UK Health Security Agency

Source or route of transmission and behaviours associated with transmission in meningococcal disease outbreaks in closed congregation social settings

A systematic evidence summary

Contents

Main messages

1. This systematic evidence summary (search up to 25 March 2026) aimed to identify and summarise evidence relating to the source or route of transmission and the behaviours associated with transmission in meningococcal disease outbreaks in closed congregation social settings.

2. Three studies were identified that reported on behaviours associated with transmission in meningococcal disease outbreaks in closed congregation social settings. Two studies were outbreak reports with case-control studies from Argentina (1) and the US (2), and one was an outbreak report from Brazil (3). No evidence relating to the source or route of transmission was identified in meningococcal disease outbreaks in closed congregation social settings.

3. In total 26 cases of meningococcal disease were identified, with case numbers per study ranging from 8 to 9. All studies reported meningococcal serogroup C outbreaks that occurred between 1991 and 2009 (1 to 3).

4. Two studies reported no significant association between cigarette smoking or passive smoking and likelihood of meningococcal disease (one after adjusting for other factors that may have impacted the outcome) (1, 2). One of these studies also reported no association with sharing of cigarettes among smokers or sharing of drinks among alcohol drinkers (2). The third study reported the numbers of cases who were illicit drug users (4 out of 9), but did not analyse the association (3).

5. The studies did not report sufficient detail to explore health inequalities as factors such as ethnicity, deprivation, or age were either not clearly reported or results were not separated for these groups.

6. Critical appraisal was not performed, which restricts the interpretation of the findings, but important limitations of the evidence have been highlighted. The number of cases of meningococcal disease in the included studies were very small and likely not sufficient to show true associations between behaviours or reflect outcomes that are generalisable to larger groups. Available evidence consisted of case-control studies and outbreak reports, which are generally more likely to be affected by methodological limitations such as not controlling for other factors that may have affected the outcome, and reliance on self-reported behaviour.

7. In summary, no evidence relating to the source or route of transmission was identified and the available evidence on behaviours associated with transmission in meningococcal disease outbreaks in closed congregation social settings was limited in both quantity and quality. The evidence suggested there was no association between behaviours such as

cigarette smoking, passive smoking, sharing cigarettes or alcoholic drinks or illicit drug use and transmission of meningococcal disease. However, the numbers included were likely too small to reliably show true associations and therefore likely to have insufficient statistical power to detect associations with behavioural outcomes. As a result, no firm conclusions can be drawn about specific behaviours associated with transmission in meningococcal disease outbreaks in closed congregation social settings.

Purpose

The purpose of this systematic evidence summary was to identify and summarise the available evidence that discussed the source or route of transmission and the behaviours associated with transmission in meningococcal disease outbreaks in closed congregation social settings.

The review question was:

1. What are the sources or routes of transmission and the behaviours associated with transmission in meningococcal outbreaks in closed congregation social settings?

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 case series or outbreak reports), published or available as preprint, up to 25 March 2026. Three databases were searched OVID Medline, OVID Embase, and Web of Science Preprint Citation Index.

Closed congregation social settings, for example: nightclubs, sex on premises venues, music venues, bars, student parties, religious venues, other crowded indoor social settings, were specified by subject matter experts as settings of interest for this evidence summary. The exposure of interest for this evidence summary was meningococcal infection (all types). The outcomes of interest for this evidence summary were source of transmission or transmission route (for example, direct contact, infectious respiratory particles (droplet or aerosol), fomite), social behaviours associated with transmission (for example, intimate kissing, sexual activity, sharing drinks, cigarettes or vapes, active or passive smoking) and behaviours that increased exposure to respiratory secretions (for example, singing, shouting, coughing and sneezing).

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 one clarification was made:

- outbreak reports were included regardless of whether they had been peer reviewed

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.

Evidence

In total, 526 studies were screened at title and abstract and 28 studies were screened at full text. Of these, 3 studies met the inclusion criteria (1 to 3). A PRISMA diagram showing the flow of studies through the systematic evidence summary 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.

Three studies were identified that reported on behaviours associated with transmission in meningococcal disease outbreaks in closed congregation social settings. Two studies were outbreak reports with case-control studies (1, 2) and one was an outbreak report (3). One study was from the USA (2), one from Brazil (3) and one from Argentina (1). The outbreaks occurred between 1991and 2009. No evidence relating to the source or route of transmission in meningococcal disease outbreaks in closed congregation social settings was identified. A summary of findings from these studies is presented in Table D.1.

Cookson and others reported an outbreak of meningococcal disease that occurred between 5 to 14 August 1996 in Argentina (1). Eight cases were identified aged 15 to 45 years: 6 men and 2 women. Ethnicity was not reported. A case-control study was conducted to determine risk factors for infection. Five out of the 8 cases attended the same disco. Three cases (one man and the 2 women) did not attend the disco and the source of their meningococcal infection was not known. None of the cases knew each other or listed friends of the same name when answering the question on social contacts. Meningococcal infection was confirmed via laboratory testing. Of the eight cases, 6 were confirmed as meningococcal serogroup C, one case was serogroup undetermined and one case not serogrouped. One case died (1 man) and 7 survived.

For the case-control study, 4 cases were matched to 4 neighbourhood school controls, and the remaining 4 cases were matched to 4 neighbourhood block controls. No demographic data for

controls was reported. There were 32 controls in total. Cases and controls had comparable numbers of people living in their households, similar numbers of rooms in their homes, and similar histories of contact with individuals who had upper respiratory tract infections during the preceding 2 weeks. None of the cases or controls had received meningococcal vaccination.

Smoking cigarettes or being passively exposed to cigarette smoke was found to not be significantly associated with higher odds of meningococcal disease:

- active smoking: 4 out of 8 cases (50%), 6 out of 32 controls (19%) odds ratio (OR): 6.0 (95% CI 0.6 to 50.0, p=0.077)
- passive exposure: 3 out of 8 cases (38%) 8 out of 32 controls (25%) OR: 1.6 (95% CI 0.2 to 11.2, p=0.49)
- combined passive and active smoking: 7 out of 8 cases (88%), 14 out of 32 controls (44%) OR: 5.7 (95% CI 0.9 to 391, p=0.035).

