been offered post-exposure prophylaxis. No information on vaccination status was reported for any of the cases. This finding was based on very limited data and is therefore not generalisable (1).

4. Evidence on the serial interval of meningococcal disease was identified from 2 studies. A small family-linked outbreak suggested that the serial interval for meningococcal disease caused by serogroup W may range from 7 to 18 days, with a mean of 13.5 days (2). Evidence from a single nursery outbreak suggested a serial interval of 6 days for meningococcal disease caused by serogroup B (3). One study reported that none of the cases had recent meningococcal vaccination (2). The other study did not report the vaccination status against *Neisseria meningitidis (N. meningitidis)* in the cases (3). These estimates are uncertain due to a small number of cases, incomplete laboratory confirmation, and potential recall bias.

5. The number of new cases of meningococcal disease specifically linked to an index case was reported by 3 studies and differed between studies reporting on different *N. meningitidis* serogroup. Two secondary cases linked to the same index case were reported in a serogroup C outbreak (1), 8 secondary cases were identified in a serogroup W cluster (2), and one secondary case occurred in a confirmed serogroup B outbreak (3). All 3 studies reported use of post-exposure prophylaxis after identification of secondary cases which may have had an impact on the number of new cases. One study reported that none of the cases had recent meningococcal vaccination (2). The other 2 studies did not report the vaccination status against *N. meningitidis* among cases (1, 3). The evidence was also limited by low case numbers, which limits confidence in the results and generalisability of the evidence.

6. Ten studies (4 to 13) reported carriage of *N. meningitidis* in selected populations with the majority at high risk of exposure in an outbreak. Carriage in these populations ranged from 0.2% to 17.4% with the highest prevalence reported among close contact groups in a

prison and lower prevalence in large community-based surveys. Vaccination status and provision of post-exposure prophylaxis differed between studies, and 3 studies aimed to study the impact of the vaccine, which will have impacted results.

7. Three studies reported active smoking and frequent participation in social venues such as pubs, clubs and parties to be associated with increased carriage of *N. meningitidis* (5, 9, 12). Two studies reported use of cannabis or other illicit drugs associated with increased carriage of *N. meningitidis* (5, 9). Higher rates of carriage were reported among people with lower educational attainment (5, 11) and in specific settings, such as people residing in the same prison cell as a person with meningococcal disease (13).

8. Critical appraisal was not performed, which restricts the interpretation of the findings, but important limitations of the evidence have been highlighted. The available evidence for incubation period, serial interval and number of new cases linked to an index case was limited by very small case numbers, incomplete laboratory confirmation for some cases and the reliance on people, including family members, to recall and report symptom onset dates and exposure histories. This reduces confidence in the results and generalisability of the evidence. In the carriage studies, vaccination status and provision of post-exposure prophylaxis differed between studies which will have impacted results.

9. In summary, available evidence on the infectious period, incubation period and transmission measures of meningococcal disease in outbreak contexts was limited in both quantity and quality. Evidence on the incubation period was limited and from a single small outbreak, with observed values ranging from 2 to 5 days. Three outbreak reports found the number of new cases linked to an index case ranged from 1 to 8 cases. Serial interval varied from 6 to 18 days in 2 outbreak reports. Carriage studies provided the largest body of evidence (10 studies) reporting carriage ranging from 0.2% to 17.5% in the populations related to the outbreak. Higher carriage was observed in close contacts in specific settings, including a prison, and may not be generalisable to other outbreaks. The evidence is limited in quality due to small sample sizes, variation in reporting and provision of vaccination or post-exposure prophylaxis, amongst other factors. As a result, there is considerable uncertainty around key transmission parameters for meningococcal disease in outbreak contexts, and the findings should be interpreted with caution.

Purpose

The purpose of this systematic evidence summary was to identify and summarise the available evidence on the infectious period, incubation period and transmission measures of meningococcal disease (any serogroup) in outbreak contexts.

The review question was:

1. What are the transmission parameters (infectious period, incubation period and transmission measures) of meningococcal disease in outbreak contexts?

This systematic evidence summary was commissioned to help inform the UKHSA response to the meningococcal disease outbreak in Kent in March 2026.

Methods

A systematic evidence summary was conducted, following streamlined systematic methods to accelerate the review process. A literature search was undertaken to look for relevant observational studies (including cohort, case control and cross-sectional studies) and descriptive studies (including outbreak reports), published or available as preprint. Three databases were searched: OVID Medline, OVID Embase, and Web of Science Preprint Citation Index. Searches were restricted to publications dated between 1 January 2010 and 2 April 2026, to capture evidence published after the rollout of the meningococcal A vaccine in West Africa in 2010.

Studies were included if they were conducted in a meningococcal disease outbreak context (defined as 2 or more cases linked by time, place, person) and reported a measure of infectious period (including culture positivity over time, or generation time), incubation period, or another measure of transmission of meningococcal disease (reproduction number, secondary attack rate, number of new cases linked to an index case, serial interval or carriage of *N. meningitidis*).

A protocol was produced before the literature search was conducted, including the review question, the eligibility criteria, and all other methods. Full details of the methodology are provided in the protocol in Annexe A. There were no deviations from the protocol, but 2 clarifications were made:

- outbreak reports were included regardless of whether they had been peer-reviewed
- number of new cases were only reported if linked to an index case

Screening on title and abstracts was undertaken in duplicate by 2 reviewers for 10% of eligible studies, with the remainder completed by one reviewer. Screening on full text was undertaken

by one reviewer and excluded studies were checked by a second. Data extraction was performed by one reviewer and checked by a second.

For this review, the definitions used were:

- infectious period: the period where an individual can infect others
- incubation period: time between exposure to *N. meningitidis* bacteria and the onset of meningococcal disease symptoms
- serial interval: time between the onset of symptoms in a primary (index) case and the onset of symptoms in a secondary case infected by that primary case

Evidence

In total, 3,258 studies were screened at title and abstract and 131 studies were screened at full text. Of these, 13 studies met the inclusion criteria. A PRISMA diagram showing the flow of studies through the review is shown in Annexe B, and studies excluded on full text screening are available with the reasons why in Annexe C. Study characteristics are available in Annexe D.

Infectious period

No studies were identified that reported evidence to inform the infectious period of *N. meningitidis* in outbreak contexts.

Incubation period

One outbreak report (1), provided information to calculate the incubation period as it reported transmission events of meningococcal serogroup C after occupational contact with a person with confirmed meningococcal disease, in the USA in 2009. The index case, a 36-year-old man, was found unconscious in his home with a partially obstructed airway and vomit and faeces on his clothes and body. Two secondary cases were subsequently reported:

1. A 30-year-old man who was a police officer began experiencing symptoms 2 days after attending the scene. After hospitalisation, blood and cerebrospinal fluid samples were positive for *N. meningitidis*.
2. A 47-year-old man who was a respiratory therapist assisted with suction of the airway of the index case and placement of a tube into their airway. He reported symptoms 5 days after coming into contact with the index case, and blood and cerebrospinal fluid samples were positive for *N. meningitidis*.

Neither of the secondary cases had been offered post-exposure prophylaxis. No information on vaccination status was reported for any of the cases, and the report did not describe the use of vaccination as part of the post-outbreak response.

The incubation period (calculated from the date of close contact with index case) was 2 days in one case and 5 days in the other case. Both the mean and median incubation period was 3.5 days with a standard deviation of 2.1 days.

Given the very small number of cases, the estimate may not be generalisable.

Transmission measures

Number of new cases

Three outbreak reports (1 to 3) reported number of new cases of meningococcal disease specifically linked to an index case.

Materna and others (1), as reported above, reported case numbers in a *N. meningitidis* serogroup C outbreak in the USA in 2009. A total of 23 workers (4 police officers, 3 firefighters, 2 paramedics, and 14 healthcare workers) were involved in the index patient's care. Following exposure to the index case, 2 new cases were reported: both men, aged 30 and 47 years old. Post-exposure prophylaxis was given to 16 workers involved in the patients care, after the identification of the 3 cases. Seven were assessed as not requiring or not eligible for prophylaxis. Neither of the secondary cases had been offered post-exposure prophylaxis, however.

No information on vaccination status was reported for any of the cases and the report did not describe the use of vaccination as part of the outbreak response.

Rude and others (2) reported a cluster of meningococcal disease caused by *N. meningitidis* serogroup W in Liberia between December 2017 and January 2018. Transmission occurred in 3 families from 3 closely linked communities. Following the index case, 8 additional cases were identified among close household and social contacts of the index case or of individuals epidemiologically linked to that case. The cases were mostly men (5 out of 8). Six of the cases were children aged 3 to 14 years and one case was an 85-year-old male. Of the 9 cases, 3 were laboratory confirmed as serogroup W, while the remaining 6 were epidemiologically linked cases. All cases were admitted to hospital and received intravenous ceftriaxone. None of the 9 cases had received a recent meningococcal vaccination.

Post-exposure prophylaxis of single dose oral ciprofloxacin 500 mg was given to 233 of 237 (99%) contacts, 103 non-contact health workers and 843 non-contact residents of affected communities after the identification of the 9 cases. None of the contacts who took ciprofloxacin developed symptoms of meningococcal disease. A meningococcal vaccination programme was

not carried out as authors reported that the vaccine was not available in the country and the outbreak was considered small in size.

Stewart and others (3) reported an outbreak of meningococcal disease caused by confirmed *N. meningitidis* serogroup B in a nursery in the UK in August 2010. Following exposure to the index case, only one new case was reported: a 3-year-old child (sex not reported).

A total of 176 nursery close contacts were identified, including 30 members of staff, all offered post-exposure prophylaxis. Rifampicin was prescribed to the children in the nursery and staff members were offered ciprofloxacin as prophylaxis except for one pregnant staff member who received rifampicin. Of those offered antibiotics, 129 prescriptions were dispensed (73% uptake). Mass vaccination was not recommended as the authors reported that at the time of the outbreak (2010) there was no licensed vaccine that could protect against *N. meningitidis* serogroup B infection.

Evidence on number of new cases was limited by the very small number of studies that reported cases of meningococcal disease specifically linked to an index case, as well as by low case counts. These factors reduce confidence in the numbers and limit the generalisability of the evidence to other outbreaks. In addition, the studies reported on different *N. meningitidis* serogroups, limiting comparability across serogroups and settings.

Serial interval

Two outbreak reports (2, 3) provided information that enabled serial interval for meningococcal infection to be calculated.

Rude and others (2) reported an outbreak of *N. meningitidis* serogroup W in Liberia between December 2017 to January 2018. In total there were 9 cases, of whom 4 died. All cases were admitted to hospital and received intravenous ceftriaxone. All cases were admitted to hospital and received intravenous ceftriaxone. None of the cases had recent meningococcal vaccination.

Transmission occurred in 3 families from 3 closely linked communities, but symptom onset dates were only reported for 5 out of the 9 cases. The index case was a 45-year-old man, and the 4 secondary cases that had symptom onset dates reported were 3 boys and one girl aged from 3 to 13 years. Four of the 5 cases died. Laboratory testing confirmed *N. meningitidis* serogroup W in 2 of the 5 cases. The remaining 3 cases were epidemiologically linked as they had compatible clinical presentations and direct contact with confirmed cases.

The index case (case 1) date of symptom onset was 23 December 2017. Cases 2 to 4 were children of the index case and lived in the same household. Case 2 developed symptoms on 5 January 2018, suggesting a serial interval of 12 days. Case 3 had symptom onset on 10 January 2018, giving a serial interval of 17 days, while case 4 developed symptoms on 11 January 2018, 18 days after the onset of symptoms in the index case. In addition, transmission

beyond the index case was observed: case 5, who attended the same school as case 3, developed symptoms on 17 January 2018, 7 days after the onset of symptoms in case 3.

The mean serial interval was 13.5 days with a standard deviation of 5.1 days.

The reliance on people, including family members, recalling and reporting their symptom onset dates and exposure histories introduced the potential for bias in the study findings. No symptom onset dates were reported for 4 out of the 9 cases and therefore they could not be used to calculate the serial interval in this outbreak. There was incomplete laboratory confirmation (only 2 of the 5 cases were lab confirmed as *N. meningitidis* serogroup W) with the remaining cases classified as epidemiologically linked.

Stewart and others (3) reported an outbreak of meningococcal disease caused by confirmed *N. meningitidis* serogroup B in a nursery in the UK in August 2010. There were 2 cases, both of whom survived. Both children were admitted to hospital (treatment information was not reported). No information on meningococcal vaccination was provided for the index case (case 1). Case 2 had a history of complete primary immunisations however no specific information on meningococcal vaccination was provided.

The index case was a 3-year-old child (sex not reported) with the onset of symptoms on 17 August 2010. Case 1 was also a 3-year-old child (sex not reported) attending the same nursery who experienced symptom onset on 23 August 2010. Case 1 had overlapping classroom sessions with the index case in the week prior to symptom onset. Both cases were confirmed as having serogroup B infection by polymerase chain reaction (PCR) blood test.

The serial interval was 6 days.

As the serial interval was based on only 2 confirmed cases, this may not be a reliable or generalisable measure of the serial interval. While both cases had confirmed serogroup B infection, genetic sub-typing of the 2 samples was not possible due to an insufficient sample.

Carriage

Ten cross-sectional studies (4 to 13) reported on meningococcal carriage following meningococcal disease outbreaks.

Only results for the *N. meningitidis* serogroup corresponding to the outbreak serogroup are presented in this section. Complete carriage results for all serogroups are provided in Annexe D, Table D.2.

N. meningitidis carriage in serogroup B outbreaks

Clark and others (4) reported an outbreak of meningococcal disease, *N. meningitidis* serogroup B, among students linked to a sixth-form college in Bristol and their wider social network. Four cases occurred over 2 phases (2016 and 2017). Two cases died (one in each phase). Genomic

analysis confirmed all cases belonged to the same outbreak strain but there were no epidemiological links, however cases 3 and 4 were linked through a shared social network including attendance at the funeral of case 3 and related gatherings. A study was conducted to assess meningococcal carriage among a high risk social group linked to cases 3 and 4 (friends, family, social contacts, funeral attendees) in September 2017 prior to vaccination (with one dose of 4CMenB vaccination) and post-exposure prophylaxis was given.

The carriage study included 129 people (93% of those who were invited), ages ranged from 3 to 74 years, with 59.7% aged 15 to 24 years. Most (59.7%) were women.

Carriage was assessed using multiple methods, including culture and PCR-based assays and samples were taken from the back of the nose and upper part of the throat.

Of the 129 samples 42 carriers were identified, however only 18 of those (13.9%) yielded a *N. meningitidis* isolate by culture. Five samples (3.9%) were *N. meningitis* serogroup B.

This carriage study reflects *N. meningitidis* carriage within the context of a social network associated with an outbreak. Although several laboratory tests were used, bacteria could only be grown from 18 of the 129 swabs. Therefore, detailed information about the type of *N. meningitidis* strains carried was only available for a small number of people.

Delbos and others (5) conducted a single-centre, cross-sectional study in the first quarter of 2008 to analyse *N. meningitidis* carriage in Dieppe and the surrounding areas at the peak of a meningococcal disease outbreak caused by *N. meningitidis* serogroup. The outbreak, which occurred between 2003 to 2010, mostly affected people under 25 years of age. The total number of cases of meningococcal disease was not reported.

Study inclusion was limited to people aged one to 25 years, 3,522 (41%) accepted an invitation to participate in the study, which was about 12% of one to 25-year-olds in the Dieppe area. Forty-three people were excluded from the study because of subsequent withdrawal of consent or swabbing failure. Swabs were taken from the back of the throat.

A serogroup B vaccine (MenBvac) was used as part of outbreak control. However, vaccination coverage at the time of the carriage study was limited and uneven across the local population. This was due to problems with vaccine supply and because vaccination was restricted to selected children, mainly those aged 1 to 7 years. Many people had antibiotic exposure (clinical antibiotic use for various infections), but it was not primarily related to post-exposure prophylaxis.

Of the 3,479 swabbed people (52% women), 196 were identified as carriers of *N. meningitidis* (6.46%, 95% CI 5.60 to 7.44 when adjusted for differences in age and geographic distribution). Of these 196 carriers, 44 were carriers of serogroup B *N. meningitidis*, representing 1.3% of the total study population and 22.4% of all identified carriers.

Juscamayta-López and others (7) reported on an outbreak of meningococcal disease serogroup B in a Peruvian military institution. Four cases were identified, all survived. A survey of carriage of *N. meningitidis* in the throat was conducted among 139 close contacts within the institution after post-exposure prophylaxis with ciprofloxacin as part of outbreak control, 58.9% were women. Vaccination status of cases, carriers, or contacts was not reported.

Carriage of *N. meningitidis* serogroup B was detected in 8 out of 139 contacts (5.8%), all aged 17 to 22 years (age range of the total group was not reported). All carrier isolates identified in this survey were serogroup B. Sex and other demographic characteristics were not reported.

Carriage assessment was limited to contacts of confirmed cases and did not include the wider military institution population.

