UK Health Security Agency

The impact of vaping on transmission of meningococcal infection

A systematic evidence summary

Contents

Main messages

1. This systematic evidence summary (search up 22 April 2026) identified and summarised evidence relating to the impact of the use of vapes or shisha pipes (also known as water or hookah pipes) on transmission of meningococcal infection.

2. Three studies were included, of which one was a prospective longitudinal cohort study (1), one used baseline data from a cluster randomised controlled trial (RCT) (2), and one was a cross-sectional study (3). One study was conducted in the USA (1), one in Australia (2), and one in Iran (3).

3. Two studies were conducted in university students who lived in university housing (1, 3), and one was conducted in school children (2). All studies reported on the risk of carriage of *N. Meningitidis* associated with the use of vapes (1) or shisha pipes (2, 3).

4. Two of the 3 studies reported that the use of vapes or shisha pipes increased the risk of carriage of *N. Meningitidis* compared to not using vapes or shisha pipes when adjusted for other factors that may affect the outcome (confounding factors) (1, 2). The third study found that, after adjusting for possible confounding factors, the association of shisha pipe use and carriage of *N. Meningitidis* was not statistically significant.

5. All 3 studies also reported on the risk of smoking cigarettes in relation to carriage of *N. Meningitidis* in the same populations in which the risk of vaping was assessed. However, the risk of smoking was not directly compared to vaping in any study (1 to 3). All studies reported that cigarette smoking increased the risk of carriage of *N. Meningitidis* compared to those who had not smoked a cigarette.

6. Critical appraisal was not performed, which restricts the interpretation of the findings, but important limitations of the evidence have been highlighted. Evidence was limited to 3 studies, with only a small number of people who were carriers of *N. Meningitidis* reporting using either a vape, shisha pipe or cigarette in the last week. The evidence relied on self-reported use of vapes, shisha pipes and cigarettes which may have been underreported due to recall or social desirability bias. Evidence was not from outbreaks of meningococcal disease and therefore was not directly relevant to the review question. In addition, all studies were conducted in school children or university students residing on campus, which restricts the ability to generalise to other settings or populations.

7. In summary, 2 out of 3 studies identified reported that the use of a vape or shisha pipe increased the risk of carriage of *N. Meningitidis* after adjusting for confounding factors. There was no comparison between risk from vaping and smoking. Evidence identified in this review was limited to 3 studies, was not formally critically appraised due to the rapid methods used and was limited by sample size and a reliance on self-reported data and

only reporting carriage, which limits the certainty with which any conclusions can be drawn. Further research is therefore needed to determine whether there is an association between vaping or the use of vapes and transmission of meningococcal infection.

Purpose

The purpose of this systematic evidence summary was to identify and summarise the available evidence on the impact of the use of vapes or shisha pipes (also known as water or hookah pipes) on transmission of meningococcal infection.

The review question was:

1. What is the available evidence on the impact of vaping in transmission of meningococcal infection?

If evidence identified for question 1, the secondary review question was:

2. Are there differences in the role of vaping in transmission of meningococcal infection compared to smoking?

This systematic evidence summary was commissioned following the meningococcal disease outbreak in Kent in March 2026 to inform ongoing work as part of the response and future outbreak preparedness.

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 experimental (including randomised controlled trials and quasi-experimental studies), observational (including cohort, cross-sectional, and case-control studies), and descriptive studies (including case series and outbreak reports) published or available as preprint, up to 22 April 2026. Three databases were searched: OVID Medline, OVID Embase, and Web of Science Preprint Citation Index.

Studies were included if they were conducted in children aged 12 to 17 years, or adults aged 18 years and over, and evaluated the effect of vaping (including e-cigarettes) or shisha pipe (including hookah or water pipes) smoking on any measure of human-to-human transmission of meningococcal infection.

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 2 deviations to the study protocol:

- the context was widened from ‘outbreaks of meningococcal disease (all serogroups A, B, C, W, X, and Y; laboratory-confirmed) to ‘Any’ to include any evidence from outside the context of an outbreak
- measures of carriage of *N. Meningitidis* were included as outcomes

Screening on title and abstracts was undertaken in duplicate by 2 reviewers for 100% of eligible studies. 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, 13 studies were screened at title and abstract and 4 studies were screened at full text. Of these, 3 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.

Three studies were identified that assessed the impact of the use of a vape (n=1) (1) or a shisha pipe (n=2) (2, 3) on the risk of carriage of *N. Meningitidis*: one cluster-RCT (data on impact of vaping on carriage only available at baseline) (2), one prospective longitudinal cohort study (1), and one cross-sectional study (3). One study was conducted in Australia (2), one in the USA (1), and one in Iran (3). One study was conducted in school children aged 15 to 18 years (2), and 2 in young adults (university students) (1, 3). The studies also reported on the effect of smoking on risk of carriage of *N. Meningitidis* in the same populations. The included studies are summarised in Table D.1.

Arnold and others reported on the association of using a vape with carriage of *N. Meningitidis* as part of a prospective longitudinal study on carriage of *N. Meningitidis* in the USA between August and November 2022 (1). Students who lived in university housing were asked to provide throat swabs on 3 occasions (baseline sampling within 48 hours of arrival on campus for the semester, then at 4 and 12 weeks after the baseline visit). This study reported the association of using a vape with carriage of *N. Meningitidis* in people who provided a baseline sample (n=1,047; age: 19.1 years [SD: 1.5 years], 60.0% women, 5.1% Asian, 16.0% African American, 68.0% white, 11% mixed/other, 0.1% information on ethnicity not reported), and those who provided swabs at all 3 visits (n=821; age: 19.1 years [SD: 1.6 years], 60% female, 5.7% Asian, 16% African American, 67% white, 10% mixed/other). They adjusted for other factors that may have impacted the results in all analyses (confounding factors). The factors adjusted for were race, student status, residential status (campus housing, living in a dormitory), smoking tobacco or cigarettes, cannabis or pot (marijuana, weed, grass) in the last week, attendance at a party in the last week, kissing or sexual contact in the last week, and vaccination status.