In subgroup analysis, men who were exposed to either passive or active smoking had significantly higher odds of getting meningococcal disease than those not exposed (6 out of 6 cases (100%), 9 out of 24 controls (38%) OR: undefined (1.4 to infinity) p=0.008). As every male case patient was exposed, the statistical calculation used to generate an odds ratio could not produce a numerical value in the usual way. This resulted in an ‘undefined’ odds ratio, with a confidence interval ranging from 1.4 to infinity. In practical terms, this means the association was very strong but could not be precisely measured. No subgroup analysis on women was reported, which may reflect a bias in only reporting significant results, or in undertaking exploratory analysis to find a significant effect, that may only be due to chance. No adjustment for potential confounding factors was reported by the authors which raises doubts as to whether this is a true association, as the observed effect may be influenced by other factors. Frequency of other activities, such as sharing of beverage glasses or cigarettes, close contact while dancing, or alcohol consumption were not asked.

The small number of identified cases meant the study was likely to have insufficient statistical power to detect associations with behavioural outcomes. Because demographic information for the control group was not reported, it was not possible to determine whether these individuals were appropriately matched to the cases. The study relied on cases recalling and reporting their own experiences, which introduced the possibility of recall bias and reporting bias. No subgroup analyses were undertaken in women, which may demonstrate bias in the analysis or reporting of results as well as representing a gap in the evidence. In addition, the authors did not report any adjustment for potential confounding factors.

Gorla and others reported an outbreak of meningococcal disease that occurred between 21 to 26 October 2009 in Brazil (3). Nine cases were identified aged 14 to 39 years: 7 men and 2 women. Ethnicity was not reported. All cases, except for one 39-year-old man, attended a dance party with approximately 1000 young people on 18 October which took place at a rural site. Authors did not report if the venue was indoors or outdoors. Meningococcal infection was

confirmed via laboratory testing. All 9 cases were confirmed as meningococcal serogroup C. Six cases died (4 men; 2 women) and 3 survived (3 men).

Alcohol consumption, cigarette smoking and illicit drug use were identified as behaviours that occurred during the outbreak investigation, however drug use was the only behaviour with numbers reported: 4 out of 9 cases were users of illicit drugs or used cocaine at the party, one of these died.

The reliance on participants recalling and reporting their own experiences introduced the potential for bias in the study findings. The sample size was very small and no comparisons with a control group were undertaken.

Imrey and others reported an outbreak of meningococcal disease that occurred between February 1991 to April 1992 in the United States (2). Nine cases were identified aged 18 to 22 years: 5 men, 4 women. Eight cases were white and one was of Asian ethnicity. A case-control study was conducted to determine factors contributing to the outbreak.

Seven of the 9 cases attended University campus-area bars during the 2 weeks preceding illness and 6 of the 9 cases had attended the same University campus bar. No cases shared common housing or lived in the same dormitory. Only one case reported a respiratory infection during the 2 weeks prior to onset of meningococcal disease. Meningococcal infection was confirmed by laboratory testing. Of the 9 cases, 8 were confirmed as meningococcal serogroup C. Three cases died (2 men, 1 woman) and 6 cases survived (3 men, 3 women).

For the case-control study, 17 to 21 controls were interviewed for each of the 6 survivors and were matched according to college, sex, and year in school. Controls were randomly selected from the university phone directory, and community college controls were chosen randomly from the university phone directory or from computer records. There were 117 controls in total. No demographic data was reported for controls.

Cigarette smoking was initially found to be associated with higher odds of meningococcal disease (4 out of 6 cases [66.7%] 23 out of 117 controls [19.7%], OR: 7.8 [95% CI: 1.3 to 64.4, p=0.012]). However, when cigarette smoking was included in a multiple logistic regression model, which adjusts for other factors that may have affected the outcome (confounding factors) including recent bar exposure, frequency of respiratory illness and the number of people sleeping in the same room, the association was no longer statistically significant (p=0.11, OR and 95% CIs not reported).

The odds of meningococcal disease associated with sharing of drinks among alcohol drinkers or sharing of cigarettes among cases who smoked were found not significant, although the raw data was not reported (OR 4.3, 95% CI: 0.7 to 36.1, p=0.11 and OR 8.0, 95% CI 0.6 to 264.6, p=0.13 respectively). No adjustment for possible confounding effects was reported.

Complete case-control data was available only for people who survived. The small number of identified cases limited the statistical power of the study and reduced the ability to detect true associations with behavioural outcomes. Because demographic information for the control group was not reported, it was not possible to assess whether these individuals were suitably matched to the cases. The study depended on cases recalling and reporting their own experiences, which introduced the potential for recall and reporting bias. In addition, adjustment for potential confounding factors was not reported for all outcomes.

Health inequalities

The majority of evidence identified in this systematic evidence summary came from people aged under 25 years of age (22 of the 26 cases included). However, the findings were not reported by age and therefore it was not possible to determine whether there were differences between age groups. No evidence was identified on ethnicity or deprivation, which were key demographic and social factors considered of interest for this systematic evidence summary.

Limitations

This systematic evidence summary used streamlined systematic methods to accelerate the rapid evidence summary 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.

The available evidence on behaviours associated with transmission in meningococcal disease outbreaks in closed congregation social settings was very limited. The studies did not all include frequency of other activities, such as sharing of beverage glasses or cigarettes, close contact while dancing, or alcohol consumption.

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.

Included studies were case-control studies and outbreak reports. Evidence from these types of studies is generally considered lower quality than controlled studies or adjusted cohort studies, and there are important methodological considerations. Small sample sizes, lack of controlling for other factors that could have affected the outcome and relying on self-reporting of behaviour-related outcomes limit the generalisability of evidence identified.

The number of people with meningococcal disease in the included studies ranged from 8 to 9, which are not sufficient to show true associations between behaviours and may not reflect

outcomes that are generalisable to larger groups. Self-reported information on social behaviours that may increase transmission, such as intimate kissing, sexual activity, sharing drinks, cigarettes or vapes, smoking, or activities that increase exposure to respiratory secretions (including singing, shouting, coughing and sneezing), is subject to several limitations. These behaviours may be under-reported because individuals feel uncomfortable disclosing activities perceived as risky or socially sensitive. Recall bias is also more likely, especially when participants are asked to remember specific behaviours during social events that took place in crowded social environments where alcohol or drugs may have been consumed.

