University of Kent

Kent Academic Repository

McGeoch, Luke J, Clark, Stephen A., Halford, Florence, Patel, Selina, Kumar, Deepti, Olufon, Oluwakemi, Hughes, Daniel, Borrow, Ray, Thompson, Stephen, Manuel, Rohini and others (2026) ***Neisseria meningitidis carriage in university students following a group B invasive meningococcal disease outbreak in Kent, England.*** **Journal of Infection, 93 (6). ISSN 0163-4453.**

Downloaded from

https://kar.kent.ac.uk/117989/ The University of Kent's Academic Repository KAR

The version of record is available from

https://doi.org/10.1016/j.jinf.2026.106898

This document version

Publisher pdf

DOI for this version

Licence for this version

CC BY-NC-ND (Attribution-NonCommercial-NoDerivatives)

Additional information

Versions of research works

Versions of Record

If this version is the version of record, it is the same as the published version available on the publisher's web site. Cite as the published version.

Author Accepted Manuscripts

If this document is identified as the Author Accepted Manuscript it is the version after peer review but before type setting, copy editing or publisher branding. Cite as Surname, Initial. (Year) 'Title of article'. To be published in ***Title of Journal*** , Volume and issue numbers [peer-reviewed accepted version]. Available at: DOI or URL (Accessed: date).

Enquiries

If you have questions about this document contact ResearchSupport@kent.ac.uk. Please include the URL of the record in KAR. If you believe that your, or a third party's rights have been compromised through this document please see our Take Down policy (available from https://www.kent.ac.uk/guides/kar-the-kent-academic-repository#policies).

Journal of Infection 93 (2026) 106898

Contents lists available at ScienceDirect

Journal of Infection

journal homepage: www.sciencedirect.com/journal/journal-of-infection

Bacteria and bacterial diseases

Neisseria meningitidis carriage in university students following a group B invasive meningococcal disease outbreak in Kent, England

Luke J. McGeoch [1,*], Stephen A. Clark [2], Florence Halford [3], Selina Patel [4], Deepti Kumar [3], Oluwakemi Olufon [3], Daniel Hughes [5,6], Ray Borrow [2], Stephen Thompson [6], Rohini Manuel [6], Eliza Alexander [7], Simon Eccles [5,6], Ben Kirkman [5,6], Jonathan Steer [6], Eve Matthews [3], Carmellie Inzoungou-Massanga [3], Neil Bray [3], Nick Andrews [1], Andre Charlett [8], Clare Humphreys [9], Jay Lucidarme [2], Xilian Bai [2], Amoolya Vusirikala [1], Emma J. Heymer [1], Helen Campbell [1], Rebecca Cordery [1], Sema Mandal [10], Aisling Potter [11], Nigel Temperton [12], Pamela Lithgow [13], Campbell Gourlay [14], Steven Riley [4], Trish Mannes [9], Mary Ramsay [1], Richard Pebody [15], Shamez N. Ladhani [1,16]

[1] *Immunisation and Vaccine Preventable Diseases Division, UK Health Security Agency, 61 Colindale Avenue, London NW9 5EQ, UK*
[2] *Meningococcal Reference Unit, UK Health Security Agency, Manchester Royal Infirmary, Manchester M13 9WL, UK*
[3] *Rapid Investigation Team, Field Service, UK Health Security Agency, 10 South Colonnade, Canary Wharf, London E14 4PU, UK*
[4] *Chief Data Officer Group, UK Health Security Agency, 10 South Colonnade, Canary Wharf, London E14 4PU, UK*
[5] *Microbiology Department, Manchester University NHS Foundation Trust, Manchester Royal Infirmary, Manchester M13 9WL, UK*
[6] *Clinical Network Laboratories, Public Health Microbiology, UK Health Security Agency, UK*
[7] *Field Service, UK Health Security Agency, 10 South Colonnade, Canary Wharf, London E14 4PU, UK*
[8] *Statistics, Modelling and Economics Department, UK Health Security Agency, 10 South Colonnade, Canary Wharf, London E14 4PU, UK*
[9] *South-East Health Protection Team, UK Health Security Agency, 10 South Colonnade, Canary Wharf, London E14 4PU, UK*
[10] *Blood Safety, Hepatitis, STI and HIV Division, UK Health Security Agency, 61 Colindale Avenue, London NW9 5EQ, UK*
[11] *Clinical Biochemistry, East Kent Hospitals University NHS Foundation Trust, Canterbury CT1 3NG, UK*
[12] *Viral Pseudotype Unit, Medway School of Pharmacy, University of Kent and University of Greenwich, Chatham ME4 4TB, UK*
[13] *Specialist Resources and Technical Services, Canterbury Christ Church University, Canterbury CT1 1QU, UK*
[14] *School of Natural Sciences, University of Kent, Kent CT2 9HY, UK*
[15] *Epidemic and Emerging Infections Directorate, UK Health Security Agency, 61 Colindale Avenuel, London NW9 5EQ, UK*
[16] *Centre for Neonatal and Paediatric Infections, City St. George's University of London, Cranmer Terrace, London SW17 0RE, UK*

ARTICLE INFO

Keywords:
Neisseria meningitidis
Meningitis
Meningococcal disease
Meningococcal carriage
Antibiotic prophylaxis
Meningococcal vaccine

ABSTRACT

Objectives: In March 2026, an invasive meningococcal disease outbreak in South-East England included 21 cases in young adults. In May 2026, we aimed to investigate carriage of meningococci in nearby universities, including the outbreak strain group B (MenB) ST-485 subtype P1·12–1,16–183.
Methods: Students aged ≥18 years attending three university campuses completed a risk factor questionnaire and oropharyngeal swab for culture. Meningococcal isolates underwent serogrouping and whole genome sequencing. Carriage prevalences were estimated using the Clopper-Pearson exact binomial method. Associations between demographic or behavioural characteristics and carriage were assessed using modified Poisson regression.
Results: Among 1991 participants, 76 meningococcal isolates were identified, including 18 (23·7%) genogroup B. Three isolates (3·9%) were ciprofloxacin resistant. The outbreak strain was not detected. Overall meningococcal carriage was 4·8% (95% CI 3·6–6·1%) among 1242 non-prophylaxed participants and 2·3% (1·3–3·6%) among 747 participants who received ciprofloxacin prophylaxis 6–9 weeks earlier. Higher carriage was associated with residence in shared accommodation (prevalence ratio 2·21, 95% CI 1·19–4·41) compared to a family home and combined smoking/vaping (1·90, 1·10–3·25), while chemoprophylaxis (0·27, 0·15–0·46) and Asian (0·44, 0·22–0·85) or Black (0·17, 0·05–0·42) compared to White ethnicity were associated with lower carriage.

* Correspondence to: Immunisation and Vaccine-Preventable Diseases Division, Public Health Programmes Directorate, Chief Medical Advisor Group, UK Health Security Agency, 10 South Colonnadel, London E14 4PU, UK.
E-mail address: luke.mcgeoch@ukhsa.gov.uk (L.J. McGeoch).

https://doi.org/10.1016/j.jinf.2026.106898
Received 6 November 2026; Accepted 13 November 2026
Available online 18 November 2026
0163-4453/Crown Copyright © 2026 Published by Elsevier Ltd on behalf of British Infection Association. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Conclusion: Lack of outbreak strain carriage may reflect a highly virulent strain and the impact of outbreak control measures. The low overall meningococcal carriage rate continues a decline in carriage among adolescents and young adults over the past 25 years. Meningococcal carriage was lower in chemoprophylaxed students but rapid recolonisation suggests short-lived protection in semi-closed populations with ongoing mixing.