Marjuki and others (8) reported on 2 serogroup B meningococcal disease outbreaks that occurred at 2 universities in the USA in 2015, primarily affecting university students. One death was reported. In response, public health authorities implemented mass vaccination campaigns targeting eligible students with most receiving the MenB-FHbp vaccine and a smaller proportion receiving MenB-4C. *N. meningitidis* carriage surveys were conducted between February 2015 and March 2016 to monitor transmission and evaluate the impact of vaccination on carriage. Both vaccinated and unvaccinated students were included. Swabs were taken from the back of back of the throat

At one university site, 2,014 students took part in the carriage study. When repeat samples of the same strain from the same person were removed, there were 540 unique *N. meningitidis* strains for analysis. Of these 540 strains, 113 were *N. meningitidis* serogroup B representing 5.6% of the total student sample and 20.9% of the *N. meningitidis* strains.

At the other university site, 3,509 students were sampled. When repeat samples of the same strain from the same person were removed, there were 573 unique *N. meningitidis* strains for analysis. Of these 573 strains, 47 were *N. meningitidis* serogroup B representing 1.3% of the total student sample and 8.2% of the *N. meningitidis* strains.

Vaccinated and unvaccinated students carried similar *N. meningitidis* strains and, among those sampled repeatedly over time, showed similar patterns of either retaining the same strain or acquiring a new one. Because vaccination was rolled out rapidly and survey rounds included both vaccinated and unvaccinated students, the analyses were not designed as a simple before and after vaccination comparison, but instead focused on comparing carriage isolates by vaccination status at the time of sampling and on their genetic characteristics. The study authors reported that there was no reduction in *N. meningitidis* carriage detected following the serogroup B meningococcal vaccination campaign.

Soeters and others (12) reported on an outbreak of meningococcal disease serogroup B between 29 January and 5 February 2015 in the USA. There were 2 cases, both survived. In

response to the outbreak, 71 contacts received ciprofloxacin as post-exposure prophylaxis and a mass vaccination campaign using MenB-FHbp was implemented. Among eligible people, 94% (3,525 out of 3,745) received the first dose of MenB-FHbp, 80% (2,988 out of 3,741) the second, and 75% (3,045 out of 4,087) the third.

Four cross-sectional surveys were conducted in conjunction with MenB-FHbp vaccination campaigns between February 2015 and March 2016. The aim was to assess prevalence and the impact of the MenB-FHbp vaccination on *N. meningitidis* carriage. Swabs were taken from the back of the throat. Samples were evaluated using culture, slide agglutination and real-time PCR.

Overall, 615 students participated in more than one carriage survey. Of these, 436 participated in 2 surveys, 144 participated in 3 surveys, and 35 participated in all 4 survey rounds. All students were aged under 25 years or graduate students living on campus. *N. meningitidis* carriage (by PCR) is reported below for each survey:

- February 2015 survey: overall *N. meningitidis* carriage 175 of 717 (24%); serogroup B 31 out of 717 (4%)
- April 2015 survey: overall *N. meningitidis* carriage 211 of 878 (24%); serogroup B 36 out of 878 (4%)
- September 2015 survey: overall *N. meningitidis* carriage 123 of 622 (20%); serogroup B: 26 out of 622 (4%)
- March 2016 survey: overall *N. meningitidis* carriage 130 of 626 (21%); serogroup B: 22 out of 626 (4%)

Serogroup B carriage remained stable at around 4% throughout the outbreak response and follow-up period. In multivariable analysis (adjusted for carriage evaluation round, student cohort, sex, smoking, frequency of social mixing, recent antibiotic use, and repeated participation) MenB-FHbp vaccination was found not to be associated with reduced *N. meningitidis* carriage (any serogroup) compared with unvaccinated people: adjusted prevalence ratio 1 dose: 1.5 (95% CI 1.0 to 2.4, 2 doses: 1.4 (95% CI 1.0 to 2.1), 3 doses: 1.6 (95% CI 0.9 to 2.7).

N. meningitidis carriage in serogroup C outbreaks

Miglietta and others (9) reported on an outbreak of serogroup C *N. meningitidis* in Tuscany, Italy from 2015 to 2016. During this period there was increased meningococcal disease incidence in young adults aged 20 to 30 years, men who have sex with men, and in people attending discos, clubs and venues frequented by sexual minority communities (LGBT+ venues). As a result, a reactive vaccination campaign offering meningococcal serogroup C conjugate vaccine or quadrivalent vaccine (covering serogroups A, C, W and Y) to people aged 11 to 45 years was started. A targeted vaccination programme for men who have sex with men was introduced later. A cross-sectional carriage survey was conducted (March to June 2016) during the outbreak to assess *N. meningitidis* carriage prevalence in people who attended vaccination

clinics on their own initiative rather than being directly invited. People were recruited at vaccination clinics during the outbreak response. Anyone aged 11 to 45 years was eligible. Samples were taken from the throat before vaccination. The final study population was 2,285 individuals. Carriage was assessed using PCR and laboratory culture.

Among the 2,285 people sampled, *N. meningitidis* carriage prevalence was 4.8%, with serogroup C detected in 4 individuals (0.2%).

All detected serogroup C carriers were aged 11 to 19 years. No serogroup C carriage was observed among people aged 20 to 30 or 31 to 45 years.

As people were recruited opportunistically at vaccination clinics rather than through random population sampling, carriage prevalence estimates may not represent the exposed population and those at high-risk of transmission might have been missed, for example people not engaging with vaccination services.

Safadi and others (11) reported on 2 outbreaks of meningococcal disease caused by *N. meningitidis* serogroup C in Brazil in 2010. Both outbreaks were linked to 2 oil refineries. In total there were 30 cases and 9 deaths. In the first outbreak at refinery A, rifampicin was given as post-exposure prophylaxis to all close contacts of the initial cases. Following additional cases among workers' family members, a mass vaccination programme using meningococcal A and C polysaccharide vaccine was implemented for all refinery A workers and later extended to children and young people in the surrounding community. In the second outbreak at refinery B, post-exposure prophylaxis (type not reported) was provided to close contacts, without vaccination.

A cross-sectional carriage study was conducted in December 2010 (around 6 months after the outbreaks) and included 483 refinery workers aged 18 to 39 years (238 vaccinated workers from refinery A and 245 unvaccinated workers from refinery B). The aim was to assess the prevalence of *N. meningitidis* carriage among workers at the 2 refineries, evaluate the effect of vaccination on carriage and transmission, as well as to identify risk factors associated with carriage. Samples were taken from the back of the throat and detection of *N. meningitidis* was based on culture and PCR.

In the carriage study, 104 of 483 workers were positive for *N. meningitidis*, giving an overall carriage prevalence of 21.5% (95% CI 18.0 to 25.5%). Carriage prevalence was similar in the 2 refineries; 21.4% (51 out of 238) in refinery A, and 21.6% (53 out of 245) in refinery B (p=1.00). Serogroup C carriage was identified in 5.6% of workers overall (27 out of 483), with no statistically significant difference between refinery A (6.3%, 15 out of 238) and refinery B (4.9%, 12 out of 245; p=0.64). Serogroup C strains were dominated by the same strain responsible for the outbreaks.

As the study only included healthy adult workers this limits the generalisability of the results. Many samples could not be fully typed, which limited the interpretation of serogroup-specific carriage patterns.

Zhang and others (13) reported on an outbreak of meningococcal disease caused by *N. meningitidis* serogroup C in an all-male prison in China in 2010. Three cases occurred within 5 days among men residing in prison. All cases survived. As part of the outbreak investigation, a study of carriage in the throat was conducted in 166 people residing in the prison. This sample included 16 people who shared a cell with the 3 serogroup C cases and 150 men who resided in other cells in the prison.

Among 166 men screened, 47 (28.3%) were identified as carriers of *N. meningitidis*. Of these 29 carried serogroup C (61.7% of carriers and 17.4% of the screened sample). Molecular typing showed that 26 of the 47 men carried the outbreak-associated serogroup. Carriage was higher among close contacts of cases; 10 of 16 men (62.5%) who shared a cell with meningococcal disease cases were carriers. Among these 10 carriers, 6 carried serogroup C strains. In contrast, 37 of 150 men (24.6%) housed in other cells were carriers; among these, 23 carried serogroup C strains. The prevalence of carriage of *N. meningitidis* was significantly higher among men sharing a cell with cases than among those in other cells ($p<0.01$).

The number of close contacts was small, with only 16 men who resided in the same prison cell screened, which limits the precision of carriage estimates in the highest-risk group. Information on factors such as smoking status, recent antibiotic use, or vaccination history was not reported.

N. meningitidis carriage in serogroup A outbreaks

Mueller at others (10) reported an outbreak of meningococcal disease caused by *N. meningitidis* serogroup A in western Burkina Faso in 2006. Children aged 1 to 4 years and 5 to 19 years were most affected. A cross-sectional study of *N. meningitidis* carriage was conducted in the local communities. A sample of 624 healthy residents aged 1 to 39 years was recruited from 3 neighbouring villages. Samples were collected from the back of the throat and analysed using culture and PCR methods to identify *N. meningitidis* carriage. Some people had recently received a meningococcal serogroup A and C polysaccharide vaccine before samples were taken. This was because the carriage study was conducted during a mass vaccination campaign. Timing varied by village, with many people in 2 villages sampled 1 to 2 weeks after vaccination, while most people in the third village were sampled before the campaign. People who had recently taken antibiotics were excluded from the carriage analysis.

People were aged 1 to 39 years (mean age ranging from 12.6 to 13.3 years across villages) and women and girls accounted for approximately 51.3% to 55.2% of people, depending on the village. Overall, 134 people screened (21.4%) were positive for *N. meningitidis* carriage. Serogroup A accounted for 70.1% of *N. meningitidis* carriage (94 out of 134), corresponding to an age-standardised serogroup A carriage prevalence of 16.2% in the overall study population.

Carriage prevalence varied substantially between villages and mirrored meningococcal disease incidence, with higher serogroup A carriage in villages experiencing higher disease rates.

As the study took place during a large vaccination campaign, some people were tested soon after being vaccinated. As a result, it is not clear how recent vaccination would have affected carriage prevalence.

N. meningitidis carriage in serogroup W outbreaks

Jacobsson and others (6) conducted a cross-sectional study to estimate the carriage of *N. meningitidis* following an outbreak of meningococcal disease caused by *N. meningitidis* serogroup W associated with the 23rd World Scout Jamboree in Japan. Throat and or nose swabs were taken from scouts who were given ciprofloxacin as post-exposure prophylaxis. Samples were collected from 1,020 people (about half of those who attended the Jamboree – it is not clear whether all attendees were invited for sampling). Full demographics were not reported.

Overall, *N. meningitidis* carriage was detected in 83 of the people tested (8%) using culture and or PCR. Among the 83 people positive for *N. meningitidis*, age ranged from 12 to 52 years and 44.5% were women or girls. Of the 83 carriers, 11 (13.2%) carried serogroup W *N. meningitidis which was* 1.1% of the overall sample (11 out of 1,020). The 11 carriers were aged 12 to 52 years, 5 (45.5%) women or girls and 6 (54.5%) men or boys.

Just over half of group who attended the Scout Jamboree were included in the study and therefore it is possible that carriage prevalence and serogroup distribution differed among those who were not sampled. The cross-sectional design and limited sample size limited the interpretation of carriage.

Summary of carriage in outbreak settings

The majority of studies were conducted in the context of identified meningococcal disease outbreaks and sampled populations at increased risk, such as students, close contacts of cases, or members of defined social networks.

Five studies reported on carriage of *N. meningitidis* in serogroup B outbreak-related contexts (4, 5, 7, 8, 12). The studies were mostly focused on children, adolescents and young adults. The proportion of individuals carrying *N. meningitidis* serogroup B in the sampled populations ranged from 1.3% to 5.8%. The lowest estimates were reported in large, community-based surveys during prolonged outbreaks, such as the study in Dieppe, France and in one of the USA university outbreaks. The highest carriage estimate reported (5.8%) was from close military contacts in Peru, a highly selected group sampled after post-exposure prophylaxis.

Three studies reported on carriage of *N. meningitidis* in serogroup C outbreak-related contexts (9, 11, 13). The proportion carrying *N. meningitidis* serogroup C in the sampled populations ranged from 0.2% to 17.4%. The highest carriage levels were observed among close contacts of cases, particularly in one study of a prison population.

One study reported on carriage of *N. meningitidis* in serogroup A in an outbreak-related context (10). In the outbreak in western Burkina Faso, serogroup A carriage accounted for 16.2% of the sampled population. As sampling took place in the context of a mass vaccination campaign, it is unclear whether this represented natural carriage or was influenced by recent vaccination.

One study reported on carriage of *N. meningitidis* in serogroup W in an outbreak-related context (6). *N. meningitidis* serogroup W carriage was detected in 1.1% of the total sample. Carriers of serogroup W ranged in age from 12 to 52 years.

Vaccination status and provision of post-exposure prophylaxis differed between studies, and 3 studies aimed to study the impact of the vaccine, which will have had an impact on results.

Health inequalities

For this systematic evidence summary, there were a number of groups highlighted at risk of health inequalities in relation to risk of exposure to *N. meningitidis* infection and outcomes of meningococcal disease. These included:

- differing early years and educational settings, (including nurseries, schools, further education colleges, sixth form, Special Educational Needs (SEN) schools, universities), and by year groups to include school and university year groups (notably first year university students)
- behaviours that increase transmission rates for example vaping, kissing, sharing social spaces, social networks
- young children who remain unvaccinated (especially children aged under one year old eligible for meningococcal disease vaccination who do not receive it)
- closed high risk settings for disease transmission including education (for example, boarding schools, university halls) and wider settings including children's homes, adult social settings, prisons and places of detention, asylum and migrant settings, homeless settings
- ethnicity and deprivation
- higher risk congregate workplaces or entertainment venues such as warehouses, factories, nightclubs

Delbos and others (5) reported that lower parental education, smaller household size, smoking, social behaviours such as attending pubs or clubs, and increasing age were all associated with higher likelihood of *N. meningitidis* carriage in adjusted analyses (adjusted, where appropriate, for age, parental education, father's employment, housing crowding, smoking, attendance at pubs or clubs). In unadjusted analyses, exposure to tobacco smoke, cannabis use, and close contact with smokers were also linked to increased carriage. See Table 1 below.

Table 1. Factors associated with *N. meningitidis* carriage (multivariable and unadjusted analyses)

Risk factor	Category or exposure	Reference group	Population	Odds ratio (95% CI), p-value, analysis type
Parental education	Primary school	University	All	4.60 (1.22 to 17.36), adjusted
Parental education	Secondary school	University	All	2.11 (1.31 to 3.38), adjusted
Household size	Per additional room	None	All	0.75 (0.60 to 0.95), p=0.02, adjusted
Smoking (individual)	≤10 cigarettes per day	Non-smoker	Age 13 to 25	2.14 (1.26 to 3.61), adjusted
Smoking (individual)	>10 cigarettes per day	Non-smoker	Age 13 to 25	Not significant, adjusted
Pub or club attendance	Regular	None	All	1.78 (1.08 to 2.92), p=0.02, adjusted
Age	6 to 10 years	1 to 5 years	Age 1 to 25	4.04 (1.53 to 10.63), p<0.0001, adjusted
Age	11 to 15 years	1 to 5 years	Age 1 to 25	5.23 (2.01 to 13.58), p<0.0001, adjusted
Age	16 to 20 years	1 to 5 years	Age 1 to 25	10.80 (4.17 to 27.94), p<0.0001, adjusted
Age	21 to 25 years	1 to 5 years	Age 1 to 25	14.96 (5.26 to 42.52), p<0.0001, adjusted
Second-hand smoke (home)	Exposure	No exposure	All	1.83 (1.37 to 2.45) p<0.0001, unadjusted
Second-hand smoke (outside)	Exposure	No exposure	All	2.38 (1.78 to 3.18), p<0.0001, unadjusted
Cannabis use	Use	No use	Age 13 to 25	2.36 (1.31 to 4.26), p=0.009, unadjusted
Kissing smoking partner	Yes	No	Age 13 to 25	1.68 (1.10 to 2.58), p=0.05, unadjusted

Miglietta and others (9) reported that attendance at discos, clubs or parties and active smoking were independently associated (when adjusted for age, sex, time and place of swab collection and a range of behavioural exposures) with increased odds of *N. meningitidis* carriage (adjusted odds ratio (AOR) 2.06, 95% CI 1.04 to 4.23 and AOR 2.78, 95% CI 1.37 to 5.63, respectively). Same-sex sexual intercourse (AOR 6.69, 95% CI 2.16 to 20.70) and illicit drug use (AOR 6.30, 95% CI 2.44 to 16.32) were also independently associated with *N. meningitidis* carriage overall. Higher observed carriage of some serogroups was also reported among people who shared drinks and among those exposed to passive smoking; however, neither drink sharing nor passive smoking was independently associated with carriage in multivariable analysis.