In students who provided a throat swab at the baseline visit only, those who reported vaping in the last week were approximately 2.7 times more likely to carry *N. Meningitidis* than those who did not (36 swabs positive for *N. Meningitidis,* adjusted OR: 2.69, 95% CI= 1.2 to 6.02, p=0.0164). In students who attended all 3 study visits, those who reported vaping in the last week were approximately 1.8 times more likely to carry *N. Meningitidis* than those who did not (106 swabs positive for *N. Meningitidis,* OR: 1.77, 95% CI= 1.09 to 2.87, p=0.0203).

Arnold and others also assessed the risk of smoking on carriage of *N. Meningitidis* in the same population, although they did not do any statistical comparison to the risk from vaping (1). In those who presented at baseline only, people who reported smoking tobacco or cigarettes in the last week were approximately 2.7 times more likely to carry *N. Meningitidis* than those who did not (adjusted OR: 2.69, 95% CI= 1.2 to 6.02, p= 0.0164). In those who attended all 3 study visits, people who reported smoking tobacco or cigarettes in the last week were approximately 1.7 times more likely to carry *N. Meningitidis* than those who did not (adjusted OR: 1.72, 95% CI= 0.94 to 3.15, p= 0.0081).

Marshall and others reported on the association of smoking a shisha pipe with carriage of *N. Meningitidis* in children aged 15 to 18 years, as part of a larger cluster RCT conducted to test the effect of vaccination on carriage of *N. Meningitidis* in Australia (2). Information on shisha pipe use was available in the baseline data, and associations between smoking and carriage of *N. Meningitidis* were reported in both groups. All children enrolled in the academic year 2017 to 2018 from 237 school were included, resulting in 34,389 children included. Of these, 18,362 students (mean age: 16 years [SD 1 year], 52.9% girls, ethnicity not reported) were in the intervention (vaccination) group, and 16,127 students were in control group which received no vaccination (mean age: 16 years [SD 1.3 years], 50.9% girls, ethnicity not reported). The number of people who were carriers of *N. Meningitidis* at baseline (identified by throat swab) was reported for the following:

- carriage of disease-causing *N. Meningitidis* (n=668 of 34,389 [1.9%], serogroups B, C, W, X, Y)
- carriage of any *N. Meningitidis* (n=1,252 of 34,389 [3.6%], serogroups B, C, W, X, Y, or undetermined)

They adjusted for confounding factors, including: sex/gender, year of schooling, current upper respiratory tract infection, smoking of cigarettes in past week, days out at pub or club in past week, number of persons kissed intimately in the last week, boarding school status, race or ethnic group, school socio-economic category, school size, school location, antibiotic use, vape use, and current relationship status.

The study reported that children who had smoked a shisha pipe in the last week were approximately 1.8 times more likely to carry disease-causing *N. Meningitidis* (adjusted OR: 1.82, 95% CI= 1.30 to 2.54), and 1.9 times more likely to carry any *N. Meningitidis* (adjusted OR: 1.89, 95% CI= 1.47 to 2.45) than those who had not smoked a shisha pipe.

Marshall and others also assessed the risk of smoking on carriage in the same population, although they did not undertake a statistical comparison to the risk of vaping (2). In children who reported smoking a cigarette in the last week, the risk of carriage of disease-causing *N. Meningitidis* was approximately 1.9 times higher than in those who did not smoke in the last week (OR: 1.91, 95% CI: 1.29 to 2.83). The risk of carriage of any *N. Meningitidis* was approximately 2.2 times higher than those who did not smoke in the last week (OR: 2.24, 95% CI: 1.67 to 3.00).

Sadeghi and others conducted a cross-sectional study of students living in dormitories at a university in Iran in the academic year of 2017 to 2018 (3). They assessed the association between shisha pipe smoking and carriage of *N. Meningitidis*. In this study of 335 men (age: 21.4 years [SD: 2.7 years], ethnicity not reported), 23 were identified as carriers of *N. Meningitidis* (serogroup C [43.5%] or undetermined [56.5%]) by throat swabs. The study reported that when adjusting for active cigarette smoking, exposure to smoke (passive smoking), presence of respiratory infection, antibiotic use, vaccination history and length of stay in dormitory, there was no significant association between shisha pipe smoking and carriage of *N. Meningitidis* ($p>0.05$, OR not reported).

In this same population, active smokers were found to have statistically significantly higher rates of carriage of *N. Meningitidis* (serogroup C or undetermined serogroup) compared with those who did not smoke when adjusted for confounding factors (exposure to smoke [passive smoking], presence of respiratory infection, antibiotic use, vaccination history, length of stay in dormitory), with active cigarette smokers approximately 5 times more likely to carry *N. Meningitidis* than non-smokers (OR = 5.02, 95% CI: 1.89 to 13.35, $p<0.05$).

Health inequalities

Within this review, variations for populations or sub-groups in whom the outcome may differ were considered, including those in educational settings, those in different ethnic groups, and children who remain unvaccinated (see Annexe A for full list).

In the prospective cohort study by Arnold and others, all students lived in university housing (1). The risk of carriage was presented in various sub-groups including by race, whether or not the individual lived in a dormitory, party attendance in the last week, and year of study.

Demographics related to health inequalities are presented in Table D.1, however, the effect of vaping on carriage of *N. Meningitidis* in the different sub-groups was not reported. Confounders controlled for in adjusted analysis on the effect of using a vape on risk of carriage of *N. Meningitidis* included ethnicity, residential status (living in campus housing or a dormitory), and attendance at a party in the last week.