Introduction

Neisseria meningitidis causes invasive meningococcal disease (IMD), a rare but severe bacterial infection associated with high morbidity and mortality [1]. The pathogen can be distinguished into 12 capsular groups based on the unique polysaccharide capsule, of which six (A, B, C, W, X, and Y) are responsible for nearly all IMD globally. Highly effective vaccines are now available against all the major capsular groups causing IMD. In England, IMD incidence has been declining since the early 2000s through a combination of an effective national immunisation programme and secular trends in circulating strains [1]. During 2025–26, there were 348 IMD cases in England; 309 (89%) were caused by serogroup B (MenB) [2]. Cases due to serogroups A, C, W and Y are rare due to the excellent direct and indirect protection offered by the adolescent MenACWY conjugate vaccine since 2015 [3]. Additionally, vaccination against MenB with 4CMenB (Bexsero®, GSK Biologicals), a multicomponent, recombinant protein-based vaccine, has been included in the infant programme since 2015 but was not introduced for adolescents due to the lack of protection against carriage and therefore lack of indirect (herd) protection [4], as well as low case numbers, resulting in unfavourable cost-effectiveness for an adolescent MenB vaccination programme [5].

The vast majority (98–99%) of IMD cases are sporadic but outbreaks can rarely occur, typically involving 2–3 cases, mainly in household settings but occasionally also in educational and other closed settings [6]. In March 2026, South-East England experienced an unprecedentedly large outbreak of MenB-IMD, with 21 confirmed cases within 7 days in adolescents and young adults, including two deaths [7]. Nineteen cases had attended a local nightclub in the previous week, 13 were university students and 10 resided in the same local university campus in Canterbury, Kent. Mass antibiotic prophylaxis with one dose of oral ciprofloxacin was offered to students living in the affected university campus, people who had attended the nightclub during a 10-day period, students in the same secondary school or college groups as cases, and other close contacts. More than 13,000 people received chemoprophylaxis within 10 days of the outbreak being declared and the same group were offered two doses of 4CMenB vaccine [7].

The MenB outbreak strain was identified as sequence type ST-485 (clonal complex 41/44) with Porin A (PorA) subtype P1·12–1,16–183 and belonged to LIN code group 6_0_0_0_1_27_4_18 [8,9]. This novel strain had never previously been isolated in carriage or disease. To better understand future risks associated with the outbreak strain, the UK Health Security Agency (UKHSA) initiated an investigation of meningococcal carriage among university students in Kent in May 2026. The primary objective of the investigation was to estimate carriage prevalence of the outbreak strain in three different populations of university students, including those who had received antibiotic prophylaxis during the outbreak response. Secondary objectives included estimating meningococcal carriage rates overall and by antibiotic prophylaxis status, describing characteristics of *Neisseria meningitidis* in carriage, and assessing risk factors for carriage.

Methods

Study design and participants

We conducted a cross-sectional investigation of meningococcal carriage prevalence among students aged ≥18 years studying in-person at one of three university sites in Kent:

1. ***Site A (denominator ~17,000)***: University campus with the largest number of cases during the March 2026 outbreak and where students were eligible for chemoprophylaxis.
2. ***Site B (denominator ~10,000)***: University campus located in the same city as site A but with only a minority of students eligible for chemoprophylaxis.
3. ***Site C (denominator ~8000)***: Associated university campus located 30 miles away from sites A and B, comprising students from three universities, including the universities represented at sites A and B, with only a minority of students eligible for chemoprophylaxis.

The investigation, which took place 6–9 weeks after the offer of chemoprophylaxis and began 2–3 weeks after students returned to university campuses following the Easter holiday break, was completed over four consecutive days at each site between 05–21 May 2026, beginning at site B and ending at site A. At each site, universities emailed all students with a weblink providing information about the investigation and options to consent online and complete a recruitment questionnaire, which was adapted from previous carriage studies [10,11]. This included information on age, gender, ethnic group, year of study, accommodation type, county of home residence, social mixing (pub, bar, club or party attendance) in the previous 3 months, cigarette smoking and vaping in the previous 3 months, relationship status, intimate kissing in the previous 7 days, receipt of antibiotic prophylaxis and MenB vaccination in response to the outbreak, and receipt of other antibiotics in the previous month. Participants were also recruited in-person on campuses by the investigation team.

At each site, the investigation team set up multiple swabbing units. Participants were assigned a unique identifier linked to their recruitment questionnaire and a flocked oropharyngeal swab (Copan eSwab®) was obtained by a healthcare professional and stored in liquid Amies transport medium. Participants received a £10 gift voucher for their time and expenses. Each evening, swabs were transported at ambient temperature to the Manchester University NHS Foundation Trust microbiology department for immediate plating on selective GC VCAT agar (Oxoid, UK) using an automated WASPLab platform (Copan, Italy). Four 30uL aliquots of vortexed amies medium were used to inoculate each plate before spreading and incubation at 37°C and 5% CO_2. Plates were checked for meningococcal growth at 18- and 40-hour timepoints. Suspected meningococcal isolates were sub-cultured and identified using MALDI-TOF (Bruker Biotyper® Sirius System). Isolates identified as *N. meningitidis* (meningococcal MALDI-TOF score of ≥2·0) were transferred to the co-located UKHSA Meningococcal Reference Unit for confirmation and additional characterisation.

Meningococcal strain characterisation

Meningococcal isolates were serogrouped using an in-house Dot-Blot ELISA assay utilising serogroup-specific monoclonal antibodies (groups A, B, C, W and Y, National Institute for Biological Standards and Control, UK). DNA extraction and genome sequencing were performed by the UKHSA Pathogen Genomics Sequencing Laboratory (Manchester) using the Omega Bio-tek Mag-Bind® Bacterial DNA 96 Kit and Illumina sequencing platforms, respectively. Genome assembly was performed using SPAdes via Shovill (v1·1·0; with minimum contig length 200 and minimum contig coverage 10) [12]. Assembled contigs were uploaded to the PubMLST.org *Neisseria* database for gene annotation and indexing [13]. For isolates with the DNA gyrase (*gyrA*) allele 91I mutation, associated with reduced ciprofloxacin susceptibility, susceptibility to

ciprofloxacin was determined using ETEST® strips (Biomerieux, UK) [14]. A minimum inhibitory concentration (MIC) resistance breakpoint of >0·016 mg/L was applied (EUCAST Clinical Breakpoints version 16·1).

Statistical methods

The primary objective was to estimate carriage prevalence of the outbreak strain (LIN code 6_0_0_0_1_27_4_18_0_0_0) among university students in the three campuses. This was a public health investigation

Table 1
Characteristics of included participants.