Mueller at others (10) reported that in villages with high *N. meningitidis* carriage prevalence (village 1 and village 3, but not in village 2), serogroup A carriage prevalence was higher among 1 year-old children than among 2 to 4-year-old children (23% compared to 6%; p=0.06). Recent vaccination with meningococcal serogroup A and C polysaccharide vaccine was not associated with reduced *N. meningitidis* carriage prevalence at the time of sampling.

Safadi and others (11) reported that low level of education, defined as not completing secondary education, was associated with a higher overall prevalence of *N. meningitidis* carriage (p=0.01), although this association did not reach statistical significance when restricted to specific *N. meningitidis* serogroup strains (p=0.07). Safadi and others reported that active smoking was not associated with an increased prevalence of carriage, either when considering all *N. meningitidis* strains combined (p=0.41) or when analyses were restricted to specific *N. meningitidis* serogroup strains (p=0.58). Crowded living conditions were also not associated with higher carriage rates (p=0.14 for all strains and p 0.35 for serogrouped strains).

Soeters and others (12) reported that in multivariable analyses (adjusted for carriage survey round, student cohort [graduation year], sex, smoking status, frequency of social mixing, recent antibiotic use and repeated participation) active smoking was independently associated with higher prevalence of *N. meningitidis* carriage (any serogroup) (adjusted prevalence ratio (APR) 1.3 95% CI 1.1 to 1.5) and serogroup B carriage (APR 1.5 95% CI 1.0 to 2.2). Frequent social mixing, defined as attending bars, clubs or parties at least once per week, was also associated with increased carriage of any *N. meningitidis* carriage serogroup (APR 1.8 95% CI 1.5 to 2.1) and serogroup B specifically (APR 1.5 95% CI 1.0 to 2.3). Recent antibiotic use was associated with reduced carriage, whereas exposure to second-hand smoke was not independently associated after adjustment. Receipt of MenB-FHbp vaccination, whether 1, 2 or 3 doses, was not associated with reduced prevalence of either overall *N. meningitidis* carriage (any serogroup) or serogroup B carriage.

Zhang and others (13) carried out a cross-sectional survey of *N. meningitidis* throat carriage among men in prison, which showed a higher carriage rate, particularly of the outbreak strain, among those who resided in the same prison cell as a case. However, authors did not provide a comparison with non-incarcerated populations.

Limitations

This summary used streamlined systematic methods to accelerate the review process. Sources of evidence searched included databases of peer-reviewed and preprint research, but an extensive search of other sources was not conducted and most article screening was completed without duplication, so it is possible relevant evidence may have been missed.

Critical appraisal was not performed due to the rapid completion of this work. This restricts the interpretation of the findings, although important limitations of the evidence have been highlighted in this report.

The evidence on incubation period, serial interval and new case numbers for meningococcal disease caused by *N. meningitidis* was based on low numbers of cases and contacts, which restrict confidence in the results and generalisability of the evidence. Results are highly uncertain due to limited cases, incomplete laboratory confirmation of meningitis, and potential recall bias of dates of exposure or onset of symptoms.

Several studies reporting on carriage of *N. meningitidis*. were undertaken in very specific settings (for examples, among close contacts of cases in a prison population), and their findings may not be generalisable to other outbreak contexts. In the carriage studies, vaccination status and provision of post-exposure prophylaxis differed between studies which will have impacted results.

As per the protocol for this rapid evidence summary, all studies were conducted in the context of identified meningococcal disease outbreaks and sampled populations at increased risk, such as students, close contacts of cases, or members of defined social networks. As a result, the findings reflect carriage patterns in outbreak-affected or high-risk groups rather than the general population.

Evidence gaps

This systematic evidence summary looked for evidence on infectious period, incubation period and transmission measures of meningococcal disease in outbreak contexts.

No studies were identified that reported on the infectious period of meningococcal disease in outbreak contexts.

No studies were identified that reported on reproduction number or secondary attack rate of meningococcal disease in outbreak contexts.

N. meningitidis serogroups A, B, C, W, X and Y were predefined as of interest for this review; however, no outbreak contexts relating to serogroups X or Y were identified.

No evidence was identified for incubation period outcomes for *N. meningitidis* serogroups A, B, W, X or Y.

No evidence was identified on variations in transmission parameters for some of the key pre-defined populations and subgroups in which disease outcomes may differ. These gaps include differences by early years and educational settings, such as nurseries, schools, further education colleges, sixth forms, and special educational needs schools, as well as variation by specific school or university year groups, including first-year university students. There was also an absence of evidence relating to young children who remain unvaccinated, particularly those under one year of age who are eligible for meningococcal vaccination but do not receive it. In addition, no evidence was found for closed or high-risk transmission settings, including boarding schools and university halls, or for other relevant environments such as children's homes, adult social settings, and asylum, migrant or homeless populations.

Conclusion

This systematic evidence summary identified 13 studies that reported on incubation period and transmission measures of meningococcal disease in outbreak contexts. No studies were identified that reported evidence to inform on the infectious period of meningococcal disease.

As per the protocol for this rapid evidence summary, all studies were conducted in the context of identified meningococcal disease outbreaks and sampled populations at increased risk, such as students, close contacts of cases, or members of defined social networks. As a result, the findings reflect carriage patterns in outbreak-affected or high-risk groups rather than the general population.

Evidence on the incubation period was limited to a single small outbreak, with observed values ranging from 2 days in one case and 5 in another. Three outbreak reports reported the number of new cases linked to an index case ranging from 1 to 8 cases. Serial interval varied from 6 to 18 days in 2 outbreak reports.

Carriage studies provided the largest body of evidence (10 studies). Prevalence of carriage varied by serogroup and setting ranging from 0.2% to 17.4% of the sampled groups. Behaviours associated with close social contact, such as smoking and frequenting social venues, were associated with increased carriage of *N. meningitidis*. Several studies were undertaken in specific settings (for examples, among close contacts of cases in a prison population), and their findings may not be generalisable to other outbreak contexts.

There was variation between studies in vaccination status and post-exposure prophylaxis provision, which may have impacted the results.

Overall, the evidence on incubation period, serial interval and new case numbers for meningococcal disease caused by *N. meningitidis* was limited by the small numbers of cases and contacts, which restrict confidence in the results and generalisability of the evidence. As a result, there is considerable uncertainty around key transmission parameters for meningococcal disease in outbreak contexts, and the findings should be interpreted with caution.

Acknowledgments

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Disclaimer

UKHSA's rapid reviews and systematic evidence summaries aim to provide the best available evidence to decision makers in a timely and accessible way, based on published peer-reviewed scientific papers, and papers on preprint servers. Note that the reviews:

- use accelerated methods and may not be representative of the whole body of evidence publicly available
- have undergone an internal independent peer review but not an external peer review
- are only valid as of the date stated on the review

In the event that this systematic evidence summary is shared externally, note additionally, to the greatest extent possible under any applicable law, that UKHSA accepts no liability for any claim, loss or damage arising out of, or connected with the use of, this review by the recipient or any third party including that arising or resulting from any reliance placed on, or any conclusions drawn from, the review.

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Annexe A. Protocol

Review question

The review question is:

1. What are the transmission parameters (infectious period, incubation period and transmission measures) of meningococcal disease in outbreak contexts?

A search for primary evidence to answer this review question will be conducted from 1 January 2010 to 2 April 2026.

Infectious period: the period where an individual can infect others.

Incubation period: time between exposure and symptom onset.

Eligibility criteria

Table A.1 Inclusion and exclusion criteria

	Included	Excluded
Population	Humans (any age)	Animals
Context	Meningococcal disease outbreak contexts	Sporadic meningococcal disease cases or case reports with single links
Setting	Any	
Intervention or exposure	Lab confirmed meningococcal disease (all serogroups A, B, C, W, X and Y)	
Outcomes	Any measure of infectious period including: • culture positivity over time • generation time Any measure of incubation period Transmission measure: • reproduction number	

	Included	Excluded
	• secondary attack rate • number of new cases (linked to an index case) • serial interval • carriage of *N. meningitidis*	
Language	English	Any other language
Date of publication	January 2010 (rationale: West Africa meningococcal A vaccine roll out in 2010)	Before January 2010
Study design	Observational studies: case-control, cross-sectional, and cohort studies Outbreak reports	Experimental studies (randomised-controlled trials, quasi-experimental studies, cross-over designs, before-and-after studies) Systematic or narrative reviews Modelling studies Case series Case reports
Publication type	Peer-reviewed published research Preprints	Editorials Letters News articles Grey literature Conference abstracts

Identification of studies

The following databases will be searched for studies from 1 January 2010 published up to 2 April 2026: OVID Medline, OVID Embase, and Web of Science Preprint Citation Index. The search strategy is presented below.

Screening

Title and abstract screening will be undertaken in duplicate by 2 reviewers for at least 10% of the eligible studies, with the remainder completed by one reviewer. Disagreement will be resolved by discussion or with involvement of a third reviewer where necessary.

Screening on full text will be undertaken by one reviewer and checked by a second.

Data extraction

Summary information for each study will be extracted and reported in tabular form. Information to be extracted will include country, study period, study design, participants, vaccination status and setting results, and any relevant contextual data. This will be undertaken by one reviewer and checked by a second.

Risk of bias assessment

Risk of bias of included studies will not be formally assessed in this systematic evidence summary due to time constraints but important limitations of the evidence will be highlighted.

Synthesis

Where studies are similar enough to combine and present data in a consistent format, a narrative synthesis will be produced to interpret the findings. The number of studies, the number of participants in each study, effect size and variance and a summary of study limitations across studies reporting each outcome will be summarised and presented. Alternatively, if studies present methodological differences that would make synthesis inappropriate, a narrative summary of each study will be provided. Evidence will be presented stratified by age and by setting where possible.

Health inequalities

Variations across the following populations and subgroups will be considered, where evidence is available: those for whom the outcome of meningococcal disease may differ such as by:

- differing early years and educational settings, (including nurseries, schools, further education colleges, sixth form, SEN schools, universities), and by year groups to include school and university year groups, (notably first year university students)
- behaviours that increase transmission rates for example, vaping, kissing, sharing social spaces, social networks
- young children who remain unvaccinated (especially under one year old eligible for MenB vaccination who do not receive it)
- closed high risk settings for disease transmission including education (for example, boarding schools, university halls) and wider settings including children’s homes, Adult Social Care (ASC) settings, prisons and places of detention, asylum and migrant settings, homeless settings
- by ethnicity and deprivation

- higher risk congregate workplaces or entertainment venues such as warehouses, factories, nightclubs

Protocol deviations

There were no deviations from the protocol, but 2 clarifications were made:

- outbreak reports were included regardless of whether they had been peer-reviewed
- number of new cases were only reported if linked to an index case

Search strategy

OVID Medline (1 January 2010 to 2 April 2026)

1. exp Meningococcal Infections/ (12,167)
2. exp Meningitis, Meningococcal/ (5,803)
3. Meningitis, Bacterial/ (8,192)
4. (meningococc* adj5 (infect* or disease* or strain* or meningit*)).tw,kf. (9,328)
5. invasive meningococc*.tw,kf. (1,697)
6. meningococcosis.tw,kf. (14)
7. (meningit* and (septic?em* or sepsis or bacter?em*)).tw,kf. (9,261)
8. (meningococc* and (septic?em* or sepsis or bacter?em*)).tw,kf. (1,980)
9. exp Neisseria meningitidis/ (10,643)
10. neisseria mening*.tw,kf. (9,641)
11. "N. meningitidis".tw,kf. (3,192)
12. (meningococc* adj2 A).tw,kf. (2,165)
13. (meningit* adj3 A).tw,kf. (11,544)
14. (meningococc* adj2 B).tw,kf. (1,726)
15. (meningit* adj3 B).tw,kf. (2,267)
16. (meningococc* adj2 C).tw,kf. (1,390)
17. (meningit* adj3 C).tw,kf. (989)
18. (meningococc* adj2 W).tw,kf. (138)
19. (meningit* adj3 W).tw,kf. (144)
20. (meningococc* adj2 X).tw,kf. (34)
21. (meningit* adj3 X).tw,kf. (77)
22. (meningococc* adj2 Y).tw,kf. (132)
23. (meningit* adj3 Y).tw,kf. (186)
24. exp Sepsis/ and Meningitis/ (1,311)
25. serogroup* A.tw,kf. (1,633)
26. serogroup* B.tw,kf. (2,467)
27. serogroup* C.tw,kf. (1,482)
28. serogroup* W-135.tw,kf. (68)
29. serogroup* X.tw,kf. (118)

30. serogroup* Y.tw,kf. (298)
31. MenA.tw,kf. (2,017)
32. MenB.tw,kf. (723)
33. MenC.tw,kf. (455)
34. MenW.tw,kf. (140)
35. MenX.tw,kf. (72)
36. MenY.tw,kf. (108)
37. or/1-36 (46,463)
38. exp Infectious Disease Incubation Period/ (424)
39. incubat*.tw,kf. (361,281)
40. (infectious* adj5 (duration* or time* or length* or period* or peak* or window* or phase*)).tw,kf. (7,485)
41. (infectiv* adj5 (duration* or time* or length* or period* or peak* or window* or phase*)).tw,kf. (2,216)
42. (contagio* adj5 (duration* or time* or length* or period* or peak* or window* or phase*)).tw,kf. (407)
43. (isolat* adj3 (duration* or time or length* or period*)).tw,kf. (12,843)
44. ((Transmis* or transmit*) adj5 (duration* or time* or length* or period* or peak* or window* or phase*)).tw,kf. (21,216)
45. transmission.ti. (89,086)
46. (communicab* adj5 (duration* or time* or length* or period* or peak* or window* or phase*)).tw,kf. (288)
47. (shed* adj5 (duration* or time* or length* or period* or peak* or window* or phase*)).tw,kf. (4,744)
48. (culture* adj5 (duration* or time* or length* or period* or peak* or window* or phase*)).tw,kf. (48,393)
49. (bacteri* proliferat* adj5 (duration* or time* or length* or period* or peak* or window* or phase*)).tw,kf. (42)
50. (bacteri* replicat* adj5 (duration* or time* or length* or period* or peak* or window* or phase*)).tw,kf. (31)
51. infector infectee pair*.tw,kf. (40)
52. (bacteri* adj5 clearance adj5 (duration* or time* or length* or period* or peak* or window*)).tw,kf. (132)
53. (bacteri* load* adj5 (duration* or time* or length* or period* or peak* or window*)).tw,kf. (403)
54. (bacteri* adj2 shedding).tw,kf. (448)
55. cycl* threshold*.tw,kf. (3,481)
56. CT value*.tw,kf. (6,819)
57. (PCR positiv* adj5 (duration* or time* or length* or period* or peak*)).tw,kf. (535)
58. (chain adj2 (transmi* or infect*)).tw,kf. (1,564)
59. ((latent or latency or silent or asymptom*) adj5 (duration* or period* or length* or time* or window* or phase* or transmi*)).tw,kf. (43,555)
60. exp Asymptomatic Diseases/ (10,988)

61. Carrier State/ (23,016)
62. ((carrier* or carriag*) adj3 (state* or infection* or disease* or asymptom* or latent or presymptom* or pre-symptom* or superspreader* or super-spreader*)).tw,kf. (18,220)
63. exp Latent Infection/ (5,478)
64. (bacteri* adj2 (latency or latent)).tw,kf. (98)
65. (microbial adj2 (latency or latent)).tw,kf. (21)
66. (time adj5 (onset or clinical presentation)).tw,kf. (45,334)
67. (period adj5 (onset or clinical presentation)).tw,kf. (6,463)
68. exp Time Factors/ (1,267,596)
69. (Communicable Diseases/ or exp Disease Transmission, Infectious/ or transmission.fs.) and exp Time/ (14,784)
70. serial interval*.tw,kf. (508)
71. (generation adj3 (time* or interval*)).tw,kf. (8,592)
72. ((primary case* adj5 secondary case*) and (time or interval* or period*)).tw,kf. (80)
73. (attack* adj2 rate*).tw,kf. (6,476)
74. (secondary adj1 (case* or attack*)).tw,kf. (3,786)
75. secondary spread rate*.tw,kf. (2)
76. person time rate*.tw,kf. (11)
77. Basic Reproduction Number/ (2,361)
78. (reproducti* adj3 (number* or ratio* or rate*)).tw,kf. (15,232)
79. reproduction dynamic*.tw,kf. (35)
80. R0*.tw,kf. (75,290)
81. (average adj3 number adj3 infect*).tw,kf. (228)
82. Incidence/ (333,470)
83. (inciden* adj4 (proportion* or cumulative or number* or rate* or ratio* or infect* or disease*)).tw,kf. (253,721)
84. (number* adj2 case*).tw,kf. (44,849)
85. transmissibility.tw,kf. (7,649)
86. (transmi* adj4 (rate* or speed* or coefficient or number*)).tw,kf. (19,862)
87. (spread* adj4 (rate* or speed*)).tw,kf. (3,750)
88. ((disease* or infect* or contagio* or pathogen*) adj3 (progress* or spread* or propagat* or replicat* or reproduc* or rate* or speed* or force)).tw,kf. (455,925)
89. (generation adj3 (time* or interval*)).tw,kf. (8,592)
90. or/38-89 (2,916,781)
91. 37 and 90 (7,318)
92. limit 91 to dt=20100101-20260402 (3,270)
93. limit 91 to yr=2010-2026 (3,253)
94. 92 or 93 (3,300)
95. limit 94 to (comment or editorial or letter or news or newspaper article) (40)
96. 94 not 95 (3,260)