In the cluster RCT by Marshall and others, none of the children included were vaccinated for meningococcal disease at baseline (2). The study also reported on baseline demographics and risk of carriage in the following sub-groups; those who attend boarding school, those who had attended a high-risk setting such as a pub or club in the last week, school deprivation level, ethnic group, and by school year group. Baseline demographics related to health inequalities are presented in Table D.1, however, comparisons of the effect of shisha pipe smoking on carriage of *N. Meningitidis* in the different sub-groups was not reported. Adjusted analyses for the risk of vaping on carriage controlled for confounders including whether they were at boarding school, year of schooling, had attended a pub or club in the last week, ethnic group, and school socioeconomic group.

In the cross-sectional study by Sadeghi and others, all participants were students who resided in dormitories at a university in Iran (3). After adjusting for confounders, this study did not find vaping to be statistically significantly associated with carriage of *N. Meningitidis.*

Limitations

This systematic evidence 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.

The available evidence on the impact of vaping on transmission of meningococcal infection was limited to 3 studies that reported on the risk of carriage in those who used vapes or shisha pipes compared to those who did not. The only available evidence was from carriage studies outside of the context of an outbreak of meningococcal disease. In all studies, the use of a vape or shisha pipe was self-reported. As such, the frequency of use of these may be underreported due to social desirability or recall bias.

The proportion and number of people within each study who were carriers of *N. Meningitidis* and reported the use of a vape, shisha pipe or cigarette was limited and may be too small to show true associations.

All studies were conducted in education settings (one study in school children, and 2 in university students who were living on campus). Findings from these studies may not be generalisable to other contexts.

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.

Evidence gaps

No evidence was identified on direct measures of human-to-human transmission (reproduction number, incidence of infection, serial interval and generation interval) including where there was a case of confirmed meningococcal disease. No evidence was identified in outbreak contexts.

No evidence was identified in adults older than 25 years who were not in education.

No studies were identified that directly compared the impact of vaping to smoking tobacco on any measure of carriage or transmission.

Conclusion

In summary, 2 out of 3 studies identified reported that the use of a vape or shisha pipe increased the risk of carriage of *N. Meningitidis* after adjusting for confounding factors. The third study found that, after adjusting for confounding factors, there was no significant association of shisha pipe use and carriage of *N. Meningitidis*. There was no comparison available between risk from vaping and smoking, but studies did report the effect of smoking a cigarette on carriage of *N. Meningitidis* in the same populations. Although not directly compared to vaping, investigations in these studies all reported an increased risk of carriage of *N. Meningitidis* in those who had reported smoking in the last week compared to those who had not smoked a cigarette.

Evidence identified in this review was not formally critically appraised due to the rapid methods used, but the main limitations included that there were only 3 studies with small sample sizes and a reliance on self-reported data only reporting on carriage, which limits the certainty with which any firm conclusions can be drawn. Further research is therefore needed to determine whether there is an association between transmission of meningococcal infection.

Acknowledgments

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

Disclaimer

References

1. Arnold FW and others. 'Meningococcal carriage and transmission dynamics in college students in Louisville, Kentucky' PLOS ONE [Electronic Resource] 2026: volume 21, issue 3, e0344194
2. Marshall HS and others. 'Meningococcal B Vaccine and Meningococcal Carriage in Adolescents in Australia' New England Journal of Medicine 2020: volume 382, issue 4, pages 318 to 327
3. Sadeghi M and others. 'Prevalence of meningococcal carriage among male university students living in dormitories in Kerman, southeast of Iran' Pathogens and Global Health 2018: volume 112, issue 6, pages 329 to 333

Annexe A. Protocol

Review question

The review question is:

1. What is the available evidence on the impact of vaping in transmission of meningococcal infection?

If evidence identified for question 1, the secondary review question will be:

2. Are there differences in the role of vaping in transmission of meningococcal infection compared to smoking?

A search for primary evidence to answer this review question will be conducted up to 22 April 2026.

Eligibility criteria

Table A.1. Inclusion and exclusion criteria

	Included	**Excluded**
Population	Humans: • children (aged between 12 and 17 years) • adults (18 years and over) ○ young adults 18 to 25 years	Animals
Context	Any	
Settings	Any	
Exposure	Vaping Shisha/Hookah	
Comparator	**For question 2 only:** Smoking	
Outcomes	Any measure of human-to-human transmission of meningococcal infection, including: • reproduction number	

	Included	**Excluded**
	• incidence of infection • serial interval • generation interval	
Language	English	Any other language
Date of publication	Up to 22 April 2026	
Study design	Experimental studies including randomised-controlled trials, quasi-experimental studies Observational studies including cohort studies, case control studies, cross sectional studies Descriptive studies including case series or outbreak reports	Cross-over studies Before-and-after studies Case reports Systematic or narrative reviews Modelling studies Qualitative studies Mixed methods studies
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 22 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, exposure, comparators, participants, results, any potential confounders, and any relevant contextual data. This will be undertaken by one reviewer and checked by a second. Data that is only available in graphs or figures and not in text will not be extracted.

Risk of bias assessment

Risk of bias of included studies will not be assessed in this systematic evidence summary due to time constraints.