Evidence gaps

This systematic evidence summary looked for evidence on the source or route of transmission and the behaviours associated with transmission in meningococcal disease outbreaks in closed congregation social settings. No evidence relating to the source or route of transmission (such as transmission through direct contact, infectious respiratory particles (droplet or aerosol), or contaminated surfaces) was identified.

For social behaviours associated with transmission, no evidence was identified on kissing, sexual activity, sharing drinks, vaping or sharing vapes and for behaviours that increase exposure to respiratory secretions, no evidence was identified on singing, shouting, coughing or sneezing.

No studies reported transmission of meningococcal serogroup B; all identified evidence related only to meningococcal serogroup C.

Conclusion

The systematic evidence summary identified 3 studies that reported behaviours associated with transmission in meningococcal disease outbreaks in closed congregation social settings. No evidence on the source or route of transmission of meningococcal disease outbreaks in closed congregation social settings was identified.

Three studies investigated behaviours that may increase susceptibility to meningococcal disease in these settings. Cigarette smoking, passive smoking, sharing cigarettes or sharing alcoholic drinks were found to not be associated with increased likelihood of meningococcal disease, though findings were based on very small numbers and self-reported behaviours and therefore might not reflect true associations. No evidence was identified on other behaviours of interest, such as intimate kissing, vaping, or other activities that increase exposure to respiratory secretions. The studies did not provide data that allowed transmission source or route to be determined.

No study provided data that enabled consideration of health inequalities and whether outcomes differed in different groups.

Critical appraisal was not performed, which restricts the interpretation of the findings, however study limitations were highlighted within the report. Included evidence consisted mainly of case-control studies and outbreak reports with small sample sizes. These types of studies are generally considered lower-quality designs which are more likely to be affected by methodological limitations such as not controlling for other factors that may affect the outcome, and reliance on self-reported behaviours.

Overall, the available evidence was limited in quantity and quality. From the evidence available, behaviours such as cigarette smoking, passive smoke exposure, sharing cigarettes or alcoholic drinks were reported not to be associated with transmission, however the number of cases were likely too small to show any true associations. Therefore, no firm conclusions can be drawn on definitive behaviours that contribute to meningococcal spread in closed congregation social settings.

Acknowledgments

We would like to thank colleagues within the All Hazards Public Health Response division who either reviewed or input into aspects of the systematic evidence summary.

Disclaimer

UKHSA's rapid systematic reviews and 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 and systematic evidence summaries:

- 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 or evidence summary

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References

1. Cookson ST and others. 'Disco fever: epidemic meningococcal disease in northeastern Argentina associated with disco patronage' Journal of Infectious Diseases 1998: volume 178, issue 1, pages 266 to 269
2. Imrey PB and others. 'Outbreak of serogroup C meningococcal disease associated with campus bar patronage' American Journal of Epidemiology 1996: volume 143, issue 6, pages 624 to 630
3. Gorla MCO and others. 'Phenotypic and molecular characterization of serogroup C Neisseria meningitidis associated with an outbreak in Bahia, Brazil' Enfermedades Infecciosas y Microbiología Clínica 2012: volume 30, issue 2, pages 56 to 59

Annexe A. Protocol

Review question

The review question is:

1. What are the sources or routes of transmission and the behaviours associated with transmission in meningococcal outbreaks in closed congregation social settings?

A search for primary evidence to answer this review question will be conducted up to 25 March 2026.

Eligibility criteria

Table A.1. Inclusion and exclusion criteria

	Included	Excluded
Population	Humans (all ages) • children (aged up to and including 17 years) • young adults (aged 18 to 25 years) • adults	Animals
Settings	Closed congregation social settings, for example: nightclubs, sex on premises venues, music venues, bars, student parties, religious venues, other crowded indoor social settings	Educational settings, for example: universities and schools
Context	Meningococcal disease outbreak (Standard definition is 2 or more cases linked by time, place, person)	
Intervention or exposure	Meningococcal infection (index case confirmed with meningococcal disease)	
Comparator	N/A	
Outcomes	Source of transmission or transmission route for example, direct contact, infectious respiratory particles (droplet or aerosol), fomite, respiratory Social behaviours associated with transmission: for example, intimate kissing, sexual activity,	

	Included	Excluded
	sharing drinks, cigarettes or vapes, active or passive smoking Behaviours that increase exposure to respiratory secretions (singing, shouting, coughing and sneezing	
Language	English	Any other language
Date of publication	Up to 25 March 2026	
Study design	Observational studies including cohort studies, case control studies, cross sectional studies Descriptive studies including case series or outbreak reports	Reviews (all types) Experimental studies including randomised-controlled trials, quasi-experimental studies, cross-over designs, before-and-after studies Modelling studies Qualitative studies Mixed methods Case reports
Publication type	Peer-reviewed published research Preprints	Conference abstracts Editorials Letters News articles Grey literature

Identification of studies

The following databases will be searched for studies published up to March 25, 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, date, study design, setting, participants, 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.