	Site A (n = 1000)		Site B (n = 488)		Site C (n = 503)		Combined (n = 1991)	
	n	%	n	%	n	%	n	%
Age group in years								
18-21	755	75·5	255	52·3	246	48·9	1256	63·1
22+	245	24·5	230	47·1	257	51·1	732	36·8
Missing	0	0·0	3	0·6	0	0·0	3	0·2
Gender								
Woman	614	61·4	321	65·8	302	60·0	1237	62·1
Man	356	35·6	150	30·7	192	38·2	698	35·1
Other	14	1·4	10	2·0	3	0·6	27	1·4
Prefer not to say	16	1·6	7	1·4	6	1·2	29	1·5
Ethnic group								
White	505	50·5	267	54·7	95	18·9	867	43·5
Asian	180	18·0	64	13·1	213	42·3	457	23·0
Black	198	19·8	101	20·7	136	27·0	435	21·8
Mixed	65	6·5	34	7·0	14	2·8	113	5·7
Other	32	3·2	10	2·0	35	7·0	77	3·9
Prefer not to say	20	2·0	12	2·5	10	2·0	42	2·1
University year of study								
First year undergraduate	311	31·1	201	41·2	105	20·9	617	31·0
Second year undergraduate	259	25·9	106	21·7	141	28·0	506	25·4
Third year undergraduate	272	27·2	85	17·4	97	19·3	454	22·8
Other	158	15·8	96	19·7	160	31·8	414	20·8
Home address in Kent								
No	645	64·5	161	33·0	258	51·3	1064	53·4
Yes	343	34·3	319	65·4	238	47·3	900	45·2
I don't know	12	1·2	8	1·6	7	1·4	27	1·4
Category of term-time residence								
Family home	123	12·3	149	30·5	175	34·8	447	22·5
Student halls	424	42·4	129	26·4	140	27·8	693	34·8
Shared house/flat	396	39·6	129	26·4	121	24·1	646	32·4
Other	57	5·7	81	16·6	67	13·3	205	10·3
Relationship status								
Single	635	63·5	261	53·5	379	75·3	1275	64·0
In an exclusive relationship	324	32·4	183	37·5	94	18·7	601	30·2
Other	19	1·9	19	3·9	10	2·0	48	2·4
Prefer not to say	22	2·2	25	5·1	20	4·0	67	3·4
Intimate kissing in past 7 days								
No	595	59·5	250	51·2	366	72·8	1211	60·8
Yes	397	39·7	230	47·1	126	25·0	753	37·8
Prefer not to say	8	0·8	8	1·6	11	2·2	27	1·4
Cigarette smoking or vaping in past 3 months								
No smoking or vaping	575	57·5	309	63·3	359	71·4	1243	62·4
Vaping but no smoking	117	11·7	56	11·5	44	8·7	217	10·9
Smoking but no vaping	77	7·7	29	5·9	36	7·2	142	7·1
Smoking and vaping	206	20·6	89	18·2	54	10·7	349	17·5
Social mixing in past 3 months								
None	146	14·6	90	18·4	214	42·5	450	22·6
Less than monthly	191	19·1	117	24·0	119	23·7	427	21·4
At least monthly	655	65·5	275	56·4	164	32·6	1094	54·9
Prefer not to say	4	0·4	2	0·4	4	0·8	10	0·5
Unknown	4	0·4	4	0·8	2	0·4	10	0·5
Current cough or cold symptoms								
No	840	84·0	426	87·3	426	84·7	1692	85·0
Yes	99	9·9	39	8·0	52	10·3	190	9·5
I don't know	61	6·1	23	4·7	0	0·0	84	4·2
Receipt of prophylactic antibiotics								
No	418	41·8	343	70·3	481	95·6	1242	62·4
Yes	581	58·1	144	29·5	22	4·4	747	37·5
I don't know	1	0·1	1	0·2	0	0·0	2	0·1
Receipt of other antibiotics in past month								
No	880	88·0	412	84·4	436	86·7	1728	86·8
Yes	81	8·1	47	9·6	29	5·8	157	7·9
I don't know	39	3·9	29	5·9	38	7·6	106	5·3
Receipt of Meningitis B vaccination								
No	478	47·8	370	75·8	487	96·8	1335	67·1
Yes, 1 dose	148	14·8	67	13·7	8	1·6	223	11·2
Yes, 2 doses	370	37·0	45	9·2	7	1·4	422	21·2
I don't know	4	0·4	6	1·2	1	0·2	11	0·6

following a large IMD outbreak, therefore we did not specify a sample size but aimed to recruit between 500–1000 participants per site. For a carriage prevalence of 0%, exact binomial 95% confidence intervals (95% CIs) were estimated as 0·00–0·74% for a sample size of 500 and 0·00–0·37% for a sample size of 1000. For a carriage prevalence of 1%, the respective 95% CIs were 0·33–2·32% and 0·48–1·83%.

We linked the questionnaire and swab results using unique participant identifiers. Baseline characteristics of participants were described using frequencies and percentages. Carriage prevalences and 95% CIs were estimated using the Clopper-Pearson exact binomial method.

Table 2
Meningococcal carriage prevalence by participant characteristics and receipt of prophylactic antibiotics.

	Overall*			Did not receive prophylactic antibiotics			Received prophylactic antibiotics		
	n	Isolates	Carriage (95% CI)	n	Isolates	Carriage (95% CI)	n	Isolates	Carriage (95% CI)
Total	1991	76	3·8% (3·0–4·8%)	1242	59	4·8% (3·6–6·1%)	747	17	2·3% (1·3–3·6%)
Site									
A	1000	33	3·3% (2·3–4·6%)	418	21	5·0% (3·1–7·6%)	581	12	2·1% (1·1–3·6%)
B	488	24	4·9% (3·2–7·2%)	343	19	5·5% (3·4–8·5%)	144	5	3·5% (1·1–7·9%)
C	503	19	3·8% (2·3–5·8%)	481	19	4·0% (2·4–6·1%)	22	0	0·0% (0·0–15·4%)
Age group in years									
18-21	1256	56	4·5% (3·4–5·8%)	700	41	5·9% (4·2–7·9%)	556	15	2·7% (1·5–4·4%)
22+	732	20	2·7% (1·7–4·2%)	539	18	3·3% (2·0–5·2%)	191	2	1·0% (0·1–3·7%)
Missing	3	0	0·0% (0·0–70·8%)	3	0	0·0% (0·0–70·8%)	0	0	-
Gender									
Woman (including trans woman)	1237	44	3·6% (2·6–4·7%)	764	33	4·3% (3·0–6·0%)	471	11	2·3% (1·2–4·1%)
Man (including trans man)	698	30	4·3% (2·9–6·1%)	444	25	5·6% (3·7–8·2%)	254	5	2·0% (0·6–4·5%)
Other	27	1	3·7% (0·1–19%)	16	1	6·2% (0·2–30·2%)	11	0	0·0% (0·0–28·5%)
Prefer not to say	29	1	3·4% (0·1–17·8%)	18	0	0·0% (0·0–18·5%)	11	1	9·1% (0·2–41·3%)
Ethnic group									
White	867	53	6·1% (4·6–7·9%)	447	38	8·5% (6·1–11·5%)	420	15	3·6% (2·0–5·8%)
Asian	457	11	2·4% (1·2–4·3%)	343	11	3·2% (1·6–5·7%)	113	0	0·0% (0·0–3·2%)
Black	435	5	1·1% (0·4–2·7%)	307	5	1·6% (0·5–3·8%)	127	0	0·0% (0·0–2·9%)
Mixed	113	4	3·5% (1·0–8·8%)	60	2	3·3% (0·4–11·5%)	53	2	3·8% (0·5–13·0%)
Other	77	3	3·9% (0·8–11%)	57	3	5·3% (1·1–14·6%)	20	0	0·0% (0·0–16·8%)
Unknown	42	0	0·0% (0·0–8·4%)	28	0	0·0% (0·0–12·3%)	14	0	0·0% (0·0–23·2%)
University year of study									
First year undergraduate	617	20	3·2% (2·0–5·0%)	363	12	3·3% (1·7–5·7%)	253	8	3·2% (1·4–6·1%)
Second year undergraduate	506	22	4·3% (2·7–6·5%)	319	17	5·3% (3·1–8·4%)	187	5	2·7% (0·9–6·1%)
Third year undergraduate	454	20	4·4% (2·7–6·7%)	265	17	6·4% (3·8–10·1%)	188	3	1·6% (0·3–4·6%)
Other	414	14	3·4% (1·9–5·6%)	295	13	4·4% (2·4–7·4%)	119	1	0·8% (0·0–4·6%)
Home address in Kent									
No	1064	42	3·9% (2·9–5·3%)	577	32	5·5% (3·8–7·7%)	486	10	2·1% (1·0–3·8%)
Yes	900	33	3·7% (2·5–5·1%)	645	26	4·0% (2·6–5·9%)	254	7	2·8% (1·1–5·6%)
I don't know	27	1	3·7% (0·1–19·0%)	20	1	5% (0·1–24·9%)	7	0	0·0% (0·0–41%)
Category of term-time residence									
Family home	447	12	2·7% (1·4–4·6%)	389	11	2·8% (1·4–5·0%)	58	1	1·7% (0·0–9·2%)
Student halls	693	24	3·5% (2·2–5·1%)	323	15	4·6% (2·6–7·5%)	369	9	2·4% (1·1–4·6%)
Shared house/flat	646	35	5·4% (3·8–7·5%)	360	28	7·8% (5·2–11%)	286	7	2·4% (1·0–5·0%)
Other	205	5	2·4% (0·8–5·6%)	170	5	2·9% (1·0–6·7%)	34	0	0·0% (0·0–10·3%)
Relationship status									
Single	1275	39	3·1% (2·2–4·2%)	795	31	3·9% (2·7–5·5%)	478	8	1·7% (0·7–3·3%)
In an exclusive relationship	601	33	5·5% (3·8–7·6%)	359	26	7·2% (4·8–10·4%)	242	7	2·9% (1·2–5·9%)
Other	48	3	6·2% (1·3–17·2%)	34	2	5·9% (0·7–19·7%)	14	1	7·1% (0·2–33·9%)
Prefer not to say	67	1	1·5% (0·0–8·0%)	54	0	0·0% (0·0–6·6%)	13	1	7·7% (0·2–36·0%)
Intimate kissing in past 7 days									
No	1211	36	3·0% (2·1–4·1%)	772	32	4·1% (2·9–5·8%)	437	4	0·9% (0·2–2·3%)
Yes	753	40	5·3% (3·8–7·2%)	448	27	6·0% (4·0–8·6%)	305	13	4·3% (2·3–7·2%)
Prefer not to say	27	0	0·0% (0·0–12·8%)	22	0	0·0% (0·0–15·4%)	5	0	0·0% (0·0–52·2%)
Cigarette smoking or vaping in past 3 months									
No smoking or vaping	1243	31	2·5% (1·7–3·5%)	809	25	3·1% (2·0–4·5%)	432	6	1·4% (0·5–3·0%)
Vaping but no smoking	217	9	4·1% (1·9–7·7%)	131	6	4·6% (1·7–9·7%)	86	3	3·5% (0·7–9·9%)
Smoking but no vaping	142	9	6·3% (2·9–11·7%)	86	7	8·1% (3·3–16·1%)	56	2	3·6% (0·4–12·3%)
Smoking and vaping	349	26	7·4% (4·9–10·7%)	191	20	10·5% (6·5–15·7%)	158	6	3·8% (1·4–8·1%)
Missing	40	1	2·5% (0·1–13·2%)	25	1	4·0% (0·1–20·4%)	15	0	0·0% (0·0–21·8%)
Social mixing in past 3 months									
None	450	9	2·0% (0·9–3·8%)	368	8	2·2% (0·9–4·2%)	82	1	1·2% (0·0–6·6%)
Less than monthly	427	11	2·6% (1·3–4·6%)	298	11	3·7% (1·9–6·5%)	128	0	0·0% (0·0–2·8%)
At least monthly	1094	56	5·1% (3·9–6·6%)	561	40	7·1% (5·1–9·6%)	532	16	3·0% (1·7–4·8%)
Prefer not to say	10	0	0% (0·0–30·8%)	7	0	0% (0·0–41·0%)	3	0	0·0% (0·0–70·8%)
Unknown	10	0	0% (0·0–30·8%)	8	0	0% (0·0–36·9%)	2	0	0·0% (0·0–84·2%)
Current cough or cold symptoms									
No	1692	65	3·8% (3·0–4·9%)	1064	52	4·9% (3·7–6·4%)	626	13	2·1% (1·1–3·5%)
Yes	190	7	3·7% (1·5–7·4%)	108	5	4·6% (1·5–10·5%)	82	2	2·4% (0·3–8·5%)
I don't know	107	4	3·7% (1·0–9·3%)	70	2	2·9% (0·3–9·9%)	37	2	5·4% (0·7–18·2%)
Missing	2	0	0·0% (0·0–84·2%)	0	0	-	2	0·0	0·0% (0·0–84·2%)
Receipt of other antibiotics in past month									
No	1728	67	3·9% (3·0–4·9%)	1091	52	4·8% (3·6–6·2%)	636	15	2·4% (1·3–3·9%)
Yes	157	3	1·9% (0·4–5·5%)	85	2	2·4% (0·3–8·2%)	72	1	1·4% (0·0–7·5%)
I don't know	106	6	5·7% (2·1–11·9%)	66	5	7·6% (2·5–16·8%)	39	1	2·6% (0·1–13·5%)