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 the risk of bias 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 for whom the outcome of meningococcal disease may differ will be considered, where evidence is available:

- those in educational settings, (including schools, further education colleges, sixth form, SEN schools, universities), considering difference by year group (both school and university)
- children (aged under 18 years) who remain unvaccinated
- those who reside in potentially high-risk settings for disease transmission including in education (boarding schools, university halls), and other residential settings such as childrens' homes, adult social care settings, prisons and places of detention, asylum and migrant settings, homeless settings
- those in different ethnic groups
- by deprivation
- those who work in or who have visited higher risk congregate workplaces or entertainment venues (warehouses, factories, nightclubs, sex on premises venues, music venues, bars, student parties, religious venues, choir practices, other crowded indoor social settings)

Search strategy

Ovid Medline (1 January 1945 to 22 April 2026)

1. exp Meningococcal Infections/ (12,174)
2. exp Meningitis, Meningococcal/ (5,805)
3. Meningitis, Bacterial/ (8,198)
4. (meningococc* adj5 (infect* or disease* or strain* or meningit*)).tw,kf. (9,341)
5. invasive meningococc*.tw,kf. (1,702)
6. meningococcosis.tw,kf. (14)
7. (meningit* and (septic?em* or sepsis or bacter?em*)).tw,kf. (9,278)
8. (meningococc* and (septic?em* or sepsis or bacter?em*)).tw,kf. (1,983)
9. exp Neisseria meningitidis/ (10,654)
10. neisseria mening*.tw,kf. (9,659)
11. "N. meningitidis".tw,kf. (3,194)
12. (meningococc* adj2 A).tw,kf. (2,168)
13. (meningit* adj3 A).tw,kf. (11,571)
14. (meningococc* adj2 B).tw,kf. (1,730)
15. (meningit* adj3 B).tw,kf. (2,271)
16. (meningococc* adj2 C).tw,kf. (1,392)
17. (meningit* adj3 C).tw,kf. (990)
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. (78)

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. (1,635)
26. serogroup* B.tw,kf. (2,473)
27. serogroup* C.tw,kf. (1,483)
28. serogroup* W-135.tw,kf. (68)
29. serogroup* X.tw,kf. (118)
30. serogroup* Y.tw,kf. (299)
31. MenA.tw,kf. (2,028)
32. MenB.tw,kf. (727)
33. MenC.tw,kf. (456)
34. MenW.tw,kf. (141)
35. MenX.tw,kf. (72)
36. MenY.tw,kf. (108)
37. or/1-36 (46,542)
38. Vaping/ (5,227)

39. vape*.tw,kf. (2,464)
40. vaping.tw,kf. (5,460)
41. Electronic Nicotine Delivery Systems/ (10,364)
42. (electr* adj4 nicotine).tw,kf. (3,091)
43 (electr* adj4 smok*).tw,kf. (1,549)
44. (novel adj2 (tobacco or nicotine)).tw,kf. (464)
45. e-cig*.tw,kf. (11,531)
46. ecig*.tw,kf. (236)
47. e-smok*.tw,kf. (74)
48. esmok*.tw,kf. (1)
49. vapo?ri#er*.tw,kf. (1,661)
50. (electr* adj4 inhal*).tw,kf. (456)
51. juul*.tw,kf. (477)
52. (heated tobacco adj4 (product* or device* or pen* or deliver*)).tw,kf. (925)
53. (heated nicotine adj4 (product* or device* or pen* or deliver*)).tw,kf. (2)
54. (heated smoking adj4 (product* or device* or pen* or deliver*)).tw,kf. (2)
55. electr* hooka*.tw,kf. (10)
56. e-hooka*.tw,kf. (31)
57. ehooka*.tw,kf. (0)
58. hooka* pen*.tw,kf. (9)
59. electr* shisha*.tw,kf. (2)
60. e-shisha*.tw,kf. (6)
61. eshisha*.tw,kf. (0)
62. shisha* pen*.tw,kf. (4)
63. electr* pipe*.tw,kf. (55)
64. e-pipe*.tw,kf. (35)
65. epipe*.tw,kf. (962)
66. (smoking adj2 pipe*).tw,kf. (487)
67. (dab* adj3 (pen* or rig*)).tw,kf. (58)
68. pod mod*.tw,kf. (117)
69. or/38-68 (21,864)
70. 37 and 69 (9)
71. limit 70 to (comment or editorial or letter or news or newspaper article) (0)
72. 70 not 71 (9)

Embase (1 January 1974 to 22 April 2026)

1. exp meningococcosis/ (15,209)
2. exp epidemic meningitis/ (3,790)
3. *bacterial meningitis/ (11,483)
4. (meningococc* adj5 (infect* or disease* or strain* or meningit*)).tw,kf. (10,811)
5. invasive meningococc*.tw,kf. (2,037)
6. meningococcosis.tw,kf. (10)

7. (meningit* and (septic?em* or sepsis or bacter?em*)).tw,kf. (12,910)
8. (meningococc* and (septic?em* or sepsis or bacter?em*)).tw,kf. (2,538)
9. exp Neisseria meningitidis/ (17,786)
10. neisseria mening*.tw,kf. (11,216)
11. "N. meningitidis".tw,kf. (3,735)
12. (meningococc* adj2 A).tw,kf. (2,709)
13. (meningit* adj3 A).tw,kf. (14,289)
14. (meningococc* adj2 B).tw,kf. (2,186)
15. (meningit* adj3 B).tw,kf. (2,674)
16. (meningococc* adj2 C).tw,kf. (1,683)
17. (meningit* adj3 C).tw,kf. (1,249)
18. (meningococc* adj2 W).tw,kf. (167)
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. (162)
23. (meningit* adj3 Y).tw,kf. (208)
24. exp sepsis/ and meningitis/ (10,201)
25. serogroup* A.tw,kf. (1,929)
26. serogroup* B.tw,kf. (2,851)
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. (349)
31. MenA.tw,kf. (2,797)
32. MenB.tw,kf. (925)
33. MenC.tw,kf. (575)
34. MenW.tw,kf. (151)
35. MenX.tw,kf. (87)
36. MenY.tw,kf. (127)
37. or/1-36 (66118)
38. exp vaping/ (9,214)
39. vape*.tw,kf. (3,425)
40. vaping.tw,kf. (7,231)
41. exp electronic cigarette/ (17,340)
42. (electr* adj4 nicotine).tw,kf. (3,646)
43. (electr* adj4 smok*).tw,kf. (2,146)
44. (novel adj2 (tobacco or nicotine)).tw,kf. (570)
45. e-cig*.tw,kf. (14,410)
46. ecig*.tw,kf. (747)
47. e-smok*.tw,kf. (87)
48. esmok*.tw,kf. (2)
49. vapo?ri#er*.tw,kf. (2,182)