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:

- ethnicity and deprivation
- age

Search strategy

Ovid Medline (1 January 1946 to 25 March 2026)

1. exp Meningococcal Infections/ (12,165)
2. exp Meningitis, Meningococcal/ (5,802)
3. Meningitis, Bacterial/ (8,189)
4. (meningococc* adj5 (infect* or disease* or strain* or meningit*)).tw,kf. (9,324)
5. invasive meningococc*.tw,kf. (1,696)
6. meningococcosis.tw,kf. (14)
7. (meningit* and (septic?em* or sepsis or bacter?em*)).tw,kf. (9,249)

8. (meningococc* and (septic?em* or sepsis or bacter?em*)).tw,kf. (1,979)
9. exp Neisseria meningitidis/ (10,640)
10. neisseria mening*.tw,kf. (9,638)
11. "N.meningitidis".tw,kf. (3,192)
12. (meningococc* adj2 A).tw,kf. 2,165)
13. (meningit* adj3 A).tw,kf. (11,535)
14. (meningococc* adj2 B).tw,kf. (1,726)
15. (meningit* adj3 B).tw,kf. (2,266)
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. (131)
23. (meningit* adj3 Y).tw,kf. (185)
24. exp Sepsis/ and Meningitis/ (1,311)
25. serogroup* A.tw,kf. (1,633)
26. serogroup* B.tw,kf. (2,466)
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. (297)
31. MenA.tw,kf. (2,006)
32. MenB.tw,kf (721)
33. MenC.tw,kf. (455)
34. MenW.tw,kf. (140)
35. MenX.tw,kf. (72)
36. MenY.tw,kf. (108)
37. or/1-36 (46,425)
38. nightclub*.tw,kf. (593)
39. night club*.tw,kf. (102)
40. night spot*.tw,kf. (4)
41. late night venue*.tw,kf. (4)
42. (social adj3 (club* or gathering* or event* or venue* or space* or place* or environment*)).tw,kf. (42,294)
43. (venue* adj5 (dance* or dancing or music* or gig* or band* or concert* or comedy or performance* or party or parties or entertainment or event* or show* or seated or unseated or ticketed)).tw,kf. (605)
44. (facilit* adj5 (dance* or dancing or music* or gig* or band* or concert* or comedy or performance* or party or parties or entertainment or event* or show* or seated or unseated or ticketed)).tw,kf. (23,496)

45. (event* adj5 (dance* or dancing or music* or gig* or band* or concert* or comedy or party or parties or entertainment or seated or unseated or ticketed)).tw,kf. (1,954)
46. (hall* adj5 (dance* or dancing or music* or concert* or comedy or performance* or party or parties or entertainment or event*)).tw,kf. (1,555)
47. (club* adj5 (dance* or dancing or music* or comedy or performance* or party or parties or entertainment or event*)).tw,kf. (605)
48. Mass Gatherings/ (189)
49. Crowding/ (4,063)
50. Dancing/ (4,025)
51. Music/ (18,759)
52. (pub or pubs).tw,kf. (3,430)
53. public house*.tw,kf. (97)
54. (bar or bars).tw,kf. (46,753)
55. lounge*.tw,kf. (380)
56. concert*.tw,kf. (47,782)
57. (gig or gigs).tw,kf. (413)
58. (live adj4 (music* or perform* or band* or sing*)).tw,kf. (9,123)
59. ((indoor* or inside) adj5 (festival* or gather* or congregat* or meet* or setting* or convention* or venue* or event*)).tw,kf. (2,309)
60. theatre*.tw,kf. (12,422)
61. theater*.tw,kf. (5,731)
62. cinema*.tw,kf. (3,972)
63. Singing/ (1,644)
64. choir*.tw,kf. (570)
65. ((choral or chorus or singing) adj3 group*).tw,kf. (309)
66. (close* adj3 contact* adj5 (setting* or venue* or environment* or space* or place*)).tw,kf. (494)
67. (crowd* adj5 (setting* or venue* or environment* or space* or place*)).tw,kf. (3,480)
68. (close* adj3 congregat*).tw,kf. (19)
69. (enclosed adj3 (setting* or venue* or environment* or space* or place*)).tw,kf. (1,398)
70. ((indoor or inside) adj3 (setting* or venue* or environment* or space* or place*)).tw,kf. (15,100)
71. funeral*.tw,kf. (1,555)
72. wedding*.tw,kf. (738)
73. (bar mitzvah* or bat mitzah*).tw,kf. (6)
74. (commun* adj3 (celebrati* or gathering* or event*)).tw,kf. (3,840)
75. (karaoke adj4 (club* or booth* or room*)).tw,kf. (9)
76. sex on premises venue*.tw,kf. (55)
77. sauna*.tw,kf. (1,277)
78. (spa or spas).tw,kf. (16,258)
79. (club* adj3 (sex* or swinger* or lifestyle* or masturbat* or erotic or adult* or strip*)).tw,kf. (315)

80. (venue* adj3 (sex* or swinger* or lifestyle* or masturbat* or erotic or adult* or strip*)).tw,kf. (453)
81. bathhouse*.tw,kf. (204)
82. bath house*.tw,kf. (35)
83. backroom*.tw,kf. (31)
84. back room*.tw,kf. (30)
85. brothel*.tw,kf. (518)
86. (student* adj5 (party or parties)).tw,kf. (169)
87. (universit* adj5 (party or parties)).tw,kf. (78)
88. (college* adj5 (party or parties)).tw,kf. (149)
89. (religio* adj3 (venue* or event* or ceremon* or gathering* or rite* or place*)).tw,kf. (998)
90. church*.tw,kf. (9,539)
91. chapel*.tw,kf. (1,571)
92. mosque*.tw,kf. (509)
93. synagogue*.tw,kf. (85)
94. temple*.tw,kf. (3,761)
95. cathedral*.tw,kf. (354)
96. gurdwara*.tw,kf. (7)
97. (worship* adj3 (place* or venue* or hall* or gathering*)).tw,kf. (235)
98. or/38-97 (285,679)
99. 37 and 98 (247)
100. limit 99 to (comment or editorial or letter or news or newspaper article) (7)
101. 99 not 100 (240)

Embase (1 January 1976 to 25 March 2016)

1. exp meningococcosis/ (15,157)
2. exp epidemic meningitis/ (3,785)
3. exp bacterial meningitis/ (33,130)
4. (meningococc* adj5 (infect* or disease* or strain* or meningit*)).tw,kf. (10,774)
5. invasive meningococc*.tw,kf. (2,026)
6. meningococcosis.tw,kf. (10)
7. (meningit* and (septic?em* or sepsis or bacter?em*)).tw,kf. (12,860)
8. (meningococc* and (septic?em* or sepsis or bacter?em*)).tw,kf. (2,532)
9. exp Neisseria meningitidis/ (17,739)
10. neisseria mening*.tw,kf. (11,186)
11. "N. meningitidis".tw,kf. (3,726)
12. (meningococc* adj2 A).tw,kf. (2,701)
13. (meningit* adj3 A).tw,kf. (14,250)
14. (meningococc* adj2 B).tw,kf. (2,176)
15. (meningit* adj3 B).tw,kf. (2,668)
16. (meningococc* adj2 C).tw,kf. (1,680)
17. (meningit* adj3 C).tw,kf. (1,249)