* Two participants reported that they did not know whether they had received prophylactic antibiotics.

Univariable and multivariable associations were assessed using modified Poisson regression with robust standard errors to estimate prevalence ratios (PRs) and 95% CIs. Demographics (age group, gender, ethnic group) and other factors previously reported to be associated with carriage (antibiotic consumption, type of residence, social mixing, intimate kissing, smoking and vaping) were included in the multivariable analysis [15,16]. Individuals with responses of 'I don't know' or 'Prefer not to say' or missing values for any included variable were excluded from regression analyses. Effect modification between receipt of antibiotic prophylaxis and other covariates was assessed by fitting interactions terms and comparing models using the Likelihood-Ratio Test.

Isolate sequence type diversity among prophylaxed and non-prophylaxed groups was assessed using Hill numbers (^{q}D) at orders $q = 0$ (ST richness), $q = 1$ (exponential Shannon diversity), and $q = 2$ (inverse Simpson diversity). Hill number profiles and 95% CIs were generated in R using the iNEXT package, with ST richness standardized to n=17 isolates [17].

All analyses were conducted using R version 4·4·1.

Role of the funding source

This public health investigation was conducted and funded by the UK Health Security Agency.

Results

Participants

There were around 35,000 eligible students across the three investigation sites. In total, 2071 (6%) were recruited and 1991 (96·1%) provided a completed questionnaire with a valid swab, including 1000 attending site A, 488 attending site B and 503 attending site C (Table 1). Among site A participants, 58·1% (581/1000) had received prophylactic antibiotics compared to 29·5% (144/488) at site B and 4·4% (22/503) at site C. Participant demographic and behavioural characteristics varied between sites (Table 1).

Meningococcal carriage

The swabs yielded 76 meningococcal isolates giving a carriage prevalence of 3·8% (95% CI 3·0–4·8%) overall, 4·8% (3·6–6·1%) among non-prophylaxed participants and 2·3% (1·3–3·6%) among prophylaxed participants (Table 2). Carriage prevalence was higher among participants aged 18–21 years, of White ethnic group, living in a shared house or flat, in a relationship, kissing in the previous 7 days, smoking and vaping in the previous 3 months, with greater social mixing in the previous 3 months, or not receiving antibiotics in the previous month (Table 2).

Of the 76 isolates, 18 (23·7%) were genogroup B (six expressing capsule, four from prophylaxed participants), 3 (3·9%) genogroup Y (one expressing capsule, one from a prophylaxed participant), 21 (27·6%) genogroup E, and one each of genogroups W, L and Z; 31 (40·1%) isolates were non-groupable/capsule null (NG/cnl). Genogroup B carriage was 0·9% (95% CI, 0·5–1·4%) overall, 1·1% (0·6–1·9%) among non-prophylaxed participants and 0·5% (0·2–1·4%) among prophylaxed participants (Supplementary Table 1).

Sequence type distribution

There were 35 unique sequence types (STs) across 14 clonal complexes (ccs) among the 76 isolates (Table 3). Seven had 'singleton' STs (i.e. STs unassigned to defined ccs). The most common cc was cc32 (n=20), broadly divided into genogroup B (n=10, four expressing capsule) and NG/cnl (n=9), with one genogroup L. Within cc32, ST-7460 was the most common ST (n=10, eight genogroup B), followed by ST-34 (all NG/cnl). The genogroup E-dominated cc1157 (n=14) and cnl-dominated cc198 (n=12), both common carriage-associated lineages, were next, followed by cc41/44 (n=6, four genogroup B, two NG/cnl), another major MenB invasive lineage, including three ST-485 (all genogroup B, one expressing capsule). None of the ST-485 isolates belonged to the outbreak strain; one belonged to the wider PorA P1,16–183 substrain, and the other two belonged to a distinct substrain within the ancestral ST-485 strain (LIN code group 6_0_0_0_1_27)

Table 3
Carriage of meningococcal capsular genogroups and clonal complexes by receipt of prophylactic antibiotics.