OVID Embase (1 January 2010 to 2 April 2026)

1. exp meningococcosis/ (15,173)
2. exp epidemic meningitis/ (3,788)
3. *bacterial meningitis/ (11,474)
4. (meningococc* adj5 (infect* or disease* or strain* or meningit*)).tw,kf. (10,793)
5. invasive meningococc*.tw,kf. (2,038)
6. meningococcosis.tw,kf. (10)
7. (meningit* and (septic?em* or sepsis or bacter?em*)).tw,kf. (12,878)
8. (meningococc* and (septic?em* or sepsis or bacter?em*)).tw,kf. (2,535)
9. exp Neisseria meningitidis/ (17,757)
10. neisseria mening*.tw,kf. (11,198)
11. "N. meningitidis".tw,kf. (3,728)
12. (meningococc* adj2 A).tw,kf. (2,707)
13. (meningit* adj3 A).tw,kf. (14,265)
14. (meningococc* adj2 B).tw,kf. (2,180)
15. (meningit* adj3 B).tw,kf. (2,669)
16. (meningococc* adj2 C).tw,kf. (1,681)
17. (meningit* adj3 C).tw,kf. (1,250)
18. (meningococc* adj2 W).tw,kf. (166)
19. (meningit* adj3 W).tw,kf. (174)
20. (meningococc* adj2 X).tw,kf. (41)
21. (meningit* adj3 X).tw,kf. (96)
22. (meningococc* adj2 Y).tw,kf. (160)
23. (meningit* adj3 Y).tw,kf. (207)
24. exp sepsis/ and meningitis/ (10,163)
25. serogroup* A.tw,kf. (1,927)
26. serogroup* B.tw,kf. (2,845)
27. serogroup* C.tw,kf. (1,690)
28. serogroup* W-135.tw,kf. (82)
29. serogroup* X.tw,kf. (140)
30. serogroup* Y.tw,kf. (350)
31. MenA.tw,kf. (2,763)
32. MenB.tw,kf. (9,19)
33. MenC.tw,kf. (574)
34. MenW.tw,kf. (150)
35. MenX.tw,kf. (87)
36. MenY.tw,kf. (127)
37. or/1-36 (65,946)
38. exp incubation time/ (65,665)
39. incubat*.tw,kf. (453,287)
40. (infectious* adj5 (duration* or time* or length* or period* or peak* or window* or phase*)).tw,kf. (9,982)

41. (infectiv* adj5 (duration* or time* or length* or period* or peak* or window* or phase*)).tw,kf. (2,731)
42. (contagio* adj5 (duration* or time* or length* or period* or peak* or window* or phase*)).tw,kf. (433)
43. (isolat* adj3 (duration* or time or length* or period*)).tw,kf. (16,529)
44. ((Transmis* or transmit*) adj5 (duration* or time* or length* or period* or peak* or window* or phase*)).tw,kf. (23,042)
45. transmission.ti. (92,564)
46. (communicab* adj5 (duration* or time* or length* or period* or peak* or window* or phase*)).tw,kf. (318)
47. (shed* adj5 (duration* or time* or length* or period* or peak* or window* or phase*)).tw,kf. (5,511)
48. (culture* adj5 (duration* or time* or length* or period* or peak* or window* or phase*)).tw,kf. (63,686)
49. (bacteri* proliferat* adj5 (duration* or time* or length* or period* or peak* or window* or phase*)).tw,kf. (53)
50. (bacteri* replicat* adj5 (duration* or time* or length* or period* or peak* or window* or phase*)).tw,kf. (39)
51. infector infectee pair*.tw,kf. (45)
52. (bacteri* adj5 clearance adj5 (duration* or time* or length* or period* or peak* or window*)).tw,kf. (175)
53. (bacteri* load* adj5 (duration* or time* or length* or period* or peak* or window*)).tw,kf. (542)
54. (bacteri* adj2 shedding).tw,kf. (514)
55. cycl* threshold*.tw,kf. (4,639)
56. CT value*.tw,kf. (10,760)
57. (PCR positiv* adj5 (duration* or time* or length* or period* or peak*)).tw,kf. (726)
58. (chain adj2 (transmi* or infect*)).tw,kf. (1,879)
59. ((latent or latency or silent or asymptom*) adj5 (duration* or period* or length* or time* or window* or phase* or transmi*)).tw,kf. (59,832)
60. exp asymptomatic disease/ (38,295)
61. exp disease carrier/ (59,308)
62. ((carrier* or carriag*) adj3 (state* or infection* or disease* or asymptom* or latent or presymptom* or pre-symptom* or superspreader* or super-spreader*)).tw,kf. (23,322)
63. exp latent infection/ (14,353)
64. (bacteri* adj2 (latency or latent)).tw,kf. (123)
65. (microbial adj2 (latency or latent)).tw,kf. (23)
66. (time adj5 (onset or clinical presentation)).tw,kf. (76,513)
67. (period adj5 (onset or clinical presentation)).tw,kf. (9,659)
68. exp time factor/ (55,230)
69. (Communicable Diseases/ or exp Disease Transmission, Infectious/ or transmission.fs.) and exp Time/ (9,811)
70. serial interval*.tw,kf. (581)

71. (generation adj3 (time* or interval*)).tw,kf. (9,410)
72. ((primary case* adj5 secondary case*) and (time or interval* or period*)).tw,kf. (94)
73. (attack* adj2 rate*).tw,kf. (7,832)
74. (secondary adj1 (case* or attack*)).tw,kf. (5,047)
75. secondary spread rate*.tw,kf. (2)
76. person time rate*.tw,kf. (21)
77. exp basic reproduction number/ (4288)
78. (reproducti* adj3 (number* or ratio* or rate*)).tw,kf. (15,633)
79. reproduction dynamic*.tw,kf. (28)
80. R0*.tw,kf. (176,330)
81. (average adj3 number adj3 infect*).tw,kf. (293)
82. exp incidence/ (884,240)
83. (inciden* adj4 (proportion* or cumulative or number* or rate* or ratio* or infect* or disease*)).tw,kf. (382,903)
84. (number* adj2 case*).tw,kf. (70,791)
85. transmissibility.tw,kf. (8,553)
86. (transmi* adj4 (rate* or speed* or coefficient or number*)).tw,kf. (22,385)
87. (spread* adj4 (rate* or speed*)).tw,kf. (4,263)
88. ((disease* or infect* or contagio* or pathogen*) adj3 (progress* or spread* or propagat* or replicat* or reproduc* or rate* or speed* or force)).tw,kf. (734,006)
89. (generation adj3 (time* or interval*)).tw,kf. (9,410)
90. or/38-89 (2,962,917)
91. 37 and 90 (9,437)
92. limit 91 to dd=20100101-20260402 (6,201)
93. limit 91 to yr=2010-2026 (6,092)
94. 92 or 93 (6,202)
95. limit 94 to (conference abstract or conference paper or "conference review" or editorial or letter) (1,607)
96. 94 not 95 (4,595)

Web of Science Preprint Citation Index (1990 to current)

Date of search: 2 April 2026

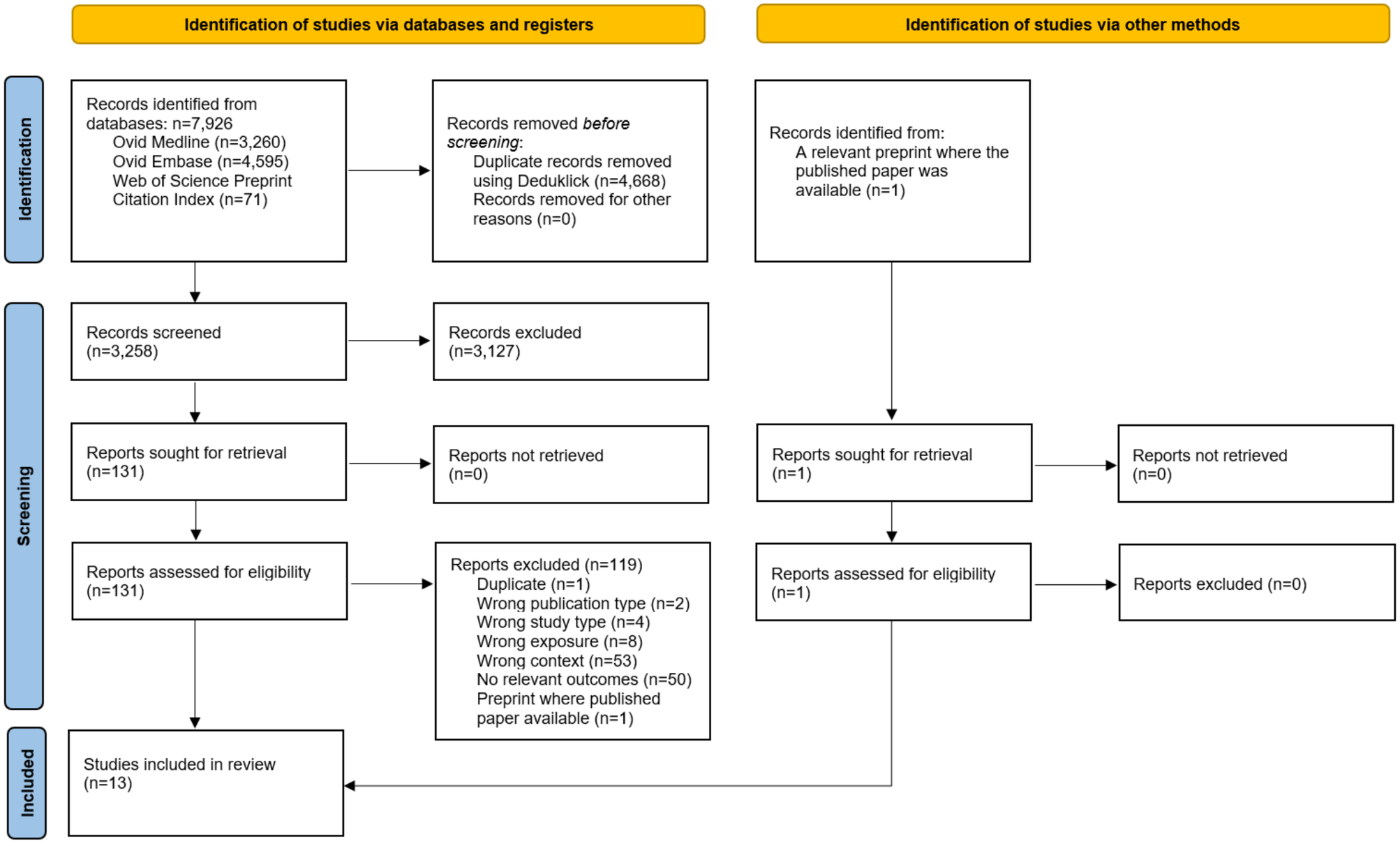
TS=((meningococc* NEAR/4 (infect* or disease* or strain* or meningit*))) OR TS=("invasive meningococc*") OR TS=(meningococcosis) OR TS=((meningit* and (septic$em* or sepsis or bacter$em*))) OR TS=((meningococc* and (septic$em* or sepsis or bacter$em*))) OR TS=("neisseria mening*") OR TS=("N. meningitidis") OR TS=((meningococc* NEAR/1 A)) OR TS=((meningit* NEAR/2 A)) OR TS=((meningococc* NEAR/1 B)) OR TS=((meningit* NEAR/2 B)) OR TS=((meningococc* NEAR/1 C)) OR TS=((meningit* NEAR/2 C)) OR TS=((meningococc* NEAR/1 W)) OR TS=((meningit* NEAR/2 W)) OR TS=((meningococc* NEAR/1 X)) OR TS=((meningit* NEAR/2 X)) OR TS=((meningococc* NEAR/1 Y)) OR TS=((meningit* NEAR/2 Y)) OR TS=("serogroup* A") OR TS=("serogroup* B") OR TS=("serogroup* C") OR TS=("serogroup* W-135") OR TS=("serogroup* X") OR

TS=("serogroup* Y") OR TS=(MenA) OR TS=(MenB) OR TS=(MenC) OR TS=(MenW) OR TS=(MenX) OR TS=(MenY)
AND

Date range: 1 January 2010 to 2 April 2026
Number of results: 71

Annexe B. Study selection flowchart

Figure B.1. PRISMA diagram



Text version of Figure B.1. PRISMA diagram

A PRISMA diagram showing the flow of studies through this review, ultimately including 13 studies.

From identification of studies via databases and registers, n=7,962 records identified from databases:

- Ovid Medline (n=3,260)
- Ovid Embase (n=4,595)
- Web of Science Preprint Citation Index (n=71)

From these, records removed before screening:

- duplicate records removed using Deduklick (n=4,668)
- records removed for other reasons (n=0)

n=3,258 records screened, of which n=3,127 were excluded, leaving n=131 papers sought for retrieval, of which n=0 were not retrieved.

Of the n=131 papers assessed for eligibility, n=119 reports were excluded:

- duplicate (n=1)
- wrong publication type (n=2)
- wrong study type (n=4)
- wrong exposure (n=8)
- wrong context (n=53)
- no relevant outcomes (n=50)
- preprint where published paper available (n=1)

n=1 study was identified from a relevant preprint where the published paper was available.

n=13 papers included in the review.

Annexe C. Excluded full texts

Duplicate (1 study)

Soeters HM and others. 'Serogroup B Meningococcal Disease Outbreak and Carriage Evaluation at a College - Rhode Island, 2015' MMWR - Morbidity and Mortality Weekly Report 2015: volume 64, issue 22, pages 606 to 607

Wrong publication type (2 studies)

Broker M and others. 'Increase of meningococcal serogroup Y cases in Europe: a reason for concern?' Human vaccines and Immunotherapeutics 2012: volume 8, issue 5, pages 685 to 688

Moayedi Y and others. 'Acute bacterial meningitis in adults' CMAJ Canadian Medical Association Journal 2012: volume 184, issue 9, page 1,060

Wrong study type (4 studies)

Bond KA and others. 'Rising incidence of invasive meningococcal disease caused by Neisseria meningitidis serogroup W in Victoria' Medical Journal of Australia 2016: volume 204, issue 7, pages 265 to 266

Guzzetta G and others. 'Evaluating the effect of targeted strategies as control tools for hypervirulent meningococcal C outbreaks: a case study from Tuscany, Italy, 2015 to 2016' Euro Surveillance: Bulletin Europeen sur les Maladies Transmissibles = European Communicable Disease Bulletin 2023: volume 28, issue 19

Hussaini N and others. 'Modeling Neisseria meningitidis transmission dynamics and the impact of pentavalent vaccination targeting serogroups A, C, W-135, Y, and X in the African meningitis belt' Infectious Disease Modelling 2025: volume 10, issue 4, pages 1,355– to 1,383

Lo Presti A and others. 'Estimates of the reproductive numbers and demographic reconstruction of outbreak associated with C:P1.5-1,10-8:F3-6:ST-11(cc11) Neisseria meningitidis strains' Infection, Genetics and Evolution 2020: volume 84, 104360

Wrong exposure (8 studies)

Berberian G and others. 'Pneumococcal meningitis: a 12 year experience in a children's hospital prior to the universal immunization with a conjugate vaccine' Archivos Argentinos de Pediatria 2014: volume 112, issue 4, page 332 to 336

Bozio CH and others. 'Continued occurrence of serotype 1 pneumococcal meningitis in two regions located in the meningitis belt in Ghana five years after introduction of 13-valent pneumococcal conjugate vaccine' PLOS ONE [Electronic Resource] 2018: volume 13, issue 9, e0203205

Chitnis AS and others. 'Outbreak of bacterial meningitis among patients undergoing myelography at an outpatient radiology clinic' Journal of the American College of Radiology 2012: volume 9, issue 3, pages 185 to 190

Khan FY and others. 'Nosocomial postneurosurgical Acinetobacter baumannii meningitis: a retrospective study of six cases admitted to Hamad General Hospital, Qatar' Journal of Hospital Infection 2012: volume 80, issue 2, pages 176 to 179

Kim Y-J and others. 'Group B streptococcal transmission via a prolonged colonizer in a neonatal intensive care unit' Journal of Microbiology, Immunology and Infection 2020: volume 53, issue 1, pages 179 to 182

Letsa T and others. 'Pneumococcal meningitis outbreak and associated factors in six districts of Brong Ahafo region, Ghana, 2016' BMC Public Health 2018: volume 18, issue 1, page 781