50. (electr* adj4 inhal*).tw,kf. (702)
51. juul*.tw,kf. (720)
52. (heated tobacco adj4 (product* or device* or pen* or deliver*)).tw,kf. (1,060)
53. (heated nicotine adj4 (product* or device* or pen* or deliver*)).tw,kf. (1)
54. (heated smoking adj4 (product* or device* or pen* or deliver*)).tw,kf. (2)
55. electr* hooka*.tw,kf. (24)
56. e-hooka*.tw,kf. (49)
57. ehooka*.tw,kf. (2)
58. hookah/ (1094)
59. hooka* pen*.tw,kf. (11)
60. electr* shisha*.tw,kf. (2)
61. e-shisha*.tw,kf. (8)
62. eshisha*.tw,kf. (0)
63. shisha*.tw,kf. (704)
64. electr* pipe*.tw,kf. (73)
65. e-pipe*.tw,kf. (44)
66. epipe*.tw,kf. (1685)
67. (dab* adj3 (pen* or rig*)).tw,kf. (65)
68. pod mod*.tw,kf. (130)
69. or/38-68 (30,864)
70. 37 and 69 (17)
71. limit 70 to (conference abstract or conference paper or "conference review" or editorial or letter) (7)
72. 70 not 71 (10)

Web of Science Preprint Citation Index

Search date: 22 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

TS=(vape* or vaping) OR TS=(electr* NEAR/4 (cig* or nicotine or smok* or hooka* or shisha* or pipe* or inhal*)) OR TS=(e-cig*) OR TS=(ecig*) OR TS=(e-smok*) OR TS=(esmok*) OR TS=(e-hooka*) OR TS=(ehooka*) OR TS=("hooka* pen*") OR TS=(e-pipe*) OR TS=(epipe*) OR TS=(shisha*) OR TS=(novel NEAR/2 (tobacco or nicotine)) OR TS=(vaporiser or vapouriser or vaporizer or vapourizer) OR TS=(juul*) OR TS=("heated tobacco" NEAR/4 (product* or device* or pen* or deliver*)) OR TS= ("heated nicotine" NEAR/4 (product* or device* or pen* or deliver*)) OR TS=("heated smoking" NEAR/4 (product* or device* or pen* or deliver*)) OR TS=(dab* NEAR/3 (pen* or rig*)) OR TS=("pod mod*")