Chemoprophylaxis status and clonal complex	Non-groupable/cnl	E	B	L	W	Y	Z	Total
Did not receive prophylactic antibiotics								
Total	**24**	**16**	**14**	**1**	**1**	**2**	**1**	**59**
ST-32 complex	6		8	1				15
ST-1157 complex		13						13
ST-198 complex	10							10
ST-41/44 complex	1		3					4
ST-35 complex	1		2					3
ST-60 complex		3						3
Singleton	2						1	3
ST-269 complex	1		1					2
ST-174 complex						1		1
ST-23 complex					1			1
ST-53 complex	1							1
ST-1136 complex	1							1
ST-167 complex						1		1
ST-175 complex	1							1
Received prophylactic antibiotics								
Total	**7**	**5**	**4**			**1**		**17**
ST-32 complex	3		2					5
Singleton	1	2	1					4
ST-41/44 complex	1		1					2
ST-198 complex	2							2
ST-865 complex						1		1
ST-60 complex		1						1
ST-178 complex		1						1
ST-1157 complex		1						1
All participants								
Total	**31**	**21**	**18**	**1**	**1**	**3**	**1**	**76**

Abbreviations: cnl, capsule null locus; ST, sequence type.

(Supplementary Figure 1). Other notable carried strains included a single cnl ST-175 isolate and a genogroup B ST-5662 isolate (singleton).

Eight unique ccs (including singletons as a group) were observed among prophylaxed individuals (n=17), compared to fourteen ccs among non-prophylaxed individuals (n=59) (Table 3). A rarefaction analysis of ST diversity standardised at a sample size of n=17 isolates showed consistently higher point estimates among the prophylaxed group ($q0$=14·00, $q1$=13·31, $q2$=12·57) compared to the non-prophylaxed population ($q0$=10·71, $q1$=8·86, $q2$=7·16). However, 95% confidence intervals overlapped across all three orders (Supplementary Table 2).

Three isolates from two prophylaxed (ST-11026 and ST-5662) and one non-prophylaxed (ST-175) participant harboured a *gyrA* T91I ciprofloxacin resistance mutation, with resistance confirmed phenotypically.

Table 4
Adjusted and unadjusted prevalence ratios and 95% CIs for the association between participant characteristics and meningococcal carriage.

	n	Isolates	Carriage (95% CI)	Univariable analysis		Multivariable analysis	
				Prevalence ratio (95% CI)	P-value	Prevalence ratio (95% CI)	P-value
Site					0·340		
A	1000	33	3·3% (2·3–4·6%)	Ref			
B	488	24	4·9% (3·2–7·2%)	1·49 (0·89–2·49)			
C	503	19	3·8% (2·3–5·8%)	1·14 (0·66–1·99)			
Age group in years					0·0515		0·196
18-21	1256	56	4·5% (3·4–5·8%)	Ref		Ref	
22+	732	20	2·7% (1·7–4·2%)	0·61 (0·37–1·01)		0·72 (0·42–1·18)	
Gender					0·427		0·545
Woman (including trans woman)	1237	44	3·6% (2·6–4·7%)	Ref		Ref	
Man (including trans man)	698	30	4·3% (2·9–6·1%)	1·21 (0·77–1·90)		1·34 (0·83–2·11)	
Ethnic group					<0·0001		0·000658
White	867	53	6·1% (4·6–7·9%)	Ref		Ref	
Asian	457	11	2·4% (1·2–4·3%)	0·39 (0·21–0·75)		0·44 (0·21–0·85)	
Black	435	5	1·1% (0·4–2·7%)	0·19 (0·08–0·47)		0·17 (0·05–0·42)	
Mixed	113	4	3·5% (1·0–8·8%)	0·58 (0·21–1·57)		0·43 (0·11–1·13)	
Other	77	3	3·9% (0·8–11%)	0·64 (0·20–1·99)		0·62 (0·15–1·64)	
University year of study					0·676		
1st year undergraduate	617	20	3·2% (2·0–5·0%)	Ref			
2nd year undergraduate	506	22	4·3% (2·7–6·5%)	1·34 (0·74–2·43)			
3rd year undergraduate	454	20	4·4% (2·7–6·7%)	1·36 (0·74–2·50)			
Other	414	14	3·4% (1·9–5·6%)	1·04 (0·53–2·04)			
Home address in Kent					0·751		
Yes	1064	42	3·9% (2·9–5·3%)	Ref			
No	900	33	3·7% (2·5–5·1%)	1·08 (0·69–1·68)			
Category of term-time residence					0·0746		0·0599
Family home	447	12	2·7% (1·4–4·6%)	Ref		Ref	
Shared house or flat	693	24	3·5% (2·2–5·1%)	2·02 (1·06–3·84)		2·21 (1·19–4·41)	
Student halls	646	35	5·4% (3·8–7·5%)	1·29 (0·65–2·55)		1·97 (1·00–4·11)	
Other	205	5	2·4% (0·8–5·6%)	0·91 (0·32–2·55)		0·97 (0·31–2·58)	
Relationship status					0·0382		
Single	1275	39	3·1% (2·2–4·2%)	Ref			
In an exclusive relationship	601	33	5·5% (3·8–7·6%)	1·80 (1·14–2·82)			
Other	48	3	6·2% (1·3–17·2%)	2·04 (0·65–6·38)			
Intimate kissing in past 7 days					0·0117		0·343
No	1211	36	3·0% (2·1–4·1%)	Ref		Ref	
Yes	753	40	5·3% (3·8–7·2%)	1·79 (1·15–2·78)		1·27 (0·80–2·03)	
Cigarette smoking or vaping in past 3 months					0·000451		0·143
No smoking or vaping	1243	31	2·5% (1·7–3·5%)	Ref		Ref	
Vaping but no smoking	217	9	4·1% (1·9–7·7%)	1·66 (0·80–3·44)		1·31 (0·59–2·63)	
Smoking but no vaping	142	9	6·3% (2·9–11·7%)	2·54 (1·24–5·23)		1·75 (0·80–3·46)	
Smoking and vaping	349	26	7·4% (4·9–10·7%)	2·99 (1·80–4·96)		1·90 (1·10–3·25)	
Social mixing in past 3 months					0·00400		0·622
Never	450	9	2·0% (0·9–3·8%)	Ref		Ref	
Less than monthly	427	11	2·6% (1·3–4·6%)	1·29 (0·54–3·08)		0·90 (0·37–2·25)	
At least monthly	1094	56	5·1% (3·9–6·6%)	2·56 (1·28–5·13)		1·24 (0·59–2·90)	
Current cough or cold symptoms					0·916		
No	1692	65	3·8% (3·0–4·9%)	Ref			
Yes	190	7	3·7% (1·5–7·4%)	0·96 (0·45–2·06)			
Receipt of prophylactic antibiotics					0·0164		<0·0001
No				Ref		Ref	
Yes				0·48 (0·28–0·82)		0·27 (0·15–0·46)	
Receipt of other antibiotics in past month					0·180		
No	1728	67	3·9% (3·0–4·9%)	Ref			
Yes	157	3	1·9% (0·4–5·5%)	0·49 (0·16–1·55)			
Receipt of MenB vaccination					0·0441		
No				Ref			
Yes, 1 dose				0·49 (0·20–1·21)			
Yes, 2 doses				0·52 (0·27–1·00)			

Individuals with responses of 'I don't know' or 'Prefer not to say' or missing values for any included variable were excluded from regression analyses. Of 1991 participants, 1617 (81·2%) had complete data for all variables included in the multivariable model and were included in the analysis.

Factors associated with carriage

Of 1991 participants, 1617 (81·2%) had complete data for all variables included in the multivariable model and were included in the multivariable analysis. In this analysis, factors independently associated with meningococcal carriage included residence in a shared house or flat (PR 2·21, 95% CI 1·19–4·41) compared to residence in a family home, and combined smoking and vaping (1·90, 1·10–3·25) (Table 4). In contrast, receipt of prophylactic antibiotics (0·27, 0·15–0·46), and Asian (0·44, 0·22–0·85) or Black (0·17, 0·05–0·42) ethnic group compared to White ethnic group, were associated with lower carriage. No interactions were identified between receipt of prophylactic antibiotics and other covariates.