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/ (10,149)
25. serogroup* A.tw,kf. (1,926)
26. serogroup* B.tw,kf. (2,842)
27. serogroup* C.tw,kf. (1,687)
28. serogroup* W-135.tw,kf. (82)
29. serogroup* X.tw,kf. (140)
30. serogroup* Y.tw,kf. (348)
31. MenA.tw,kf. (2,741)
32. MenB.tw,kf. (917)
33. MenC.tw,kf. (574)
34. MenW.tw,kf. (150)
35. MenX.tw,kf. (87)
36. MenY.tw,kf. (127)
37. or/1-36 (79,367)
38. exp nightclub/ (52)
39. nightclub*.tw,kf. (716)
40. night club*.tw,kf. (138)
41. night spot*.tw,kf. (6)
42. late night venue*.tw,kf. (5)
43. (social adj3 (club* or gathering* or event* or venue* or space* or place* or environment*)).tw,kf. (51,497)
44. (venue* adj5 (dance* or dancing or music* or gig* or band* or concert* or comedy or performance* or party or parties or entertainment or event* or show* or seated or unseated or ticketed)).tw,kf. (773)
45. (facilit* adj5 (dance* or dancing or music* or gig* or band* or concert* or comedy or performance* or party or parties or entertainment or event* or show* or seated or unseated or ticketed)).tw,kf. (29,119)
46. (event* adj5 (dance* or dancing or music* or gig* or band* or concert* or comedy or party or parties or entertainment or seated or unseated or ticketed)).tw,kf. (2,481)
47. (hall* adj5 (dance* or dancing or music* or concert* or comedy or performance* or party or parties or entertainment or event*)).tw,kf. (2,075)
48. (club* adj5 (dance* or dancing or music* or comedy or performance* or party or parties or entertainment or event*)).tw,kf. (747)
49. exp mass gathering/ (604)
50. exp "crowding (area)"/ (11,127)
51. exp dancing/ (8,703)
52. exp music/ (28,633)

53. (pub or pubs).tw,kf. (5,655)
54. public house*.tw,kf. (95)
55. (bar or bars).tw,kf. (58,004)
56. lounge*.tw,kf. (608)
57. concert*.tw,kf. (56,733)
58. (gig or gigs).tw,kf. (477)
59. (live adj4 (music* or perform* or band* or sing*)).tw,kf. (13,500)
60. ((indoor* or inside) adj5 (festival* or gather* or congregat* or meet* or setting* or convention* or venue* or event*)).tw,kf. (2,782)
61. theatre*.tw,kf. (25,379)
62. theater*.tw,kf. (7,567)
63. cinema*.tw,kf. (4,264)
64. exp singing/ (5,165)
65. exp "choir (singing)"/ (211)
66. choir*.tw,kf. (814)
67. ((choral or chorus or singing) adj3 group*).tw,kf. (422)
68. (close* adj3 contact* adj5 (setting* or venue* or environment* or space* or place*)).tw,kf. (602)
69. (crowd* adj5 (setting* or venue* or environment* or space* or place*)).tw,kf. (3,869)
70. (close* adj3 congregat*).tw,kf. (24)
71. (enclosed adj3 (setting* or venue* or environment* or space* or place*)).tw,kf. (1,689)
72. ((indoor or inside) adj3 (setting* or venue* or environment* or space* or place*)).tw,kf. (18,512)
73. exp posthumous care/ (9,186)
74. funeral*.tw,kf. (1,961)
75. wedding*.tw,kf. (933)
76. (bar mitzvah* or bat mitzah*).tw,kf. (7)
77. (commun* adj3 (celebrati* or gathering* or event*)).tw,kf. (5,597)
78. (karaoke adj4 (club* or booth* or room*)).tw,kf. (13)
79. sex on premises venue*.tw,kf. (91)
80. sauna*.tw,kf. (1,688)
81. (spa or spas).tw,kf. (25,509)
82. (club* adj3 (sex* or swinger* or lifestyle* or masturbat* or erotic or adult* or strip*)).tw,kf. (356)
83. (venue* adj3 (sex* or swinger* or lifestyle* or masturbat* or erotic or adult* or strip*)).tw,kf. (621)
84. bathhouse*.tw,kf. (240)
85. bath house*.tw,kf. (30)
86. backroom*.tw,kf. (38)
87. back room*.tw,kf. (34)
88. brothel*.tw,kf. (595)
89. (student* adj5 (party or parties)).tw,kf. (224)
90. (universit* adj5 (party or parties)).tw,kf. (130)

91. (college* adj5 (party or parties)).tw,kf. (180)
92. (religio* adj3 (venue* or event* or ceremon* or gathering* or rite* or place*)).tw,kf. (1,247)
93. church*.tw,kf. (10,955)
94. chapel*.tw,kf. (2,755)
95. mosque*.tw,kf. (785)
96. synagogue*.tw,kf. (88)
97. temple*.tw,kf. (5,877)
98. cathedral*.tw,kf. (409)
99. gurdwara*.tw,kf. (16)
100. (worship* adj3 (place* or venue* or hall* or gathering*)).tw,kf. (316)
101. or/38-100 (393,863)
102. 37 and 101 (480)
103. limit 102 to (conference abstract or conference paper or "conference review" or editorial or letter) (124)
104. 102 not 103 (356)

Web of Science Preprint Citation Index

Date of search: 1 January 1990 - 25 March 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)