Results: 0

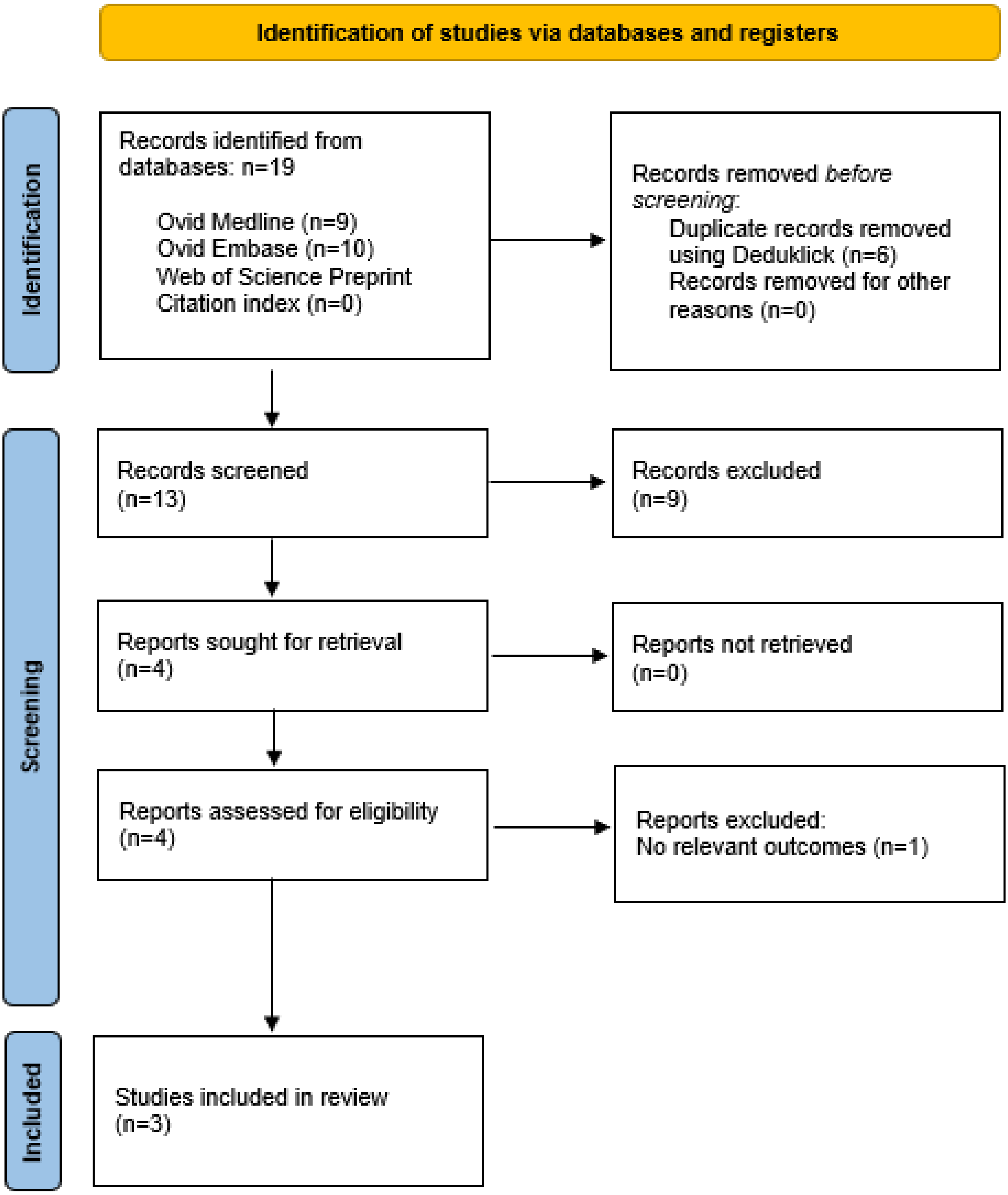
Deviations

There were 2 deviations to the study protocol:

- the context was widened from 'outbreaks of meningococcal disease (all serogroups A, B, C, W, X, and Y; laboratory-confirmed) to 'Any' to include any evidence from outside the context of an outbreak
- measures of carriage of *N. Meningitidis* were included as outcomes

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 3 studies.

From identification of studies via databases and registers, n=19 records identified from databases:

- Ovid Medline (n=9)
- Ovid Embase (n=10)
- Web of Science Preprint Citation Index (n=0)

From these, records removed before screening:

- duplicate records removed using Deduklick (n=6)
- records removed for other reasons (n=0)

n=13 records screened, of which n=9 were excluded, leaving n=4 papers sought for retrieval, of which n=0 were not retrieved.

Of the n=4 papers assessed for eligibility, n=1 report was excluded:

- no relevant outcomes (n=1)

n=3 papers included in the review.

Annexe C. Excluded full texts

No relevant outcomes (1 study)

Mohammed H and others. 'Social and behavioral predictors of two-doses 4CMenB vaccine series among adolescents enrolled in a cluster randomized controlled trial in Australia' Human Vaccines and Immunotherapeutics 2022: volume 18, issue 1, 1953345

Annexe D. Data extraction tables

Table D.1. Summary of studies reporting the impact of vaping on transmission of meningococcal infection

Abbreviations: CI: confidence interval, ISCEA: Index of Community, Socio-Educational Advantage, N. meningitidis: Neisseria Meningitidis, OR: Odds ratio, PCR: Polymerase Chain Reaction, USA: United States of America

Study, Year Country, time period Study type	Population (including reported health inequalities	Meningitis	Exposure	Confounding factors adjusted for in analyses	Review question one: impact of vaping on transmission	Review question 2: comparisons with smoking
Arnold FW and others, 2026 (1) USA, August to November 2022 Prospective cohort	Students who completed baseline visit (n=1,047): Age: 19.1 years (SD: 1.5 years) Gender: 40% men (423 out of 1,047) Race: Asian: 54 out of 1,047 (5.1%) African American: 171 out of 1,047 (16.0%) White: 711 out of 1,047 (68.0%) Mixed/other: 110 out of 1,047 (11.0%) Missing: 1 out of 1,047 (0.1%) Ethnicity: Hispanic: 67 out of 1,047 (6.4%) Non-Hispanic: 902 out of 1,047 (86.0%) Not specific: 78 out of 1,047 (7.4%) Students residing in university-housing: 100% Student status (year of study): 1st Year: 775 out of 1,047 (74.0%)	Throat swab Genomic sequencing to identify genogroup. At any visit, rate of carriage varied from between 1.1% and 2.5% of people swabbed. Genogroup undetermined was the most frequently carried, followed by genogroup B, genogroup E, then genogroup Z. Further details of genogroup breakdowns by visit, as well as clonal complexes of isolates, are	Vape	• race • student status • residential status (campus housing, living in a dormitory) • smoking tobacco or cigarettes, • nicotine vapes or cannabis or pot in the last week • attendance at a party in the last week • kissing or sexual contact in the last week • vaccination status	Students who completed baseline visit and reported smoking a vape in the last week: • unadjusted OR compared to those who did not report vape use: 3.61 (95% CI= 1.65 to 7.93, p= 0.0014) • adjusted OR compared to those who did not report vape use: 2.69 (95% CI= 1.2 to 6.02, p= 0.0164) Students who provided swabs at 3 visits and reported smoking a vape in the last week: • unadjusted OR compared to those who did not report vape use: 3.13 (95% CI= 2.09 to 4.69, p < 0.0001) • adjusted OR compared to those who did not report	The impact of vaping and smoking were not directly compared, but the association of smoking and carriage of *N. meningitidis* in the same population was presented. Students who completed baseline visit and reported smoking cigarette in the last week: • unadjusted OR compared to those who did not smoke in the last week: 3.68 (95% CI= 1.11 to 12.15, p= 0.0327) • adjusted OR compared to those who did not smoke in the last week: 2.69 (95% CI= 1.2 to 6.02, p= 0.0164) Students who completed 3 visits and reported smoking cigarette in the last week: • unadjusted OR compared to those