Discussion

Main findings

In this multi-site university carriage investigation, we did not detect the meningococcal strain responsible for the March 2026 outbreak in Canterbury, Kent in any of the three campuses. Overall meningococcal carriage was 4·8% in students who had not received antibiotic prophylaxis and 2·3% in students who had received antibiotic prophylaxis approximately 6–9 weeks earlier. Reassuringly, carriage of disease-causing meningococci was rare and predominantly MenB, which was isolated from 1·1% of non-prophylaxed students. Significantly higher carriage was identified among students living in a shared house or flat and those reporting combined smoking and vaping, whilst the converse was true for chemoprophylaxis and Asian or Black ethnic group.

We did not detect carriage of the outbreak strain, and our investigation was sufficiently powered to detect carriage above 0·5%. This finding is consistent with the lack of any additional IMD cases caused by the outbreak strain in England, especially given the very high attack rate during the initial outbreak where nearly all cases were associated with attendance at a single nightclub [7]. This may reflect the strain being highly virulent but unable to support sustained transmission, with evidence that the strain acquired traits from carriage-associated *N. meningitidis* and *Neisseria cinerea* that may have supported invasiveness [18]. Mass antibiotic prophylaxis employed to interrupt transmission and control the outbreak is also likely to have contributed to eradication of the outbreak strain from carriage.

In our cohort that did not receive antibiotic prophylaxis, the meningococcal carriage rate overall (4·8%) and for disease-causing genogroups (1·4%) was the lowest recorded in UK adolescents or young adults for decades, which coincides with a declining IMD incidence over the past 25 years [2]. In a systematic review and meta-analysis covering Europe and countries with similar epidemiology until 2010, meningococcal carriage prevalence increased through childhood from 4·5% in infants to 23·7% in 19-year-olds, then decreased in adulthood [19]. In the UK, meningococcal carriage in 15–19-year-olds was 16·6% in 1999 and 7·2% in 2014–15 [11]. Declines in MenB carriage are likely to reflect secular trends and, potentially, changes in social behaviours [11]. Introduction of the MenACWY conjugate vaccine for adolescents in August 2015 reduced carriage of the respective serogroups [3,10]. The COVID-19 pandemic was associated with large declines in IMD because of reduced transmission resulting from national lockdowns and social distancing measures [20]. This may also have affected post-pandemic meningococcal carriage rates although, once pandemic restrictions were removed, IMD cases in adolescents and young adults did increase to pre-pandemic levels, with most cases caused by MenB [21].

Among the carried meningococci, carriage of strains with invasive potential was very low and predominantly MenB, consistent with other studies in Europe and North America and likely reflecting the success of the adolescent MenACWY immunisation programme in reducing carriage of vaccine-associated serogroups [11,22–28]. We did identify carriage of ST-485 (cc41/44) isolates in three participants, which has been increasingly responsible for IMD cases and outbreaks in England since 2010 [21]. We also found ten ST-7460 (cc32) isolates (eight genogroup B), which expanded among IMD cases in France following the COVID-19 pandemic [29], and one ST-1161 (cc269) isolate, which was associated with an IMD outbreak among university students in South-West England in 2021–22 [30].

We specifically focussed our investigation on university students because 13 of the 21 cases in the initial outbreak were university students and this group have high meningococcal carriage rates and up-to 12-fold higher IMD risk compared to their peers who do not attend higher education [31,32], especially new university entrants who gather for the first time from different parts of the country [32–36]. In 2010, meningococcal carriage was 33% among 2946 students aged 18–24 years attending ten universities in England [37]. Carriage rates among university students in other European countries, Australia and USA during 2013–23 varied from 3·7% (Lithuania, 2021–23) to 24% (Rhode Island, USA, 2015) [15,22–25,27,38–42]. A 2024 study enrolling 400 first-year students attending a single English university demonstrated higher meningococcal carriage (12·5% at university entry, 25·3% when re-sampled two months later) than observed in this investigation [43]. This could reflect differences in the participant cohort, study timing and microbiological methods, as well as a decline in carriage-promoting behaviours among participants in our investigation following the outbreak.

In our cohort, only shared accommodation, combined smoking and vaping, and ethnic group were associated with higher carriage rates. We also identified higher absolute carriage prevalences for other risk factors reported in previous carriage studies, but associations for these variables did not reach statistical significance [15,16,44,45].

Our investigation provided a unique opportunity to assess carriage prevalence after mass antibiotic prophylaxis in an IMD outbreak. By 6–9 weeks after prophylaxis, meningococcal colonisation in the chemoprophylaxed group was already 2·3% compared to 4·8% in those who did not receive chemoprophylaxis, including four MenB and one MenY carriers. Given limited evidence of ciprofloxacin resistance among the isolates and previous studies reporting very high eradication rates with ciprofloxacin prophylaxis [46], it is likely that most carriage after antibiotic prophylaxis reflected new acquisitions. Interestingly, sequence type diversity estimates were higher among prophylaxed than non-prophylaxed individuals across all three diversity orders, although the differences were not statistically significant, possibly reflecting underpowering. In contrast, the non-prophylaxed group was dominated by a few well-established lineages (e.g. ST-1157 (cc1157), ST-823 (cc198) and ST-7460 (cc32)), potentially suggesting that clearance of the pharyngeal niche with chemoprophylaxis facilitated subsequent re-colonisation by a more diverse array of meningococcal strains.

Previous studies have demonstrated that mass antibiotic prophylaxis during IMD outbreaks can substantially reduce meningococcal carriage for weeks to months provided high antibiotic coverage is achieved in relatively closed populations [46,47]. Six months after a community intervention programme including mass antibiotic prophylaxis to control a MenC outbreak in Rotherham, England during 1995–96, overall meningococcal and MenB carriage rates were, respectively, 72% and 82% lower in 11–18-year-old students attending secondary schools in the intervention regions compared to matched schools outside the area [48]. In Israel, mass antibiotic prophylaxis with ciprofloxacin (ceftriaxone for children under 5 years) in response to a MenB-IMD outbreak achieved 96% uptake and meningococcal carriage declined by 85% (from 8·3% to 1·3%) but the intervention failed to eradicate carriage of the outbreak strain or reduce IMD incidence [49]. Our investigation illustrates that recolonisation may be accelerated in semi-closed populations with ongoing social mixing, especially with peers who did not receive antibiotic prophylaxis. In this context, mass antibiotic prophylaxis provided individuals with short-term protection, with 4CMenB vaccination affording longer-term protection. We did not find

convincing evidence that risk factors for carriage varied between prophylaxed and non-prophylaxed participants.

Implications of findings

Although, at the time of writing, there have been no further IMD cases in England due to the Kent outbreak strain, England experienced two additional MenB-IMD outbreaks caused by distinct strains during April-May 2026, including one resulting in mass chemoprophylaxis [50]. National MenB-IMD rates overall and by age group remain similar to previous years, but the recent outbreaks caused by different MenB strains, in the context of the very low carriage rates in our investigation, highlight the need for ongoing surveillance to determine whether these represented isolated outbreaks or early changes in disease epidemiology. Though declining meningococcal carriage could be taken to indicate reduced exposure to and development of immunity against meningococci, the latter is not currently indicated by available seroprevalence data [51]. Following these outbreaks, the UK implemented an immediate time-limited MenB vaccination programme starting in July 2026 for 17–18 year old and new university entrants aged <25 years [52]. Additionally, on 16 July 2026, the UK Joint Committee on Vaccination and Immunisation (JCVI) recommended a routine offer of a 4CMenB booster for adolescents who were eligible for 4CMenB in infancy, and strongly supported a vaccination offer for other adolescents [53]. Our findings and the recent JCVI decisions may be applicable to similar countries experiencing declining IMD incidence over recent decades.

Strengths and weaknesses

The key strength of this investigation was the speed of implementation with timely generation of carriage results to inform local and national public health actions to control IMD. By including individuals who were offered antibiotic prophylaxis as part of the outbreak response, we were also able to assess recolonisation rates and risk factors to help inform future decisions on mass chemoprophylaxis. There were some limitations. We did not assess carriage before antibiotic prophylaxis and, therefore, are unable to comment on the effectiveness of carriage eradication by ciprofloxacin. Another limitation is that we did not plate the oropharyngeal swabs immediately but transported them every evening to be plated and cultured; this might have reduced positivity rates and, therefore, carriage rates may be underestimated [19]. Additionally, despite the large number of participants recruited, the low carriage rates within our sample size limited the power to assess risk factors for carriage. Finally, our investigation was restricted to a single English region and may not be applicable to other regions or countries.