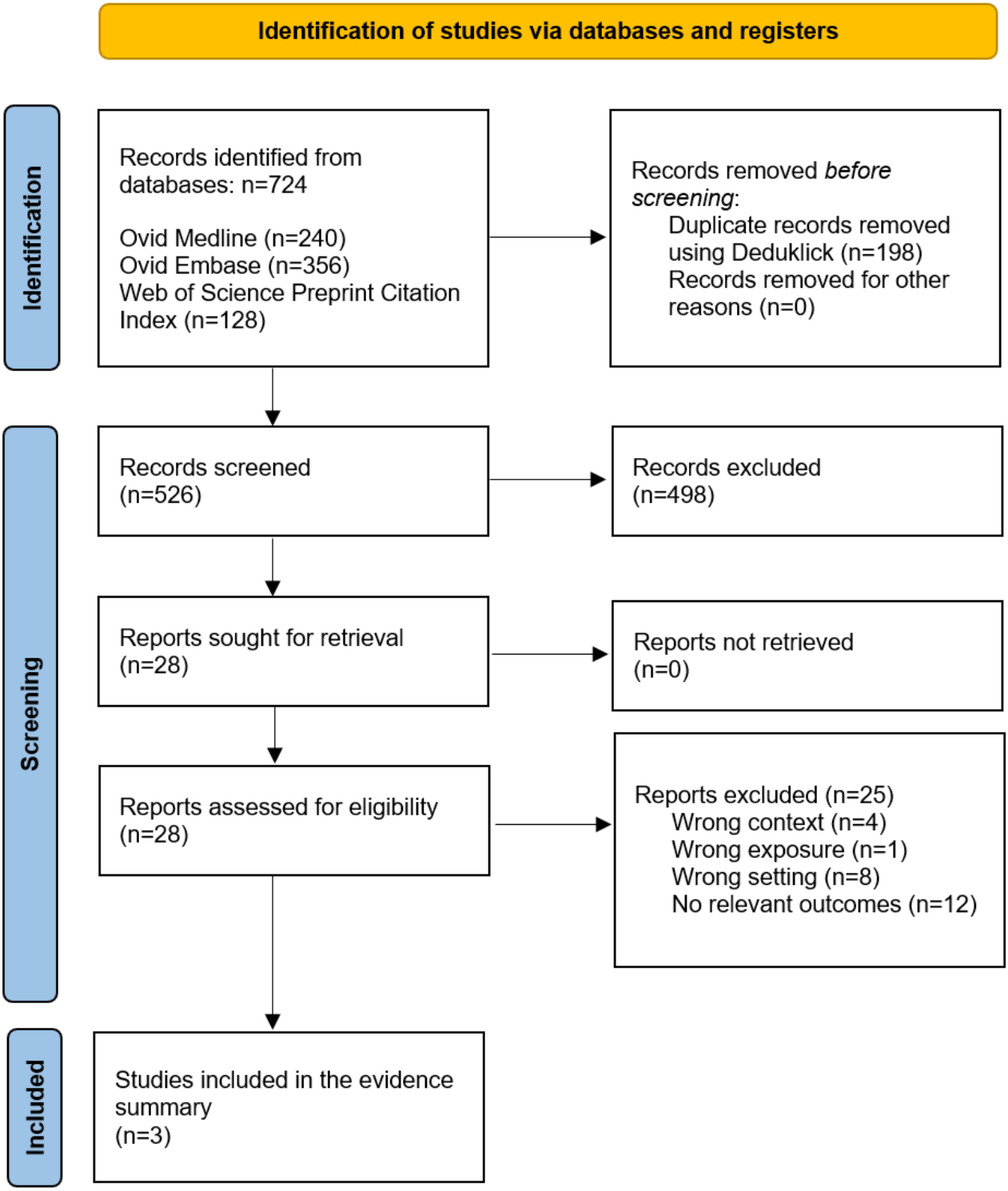
AND

TS=(nightclub) OR TS=(night NEAR/2 (club* or spot*)) OR TS=(“late night venue*”) OR TS=(social NEAR/3 (club* or gathering* or event* or venue* or space* or place* or environment*)) OR TS=(venue* NEAR/5 (dance* or dancing or music* or gig* or band* or concert* or comedy or performance* or party or parties or entertainment or event* or show* or seated or unseated or ticketed)) OR TS=(facilit* NEAR/5 (dance* or dancing or music* or gig* or band* or concert* or comedy or performance* or party or parties or entertainment or event* or show* or seated or unseated or ticketed)) OR TS=(event* NEAR/5 (dance* or dancing or music* or gig* or band* or concert* or comedy or party or parties or entertainment or seated or unseated or ticketed)) OR TS=(hall* NEAR/5 (dance* or dancing or music* or concert* or

comedy or performance* or party or parties or entertainment or event*)) OR TS=(club* NEAR/5 (dance* or dancing or music* or comedy or performance* or party or parties or entertainment or event*)) OR TS=(“mass gathering*”) OR TS=(crowd*) OR TS=(danc*) OR TS=(pub*) OR TS=(“public house*”) OR TS=(bar*) OR TS=(lounge*) OR TS=(concert*) OR TS=(gig or gigs) OR TS=(live NEAR/4 (music* or perform* or band* or sing*)) OR TS=((indoor* or inside) NEAR/5 (festival* or gather* or congregat* or meet* or setting* or convention* or venue* or event*)) OR TS=(theatre* or theater*) OR TS=(cinema*) OR TS=(sing*) OR TS=(choir*) OR TS=((choral or chorus or singing) NEAR/3 group*) OR TS=((close* NEAR/3 contact*) NEAR/5 (setting* or venue* or environment* or space* or place*)) OR TS=(crowd* NEAR/5 (setting* or venue* or environment* or space* or place*)) OR TS=(close* NEAR/3 congregat*) OR TS=(enclosed NEAR/3 (setting* or venue* or environment* or space* or place*)) OR TS=((indoor* or inside) NEAR/3 (setting* or venue* or environment* or space* or place*)) OR TS=(funeral*) OR TS=(wedding*) OR TS=(“bar mitzvah*” or “bat mitzvah*”) OR TS=(commun* NEAR/3 (celebrati* or gathering* or event*)) OR TS=(karaoke NEAR/4 (club* or booth* or room*)) OR TS=(“sex on premises venue*”) OR TS=(sauna*) OR TS=(spa*) OR TS=(club* NEAR/3 (sex* or swinger* or lifestyle* or masturbat* or erotic or adult* or strip*)) OR TS=(venue* NEAR/3 (sex* or swinger* or lifestyle* or masturbat* or erotic or adult* or strip*)) OR TS=(bathhouse*) OR TS=(“bath house*”) OR TS=(backroom*) OR TS=(“back room*”) OR TS=(brothel*) OR TS=(student* NEAR/5 (party or parties)) OR TS=(universit* NEAR/5 (party or parties)) OR TS=(college* NEAR/5 (party or parties)) OR TS=(religio* NEAR/3 (venue* or event* or ceremon* or gathering* or rite* or place*)) OR TS=(church*) OR TS=(chapel*) OR TS=(mosque*) OR TS=(synagogue*) OR TS=(temple*) OR TS=(cathedral*) OR TS=(gurdwara*) OR TS=(worship* NEAR/3 (place* or venue* or hall* or gathering*))
Results: 128

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 4 studies.