Study, Year Country, time period Study type	Population (including reported health inequalities	Meningitis	Exposure	Confounding factors adjusted for in analyses	Review question one: impact of vaping on transmission	Review question 2: comparisons with smoking
	2nd Year: 179 out of 1,047 (17.0%) 3rd Year: 63 out of 1,047 (6.0%) 4th Year: 23 out of 1,047 (2.2%) 5th Year or higher: 7 out of 1,047 (0.7%) Vape use and smoking status not reported for the full population Students who provided swabs at 3 visits (n=821): Age: 19.1 years (SD: 1.6 years) Gender: 40% men (329 out of 821) Race: Asian: 47 out of 821 (5.7%) African American: 136 out of 821 (16.0%) White: 552 out of 821 (67.0%) Mixed or other: 86 out of 821 (10.0%) Ethnicity: Hispanic: 51 out of 821 (6.2%) Non-Hispanic: 718 out of 821 (88.0%) Not specific: 52 out of 821 (6.3%) Students residing in university-housing: 100% Student status (year of study): 1st Year: 597 out of 821 (73.0%)	available in the original paper.			vape use: 1.77 (95% CI= 1.09 to 2.87, p= 0.0203)	who did not smoke in the last week: 3.73 (95% CI= 2.19 to 6.36, p< 0.0001) • adjusted OR compared to those who did not smoke in the last week: 1.72 (95% CI= 0.94 to 3.15, p= 0.0081)

Study, Year Country, time period Study type	Population (including reported health inequalities	Meningitis	Exposure	Confounding factors adjusted for in analyses	Review question one: impact of vaping on transmission	Review question 2: comparisons with smoking
	2nd Year: 150 out of 821 (18.0%) 3rd Year: 49 out of 821 (6.0%) 4th Year: 19 out of 821 (2.3%) 5th Year or higher: 6 out of 821 (0.7%) Students who smoked nicotine vape in last week: Visit 1: 117 out of 821 (14.0%) Visit 2: 140 out of 821 (17.0%) Visit 3: 161 out of 821 (20.0%) Students who smoked tobacco/cigarettes in last week: Visit 1: 31 out of 821 (3.8%) Visit 2: 47 out of 821 (5.7%) Visit 3: 63 out of 821 (7.7%) Students who smoked cannabis or pot (marijuana, weed, grass) in last week: Visit 1: 103 out of 821 (13.0%) Visit 2: 145 out of 821 (18.0%) Visit 3: 168 out of 821 (21.0%) Method of use (among those who reported smoking cannabis or pot in last week): Visit 1: Bong: 16 out of 821 (2.0%) Bowl: 10 out of 821 (1.2%) Joint: 35 out of 821 (4.3%) Vape: 38 out of 821 (4.6%)					

Study, Year Country, time period Study type	Population (including reported health inequalities	Meningitis	Exposure	Confounding factors adjusted for in analyses	Review question one: impact of vaping on transmission	Review question 2: comparisons with smoking
	Other: 4 out of 821 (0.5%) Visit 2: Bong: 18 out of 821 (2.2%) Bowl: 12 out of 821 (1.5%) Joint: 54 out of 821 (6.6%) Vape: 53 out of 821 (6.5%) Other: 8 out of 821 (1.0%) Visit 3: Bong: 21 out of 821 (2.6%) Bowl: 18 out of 821 (2.2%) Joint: 66 out of 821 (8.0%) Vape: 55 out of 821 (6.7%) Other: 8 out of 821 (1.0%) Students who smoked by sharing device: Visit 1: 33 out of 821 (4.0%) Visit 2: 48 out of 821 (5.9%) Visit 3: 63 out of 821 (7.7%)					
Marshall and others, 2020 (2) Australia, June 2017 to 2018 Cluster RCT	n=34,489 students [A]: • Intervention group: n=18,362 • Control group: 16,127 Age: Intervention group: 16 years (SD: 1.0 years) Control group: 16 years (SD: 1.3 years)	Throat swab, confirmed by PCR *N. meningitidis* genogroup A, B, C, W, X and Y. Samples and isolates were classified as not able to be grouped if the capsule biosynthesis genes for these	Shisha pipe	Analysis of disease-causing genogroups at baseline: • sex • year of schooling • current upper respiratory tract infection • smoking of cigarettes in past week • smoking of shisha pipe in the last week	Students carrying disease - causing *N. meningitidis* (B, C, W, X and Y) at baseline: • adjusted OR for those who smoked a shisha pipe in the last week compared to those who did not: 1.82 (95% CI= 1.30 to 2.54) Students carrying any *N. meningitidis* at baseline:	The impact of vaping and smoking were not directly compared, but the association of smoking and carriage of *N. meningitidis* in the same population was presented. Students carrying disease - causing *N. meningitidis* (B, C, W, X and Y) at baseline: • adjusted OR for those who smoked a cigarette in the

Study, Year Country, time period Study type	Population (including reported health inequalities)	Meningitis	Exposure	Confounding factors adjusted for in analyses	Review question one: impact of vaping on transmission	Review question 2: comparisons with smoking
	Age range: 15 to 18 years (students in Years 10, 11 and 12) Gender: Intervention group: 52.9% girls (9,713 out of 18,362) Control group: 50.9% girls (8,210 out of 16,127) Year of schooling: Year 10: Intervention group: 6,576 out of 18,362 (35.8%) Control group: 6,188 out of 16,127 (38.4%) Year 11: Intervention group: 6,170 out of 18,362 (33.6%) Control group: 5,335 out of 16,127 (33.1%) Year 12 or 13: Intervention group: 5,616 out of 18,362 (30.6%) Control group: 4,604 out of 16,127 (28.6%) Smoked vape in last week: Intervention group: 170 out of 18,199 (0.9%)	genogroups were not detected The most frequently detected genogroups were B (carriage in 1.2% of intervention group, 0.9% of control group), followed by Y (carriage in 0.6% of intervention group, 0.7% of control group), w (carriage in 0.2% of intervention group, 0.1% of control group), C (carriage in 0.05% of intervention group, 0.07% of control group), and X (carriage in 0.03% of intervention group, 0.01% of control group). Disease causing refers to all genotypes identified (B, C, W, X, Y)		• days out at pub or club in past week • number of persons kissed intimately in the last week • boarding student • race or ethnic group • school ISCEA category • school size • school location • antibiotic use • vape use • current relationship status Analysis of all genogroups at baseline: • gender • year of schooling • current cold or school throat • smoking of cigarettes in past week • smoking of shisha pipe in the last week • days out in past week • number of persons kissed in the last week • boarding student • ethnicity • school type (private/public)	• adjusted OR for those who smoked a shisha pipe in the last week compared to those who did not: 1.89 (95% CI= 1.47 to 2.45)	last week compared to those who did not: 1.91 (95% CI: 1.29 to 2.83) Students carrying any *N. meningitidis* at baseline: • adjusted OR for carriage of *N. meningitidis* in those who had smoked a cigarette in the last week compared to those who had not: 2.24 (95% CI: 1.67 to 3.00)