Mantadakis E and others. 'Echovirus 30 outbreak associated with a high meningitis attack rate in Thrace, Greece' Pediatric Infectious Disease Journal 2013: volume 32, issue 8, pages 914 to 916

Turabelidze G and others. 'Outbreak of echovirus 18 meningitis in a rural Missouri community' Missouri Medicine 2009: volume 106, issue 6, pages 420 to 424

Wrong context (53 studies)

Al-Sanouri T and others. 'The epidemiology of meningococcal meningitis: multicenter, hospital-based surveillance of meningococcal meningitis in Iraq' IJID Regions (Online) 2021: volume 1, page 100 to 106

Arnold FW and others. 'Meningococcal carriage and transmission dynamics in college students in Louisville, Kentucky' PLOS ONE [Electronic Resource] 2026: volume 21, issue 3, 0344194

Barnes GK and others. 'Prevalence and epidemiology of meningococcal carriage in Southern Ethiopia prior to implementation of MenAfriVac, a conjugate vaccine' BMC Infectious Diseases 2016: volume 16, issue 1, page 639

Basta NE and others. 'Meningococcal carriage within households in the African meningitis belt: A longitudinal pilot study' Journal of Infection 2018: volume 76, issue 2, page 140 to 148

Bello CI and others. 'Nasopharyngeal carriage and risk factors of major meningitis pathogens among asymptomatic healthcare workers in paediatric units in Benin, with serogroup distribution of Neisseria meningitidis' BMC Infectious Diseases 2025: volume 25, issue 1, page 1,056

Ben-Shimol S and others. 'Dynamics of childhood invasive meningococcal disease in Israel during a 22-year period (1989-2010)' Infection 2013: volume 41, issue 4, pages 791 to 798

Ben-Shimol S and others. 'Comparative incidence dynamics and serotypes of meningitis, bacteremic pneumonia and other-IPD in young children in the PCV era: Insights from Israeli surveillance studies' Vaccine 2018: volume 36, issue 36, pages 5,477 to 5,484

Bethea J and others. 'Clinical characteristics and public health management of invasive meningococcal group W disease in the East Midlands region of England, United Kingdom, 2011 to 2013' Euro Surveillance: Bulletin Europeen sur les Maladies Transmissibles = European Communicable Disease Bulletin 2016: volume 21, issue 24

Biaukula VL and others. 'Meningitis in children in Fiji: etiology, epidemiology, and neurological sequelae' International Journal of Infectious Diseases 2012: volume 16, issue 4, pages e289 to e295

Bidmos FA and others. 'Persistence, replacement, and rapid clonal expansion of meningococcal carriage isolates in a 2008 university student cohort' Journal of Clinical Microbiology 2011: volume 49, issue 2, pages 506 to 512

Bratcher HB and others. 'UKMenCar4: A cross-sectional survey of asymptomatic meningococcal carriage amongst UK adolescents at a period of low invasive meningococcal disease incidence' Wellcome Open Research 2019: volume 4, page 118

Breakwell L and others. 'Meningococcal carriage among a university student population - United States, 2015' Vaccine 2018: volume 36, issue 1, pages 29 to 35

Broderick M and others. 'Naval Health Research Center Surveillance for Meningococcal Disease' Military Medicine 2019: volume 184, pages 102 to 105

Bumburidi Y and others. 'Etiology of acute meningitis and encephalitis from hospital-based surveillance in South Kazakhstan oblast, February 2017-January 2018' PLOS ONE [Electronic Resource] 2021: volume 16, issue 5, e0251494

Ceyhan M and others. 'Acquisition of meningococcal serogroup W-135 carriage in Turkish Hajj pilgrims who had received the quadrivalent meningococcal polysaccharide vaccine' Clinical and Vaccine Immunology: CVI 2013: volume 20, issue 1, pages 66 to 68

Choi H and others. 'Longitudinal study of meningococcal carriage rates in university entrants living in a dormitory in South Korea' PLOS ONE [Electronic Resource] 2021: volume 16, issue 1, e0244716

Coch Gioia CA and others. 'Detection of Neisseria meningitidis in asymptomatic carriers in a university hospital from Brazil' Revista Argentina de Microbiologia 2015: volume 47, issue 4, pages 322 to 327

Cooper LV and others. 'Risk factors for acquisition of meningococcal carriage in the African meningitis belt' Tropical Medicine and International Health 2019: volume 24, issue 4, pages 392 to 400

Diallo K and others. 'Pharyngeal carriage of Neisseria species in the African meningitis belt' Journal of Infection 2016: volume 72, issue 6, pages 667 to 677

Gilca R and others. 'A Longitudinal Epidemiology Study of Meningococcal Carriage in Students 13 to 25 Years Old in Quebec' Msphere 2018: volume 3, issue 6

Gobin M and others. 'The epidemiology and management of clusters of invasive meningococcal disease in England, 2010-15' Journal of Public Health 2020: volume 42, issue 1, pages e58 to e65

Gonzales MLA and others. 'Meningococcal carriage in children and young adults in the Philippines: a single group, cross-sectional study' Epidemiology and Infection 2017: volume 145, issue 1, pages 126 to 132

Guimont C and others. 'Invasive meningococcal disease--improving management through structured review of cases in the Hunter New England area, Australia' Journal of Public Health 2010: volume 32, issue 1, pages 38 to 43

Harrison LH and others. 'Meningococcal carriage among Georgia and Maryland high school students' Journal of Infectious Diseases 2015: volume 211, issue 11, pages 1,761 to 1,768

He F and others. 'Neisseria meningitidis carriage and risk factors among teenagers in Suizhou city in China' Epidemiology and Infection 2020: volume 148, page e227

Holmes JC and others. 'Rapid Transmission of a Hyper-Virulent Meningococcal Clone Due to High Effective Contact Numbers and Super Spreaders' Frontiers in Genetics 2020: volume 11, 579411

Hovmand N and others. 'Recent increased incidence of invasive serogroup W meningococcal disease: A retrospective observational study' International Journal of Infectious Diseases 2021: volume 108, pages 582 to 587

Husain EH and others. 'Absence of Neisseria meningitidis from throat swabs of Kuwaiti pilgrims after returning from the Hajj' Medical Principles and Practice 2010: volume 19, issue 4, page 321 to 323

Jaca A and others. 'The burden of meningococcal meningitis in the African Meningitis Belt, from 2009 to 2014: a trend analysis' The Pan African Medical Journal 2021: volume 39, page 57

Jannic A and others. 'Oro genital' Emerging Infectious Diseases 2019: volume 25, issue 1, pages 175 to 176

Kavuncuoglu S and others. 'Neonatal bacterial meningitis in Turkey: epidemiology, risk factors, and prognosis' Journal of Infection in Developing Countries 2013: volume 7, issue 2, pages 73 to 81

Kohutych AI and others. 'Clinical and epidemiological features of meningococcal infection and its early diagnosis in residents of the transcarpathian region' Wiadomosci Lekarskie 2023: volume 76, issue 11, pages 2,448 to 2,454

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Niemela S and others. 'Bacterial meningitis in adults: a retrospective study among 148 patients in an 8-year period in a university hospital, Finland' BMC Infectious Diseases 2023: volume 23, issue 1, page 45

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Parent du Chatelet I and others. 'W135 invasive meningococcal infections imported from Sub-Saharan Africa to France, January to April 2012' Euro Surveillance: Bulletin Europeen sur les Maladies Transmissibles = European Communicable Disease Bulletin 2012: volume 17, issue 21

Sharma S and others. 'Meningococcal Carriage among Household Contacts of Patients with Invasive Meningococcal Disease in Kathmandu, Nepal: A Longitudinal Study' Pathogens 2021: volume 10, issue 7

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Sidorenko S and others. 'Observational study of nasopharyngeal carriage of Neisseria meningitidis in applicants to a military academy in the Russian Federation' International Journal of Infectious Diseases 2019: volume 81, pages 12 to 16

Soeters HM and others. 'Bacterial Meningitis Epidemiology in Five Countries in the Meningitis Belt of Sub-Saharan Africa, 2015-2017' Journal of Infectious Diseases 2019: volume 220, issue 220, pages S165 to S174

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Tryfinopoulou K and others. 'Meningococcal Carriage in Military Recruits and University Students during the Pre MenB Vaccination Era in Greece (2014-2015)' PLOS ONE [Electronic Resource] 2016: volume 11, issue 12, e0167404

Vachon MS and others. 'Cases of Meningococcal Disease Associated with Travel to Saudi Arabia for Umrah Pilgrimage - United States, United Kingdom, and France, 2024' MMWR - Morbidity and Mortality Weekly Report 2024: volume 73, issue 22, pages 514 to 516

Watle SV and others. 'Meningococcal carriage in Norwegian teenagers: strain characterisation and assessment of risk factors' Epidemiology and Infection 2020: volume 148, page e80

Zhang X and others. 'What Works for Controlling Meningitis Outbreaks: A Case Study from China' Vaccines 2023: volume 11, issue 12

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No relevant outcomes (50 studies)

Ajibola O and others. 'Current status of cerebrospinal meningitis and impact of the 2015 meningococcal C vaccination in Kebbi, Northwest Nigeria' Vaccine 2018: volume 36, issue 11, pages 1,423–1,428

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Barret AS and others. 'Cluster of serogroup W invasive meningococcal disease in a university campus' Medecine et Maladies Infectieuses 2020: volume 50, issue 4, pages 335 to 341

Bita Fouda AA and others. 'The Bacterial Meningitis Epidemic in Banalia in the Democratic Republic of Congo in 2021' Vaccines 2024: volume 12, issue 5

Bozio CH and others. 'Outbreak of Neisseria meningitidis serogroup C outside the meningitis belt-Liberia, 2017: an epidemiological and laboratory investigation' The Lancet Infectious Diseases 2018: volume 18, issue 12, pages 1,360 to 1,367

Campbell H and others. 'Impact of an adolescent meningococcal ACWY immunisation programme to control a national outbreak of group W meningococcal disease in England: a national surveillance and modelling study' The Lancet Child and Adolescent Health 2022: volume 6, issue 2, pages 96 to 105

Caron F and others. 'From tailor-made to ready-to-wear meningococcal B vaccines: longitudinal study of a clonal meningococcal B outbreak' The Lancet Infectious Diseases 2011: volume 11, issue 6, pages 455 to 463

Carville KS and others. 'Increase in Meningococcal Serogroup W Disease, Victoria, Australia, 2013-2015' Emerging Infectious Diseases 2016: volume 22, issue 10, pages 1,785 to 1,787

Chow J and others. 'Invasive Meningococcal Meningitis Serogroup C Outbreak in Northwest Nigeria, 2015 - Third Consecutive Outbreak of a New Strain' PLOS currents 2016: volume 8

Coldiron ME and others. 'Outbreak of Pneumococcal Meningitis, Paoua Subprefecture, Central African Republic, 2016-2017' Emerging Infectious Diseases 2018: volume 24, issue 9, pages 1,720 to 1,722

Delisle E and others. 'Community outbreak of group B meningococcal disease in southwest France--December 2008 to September 2009' Euro Surveillance: Bulletin Europeen sur les Maladies Transmissibles = European Communicable Disease Bulletin 2010: volume 15, issue 37

Delrieu I and others. 'Emergence of epidemic Neisseria meningitidis serogroup X meningitis in Togo and Burkina Faso' PLOS ONE [Electronic Resource] 2011: volume 6, issue 5, e19513

Diallo K and others. 'Hierarchical genomic analysis of carried and invasive serogroup A Neisseria meningitidis during the 2011 epidemic in Chad' BMC Genomics 2017: volume 18, issue 1, page 398

Domo NR and others. 'Uncommon mixed outbreak of pneumococcal and meningococcal meningitis in Jirapa District, Upper West Region, Ghana, 2016' Ghana Medical Journal 2017: volume 51, issue 4, pages 149 to 155

Doyle TJ and others. 'Concurrent Outbreaks of Hepatitis A, Invasive Meningococcal Disease, and Mpox, Florida, USA, 2021-2022' Emerging Infectious Diseases 2024: volume 30, issue 4

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Fazio C and others. 'Reactive vaccination as control strategy for an outbreak of invasive meningococcal disease caused by Neisseria meningitidis C:P1.5-1,10-8:F3-6:ST-11(cc11), Bergamo province, Italy, December 2019 to January 2020' Euro Surveillance: Bulletin Europeen sur les Maladies Transmissibles = European Communicable Disease Bulletin 2022: volume 27, issue 24

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Fernandez K and others. 'Meningococcal Meningitis Outbreaks in the African Meningitis Belt After Meningococcal Serogroup A Conjugate Vaccine Introduction, 2011-2017' Journal of Infectious Diseases 2019: volume 220, issue 220, pages S225 to S232

Fisher EA and others. 'Evaluation of Mass Vaccination Clinics in Response to a Serogroup B Meningococcal Disease Outbreak at a Large, Public University-Oregon, 2015' Journal of Adolescent Health 2018: volume 63, issue 2, pages 151 to 156

Folaranmi TA and others. 'Increased Risk for Meningococcal Disease Among Men Who Have Sex With Men in the United States, 2012-2015' Clinical Infectious Diseases 2017: volume 65, issue 5, pages 756 to 763

Goretzki SC and others. 'Outbreak of severe community-acquired bacterial infections among children in North Rhine-Westphalia (Germany), October to December 2022' Infection 2024: volume 52, issue 3, pages 1,099 to 1,111

Hossain MJ and others. 'Serogroup W135 meningococcal disease, The Gambia, 2012' Emerging Infectious Diseases 2013: volume 19, issue 9, pages 1,507 to 1,510

Irvine AJ and others. 'Informing the use of a supplementary immunisation programme for the management of a community cluster of invasive meningococcal disease, Yorkshire, 2022' Public Health 2023: volume 225, pages 263 to 266

Iser BPM and others. 'Outbreak of Neisseria meningitidis C in workers at a large food-processing plant in Brazil: challenges of controlling disease spread to the larger community' Epidemiology and Infection 2012: volume 140, issue 5, pages 906 to 915

Kekeisen-Chen JF and others. 'Expansion of Neisseria meningitidis Serogroup C Clonal Complex 10217 during Meningitis Outbreak, Burkina Faso, 2019' Emerging Infectious Diseases 2024: volume 30, issue 3, pages 460 to 468

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Liphaus BL and others. 'Outbreak of Neisseria meningitidis C in a Brazilian oil refinery involving an adjacent community' Enfermedades Infecciosas y Microbiologia Clinica 2013: volume 31, issue 2, pages 88 to 92

Mbaeyi SA and others. 'Epidemiology of Meningococcal Disease Outbreaks in the United States, 2009-2013' Clinical Infectious Diseases 2019: volume 68, issue 4, pages 580 to 585

Mbaeyi SA and others. 'Meningococcal Disease Among College-Aged Young Adults: 2014-2016' 2019: volume 143

McMahan DA and others. 'Notes from the Field: Expanded Chemoprophylaxis Offered in Response to a Case of Meningococcal Meningitis in an Elementary School - Indiana, 2015' MMWR - Morbidity and Mortality Weekly Report 2016: volume 65, issue 20, page 522

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Miglietta A and others. 'Interconnected clusters of invasive meningococcal disease due to Neisseria meningitidis serogroup C ST-11 (cc11), involving bisexuals and men who have sex with men, with discos and gay-venues hotspots of transmission, Tuscany, Italy, 2015 to 2016' Euro Surveillance: Bulletin Europeen sur les Maladies Transmissibles = European Communicable Disease Bulletin 2018: volume 23, issue 34

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Annexe D. Data extraction tables

Table D.1. Data extraction table for studies with number of new cases, serial interval or incubation period as an outcome

Abbreviations: CDC: Centre for Disease Control and Prevention, PCR: polymerase chain reaction, SI: serial interval, ST: sequence type, USA: United States of America.