Conclusion

This rapid, multi-site carriage investigation following an unprecedented IMD outbreak provided reassurance that the outbreak strain was no longer circulating in carriage locally, plausibly reflecting a combination of the characteristics of the outbreak strain and the impact of outbreak control measures. We observed low overall meningococcal carriage compared to historical studies, particularly of disease-causing strains, which mirrors declining IMD incidence in recent decades. These findings contributed to the evidence base considered prior to the recent UK recommendation to initiate a MenB immunisation programme for adolescents.

Ethics statement

This public health investigation received approval from the UKHSA Research Ethics and Governance Group (application ID NR0445).

Funding

This investigation was funded by UK Health Security Agency.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests. SAC, JL, XB and RB perform contract research on behalf of UK Health Security Agency for GlaxoSmithKline, Pfizer, and Sanofi Pasteur. SNL performs contract work on behalf of City St. George's University of London for pharmaceutical companies, including vaccine manufacturers, but receives no personal remuneration. These organisations had no role in the funding, design or conduct of this investigation. All other authors declare no competing interests related to this work.

Acknowledgement

The authors are very grateful to all students and staff at the participating universities and staff at UK Health Security Agency who contributed to the planning and conduct of this investigation, as well as staff at the UKHSA Pathogen Genomics Sequencing Laboratory in Manchester for performing DNA extraction and genome sequencing.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.jinf.2026.106898.

References

[1] Parikh SR, Campbell H, Bettinger JA, Harrison LH, Marshall HS, Martinon-Torres F, et al. The everchanging epidemiology of meningococcal disease worldwide and the potential for prevention through vaccination. J Infect 2020;81(4):483–98.
[2] UKHSA. Invasive meningococcal disease in England: annual laboratory-confirmed reports for epidemiological year 2025 to 2026 [Accessed 13 October 2026]: https://www.gov.uk/government/publications/meningococcal-disease-laboratory-confirmed-cases-in-england-2025-to-2026/invasive-meningococcal-disease-in-england-annual-laboratory-confirmed-reports-for-epidemiological-year-2025-to-2026.
[3] Campbell H, Andrews N, Parikh SR, White J, Edelstein M, Bai X, et al. Impact of an adolescent meningococcal ACWY immunisation programme to control a national outbreak of group W meningococcal disease in England: a national surveillance and modelling study. Lancet Child Adolesc Health 2022;6(2):96–105.
[4] Marshall HS, McMillan M, Koehler AP, Lawrence A, Sullivan TR, MacLennan JM, et al. Meningococcal B vaccine and meningococcal carriage in adolescents in Australia. N Engl J Med 2020;382(4):318–27.
[5] Christensen H, Trotter CL, Hickman M, Edmunds WJ. Re-evaluating cost effectiveness of universal meningitis vaccination (Bexsero) in England: modelling study. BMJ 2014;349:g5725.
[6] van Kessel F, van den Ende C, Oordt-Speets AM, Kyaw MH. Outbreaks of meningococcal meningitis in non-African countries over the last 50 years: a systematic review. J Glob Health 2019;9(1):010411.
[7] I'Anson J, Anderson C, Arora S, Borrow R, Bray N, Campbell H, et al. Large outbreak of group B invasive meningococcal disease in young adults in South East England, March 2026. Eur Surveill 2026;31(15).
[8] UKHSA. Invasive Meningococcal Disease outbreak 2026: technical briefing 1 [Accessed 13 October 2026]: https://www.gov.uk/government/publications/invasive-meningococcal-disease-outbreak-2026-technical-briefings/invasive-meningococcal-disease-outbreak-2026-technical-briefing-1.
[9] ([Preprint]) Parfitt KM, Jolley KA, Unitt A, Bray JE, Colles FM, Harrison OB, et al. A Life Identification Number Barcoding (LIN Code) System for Neisseria meningitidis: high resolution multi-level typing of meningococci. bioRxiv 2026:708563.
[10] Carr JP, MacLennan JM, Plested E, Bratcher HB, Harrison OB, Aley PK, et al. Impact of meningococcal ACWY conjugate vaccines on pharyngeal carriage in adolescents: evidence for herd protection from the UK MenACWY programme. Clin Microbiol Infect 2022;28(12). 1649e1–e8.
[11] MacLennan JM, Rodrigues CMC, Bratcher HB, Lekshmi A, Finn A, Oliver J, et al. Meningococcal carriage in periods of high and low invasive meningococcal disease incidence in the UK: comparison of UKMenCar1-4 cross-sectional survey results. Lancet Infect Dis 2021;21(5):677–87.
[12] [Preprint] Shovill: Robust Microbial Short-Read Genome Assembly. Preprints 2026; 2026071422.
[13] Jolley KA, Bray JE, Maiden MCJ. Open-access bacterial population genomics: BIGSdb software, the PubMLST.org website and their applications. Wellcome Open Res 2018;3:124.

