Meningococcal Disease Among College-Aged Young Adults: 2014–2016

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abstract

BACKGROUND: Freshman college students living in residence halls have previously been identified as being at an increased risk for meningococcal disease. In this evaluation, we assess the incidence and characteristics of meningococcal disease in college-aged young adults in the United States.

METHODS: The incidence and relative risk (RR) of meningococcal disease among college students compared with noncollege students aged 18 to 24 years during 2014–2016 were calculated by using data from the National Notifiable Diseases Surveillance System and enhanced meningococcal disease surveillance. Differences in demographic characteristics and clinical features of meningococcal disease cases were assessed. Available meningococcal isolates were characterized by using slide agglutination, polymerase chain reaction, and whole genome sequencing.

RESULTS: From 2014 to 2016, 166 cases of meningococcal disease occurred in persons aged 18 to 24 years, with an average annual incidence of 0.17 cases per 100 000 population. Six serogroup B outbreaks were identified on college campuses, accounting for 31.7% of serogroup B cases in college students during this period. The RR of serogroup B meningococcal (MenB) disease in college students versus noncollege students was 3.54 (95% confidence interval: 2.21–5.41), and the RR of serogroups C, W, and Y combined was 0.56 (95% confidence interval: 0.27–1.14). The most common serogroup B clonal complexes identified were CC32/ET-5 and CC41/44 lineage 3.

CONCLUSIONS: Although the incidence is low, among 18- to 24-year-olds, college students are at an increased risk for sporadic and outbreak-associated MenB disease. Providers, college students, and parents should be aware of the availability of MenB vaccines.

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Dr Mbaeyi conceptualized and designed the study, conducted the epidemiologic data analysis, and drafted the initial manuscript; Dr Joseph conducted the laboratory data analysis and reviewed and revised the manuscript; Ms Blain coordinated the data collection, conducted the epidemiologic data analysis in parallel to assure accuracy, and reviewed and revised the manuscript; Dr Wang conceptualized the laboratory data analysis, supervised the analysis of laboratory data, and reviewed and revised the manuscript; Dr Hariri supervised the epidemiologic data analysis and reviewed and revised the manuscript; Ms MacNeil conceptualized the study, supervised the epidemiologic data analysis, and reviewed and revised the manuscript; and all authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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WHAT'S KNOWN ON THIS SUBJECT: College freshmen living in residence halls have previously been identified as being at an increased risk of meningococcal disease, although college students overall have been shown to have similar rates of disease compared with noncollege students of the same age.

WHAT THIS STUDY ADDS: Although the incidence is low, college students aged 18 to 24 years are at an increased risk of serogroup B meningococcal disease compared with noncollege students. The incidences of serogroups C, W, and Y are low in this age group.

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Although the incidence of meningococcal disease has steadily declined in the United States since the 1990s, adolescents and young adults remain at an increased risk for meningococcal disease.[1] College freshmen living in residence halls, though not college students overall, have previously been identified as being at an increased risk for meningococcal disease compared with noncollege students of the same age.[2]

Since 2005, a quadrivalent meningococcal conjugate (MenACWY) vaccine has been licensed in the United States, and it is currently recommended by the Advisory Committee on Immunization Practices (ACIP) for all adolescents, with the first dose at age 11 to 12 years and a booster dose at age 16 years, as well as for unvaccinated or under-vaccinated college freshmen living in residence halls.[3] By 2016, 83.5% of 17-year-olds had received at least 1 dose of MenACWY, and 39.1% received 2 doses.[4] In 2014 and 2015, 2 serogroup B meningococcal (MenB) vaccines, MenB-4C (Bexsero; GlaxoSmithKline, Brentford, United Kingdom) and MenB-FHbp (Trumenba; Pfizer, New York, NY), were licensed in the United States.[5,6] Although not routinely recommended for all adolescents or college students, a MenB series may be administered to persons aged 16 to 23 years, with the preferred age of 16 to 18 years, on the basis of clinical decision-making.[7] Although no coverage estimates are available, preliminary data suggest that the estimated coverage of at least 1 dose of MenB vaccine among 16- to 18-year-olds was <10% by the end of 2017.[8] Both MenACWY and MenB vaccines are recommended for groups at an increased risk for meningococcal disease, including persons at risk during an outbreak.

Although several recent outbreaks of MenB disease have been reported,[9] the current epidemiology and risks of meningococcal disease among college students are not well described. Previous evaluations among college students were conducted when rates of disease were higher, serogroup C was the predominant cause of disease, MenACWY and MenB vaccines had not yet become available, and the ability to characterize the molecular features of *Neisseria meningitidis* strains in this population had not yet been developed.[2,10] In this evaluation, we describe the epidemiology of meningococcal disease in college students, estimate the relative risk (RR) of meningococcal disease in college students compared with noncollege students among persons aged 18 to 24 years, and characterize the disease-causing strains.

METHODS

Surveillance and Descriptive Epidemiology

In the United States, surveillance for meningococcal disease is conducted through the National Notifiable Diseases Surveillance System (NNDSS), and cases are classified by state and local public health personnel as suspected, probable, or confirmed according to the Council of State and Territorial Epidemiologists' case definition.[11,12] In 2014–2015, enhanced meningococcal disease surveillance activities were implemented to collect additional data and isolates on cases reported through the NNDSS. Enhanced meningococcal disease surveillance activities are currently conducted in 45 states, representing 98% of the US population.[13] All confirmed and probable cases in persons aged 18 to 24 years reported during January 1, 2014, to December 31, 2016, were included in the analysis.