Study	Country, time period	Description of outbreak and outbreak response	Population	Meningitis type and diagnosis	Outcome	Health inequalities
Materna B and others, 2010 (1)	USA, December 2009	In December 2009, a man aged 36 years in California was hospitalised with severe meningococcal disease caused by *N. meningitidis* serogroup C after being found unconscious at home, requiring emergency airway management and intubation. During pre-hospital and emergency department care, multiple responders and health-care workers had close contact with the patient, several without appropriate droplet protection. Following this exposure, 2 secondary cases occurred: a police officer involved at the scene and a respiratory therapist who assisted with intubation. Post-exposure prophylaxis given to 16 workers involved in patients care, after the identification of the 3 cases. The report does not describe the use of vaccination as part of the post-outbreak response.	Three cases: Index case: 36 year old man, ethnicity not reported Case 1: 30 year old man, ethnicity not reported Case 2: 47 year old man, ethnicity not reported, sexual orientation not reported 23 = all workers involved in the patient's care 10 = workers reported to have been within ≤3 feet of the patient while providing care, based on CDC guidelines	*N. meningitidis* serogroup C ST-11 clonal complex Culture-confirmed from blood and cerebrospinal fluid	Total cases = 3 Index case = 1 Subsequent cases = 2	Health inequalities not reported, including vaccination status of the cases
As above	As above	As above	As above	As above	Observed incubation period: 2 to 5 days Mean incubation period (calculated by review authors from the date of close contact with confirmed case) Mean incubation period: 3.5 days	As above

Study	Country, time period	Description of outbreak and outbreak response	Population	Meningitis type and diagnosis	Outcome	Health inequalities
					Median incubation period: 3.5 days Sample standard deviation = 2.12 days	
Rude JM and others, 2019 (2)	Liberia, 23 December 2017 to 29 January 2018	An outbreak of meningococcal infection in Foya district in Liberia between December 2017 to January 2018. Transmission involved 3 families in 3 closely linked communities. There were 9 cases, of whom 4 died. Laboratory testing confirmed *N. meningitidis* serogroup W in 3 cases - remaining cases were epidemiologically linked. The outbreak was contained through rapid public health measures (active case finding, isolation and treatment with ceftriaxone, post-exposure prophylaxis with ciprofloxacin for contacts, and community engagement). Single dose oral ciprofloxacin 500 mg was given to 233 of 237(99%) contacts, 103 non-contact health workers and 843 non-contact residents of affected communities after the identification of the 9 cases. None of the contacts that took ciprofloxacin developed symptoms of meningococcal disease. A meningococcal vaccination programme was not conducted post outbreak because the vaccine was not available in the country and the outbreak was deemed small.	Overall: Men: 6 (67%), Women: 3 (33%) Median age: 12 years (Range: 3 to 85 years) Index case (case 1): 45 year old man (died) Case 2: 3 years old boy (died) Case 3: 6 years old girl (died) Case 4: 13 years old boy (survived) Case 5: 12 years old boy (died) Case 6: 85 years old man (survived) Case 7: 12 years old girl (survived) Case 8: 3 years old girl (survived) Case 9: 4 years old boy (survived)	Three cases were laboratory-confirmed as *N. meningitidis* serogroup W. The remaining 6 cases were epidemiologically linked to these confirmed cases and classified as the same infection. Confirmed using reverse transcription-PCR	Total cases = 9 Index case = 1 Subsequent cases = 8	67% of cases were aged 3 to 14 years None of the 9 cases had received a recent meningococcal vaccination.
As above	As above	As above	As above	As above	Serial interval for the 5 cases with symptom onset dates (calculated by review authors)	As above

Study	Country, time period	Description of outbreak and outbreak response	Population	Meningitis type and diagnosis	Outcome	Health inequalities
					Index case (case 1): symptom onset 23 December 2017 Case 2: symptom onset 5 January 2018 (SI: 12 days) Index case (case 1): symptom onset 23 December 2017 Case 3: symptom onset 10 January 2018 (SI: 17 days) Index case (case 1): symptom onset 23 December 2017 Case: symptom onset 11 January 2018 (SI: 18 days) Case 3: symptom onset 10 January 2018 Case 5: symptom onset 17 January 2018 (SI: 7 days) Mean serial interval: 13.5 days Sample standard deviation: 5.1 days	
Stewart A and others, 2013 (3)	UK, 17 August to 23 September 2010	Outbreak declared in a nursery. Two cases of confirmed meningococcal infection. Both survived No further cases were identified. 176 nursery close contacts were identified (including 30 members of staff) for post-exposure prophylaxis, 129 prescriptions were dispensed (73% uptake). Staff members were prescribed ciprofloxacin. Rifampicin was prescribed to children and one pregnant staff member. Mass vaccination was not recommended because there was no	Index case (case 1): 3 year old (sex not reported) Case 2: 3 year old (sex not reported)	*N. meningitidis* serogroup B Confirmed by PCR blood testing in cases 1 and 2	Serial interval: 6 days Index case (case 1) symptom onset: 17 August 2010 Case 2 symptom onset: 23 August 2010	No vaccination history for the index case (case 1) reported. Case 2 had a history of complete primary immunisations however no specific information on meningococcal vaccination was provided .

Study	Country, time period	Description of outbreak and outbreak response	Population	Meningitis type and diagnosis	Outcome	Health inequalities
		licensed vaccine that could protect against serogroup B infection at that time.				
As above	As above	As above	2 cases (case 1 was the index): both 3 years old (sex not reported) 176 nursery close contacts (30 were staff) (close contacts defined as all children and staff who regularly attended/worked at the nursery from 10th to 23rd August 2010)	As above	Number of new cases: One confirmed new case	As above

Table D.2. Data extraction table for studies with carriage as an outcome

Abbreviations: UK: United Kingdom, ST: sequence type, PCR: polymerase chain reaction, CI: confidence interval, OR: odds ratio, Ng: non groupable, Nm: Neisseria meningitidis, MSM: men who have sex with men, AOR: adjusted odds ratio, PFGE: pulsed field gel electrophoresis, MLST: multilocus sequence typing, NS: not significant.

Study	Country, time period	Description of outbreak, outbreak response and aim of study	Population	Meningitis type and diagnosis	Outcome	Health inequalities
Clark SA and others, 2019 (4)	UK, April 2016 to September 2017 (outbreak), September 2017 (carriage study)	Outbreak of invasive meningococcal disease among students associated with a sixth-form college in Bristol and their wider social network. Four cases occurred over 2 phases (2016 and 2017). Genomic analysis confirmed all cases were closely related and belonged to the same outbreak strain but there was no epidemiological link, however cases 3 and 4 were linked through a shared social network including attendance at the funeral of case 3 and related gatherings. Two cases died (one in each phase). Carriage study was conducted amongst the social group of cases 3 and 4, prior to vaccination with one dose of 4CMenB vaccination and post-exposure prophylaxis Aim: to assess meningococcal carriage through nasopharygeal swabbing amongst an extended social group close to an outbreak before administration of post-exposure prophylaxis and one does of the 4CMenB vaccination	Number of people surveyed = 129 Age: 0 to 4 years, n=1, 5 to 14 years, n=13, 15 to 24 years, n=77, over 25 years, n=38 Sex: men/boys n=52 women/girls n=77 (59.7%) Carriers = 42 people (recruited from high risk social group linked to cases (friends, family, social contacts, funeral attendees)) Demographics of positive carriers only not reported	Outbreak: *N. meningitidis* Serogroup B (ST-41 out of 44 clonal complex) Carriage study: serogroup B, C, E, Y, W, X and non-groupable Confirmed using culture and multiple PCR methods [sodC, ctrA/siaDB, PorA, fHbp assays]	Among the 42 carriers, 18 yielded culture-confirmed *N. meningitidis* isolates. Of the 129, 5 were serogroup B, 2 were serogroup W, one was serogroup C, one was serogroup Y and one was serogroup X, 8 were serogroup E or non-groupable, 111 swabs had no serogroup assigned	Setting was a sixth form education The carriage sample was limited to a specific high-risk social group linked to outbreak cases
Delbos V and others, 2013 (5)	France, 2003 to 2010 (outbreak), January 2008 to March 2008 (carriage study)	Population-based meningococcal carriage study conducted in the Dieppe area of France during the peak of the outbreak, described as the epicentre of a meningococcal serogroup B epidemic phenomenon. No further detail on the outbreak or number of cases reported	Number of people surveyed= 3,479 Age groups: 1 to 5 years = 720 6 to 10 years = 864 11 to 15 years = 904 16 to 20 years = 649	Outbreak: *N. meningitidis* serogroup B outbreak strain B:14:P1.7,16/ST-32 and related strains defined as genogroup B *N. meningitidis* belonging to the	Number of carriers = 196 people Carriage detected in 196 out of 3,479 people screened (crude prevalence 5.63%, 95% CI 4.89 to 6.45; standardised prevalence 6.46%, 95% CI 5.60 to 7.44).	In a multivariate analysis (adjusted for age, parental education, father's employment, housing crowding, smoking (restricted to ages 13 to 25), attendance at pubs or clubs (13 to 25 only)) for the overall population aged 1 to 25 years, carriage increased with age:

Study	Country, time period	Description of outbreak, outbreak response and aim of study	Population	Meningitis type and diagnosis	Outcome	Health inequalities
		A MenB vaccine campaign began in 2006, but due to shortage of production, had only been applied mainly since 2008, however MenBvac exposure was not analysed in this study because the vaccine targeted population did not match the carriage study population. Due to the shortage of production, only some children aged 1 to 7 had been given vaccination, namely some of the children aged 1 to 5 years in 3 areas of Dieppe and some of the children aged 3 to 7 years in the other 3 areas of Dieppe. Such distribution precluded to consider MenBvac analysis in the current study. Some of those involved in the study had also taken recent antibiotics Aim: to analyse the pharyngeal meningococcal carriage at the peak of a meningococcal B outbreak	21 to 25 years = 329 Sex: Men = 1,680 Women = 1,786 Carriers: 196 people 6 people 6 people Age groups: 1 to 5 years = 8 (4%) 6 to 10 years = 32 (16.3%) 11 to 15 years = 49 (25%) 16 to 20 years = 70 (35.7%) 21 to 25 years = 37 (18.9%) Sex: Men = 100 (51.1%) Women = 96 (48.9%)	ST-32 clonal complex. Carriage study: serogroup B, C, Y, W, X and non-groupable Diagnosis by culture and PCR from pharyngeal swabs.	Outbreak strain carriage (5 carriers; crude prevalence: 0.14% (95% CI 0.05 to 0.34, Standardised prevalence: 0.18% (95% CI 0.08 to 0.44) Outbreak + related ST-32 strain carriage (13 carriers, 5 outbreak and 8 related; crude prevalence: 0.37% (95% CI 0.17 to 0.58), standardised prevalence: 0.44% (95% CI 0.25 to 0.78)) One strain per carrier; no polyclonal carriage detected The remaining 183 carriers carried strains that were not classified as the outbreak strain or related ST-32 clonal complex strains. Among all 196 carriage isolates, 89 isolates (45%) did not have a serogroup detectable by serological methods and 124 isolates (63%) had their genogroup identified using PCR	compared with children aged 1 to 5 years, the odds ratios rose progressively Age 6 to 10 years: OR 4.04 (95% CI 1.53 to 10.63) Age 11 to 15 years: OR 5.23 (95% CI 2.01 to 13.58) Age 16 to 20 years: OR 10.80 (95% CI 4.17 to 27.94) Age 21 to 25: OR 14.96 (95% CI 5.26 to 42.52) (p<0.0001). Higher carriage associated with lower parental education (compared to university): Primary school: OR 4.60 (95% CI 1.22 to 17.36) Secondary school: OR 2.11 (95% CI 1.31 to 3.38). Increasing number of rooms in the household was protective (OR 0.75 per additional room, 95% CI 0.60 to 0.95; p=0.0166). Among adolescents and young adults aged 13 to 25 years, compared with non-smokers, those smoking up to 10 cigarettes per day had higher odds of carriage (OR 2.14, 95% CI 1.26 to 3.61), while those smoking more than 10 cigarettes per day had an odds ratio of 2.24 (95% CI 0.90 to 5.62) (p=0.0103 overall). Regular attendance at pubs or clubs was also associated with increased carriage (OR 1.78, 95% CI 1.08 to 2.92; p=0.0238) Univariate analysis (unadjusted) – higher carriage reported in:

Study	Country, time period	Description of outbreak, outbreak response and aim of study	Population	Meningitis type and diagnosis	Outcome	Health inequalities
						Individuals with smoking exposure at home (OR 1.83, 95% CI 1.37 to 2.45, p<0.0001) Individuals with smoking exposure outside the home (OR 2.38, 95% CI 1.78 to 3.18, p<0.0001) Individuals aged 13 to 25 who smoke 10 or less cigarettes per day (OR 2.20, 95% CI 1.49 to 3.25, p<0.0001) Individuals aged 13 to 25 who smoke less than 10 cigarettes per day (OR 3.56, 95% CI 2.02 to 6.28, p<0.0001) Individuals aged 13 to 25 with cannabis use (OR 2.36, 95% CI 1.31 to 4.26, p=0.0087) Individuals aged 13 to 25 kissing a smoking partner (OR 1.68, 95% CI 1.10 to 2.58, p=0.0547 overall) Individuals aged 13 to 25 attending pubs or clubs (OR 2.24, 95% CI 1.54 to 3.26, p<0.0001)
Jacobsson S and others, 2013 (6)	Sweeden, August 2015 (carriage study on return from Japan)	World Scout Jamboree, Japan, August 2015, including 33,628 people from 155 countries (1,890 Swedish scouts). After returning home, 3 scouts from Scotland and one relative were diagnosed with invasive meningococcal disease. Several suspected cases of invasive meningococcal disease were immediately reported in Sweden, but only 2 additional cases within a week later were confirmed. No additional cases were reported in Europe or Japan.	Number of people surveyed = 1,020 Demographics for overall number of people not reported Of 83 positive people: Age: 12 to 52 years old Sex: 37 women/girls, 46 men/boys Demographics by subgroup (age, sex)	Outbreak: *N. meningitis* serogroup W, P1.5,2,36-2 Carriage study: meningitis W (11), Y (4), B (4), C (3), non-groupable (61) Diagnosis by positive culture or PCR isolated from throat/nasopharynx	Overall positivity in either culture and/or PCR isolated from throat and/or nasopharynx: 83 out of 1,020 (8%) Total number NmW: 11 NmY: 4 NmB: 4 NmC: 3 Ng: 61 Number with positive culture	No health inequalities reported, including vaccination status

Study	Country, time period	Description of outbreak, outbreak response and aim of study	Population	Meningitis type and diagnosis	Outcome	Health inequalities
		All Swedish scouts were offered ciprofloxacin as post-exposure prophylaxis at the time of swabbing. Throat and/or nasopharyngeal swabs were taken from people receiving antibiotic prophylaxis to aid the decision on the need for further prophylactic treatment to close contacts of returning scouts Aim: to estimate the carrier state of meningococci in Swedish teenagers being given post-exposure prophylaxis and its association with the outbreak at the World Scout Jamboree in 2015	NmW: 12 to 52 years, 5 girls/women, 6 boys/men NmY: 17 to 49 years, 1 woman/girl, 3 men/boys NmB: 17 to 38 years, 0 women/girls, 4 men/boys NmC: 13 to 52 years, 1 woman/girl, 2 men/boys Ng: 13 to 52 years, 30 women/girls, 31 men/boys Ethnicity not reported		NmW: 11 NmY: 3 NmB: 3 NmC: 2 Non-groupable (ng): 12 Total: 31	
Juscamayta-Lopez E and others, 2021 (7)	Peru, 2017 (carriage study during the outbreak)	A meningococcal disease outbreak caused by ciprofloxacin-resistant *N. meningitidis* serogroup B occurred in a Peruvian military institution and led to 4 cases. As part of the outbreak response, the Ministry of Health implemented ciprofloxacin post-exposure prophylaxis among contacts. Cases and contacts were identified within the closed military setting, a carriage study was conducted after post-exposure prophylaxis amongst contacts of cases Vaccination status of cases, carriers, or contacts was not reported Aim: to perform a pharyngeal carriage study during a 2017 outbreak in Peru caused by a ciprofloxacin-resistant *N. meningitidis* B, in a military institution after administration of ciprofloxacin post-exposure prophylaxis	Number of people surveyed = 139 Women = 58.9% Men = 41.1% Other demographics not reported Number of carriers = 8 out of 139 people (5.8%) screened Age: 17 to 22 years = 8 (100%) Other demographic characteristics and comorbidities were not reported	Outbreak: *N. meningitidis* serogroup B (ciprofloxacin-resistant outbreak strain (gyrA Thr91Ile mutation)) ST-1784 (within ST-32 clonal complex) Carriage: *N meningitidis* serogroup B (ciprofloxacin resistant) Case and carriers confirmed by culture or real time PCR method, serotype determined using slide agglutination	Carriage of *N. meningitidis* serogroup B was detected in 8 out of 139 contacts (5.8%) during the outbreak investigation	No health inequalities reported, including vaccination status