[14] Willerton L, Lucidarme J, Walker A, Lekshmi A, Clark SA, Walsh L, et al. Antibiotic resistance among invasive Neisseria meningitidis isolates in England, Wales and Northern Ireland (2010/11 to 2018/19). PLoS One 2021;16(11):e0260677.
[15] Arnold FW, Parrish LW, Marimuthu S, Findlow J, Quinn A, Salunkhe V, et al. Meningococcal carriage and transmission dynamics in college students in Louisville, Kentucky. PLoS One 2026;21(3):e0344194.
[16] MacLennan J, Kafatos G, Neal K, Andrews N, Cameron JC, Roberts R, et al. Social behavior and meningococcal carriage in British teenagers. Emerg Infect Dis 2006;12(6):950–7.
[17] Hsieh TC, Ma KH, Chao A. iNEXT: an R package for rarefaction and extrapolation of species diversity (Hill numbers). Methods Ecol Evol 2016;7:1451–6.
[18] ([Preprint]) Rodrigues CMC, Lucidarme J, Exley R, Clark JL, Bai X, Bayliss C, et al. Emergence of short-lived meningococci causing focal epidemics can be associated with gene transfer from carriage-associated *Neisseria.*. bioRxiv 2026:752363.
[19] Christensen H, May M, Bowen L, Hickman M, Trotter CL. Meningococcal carriage by age: a systematic review and meta-analysis. Lancet Infect Dis 2010;10(12):853–61.
[20] Brueggemann AB, Jansen van Rensburg MJ, Shaw D, McCarthy ND, Jolley KA, Maiden MCJ, et al. Changes in the incidence of invasive disease due to Streptococcus pneumoniae, Haemophilus influenzae, and Neisseria meningitidis during the COVID-19 pandemic in 26 countries and territories in the Invasive Respiratory Infection Surveillance Initiative: a prospective analysis of surveillance data. Lancet Digit Health 2021;3(6):e360–70.
[21] Clark SA, Campbell H, Ribeiro S, Bertran M, Walsh L, Walker A, et al. Epidemiological and strain characteristics of invasive meningococcal disease prior to, during and after COVID-19 pandemic restrictions in England. J Infect 2023;87(5):385–91.
[22] Breakwell L, Whaley M, Khan UI, Bandy U, Alexander-Scott N, Dupont L, et al. Meningococcal carriage among a university student population - United States, 2015. Vaccine 2018;36(1):29–35.
[23] Huber A, Kovacs E, Horvath A, Sahin-Toth J, Kaptas A, Juhasz E, et al. Prevalence, serogroup distribution and risk factors of Neisseria meningitidis carriage in high school and university students in Hungary. Vaccine 2024;42(9):2271–7.
[24] Kristinsdottir I, Visser LJ, Miellet WR, Mariman R, Pluister G, Haraldsson G, et al. Meningococcal carriage in children and young adults: a cross-sectional and longitudinal study, Iceland, 2019 to 2021. Eur Surveill 2023;28(39).
[25] McNamara LA, Thomas JD, MacNeil J, Chang HY, Day M, Fisher E, et al. Meningococcal Carriage following a vaccination campaign with MenB-4C and MenB-FHbp in response to a university serogroup b meningococcal disease outbreak - Oregon, 2015-2016. J Infect Dis 2017;216(9):1130–40.
[26] Peterson ME, Li Y, Shanks H, Mile R, Nair H, Kyaw MH, et al. Serogroup-specific meningococcal carriage by age group: a systematic review and meta-analysis. BMJ Open 2019;9(4):e024343.
[27] Soeters HM, Whaley M, Alexander-Scott N, Kanadanian KV, MacNeil JR, Martin SW, et al. Meningococcal Carriage evaluation in response to a serogroup B meningococcal disease outbreak and mass vaccination campaign at a college - Rhode Island, 2015-2016. Clin Infect Dis 2017;64(8):1115–22.
[28] van Ravenhorst MB, Bijlsma MW, van Houten MA, Struben VMD, Anderson AS, Eiden J, et al. Meningococcal carriage in Dutch adolescents and young adults; a cross-sectional and longitudinal cohort study. Clin Microbiol Infect 2017;23(8):573e1–57e7e1.
[29] Taha S, Hong E, Denizon M, Falguieres M, Terrade A, Deghmane AE, et al. The rapid rebound of invasive meningococcal disease in France at the end of 2022. J Infect Public Health 2023;16(12):1954–60.
[30] Lucidarme J, Clark SA, Borrow R, Murthy AK, Tan C, Naqvi R, et al. Ability of the MenB-fHbp vaccine to provide immune protection against meningococcal serogroup B ST-1161 UK university "South West Outbreak" strain isolates. Vaccine 2026;80:128503.
[31] Mandal S, Campbell H, Ribeiro S, Gray S, Carr T, White J, et al. Risk of invasive meningococcal disease in university students in England and optimal strategies for protection using MenACWY vaccine. Vaccine 2017;35(43):5814–8.
[32] Neal KR, Nguyen-Van-Tam JS, Jeffrey N, Slack RC, Madeley RJ, Ait-Tahar K, et al. Changing carriage rate of Neisseria meningitidis among university students during the first week of term: cross sectional study. BMJ 2000;320(7238):846–9.
[33] Ala'Aldeen DA, Neal KR, Ait-Tahar K, Nguyen-Van-Tam JS, English A, Falla TJ, et al. Dynamics of meningococcal long-term carriage among university students and their implications for mass vaccination. J Clin Microbiol 2000;38(6):2311–6.
[34] Ala'aldeen DA, Oldfield NJ, Bidmos FA, Abouseada NM, Ahmed NW, Turner DP, et al. Carriage of meningococci by university students, United Kingdom. Emerg Infect Dis 2011;17(9):1762–3.
[35] Bidmos FA, Neal KR, Oldfield NJ, Turner DP, Ala'Aldeen DA, Bayliss CD. Persistence, replacement, and rapid clonal expansion of meningococcal carriage isolates in a 2008 university student cohort. J Clin Microbiol 2011;49(2):506–12.
[36] Oldfield NJ, Cayrou C, AlJannat MAK, Al-Rubaiawi AAA, Green LR, Dada S, et al. Rise in Group W Meningococcal Carriage in University Students, United Kingdom. Emerg Infect Dis 2017;23(6):1009–11.
[37] Read RC, Baxter D, Chadwick DR, Faust SN, Finn A, Gordon SB, et al. Effect of a quadrivalent meningococcal ACWY glycoconjugate or a serogroup B meningococcal vaccine on meningococcal carriage: an observer-blind, phase 3 randomised clinical trial. Lancet 2014;384(9960):2123–31.
[38] Drew RJ, Bennett D, O'Donnell S, Mulhall R, Cunney R. Risk factors for carriage of meningococcus in third-level students in Ireland: an unsupervised machine learning approach. Hum Vaccin Immunother 2021;17(10):3702–9.
[39] Ivaskeviciene I, Silickaite J, Macioniene A, Ivaskevicius R, Bulavaite A, Gegzna V, et al. Molecular characteristics of Neisseria meningitidis carriage strains in university students in Lithuania. BMC Microbiol 2023;23(1):352.
[40] Kizil MC, Kara Y, Karbuz A, Oz FN, Ciftci E, Kurugol Z, et al. The prevalence, serogroup distribution and risk factors of meningococcal carriage in children, adolescents and young adults in Turkey Meningo-Carr-TR Study PART 3: COVID-19 Pandemic Situation. Pediatr Infect Dis J 2025;44(4):281–6.
[41] McMillan M, Mohammed H, Bednarz J, Leong LEX, Lawrence A, Sullivan TR, et al. Longitudinal study of meningococcal carriage in adolescents and young adults in South Australia 2017-2020. J Infect 2024;88(2):149–57.
[42] Sall O, Eriksson L, Berhane IA, Persson A, Magnuson A, Thulin Hedberg S, et al. Prevalence and persistence of Neisseria meningitidis carriage in Swedish university students. Epidemiol Infect 2024;152:e99.
[43] Harvey-Cowlishaw T, Wartnaby S, Trujillo-Mendoza J, Clark JL, Lekshmi A, Clark SA, et al. Meningococcal carriage in UK university students post-pandemic: evidence for MenACWY vaccine impact and ongoing genogroup B risk. Front Public Health 2026;14:1917586.
[44] McMillan M, Koehler AP, Lawrence A, Sullivan TR, Bednarz J, MacLennan JM, et al. B Part of It School Leaver Study: a repeat cross-sectional study to assess the impact of increasing coverage with meningococcal B (4CMenB) vaccine on carriage of Neisseria meningitidis. J Infect Dis 2022;225(4):637–49.
[45] McMillan M, Walters L, Mark T, Lawrence A, Leong LEX, Sullivan T, et al. B Part of It study: a longitudinal study to assess carriage of Neisseria meningitidis in first year university students in South Australia. Hum Vaccin Immunother 2019;15(4):987–94.
[46] McNamara LA, MacNeil JR, Cohn AC, Stephens DS. Mass chemoprophylaxis for control of outbreaks of meningococcal disease. Lancet Infect Dis 2018;18(9):e272–81.
[47] Zalmanovici Trestioreanu A, Fraser A, Gafter-Gvili A, Paul M, Leibovici L. Antibiotics for preventing meningococcal infections. Cochrane Database Syst Rev 2013;2013(10):CD004785.
[48] Neal KR, Irwin DJ, Davies S, Kaczmarski EB, Wale MC. Sustained reduction in the carriage of Neisseria meningitidis as a result of a community meningococcal disease control programme. Epidemiol Infect 1998;121(3):487–93.
[49] Shehab S, Keller N, Barkay A, Leitner L, Leventhal A, Block C. Failure of mass antibiotic prophylaxis to control a prolonged outbreak of meningococcal disease in an Israeli village. Eur J Clin Microbiol Infect Dis 1998;17(11):749–53.
[50] Wise J. New meningitis B outbreak: Three cases in Dorset are not linked to recent Kent wave. BMJ 2026;393:s746.
[51] The Joint Committee on Vaccination and Immunisation. Draft minute of the meeting held on 3rd of June 2026. [Accessed 13 October 2026]: https://app.box.com/s/iddfb4ppwkmtjusir2tc.
[52] UKHSA. Meningococcal B (MenB) time limited vaccination offer letter: Annex A: detailed information, guidance and resources for healthcare professionals 2026 [Accessed 13 October 2026]: https://www.gov.uk/government/publications/meningococcal-b-menb-time-limited-vaccination-offer-letter/annex-a-detailed-information-guidance-and-resources-for-healthcare-professionals.
[53] DHSC. JCVI statement on meningococcal B vaccination in older children and young adults, 16 July 2026 2026 [Accessed 13 October 2026]: https://www.gov.uk/government/publications/jcvi-statement-on-meningococcal-b-vaccination-in-older-children-and-young-adults-16-july-2026/jcvi-statement-on-meningococcal-b-vaccination-in-older-children-and-young-adults-16-july-2026.