From identification of studies via databases and registers, n=724 records identified from databases:

- Ovid Medline (n=240)
- Ovid Embase (n=356)
- Web of Science Preprint Citation Index (n=128)

From these, records removed before screening:

- duplicate records removed using Deduklick (n=198)
- records removed for other reasons (n=0)

n=526 records screened, of which n=498 were excluded, leaving n=28 papers sought for retrieval, of which n=0 were not retrieved.

Of the n=28 papers assessed for eligibility, n=25 reports were excluded:

- wrong context (n=4)
- wrong exposure (n=1)
- wrong setting (n=8)
- no relevant outcomes (n=12)

n=3 papers included in the evidence summary.

Annexe C. Excluded full texts

Wrong context (4 studies)

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,article e0244716

Grein T and others. 'Day-care and meningococcal disease in young children' Epidemiology and Infection 2001: volume 127, issue 3, pages 435 to 441

Mebonia N and others. 'Unexpected non-seasonal increase of bacterial meningitis cases in Georgia in 2009' Georgian Medical News 2010: issue 184, pages 44 to 50

Terrat Y and others. 'Two cases of type-a Haemophilus influenzae meningitis within the same week in the same hospital are phylogenetically unrelated but recently exchanged capsule genes' bioRxiv 2019

Wrong exposure (1 study)

Hubert B and others. 'An outbreak of pneumonia and meningitis caused by a previously undescribed gram-negative bacterium in a hot spring spa' Epidemiology and Infection 1991: volume 107, issue 2, pages 373 to 381

Wrong setting (8 studies)

Al-Gahtani YM and others. 'Epidemiological investigation of an outbreak of meningococcal meningitis in Makkah (Mecca), Saudi Arabia, 1992' Epidemiology and Infection 1995: volume 115, issue 3, pages 399 to 409

Arnold C and others. 'Day care attendance and other risk factors for invasive Haemophilus influenzae type b disease' American Journal of Epidemiology 1993: volume 138, issue 5, pages 333 to 340

Honish L and others. 'Modifiable risk factors for invasive meningococcal disease during an Edmonton, Alberta outbreak, 1999-2002' Canadian Journal of Public Health. Revue Canadienne de Sante Publique 2008: volume 99, issue 1, pages 46 to 51

Kratz MM and others. 'Community-Based Outbreak of Neisseria meningitidis Serogroup C Infection in Men who Have Sex with Men, New York City, New York, USA, 2010-2013' Emerging Infectious Diseases 2015: volume 21, issue 8, pages 1,379 to 1,386

Mandal S and others. 'Prolonged university outbreak of meningococcal disease associated with a serogroup B strain rarely seen in the United States' Clinical Infectious Diseases 2013: volume 57, issue 3, pages 344 to 348

Menichetti F and others. 'Invasive Meningococcal Disease due to group C *N. meningitidis* ST11 (cc11): The Tuscany cluster 2015-2016' Vaccine 2018: volume 36, issue 40, pages 5,962 to 5,966

Olea A and others. 'Case-control study of risk factors for meningococcal disease in Chile' Emerging Infectious Diseases 2017: volume 23, issue 7, pages 1,070 to 1,078

Round A and others. 'Public health management of an outbreak of group C meningococcal disease in university campus residents' European Journal of Public Health 2001: volume 11, issue 4, pages 431 to 436

No relevant outcomes (12 studies)

Abad R and others. 'Outbreak of invasive meningococcal disease caused by a meningococcus serogroup B expressing a rare porA genosubtype (19-54, 15), Spain, March to April 2024' Euro Surveillance: European Communicable Disease Bulletin 2025: volume 30, issue 44

Aubert L and others. 'Serogroup C invasive meningococcal disease among men who have sex with men and in gay-oriented social venues in the Paris region: July 2013 to December 2014' Euro Surveillance: European Communicable Disease Bulletin 2015: volume 20, issue 3

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

Burmaz T and others. 'Organization or Community-Based Outbreak? Responding to Cases of Meningitis Under Epidemiologic Uncertainty' Disaster Medicine and Public Health Preparedness 2019: volume 13, issue 2, pages 368 to 371

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

Gilmore A and others. 'Meningococcal disease at the University of Southampton: outbreak investigation' Epidemiology and Infection 1999: volume 123, issue 2, pages 185 to 192

Hauri AM and others. 'Serogroup C meningococcal disease outbreak associated with discotheque attendance during carnival' Epidemiology & Infection 2000: volume 124, issue 1, pages 69 to 73

Jelfs J and others. 'A cluster of meningococcal disease in western Sydney, Australia initially associated with a nightclub' Epidemiology and Infection 1998: volume 120, issue 3, pages 263 to 270

McLaughlin JB and others. 'Association of regulatory issues with an echovirus 18 meningitis outbreak at a children's summer camp in Alaska' Pediatric Infectious Disease Journal 2004: volume 23, issue 9, pages 875 to 877

Perron L and others. 'Four cases of *Neisseria meningitidis* infection linked to frequenting a bar--Quebec' Canada Diseases Weekly Report 1991: volume 17, issue 52, pages 294 to 295

Riesbeck K and others. 'Long-term persistence of a discotheque-associated invasive *Neisseria meningitidis* group C strain as proven by pulsed-field gel electrophoresis and porA gene sequencing' Journal of Clinical Microbiology 2000: volume 38, issue 4, pages 1,638 to 1,640

Stefanelli P and others. 'An outbreak of severe invasive meningococcal disease due to a capsular switched *Neisseria meningitidis* hypervirulent strain B :cc11' Clinical Microbiology and Infection 2019: volume 25, issue 1, pages 111.e1 to 111.e4

Annexe D. Data extraction tables

Table D.1. Summary of studies investigating behaviours associated with transmission
Abbreviations: OR: odds ratio, CI: confidence interval.