Study	Country, time period	Description of outbreak, outbreak response and aim of study	Population	Meningitis type and diagnosis	Outcome	Health inequalities
Marjuki H and others, 2021 (8)	USA, outbreaks in 2015 at both universities. Carriage study occurring February 2015 to March 2016 (Rhode Island university) and March 2015 to February 2016 (Oregon university)	In 2015, meningococcal disease outbreaks occurred at 2 universities in the USA, one in Rhode Island and one in Oregon, primarily affecting university students. In response, public health authorities implemented mass vaccination campaigns targeting eligible students with most receiving the MenB-FHbp vaccine and a smaller proportion (181 out of 3,509) at the Oregon university receiving MenB-4C. No deaths were reported in Rhode Island, one person died in Oregon. Aim: carriage studies were conducted to monitor transmission and evaluate the impact of vaccination on carriage	Number of people surveyed: Rhode Island: 2,014 Oregon: 3,509 University students in outbreak settings Age group: late adolescents/young adults Other demographic characteristics and comorbidities not reported	Outbreak: meningitis serogroup B Carriage: meningitis serogroup B, C, E, W, X, Y, Z Diagnosis: real-time PCR targeting sodC Serogroup determination: slide agglutination	Primary genomic analysis retained a single isolate per people per strain Rhode Island: People sampled: 2,014 Carriage isolates recovered: 650 Single isolate per person per strain (excluding duplicate isolates from repeat carriers): 540 No reduction in meningococcal carriage following vaccination Oregon: People sampled: 3,509 Carriage isolates recovered: 616 Single isolate per person per strain (excluding duplicate isolates from repeat carriers): 573 No reduction in meningococcal carriage following vaccination Number of carriage isolates by genogroup: Rhode Island: Genogroup B: 113 Genogroup C: 11 Genogroup W: 2 Genogroup X: 6 Genogroup Y: 10 Genogroup E,Z or undetermined: 398	Number of isolates from people with known MenB vaccine records: Count: Rhode Island: 646 out of 650 (99.4%) Oregon: 528 out of 616 (85.7%) Vaccinated (any MenB vaccine): Rhode Island: 451 out of 646 (69.8%) Oregon: 317 out of 528 (60.0%) Unvaccinated: Rhode Island: 195 out of 646 (30.2%) Oregon: 211 out of 528 (40.0%) MenB-FHbp (vaccinated isolates only): Rhode Island: 451 out of 451 (100%) Oregon: 275 out of 317 (86.8%) MenB-4C: Rhode Island: 0 Oregon: 42 out of 317 (13.2%) MenB-FHbp doses: Rhode Island: 1 dose: 233 2 doses: 182 3 doses: 36 Oregon: 1 dose: 181 2 doses: 124

Study	Country, time period	Description of outbreak, outbreak response and aim of study	Population	Meningitis type and diagnosis	Outcome	Health inequalities
					Oregon: Genogroup B: 74 Genogroup C: 8 Genogroup W: 2 Genogroup X: 2 Genogroup Y: 11 Genogroup E,Z or undetermined: 476	3 doses: 12 MenB-4C doses (Oregon only): 1 dose: 7 2 doses: 35 Carriage isolates by genogroup and MenB vaccination status: Rhode Island outbreak: Capsular genogroup B: Vaccinated isolates: 89 Unvaccinated isolates: 41 Capsular genogroup non-B: Vaccinated isolates: 362 Unvaccinated isolates: 154 Oregon outbreak: Capsular genogroup B: Vaccinated isolates: 33 Unvaccinated isolates: 29 Capsular genogroup non-B: Vaccinated isolates: 242 Unvaccinated isolates: 182
Miglietta and others, 2019 (9)	Italy, 2015 to 2016 (outbreak), March 1 to 30 June 2016 (carriage study)	During 2015 to 2016, a serogroup C *N. meningitidis* ST-11 (cc11) outbreak occurred in Tuscany, Italy, with increased invasive meningococcal disease incidence in young adults (20 to 30 years), MSM and people attending discos, clubs and venues serving sexual minority communities (LGBT+ venues) A reactive mass vaccination campaign offering a single dose of meningococcal serogroup C conjugate vaccine (MCC) or quadrivalent meningococcal	Number of people surveyed: 2,285 (95.2% of the recruitment target) Convenience sample of individuals aged 11 to 45 years attending vaccination clinics in outbreak-affected areas (Florence, Empoli) and control areas (Siena, Grosseto) in Tuscany, Italy No other demographics reported	Outbreak: meningitis serogroup C Carriage: meningitis serogroup B, C, E, Y, Z, non-serogrouped Diagnosis: culture and rt-PCR	Total oropharyngeal samples collected: 2,285 Overall carriage prevalence of *N. meningitidis*: 110 out of 2,285 (4.8%) 95% CI 2.0 to 5.3% Nonserogrouped: 52 out of 2,285 (2.3%), 95% CI 1.7 to 3.1% Serogroup B: 41 out of 2,285 (1.8%), 95% CI 1.3 to 2.4%	Meningococcal carriage prevalence by demographic characteristics and risk factors: Attended bars, restaurants and pubs: Serogroup B: No: 1.9% (95% CI 1.1 to 3.0) Yes: 1.7% (95% CI 1.1 to 2.6) Serogroup C: No: 0.2% (95% CI 0.0 to 0.8) Yes: 0.1% (95% CI 0.0 to 0.5) Serogroup Y:

Study	Country, time period	Description of outbreak, outbreak response and aim of study	Population	Meningitis type and diagnosis	Outcome	Health inequalities
		conjugate vaccine (ACWY) to people aged 11 to 45 years was implemented in 2015, followed by targeted MSM vaccination in 2016. Whilst a roll out of the vaccine was already in place for a year, the carriage sample in this population was taken before vaccination No deaths were reported Aim: an outbreak investigation and cross-sectional carriage survey was conducted during the outbreak to assess the prevalence and risk factors for meningococcal carriage, noting collection was taken before vaccination in this sample			Serogroup Y: 11 out of 2,285 (0.5%), 95% CI 0.2 to 0.9% Serogroup C: 4 out of 2,285 (0.2%), 95% CI 0.0 to 0.4% Serogroup E: 1 out of 2,285 (0.04%), 95% CI 0.0 to 0.2% Serogroup Z: 1 out of 2,285 (0.04%), 95% CI 0.0 to 0.2% Gender: Serogroup B: Men: 1.8% (95% CI 1.1 to 2.9) Women: 1.8% (95% CI 1.1 to 2.6) Serogroup C: Men: 0.2% (95% CI 0.0 to 0.9) Women: 0.1% (95% CI 0.0 to 0.4) Serogroup Y: Men: 0.7% (95% CI: 0.3 to 1.5) Women: 0.3% (95% CI 0.1 to 0.8) Nonserogrouped: Men: 2.1% (95% CI 1.8 to 3.0) Women: 2.4% (95% CI 2.0 to 3.1) Age group: Serogroup B: 11 to 19 years: 2.8% (95% CI 1.8 to 4.1) 20 to 30 years: 3.0% (95% CI 1.6 to 5.1) 31 to 45 years: 0.5% (95% CI 0.2 to 1.1)	No: 0.4% (95% CI 0.1 to 1.1) Yes: 0.5% (95% CI 0.2 to 1.0) Non-serogrouped: No: 2.5% (95% CI 1.9 to 3.0) Yes: 2.2% (95% CI 1.8 to 2.8) Attended discos, clubs, parties: Serogroup B: No: 0.8% (95% CI 0.3 to 1.6) Yes: 2.4% (95% CI 1.7 to 3.4) Serogroup C: No: 0.0% (95% CI 0.0 to 0.4) Yes: 0.3% (95% CI 0.1 to 0.7) Serogroup Y: No: 0.1% (95% CI 0.0 to 0.6) Yes: 0.7% (95% CI 0.3 to 1.3) Non-serogrouped: No: 1.4% (95% CI 1.0 to 2) Yes: 2.9% (95% CI 2.3 to 4.1) Attended other close groups: Serogroup B: No: 1.1% (95% CI 0.6 to 2) Yes: 2.4% (95% CI 1.6 to 3.4) Serogroup C: No: 0.2% (95% CI 0.0 to 0.7) Yes: 0.2% (95% CI 0.0 to 0.6) Serogroup Y: No: 0.5% (95% CI 0.2 to 1.1) Yes: 0.5% (95% CI 0.2 to 1.1) Non-serogrouped: No: 2.5% (95% CI 2.0 to 3.1) Yes: 2.1% (95% CI 1.8 to 3.3) Shared drinks: Serogroup B: No: 1.2% (95% CI 0.7 to 1.9)

Study	Country, time period	Description of outbreak, outbreak response and aim of study	Population	Meningitis type and diagnosis	Outcome	Health inequalities
					Serogroup C: 11 to 19 years: 0.5% (95% CI 0.1 to 1.2) 20 to 30 years: 0.0% (95% CI 0.0 to 1.4) 31 to 45 years: 0.0% (95% CI 0.0 to 0.4) Serogroup Y: 11 to 19 years: 0.8% (95% CI 0.3 to 1.7) 20 to 30 years: 0.5% (95% CI 0.1 to 1.7) 31 to 45 years: 0.2% (95% CI 0.0 to 0.7) Non-serogrouped: 11 to 19 years: 1.6% (95% CI 1.1 to 1.9%) 20 to 30 years: 5.5% (95% CI 3.1 to 6.4%) 31 to 45 years: 1.5% (95% CI 0.9 to 2.2%)	Yes: 2.7% (95% CI 1.7 to 4.0) Serogroup C: No: 0.0% (95% CI 0.0 to 0.3) Yes: 0.4% (95% CI 0.1 to 1.1) Serogroup Y: No: 0.5% (95% CI 0.2 to 1.0) Yes: 0.4% (95% CI 0.1 to 1.1) Non-serogrouped: No: 2.5% (95% CI 1.3 to 6.9) Yes: 1.9% (95% CI 0.4 to 3.1) Sexual intercourse: Serogroup B: No: 0.9% (95% CI 0.3 to 3.1) Same-sex: 4.8% (95% CI 0.1 to 20.4) Heterosexual: 1.9% (95% CI 1.3 to 2.6) Serogroup C: No: 1.2% (95% CI 0.0 to 3.1) Same-sex: 0.0% (95% CI 0.0 to 0.6) Heterosexual: 0.0% (95% CI 0.0 to 0.2) Serogroup Y: No: 0.9% (95% CI 0.2 to 2.6) Same-sex: 4.8% (95% CI 0.1 to 20.4) Heterosexual: 0.4% (95% CI 0.1 to 0.7) Non-serogrouped: No: 3.6% (95% CI 2.2 to 6.3) Same-sex: 76.2% (95% CI 34.2 to 94.0) Heterosexual: 1.2% (95% CI 0.4 to 1.9) Illicit drug consumption:

Study	Country, time period	Description of outbreak, outbreak response and aim of study	Population	Meningitis type and diagnosis	Outcome	Health inequalities
						Serogroup B: No: 1.7% (95% CI 1.2 to 2.3) Yes: 8.6% (95% CI 1.8 to 22.5) Serogroup C: No: 0.1% (95% CI 0.0 to 5.2) Yes: 2.9% (95% CI 0.5 to 14.2) Serogroup Y: No: 0.3% (95% CI 0.1 to 0.6) Yes: 11.4% (95% CI 3.1 to 26.1) Non-serogrouped: No: 2.1% (95% CI 0.8 to 3.7) Yes: 8.6% (95% CI 4.7 to 87.6) Active smoking: Serogroup B: No: 1.4% (95% CI 0.9 to 2.0) Yes: 3.6% (95% CI 2.1 to 5.8) Serogroup C: No: 0.2% (95% CI 0.0 to 0.12) Yes: 0.2% (95% CI 0.0 to 2.3) Serogroup Y: No: 0.3% (95% CI 0.1 to 0.7) Yes: 1.4% (95% CI 0.4 to 2.6) Non-serogrouped: No: 1.1% (95% CI 0.1 to 8.3) Yes: 7.2% (95% CI 2.6 to 17.9) Passive smoking: Serogroup B: No: 1.5% (95% CI 0.9 to 2.3) Yes: 2.3% (95% CI 1.4 to 3.6) Serogroup C: No: 0.0% (95% CI 0.0 to 0.3) Yes: 0.5% (95% CI 0.1 to 1.2) Serogroup Y: No: 0.4% (95% CI 0.2 to 0.9) Yes: 0.6% (95% CI 0.2 to 1.4)

Study	Country, time period	Description of outbreak, outbreak response and aim of study	Population	Meningitis type and diagnosis	Outcome	Health inequalities
						Non-serogrouped: No: 2.7% (95% CI 2.0 to 3.1) Yes: 1.5% (95% CI 1.0 to 2.6) High adjusted risk of carriage: Age: 20 to 30 years AOR: 3.08 (95% CI 1.97 to 9.79) compared with 31 to 45 years (reference group), p<0.01 Sexual intercourse: Same-sex intercourse AOR: 6.69 (95% CI 2.16 to 20.70), p<0.01 Illicit drug users: AOR: 6.30 (95% CI 2.44 to 16.32), p<0.01 Active smoking: AOR: 2.78 (95% CI 1.37 to 5.63), p=0.01 Attendance at discos, clubs or parties: AOR: 2.06 (95% CI 1.04 to 4.23), p=0.04
Mueller JE and others, 2011 (10)	Burkina Faso, February to March 2006 (outbreak) between 13 and 18 March 2006 (carriage study)	Meningococcal disease outbreak caused by *N. meningitidis* serogroup A in western Burkina Faso in 2006. Children aged 1 to 4 years and 5 to 19 years were most affected. Carriage study conducted in 3 villages (Kofilia, Lena, Konkourouna) A mass campaign with	Total number surveyed= 624 Age = 1 to 39 years, mean age 12.6 to 13.3 years (SD: 10.2 to 10.8) Gender: Women or girls = 51.3 to 55.2% in different villages	Outbreak: *N. meningitidis* A (ST-2859, clonal complex ST-5) Carriage study: *N. meningitidis* A (ST-2859, clonal complex ST-5), *N. meningitidis* Y, and *N. meningitidis* NG	Out of 624 people screened, 134 were carriers of *N. meningitidis*. 94 people carried serogroup A, 37 carried serogroup Y and 3 were non-groupable. The age-standardised *N. meningitidis* carriage prevalence was 22.5%, with serogroup A 16.2%,	Carriage prevalence varied substantially between villages and age groups, with higher carriage in villages with highest meningitis incidence. In villages with high carriage prevalence (Lena and Konkourouna), but not in Kofila, NmA carriage prevalence was substantially higher among 1-

Study	Country, time period	Description of outbreak, outbreak response and aim of study	Population	Meningitis type and diagnosis	Outcome	Health inequalities
		meningococcal serogroup A and C polysaccharide vaccine targeting the 2 to 30 year old population was conducted on from March 12 to 15. Whereas most people from Konkourouna were sampled before the vaccine campaign, most people from Kofila and Lena were sampled 1 to 2 weeks after. Aim: to report a study of incidence, carriage and seroprevalence during a localised epidemic, and evaluate the early impact of vaccination on carriage and antimeningoccocal antibody titers as the study coincided with a vaccine mass campaign.	Recent meningococcal vaccination: 45.7 to 95.1% across villages Meningococcal vaccination before 2006: 2.0 to 33.0% across villages Recent antibiotic use: 0 to 2.4% (2.4% in one village only) Sharing bedroom with more than 4 persons: 20.7 to 40.0% across villages Malnutrition (for under 9's): 9.1% to 24.5% across villages Positive carriers: 134 out of 624 (21.5%) screened, demographics for carriers only not reported	Confirmed by culture and PCR from pharyngeal swabs; isolates sero(sub)typed and genotyped by PFGE and MLST.	serogroup Y 6.0%, and non-genogroupable Nm 0.4%. Most serogroup A carriage isolates belonged to clonal complex ST-5 (ST-2859).	year-old children than among 2- to 4-year-old children (23% vs 6%; p=0.055) Recent vaccination with meningococcal serogroup A and C polysaccharide vaccine was not associated with reduced carriage prevalence at the time of sampling
Safadi MAP and others, 2014 (11)	Brazil, March 29 2010 to June 30 2010 (outbreak 1) July 10 2010 to August 8 2010 (outbreak 2), December 2010 (carriage study)	During March 29 to June 30 2010, an outbreak of Meningitis C disease occurred in an oil refinery (Refinery A) in Brazil resulting in 18 cases and 3 deaths. Six of the cases and 2 deaths involved Refinery A workers, and 12 of the cases and 1 death involved contacts (family members) of the refinery workers. Post-exposure prophylaxis with rifampicin was recommended for all close contacts of the 3 index case-patients. During the following 2 weeks, 5 new cases of MenC disease were identified (3 in Refinery A workers and 2 in children who were relatives of Refinery A workers). Meningococcal A and C	Total people surveyed= 483 238 vaccinated workers from Refinery A 245 non-vaccinated workers from Refinery B No other demographics reported Demographics of carriers only not reported	Outbreak: Meningitis serogroup C, ST103 complex Carriage: Meningitis serogroup C (27), B (9), W (5), Y (7), E (8) and non-groupable (48) Diagnosis by culture or PCR	Overall positivity (95 by culture and PCR, one by culture only, 8 by PCR only): 104 out of 483 (21.5%, 95% CI 18.0 to 25.5%) Refinery A: 51 out of 238 (21.4%) Refinery B: 53 out of 245 (21.6%) p=1.00 Serogroup C positivity: Overall: 27 out of 483 (5.6%) Refinery A: 15 out of 238 (6.3%) Refinery B: 12 out of 245 (4.9%) p=0.64	The difference in Meningitis C carriage rates between vaccinated and nonvaccinated workers (vaccinated: 238 (Refinery A) non-vaccinated: 245 (Refinery B)) was not significant (p=0.64) Active smoking was not associated with an increase in carriage rates (p=0.41 for all *N. meningitidis* strains, p=0.58 for serogrouped strains) Crowded living conditions was not associated with an increase in carriage rates (p=0.14 for all *N. meningitidis* strains, p=0.35 for serogrouped strains)