Study, Year Country, time period Study type	Population (including reported health inequalities)	Meningitis	Exposure	Confounding factors adjusted for in analyses	Review question one: impact of vaping on transmission	Review question 2: comparisons with smoking
	Control group: 200 out of 15,952 (1.3%) Smoked shisha pipe in last week: Intervention group: 561 out of 18,198 (3.1%) Control group: 481 out of 15,948 (3.0%) Smoked cigarettes in last week: Intervention group: 334 out of 18,257 (1.8%) Control group: 294 out of 16,020 (1.8%) School location for year 10, 11 and 12 students by trial group allocation: Boarding school student: Intervention group: 501 out of 18,284 (2.7%) Control group: 256 out of 16,037 (1.6%) School ISCEA category: Intervention group: low 16.6%, medium 29.2%, high 54.17% Control group: low 21.6%, medium 31.1%, high 47.3% Students carrying disease causing *N. meningitidis* (B, C, W, X or Y) at baseline: Gender:			• school ISCEA category • school size • school location • antibiotic use • vape use • current relationship status		

Study, Year Country, time period Study type	Population (including reported health inequalities	Meningitis	Exposure	Confounding factors adjusted for in analyses	Review question one: impact of vaping on transmission	Review question 2: comparisons with smoking
	Girls: 338 out of 17,909 (1.9%) Boys: 330 out of 16,550 (2.0%) Students who smoked shisha pipe in previous week: No: 600 out of 33,085 (1.8%) Yes: 63 out of 1,042 (6.1%) Students who smoked cigarettes in past week: No: 615 out of 33,630 (1.8%) Yes: 49 out of 628 (7.8%) Days out at pub or club in past week: 0 times: 421 out of 27,226 (1.6%) One or more times: 246 out of 7,064 (3.5%) Boarding student: No: 644 out of 33,546 (1.9%) Yes: 21 out of 756 (2.8%) Ethnicity: White: 506 out of 24,686 (2.1%) Aboriginal or Torres Strait Islander: 32 out of 953 (3.4%) Asian: 31 out of 3,383 (0.9%) Other: 87 out of 4,936 (1.8%) Students carrying any *N. meningitidis* at baseline:					

Study, Year Country, time period Study type	Population (including reported health inequalities	Meningitis	Exposure	Confounding factors adjusted for in analyses	Review question one: impact of vaping on transmission	Review question 2: comparisons with smoking
	Gender: Girls: 633 out of 17,909 (3.5%) Boys: 589 out of 16,550 (3.6%) Students who smoked shisha pipe in last week: No: 1,086 out of 33,085 (3.3%) Yes: 116 out of 1,042 (11.1%) Students who smoked cigarette in last week: No: 1,117 out of 33,630 (3.3%) Yes: 96 out of 628 (15.3%) Days out at pub or club in past week: 0 times out: 767 out of 27,226 (2.8%) One or more times: 452 out of 7,064 (6.4%) Boarding student: No: 1,162 out of 33,546 (3.5%) Yes: 54 out of 756 (7.1%) Ethnicity: Caucasian: 903 out of 24,686 (3.7%) Aboriginal or Torres Strait Islander: 64 out of 953 (6.7%) Asian: 64 out of 3,383 (1.9%) Other: 167 out of 4,936 (3.4%)					

Study, Year Country, time period Study type	Population (including reported health inequalities	Meningitis	Exposure	Confounding factors adjusted for in analyses	Review question one: impact of vaping on transmission	Review question 2: comparisons with smoking
Sadeghi M and others 2018 (3) Iran, October 2017 to March 2018 Cross-sectional	Students residing on campus in dormitories for at least one academic term (n=335): Age: 21.4 years (SD: 2.7 years, range: 18 to 34 years) Gender: 100% male (335 out of 335) Ethnicity: not reported	Throat swab, confirmed by PCR Carriage in 23 individuals: serogroup C (43.5%) and indeterminate (56.5%)	Shisha pipe	• active smoking • exposure to smoke (passive smoking) • presence of respiratory infection • antibiotic use • vaccination history • length of stay in dormitory	**Students who reported shisha pipe smoking:** • unadjusted analysis: Significant association found between shisha pipe smoking and meningococcal carriage (p= 0.018) • adjusted analysis: No effect found between shisha pipe smoking and meningococcal carriage (p value not reported)	The impact of vaping and smoking were not directly compared, but the association of smoking and carriage of *N. meningitidis* in the same population was presented. Students who self-reported as active cigarette smokers: • unadjusted analysis: active cigarette smokers had statistically significantly higher carriage rate of *N Meningitidis* than non-smokers (21.9% vs. 5.3%, p= 0.003) • adjusted analysis: active cigarette smokers were statistically significantly more likely to carry *N Meningitidis* than non-smokers (OR: 5.02, 95% CI: 1.89 to 13.35, p value not reported)

[A] Only baseline data used

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

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Completed: 5 June 2026

Published: August 2026
Publication reference: GOV-21402 (PHR045e)

Suggested citation: Harris T, Bhatia A, Walker J and Carville S. 'The impact of vaping on transmission of meningococcal infection: a systematic evidence review' UKHSA 2025