Study	Country, time period	Setting	Meningitis type and diagnosis	Population	Transmission outcome	Behaviour outcome
Cookson ST and others 1998 (1)	Argentina, 5 to 14 August 1996	Corrientes (Argentina)	Lab confirmed: Seven isolates were confirmed as *Neisseria meningitidis* (*N. meningitidis*) through culture. One case had gram-negative diplococci observed on Gram stain, consistent with *N. meningitidis*, although culture confirmation was not obtained. Of the eight cases, 6 were confirmed as serogroup C, one case was identified only by Gram stain, with serogroup undetermined One case was culture-positive for *N. meningitidis* but was not serogrouped. Diagnosis by *N. meningitidis* being isolated from cerebrospinal fluid or Gram's stain showing gram-negative diplo-cocci from cerebrospinal fluid or tissue confirmed by at least 2 observers.	Cases: 8 Sex: 6 men, 2 women Case outcome: 1 died (man), 7 survived Age: 15 to 45 years (5 between 15 and 19 years) Ethnicity: not reported Health inequalities: not reported Control: 32 (4 cases were matched to 4 each neighbourhood school controls and the other 4 cases to 4 each neighbourhood block controls). 5 out of 32 controls went to the disco No demographic data for controls reported Five out of the 8 cases attended the same disco. One man and the 2 women cases did not attend the disco, and the origin of their meningococcal infection is not known.	Not reported	Cigarette smoking Passive only Cases: 3 out of 8 (38%) Control: 8 out of 32 (25%) OR: 1.6 (95% CI 0.2 to 11.2, p=0.49) Active (more than one a day) Cases: 4 out of 8 (50%) Control: 6 out of 32 (19%) OR: 6.0 (95% CI 0.6 to 50.0, p=0.077) Passive or active Cases: 7 out of 8 (88%) Control: 14 out of 32 (44%) OR: 5.7 (95% CI 0.9 to 391, p=0.008) In subgroup analysis, men who were exposed to the category combining passive or active smoking were more likely to be a case-patient (data not reported) p=0.008. No subgroup analysis in females was reported Other 2 of the 5 control-patients who went to disco A took antimicrobials for upper respiratory tract symptoms (without symptoms of oropharyngitis) after this exposure Case patients and controls had comparable numbers of people living in their households, similar numbers of rooms in their homes, and similar histories of contact with individuals who had upper respiratory tract infections during the preceding 2 weeks. None of the cases or controls had received meningococcal vaccination.

Study	Country, time period	Setting	Meningitis type and diagnosis	Population	Transmission outcome	Behaviour outcome
Gorla and others 2012 (3)	Brazil, 21 to 26 October 2009	Dance party (rural site - unclear if indoor or outdoor)	*N. meningitidis* serogroup C, ST-103 complex. Meningococcal isolates belonged to *N. meningitidis* serogroup C, ST-103 complex and were laboratory confirmed with serogroups either by isolation of *N. meningitidis* serogroup C in blood or cerebrospinal fluid (5/9, 55.5%), or by detection of serogroup C meningococcal polysaccharide in cerebrospinal fluid by latex agglutination (4/9; 44.5%)	Cases: 9 Sex: 7 men, 2 women Case outcome: 6 died (4 males; 2 females), 3 survived (3 males) Age: 14 to 39 years Ethnicity: not reported Health inequalities: not reported All cases, except for one 39-year-old man, attended the same dance party	Not reported	4 out of 9 cases (1 died, 3 survived) were users of illicit drugs or used cocaine at the party
Imrey PB and others 1996 (2)	USA, February 1991 to April 1992	US residential university	Serogroup C meningococcal disease recovered from all but one patient Diagnosis was established either by isolating *N. meningitidis* from blood or cerebrospinal fluid, or through a positive latex agglutination test performed on cerebrospinal fluid or blood to detect meningococcal antigen.	Cases: 9 Sex: 5 men, 4 women Case outcome: 3 died (2 men, 1 woman); 6 survived (3 men, 3 women) Age: 18 to 22 years Ethnicity: 8 white, one Asian Health inequalities: not reported Controls: 117 (between 17 and 21 controls obtained per case) Controls were randomly selected from the university phone directory, and community college controls were chosen randomly from the university phone directory or from computer records.	Not reported	Cigarette smoking (unadjusted) Cases: 4 out of 6 Controls: 23 out of 117 OR: 7.8 (95% CI 1.3 to 64.4, p=0.012) Cigarette smoking (multiple logistic regression model (adjusted for recent bar exposure, frequency of respiratory illness and number of people sleeping in the same room) p=0.11(OR and 95% CIs not reported) Sharing of drinks by alcohol drinkers (unadjusted) Raw data not reported OR: 4.3 (95% CI 0.7 to 36.1, p=0.11) Sharing of cigarettes by cases who smoked (unadjusted) Raw data not reported OR: 8.0 (95% CI 0.6 to 264.6, p=0.13

Study	Country, time period	Setting	Meningitis type and diagnosis	Population	Transmission outcome	Behaviour outcome
				No demographic data for controls reported. 7 of the 9 cases attended campus-area bars during the 2 weeks preceding illness 6 of the 9 cases had attended the same campus bar. No cases shared common housing or lived in the same dormitory. One case had had a respiratory infection during the 2 weeks prior to onset of meningococcal disease.		

About the UK Health Security Agency

UK Health Security Agency (UKHSA) prevents, prepares for and responds to infectious diseases and environmental, radiological and chemical hazards, to keep all our communities safe, save lives and protect livelihoods. We provide scientific and operational leadership, working with local, national and international partners to protect the public's health.

UKHSA is an executive agency, sponsored by the Department of Health and Social Care.

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