Study	Country, time period	Description of outbreak, outbreak response and aim of study	Population	Meningitis type and diagnosis	Outcome	Health inequalities
		polysaccharide vaccination was recommended for all 17,590 workers at Refinery A. However, despite the vaccination program, 10 new cases of MenC disease occurred: 9 cases were in family contacts and one case was in a Refinery A worker who had received vaccine one day before symptom onset. Cases occurred in relatives (8 months to 16 years of age) of Refinery A workers, prompting a mass vaccination of 18,571 inhabitants of Cosmópolis who were 2 months to 19 years of age. In the months following the vaccination campaign, no more MenC cases were reported, and the outbreak was considered controlled. The second outbreak of MenC disease occurred in a refinery (Refinery B) in São José dos Campos. On July 10, 2010, a worker at Refinery B was reported to have MenC disease, and on July 18, a second worker was reported to be infected. An investigation identified 10 other reported cases in São José dos Campos during April to July 2010; the 10 cases were in children under 4 years of age who were household contacts of Refinery B workers. Of the 12 identified cases, 6 died. In Refinery B, a decision was made to provide post-exposure prophylaxis, but not vaccine, to all close contacts of index case-patients. On August 8, one new case of meningococcal disease was reported in a family contact of a Refinery B worker; no further cases were reported in 2010.			Serogroup B positivity: Overall: 9 out of 483 (1.9%) Refinery A: 4 out of 238 (1.6%) Refinery B: 5 out of 245 (2.0%) p=1.00 Serogroup W positivity: Overall: 5 out of 483 (1.0%) Refinery A: 4 out of 238 (1.6%) Refinery B: 1 out of 245 (0.4%) p=0.35 Serogroup Y positivity: Overall: 7 out of 483 (1.4%) Refinery A: 5 out of 238 (2.1%) Refinery B: 2 out of 245 (0.8%) p=0.43 Serogroup E positivity: Overall: 8 out of 483 (1.7%) Refinery A: 3 out of 238 (1.2%) Refinery B: 5 out of 245 (2.0%) p=0.76 Serogroup non groupable positivity: Overall: 48 out of 483 (9.9%) Refinery A: 20 out of 238 (8.4%)	Low level of education (not completing secondary education) was associated with an increase in carriage rates (p=0.01 for all *N. meningitidis* strains, p=0.07 for serogrouped strains)

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		Aim: to assess the prevalence of meningococcal carriage among workers at both oil refineries, and to assess the effect of the meningococcal A and C polyaccharide vaccination and risk of factors on pharyngeal carriage of meningococci.			Refinery B: 28 out of 245 (11.4%) p=0.34 Negative Overall: 379 out of 483 (78.5%) Refinery A: 187 out of 238 (78.6%) Refinery B: 192 out of 245 (78.4%)	
Soeters HM and others, 2017 (12)	USA, January 29 2015 to 5 February 2015 (outbreak), February 2015 to March 2016 (carriage study, 4 repeated surveys in conjunction with vaccine administration)	On 29 January 2015 and 5 February 2015, 2 cases of serogroup B meningococcal disease occurred in undergraduate students at Providence College. Both cases were caused by a rare strain of serogroup B ST-9069 not previously seen in the USA. Neither case died. In response to the outbreak, 71 contacts received ciproflocavin post-exposure prophylaxis and a mass vaccination campaign using MenB-FHbp was implemented (3 dose schedule). Aim: a carriage study was done to assess prevalence and the impact of the MenB-FHbp vaccination on carriage.	615 completed multiple surveys, 436 participated twice, 144 3 times and 35 in all 4 rounds All people under the age of 25 Survey 1 (Feb 2015): 717 Men: 247 (34%) Smoker: 154 (21%) Second hand smoke: 260 (36%) Received MenACWY vaccine: 696 (97%) Visited bars, clubs, parties more than once a week: 532 (74%) Survey 2 (April 2015): 878 Men: 353 (40%) Smoker: 252 (29%) Second hand smoke: 441 (50%) Received MenACWY vaccine: 845 (96%)	Outbreak: *N. Meningitis* serogroup B ST-9069 Carriage: Meningitis serogroup B, C, E, W, X, Y, Z, and non-groupable Diagnosis by culture, PCR or slide agglutination	February 2015 survey 1: overall *N. meningitidis* carriage 175 of 717 (24%); serogroup B 31 out of 717 (4%) April 2015 survey 2: overall *N. meningitidis* carriage 211 of 878 (24%); serogroup B 36 out of 878 (4%) September 2015 survey 3: overall *N. meningitidis* carriage 123 of 622 (20%); serogroup B: 26 out of 622 (4%) March 2016 survey 4: overall *N. meningitidis* carriage 130 of 626 (21%); serogroup B: 22 out of 626 (4%) Only one individual carried the ST-9069 outbreak strain (survey 2 and 3) PCR confirmation (% of positive isolates): Survey 1: 18% serogroup B, 5% C, 1% X, 2% Y, 75% non groupable	Attended bar, restaurants, pub: Serogroup B: No: 17 out of 892 Yes: 24 out of 1,393 Serogroup C: No: 2 out of 892 Yes: 2 out of 1,393 Serogroup Y: No: 4 out of 892 Yes: 7 out of 1,393 Non-serogrouped: No: 22 out of 892 Yes: 30 out of 1,393 Attended disco, clubs, parties: Serogroup B: No: 7 out of 886 Yes: 34 out of 1,399 Serogroup C: No: 0 out of 886 Yes: 4 out of 1,399 Serogroup Y: No: 1 out of 886 Yes: 10 out of 1,399 Non-serogrouped: No: 12 out of 886

Study	Country, time period	Description of outbreak, outbreak response and aim of study	Population	Meningitis type and diagnosis	Outcome	Health inequalities
			Received MenB-FHbp vaccine dose 0 dose: 11 (1%), 1 dose (867 (99%) Visited bars, clubs, parties more than once a week: 600 (68%) Survey 3 (September 2015): 622 Men: 263 (42%) Smoker: 187 (30%) Second hand smoke: 318 (51%) Received MenACWY vaccine: 570 (92%) Received MenB-FHbp vaccine dose 0 dose: 109 (18%), 1 dose 12 (2%), 2 dose 501 (81%) Visited bars, clubs, parties more than once a week: 417 (67%) Survey 4 (March 2016): 626 Men: 230 (37%) Smoker: 148 (24%) Second hand smoke: 278 (44%) Received MenACWY vaccine: 583 (93%) Received MenB-FHbp vaccine dose 0 dose: 37 (6%), 1 dose 82 (13%), 2 dose 338 (54%), 3 dose 169 (27%) Visited bars, clubs, parties more than once a week: 438 (70%)		Survey 2: 17% serogroup B, 1% C, 1% X, 2% Y, 79% nongroupable Survey 3: 21% serogroup B, 1% W, 1% Y, 77% non groupable Survey 4: 17% serogroup B, 1% W, 4% X, 2% Y, 77% non groupable Slide agglutination: Survey 1: 5% serogroup B, 1% C, 2% E, 2% X, 1% Y, 89% non groupable Survey 2: 6% serogroup B, 2% E, 1% X, 1% Y, 91% nongroupable Survey 3: 6% serogroup B, 5% E, 1% Z, 89% nongroupable Survey 4: 5% serogroup B, 6% E, 89% nongroupable (serogroups E and Z only assessed with slide agglutination) Of those who did repeat surveys: 436 (71%) had no carriage in any round 89 (14%) were consistently carrying bacteria in each round they participated in (but not necessarily same strain or subgroup) 0% were carriers in all 4 rounds	Yes: 40 out of 1,399 Attended other close groups: Serogroup B: No: 12 out of 1,068 Yes: 29 out of 1,217 Serogroup C: No: 2 out of 1,068 Yes: 2 out of 1,217 Serogroup Y: No: 5 out of 1,068 Yes: 6 out of 1,217 Non-serogrouped: No: 27 out of 1,068 Yes: 25 out of 1,217 Shared drinks: Serogroup B: No: 17 out of 1,395 Yes: 24 out of 890 Serogroup C: No: 0 out of 1,395 Yes: 4 out of 890 Serogroup Y: No: 7 out of 1,395 Yes: 4 out of 890 Non-serogrouped: No: 35 out of 1,395 Yes: 17 out of 890 Sexual intercourse: Serogroup B: No: 3 out of 335 Same-sex: 1 out of 21 Heterosexual: 37 out of 1,929 Serogroup C: No: 4 out of 335

Study	Country, time period	Description of outbreak, outbreak response and aim of study	Population	Meningitis type and diagnosis	Outcome	Health inequalities
			Ethnicity not reported		50 (8%) carried bacteria in one round but not in a later round 45 (7%) did not have carriage and then acquired it in later round Multivariable analysis (adjusted for carriage evaluation round, student cohort, sex, smoking, frequency of social mixing, recent antibiotic use, and repeated participation): MenB-FHbp vaccination was not associated with reduced meningococcal carriage (compared with unvaccinated people): prevalence ratio for any meningococcal carriage: 1 dose 1.5: (95% CI 1.0 to 2.4) 2 doses: 1.4 (95% CI 1.0 to 2.1) 3 doses: 1.6 (95% CI 0.9 to 2.7) Gender: Serogroup B: Men: 17 out of 940 Women: 24 out of 1,345 Serogroup C: Men: 2 out of 940 Women: 2 out of 1,345 Serogroup Y: Men: 7 out of 940 Women: 4 out of 1,345 Nonserogrouped:	Same-sex: 0 out of 21 Heterosexual: 0 out of 1,929 Serogroup Y: No: 3 out of 335 Same-sex: 1 out of 21 Heterosexual: 7 out of 1,929 Non-serogrouped: No: 12 out of 335 Same-sex: 16 out of 21 Heterosexual: 24 out of 1,929 Illicit drug consumption: Serogroup B: No: 38 out of 2,250 Yes: 3 out of 35 Serogroup C: No: 3 out of 2,250 Yes: 1 out of 35 Serogroup Y: No: 7 out of 2,250 Yes: 4 out of 35 Non-serogrouped: No: 49 out of 2,250 Yes: 3 out of 35 Active smoking: Serogroup B: No: 25 out of 1,841 Yes: 16 out of 444 Serogroup C: No: 3 out of 1,841 Yes: 1 out of 444 Serogroup Y: No: 5 out of 1,841 Yes: 6 out of 444 Non-serogrouped: No: 20 out of 1,841

Study	Country, time period	Description of outbreak, outbreak response and aim of study	Population	Meningitis type and diagnosis	Outcome	Health inequalities
					Men: 20 out of 940 Women: 32 out of 1,345 Age groups: Serogroup B: 11 to 19 years: 23 out of 828 20 to 30 years: 13 out of 434 31 to 45 years: 5 out of 1,023 Serogroup C: 11 to 19 years: 4 out of 828 20 to 30 years: 0 out of 434 31 to 45 years: 0 out of 1,023 Serogroup Y: 11 to 19 years: 7 out of 828 20 to 30 years: 2 out of 434 31 to 45 years: 2 out of 1,023 Non-serogrouped: 11 to 19 years: 13 out of 828 20 to 30 years: 24 out of 434 31 to 45 years: 15 out of 1,023 People were recruited as part of the outbreak vaccination response campaign	Yes: 32 out of 444 Passive smoking: Serogroup B: No: 22 out of 1,465 Yes: 19 out of 820 Serogroup C: No: 0 out of 1,465 Yes: 4 out of 820 Serogroup Y: No: 6 out of 1,465 Yes: 5 out of 820 Non-serogrouped: No: 40 out of 1,465 Yes: 12 out of 820 Associations with any carriage (bivariate prevalence ratio, multivariable prevalence ratio) Male: 1.5 (95% CI 1.3 to 1.8, p<0.001), 1.3 (95% CI 1.1 to 1.5, p<0.001) Smoker: 1.5 (95% CI 1.3 to 1.7, p<0.001), 1.3 (95% CI 1.1 to 1.5, p=0.003) Second hand smoke: 1.2 (95% CI 1.1 to 1.4, p=0.006), 1.0 (95% CI 0.8 to 1.1), p=0.610 Visits bars, clubs, parties more than once a week: 1.9 (95% CI 1.6 to 2.2, p<0.001), 1.8 (95% CI 1.5 to 2.1, p<0.001) Received MenACWY: 1.1 (95% CI 0.8 to 1.6, p=0.633), not reported Received MenB-FHbp vaccine dose, 0 doses: 1.0, 1.0

Study	Country, time period	Description of outbreak, outbreak response and aim of study	Population	Meningitis type and diagnosis	Outcome	Health inequalities
						One dose: 1.8 (95% CI 1.1 to 2.8, p=0.014), 1.5 (95% CI 1.0 to 2.4, p=0.074) Two dose: 1.5 (95% CI 1.0 to 2.1, p=0.037), 1.4 (95% CI 1.0 to 2.1, p=0.082) Three dose: 1.8 (95% CI 1.1 to 2.9, p=0.015), 1.6 (95% CI 0.9 to 2.7, p=0.124) Associations with serogroup B carriage by rtPCR (bivaraite prevalence ratio, multivariable prevalence ratio) Male: 1.9 (95% CI 1.3 to 2.7, p=0.002), 1.6 (95% CI 1.0 to 2.4, p=0.037) Smoker: 1.8 (95% CI 1.3 to 2.6, p=0.001), 1.5 (95% CI 1.0 to 2.2, p=0.047) Second hand smoke: 1.5 (95% CI 1.1 to 2.1, p=0.007), not reported Visits bars, clubs, parties more than once a week: 1.6 (95% CI 1.1 to 2.3, p<0.016), 1.5 (95% CI 1.0 to 2.3, p=0.043) Received MenACWY: 0.6 (95% CI 0.3 to 1.3, p=0.182), not reported Received MenB-FHbp vaccine dose, 0 doses: 1.0, 1.0 One dose: 1.4 (95% CI 0.4 to 4.6, p=0.599), 1.8 (95% CI 0.6 to 5.8, p=0.329) Two dose: 0.9 (95% CI 0.5 to 1.8, p=0.829), 1.3 (95% CI 0.6 to 2.8, p=0.567) Three dose: 0.9 (95% CI 0.3 to 2.7, p=0.887), 1.8 (95% CI 0.4 to 8.7, p=0.489

Study	Country, time period	Description of outbreak, outbreak response and aim of study	Population	Meningitis type and diagnosis	Outcome	Health inequalities
Zhang J and others, 2013 (13)	China, May 2010 (carriage study during outbreak)	Outbreak of invasive meningococcal disease caused by *N. meningitidis* serogroup C in a male prison in Jinan City. Three cases occurred within 5 days among men sharing the same cell, which prompted post-exposure prophylaxis and mass polysaccharide A plus C vaccination amongst people in close contact with the cases Aim: to understand the meningococcal carriage of the men residing in the prison (unclear if before or after prophylaxis or vaccination)	Total people surveyed = 166 (16 men residing in the same cell as the cases [close contacts], 150 men residing in other cells) Men = 100% Age and other comorbidities were not reported for total surveyed or for positive carriers only	*N. meningitidis* serogroup C, ST-4821 clonal complex. Carriage study: serogroup C, B, A, W135, Y and non-groupable Culture confirmed by cerebrospinal fluid and blood. *N. meningitidis* isolates were characterized by PFGE and MLST	Out of 166 men residing in the prison screened, 47 were identified as carriers of *N. meningitidis*. Among these 47 carriers, number of people with: • serogroup C strain = 29 • serogroup B strain = 10 • serogroup A strain = 2 • serogroup W135 strain = 1 • non-groupable strain = 4 • not reported = 1 Of the 47 carriers, 26 carried the outbreak-associated serogroup C ST-4821 clone. Carriage among men who resided in the same cell as the cases: Out of the 47 identified carriers, 10 were men who shared a cell with the meningococcal disease cases. Among the 16 men who resided in the same cell as the cases, 10 were carriers, giving a carriage rate of 62.5%. Strain distribution among the 10 carriers: • serogroup C = 6 • serogroup B = 1 • serogroup W135 = 1 • non-groupable = 2 Carriage among men residing in other cells:	No specific health inequalities reported, but noting study setting is in a prison (closed high risk setting).

Study	Country, time period	Description of outbreak, outbreak response and aim of study	Population	Meningitis type and diagnosis	Outcome	Health inequalities
					Out of the 47 identified carriers of *N. meningitidis*, 37 were men who resided in other cells of the prison. Among the 150 men in other cells who were screened, 37 were carriers, giving a carriage rate of 24.6% Strain distribution among these 37 carriers: • serogroup C = 23 • serogroup B = 9 • serogroup A = 2 • serogroup Y = 1 • non-groupable = 2 The prevalence of *N. meningitidis* pharyngeal carriage was significantly higher among men sharing a cell with the cases than among men residing in other cells ($p<0.01$, Mantel-Haenszel chi-square test).	

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