Patients with meningococcal disease were classified as college students or noncollege students on the basis of information collected through enhanced surveillance activities or in cases from the 5 nonparticipating states through reviews of case investigation records. College student status is a self-identified surveillance variable and may include students at 4-year, 2-year, or technical institutions. In addition, we reviewed information on outbreaks in which the Centers for Disease Control and Prevention (CDC) was consulted as part of routine technical assistance to state health departments to ensure completeness of the outbreak variable in the NNDSS.

The number of college students aged 18 to 24 years overall in the 50 US states and District of Columbia was obtained from the 2015 National Center for Education Statistics Integrated Postsecondary Education Data System Fall Enrollment Survey and classified by age group (18- to 19-year-olds, 20- to 21-year-olds, and 22- to 24-year-olds).[14] The number of noncollege students was calculated by subtracting the number of college students from the overall 2015 population estimates reported by the US Census Bureau.[15] The proportion of college students was calculated overall (38.3%) and for each age group: 18- to 19-year-olds (52.1%), 20- to 21-year-olds (47.0%), and 22- to 24-year-olds (24.4%). To estimate the number of students and nonstudents by each year of age, the proportion of students and nonstudents was assumed to be constant within each age group and was multiplied by the total number of persons of that age.

Significant differences ($P < .05$) in demographic characteristics and clinical features of meningococcal disease among college students and noncollege students were assessed through Pearson's χ^2 tests. The incidences of meningococcal disease overall and by college attendance status were calculated as the numbers of confirmed or probable cases in persons aged 18 to 24 years per 100 000 population. RRs and

95% confidence intervals (CIs) of meningococcal disease among college students, overall, and by serogroup were calculated by dividing the incidence of meningococcal disease among college students by the incidence in noncollege students. All analyses were conducted in SAS 9.4 (SAS Institute, Inc, Cary, NC).

The analysis of data collected through the NNDSS and enhanced meningococcal disease surveillance activities was determined by human subjects review at the CDC to be public health nonresearch, and institutional review board review was not required.

Laboratory Methods

Available meningococcal isolates from patients aged 18 to 24 years were sent to the CDC Bacterial Meningitis Laboratory for confirmatory testing and molecular typing. The serogroup was determined by the expression of the capsular polysaccharide by using slide agglutination and/or serogroup specific, real-time polymerase chain reaction targeting meningococcal genes in the capsular locus as previously described.[16]

Genomes of all isolates were sequenced by using Illumina technology and assembled as previously described.[17] Sequence type (ST), clonal complex (CC), outer membrane proteins (PorA and FetA), and vaccine antigens (FHbp, NhbA, and NadA) were determined on the basis of a Basic Local Alignment Search Tool search of the assembled genomes against the PubMLST allele lists.[16,18,19] Phylogenetic analysis was performed on MenB isolates to assess their relationships within each CC. Only CCs with at least 4 isolates were included in the analysis. In short, trimmed and quality-filtered Illumina sequencing reads were aligned to reference genomes within each CC by using Snippy version 3.1, and the whole genome alignment was generated by using snippy-core. Potential recombination regions were identified by using Gubbins.[20] The single nucleotide polymorphism (SNP) sites outside the predicted recombinant segments were used to infer the maximum-likelihood phylogenetic tree by using RAxML[21] with a general time reversible model of nucleotide substitution along with 100 bootstrap replicates to determine the branch support. All phylogenetic visualizations were generated by using the R package ggtree.[22]

RESULTS

Epidemiology of Meningococcal Disease in College Students

Among the 1174 confirmed or probable meningococcal disease cases reported from January 1, 2014, to December 31, 2016, 166 (14.1%) occurred in persons aged 18 to 24 years. All subsequent analyses include the 163 (98.2%) cases in persons aged 18 to 24 years with known information on college student status, including 83 (50.9%) college students and 80 (49.1%) noncollege students.

Overall, 88 (58.3%) cases in this age group were due to serogroup B, although the distribution differed by student status, with 60 (76.9%) cases in college students due to serogroup B compared with 28 (38.4%) cases in noncollege students. In addition, 19 (12.6%) cases were due to serogroup C, 15 (9.9%) to serogroup Y, and 5 (3.3%) to serogroup W, with 22 (14.6%) reported as nongroupable and 2 (1.3%) as other (not specified). College students with meningococcal disease were more likely to be younger (aged 18–20 years) and to have received at least 1 dose of MenACWY vaccine compared with noncollege students with meningococcal disease (Table 1).

During 2014–2016, 6 MenB disease outbreaks were reported on college campuses (Table 2). Outbreak-associated cases accounted for 17 of the 60 (31.7%) serogroup B cases during this time period, with the proportion varying by age group: 14 of 37 (37.8%) cases in persons aged 18 to 19 years, 5 of 22 (22.7%) cases in persons aged 20 to 21 years, and no cases in persons aged 22 to 24 years. All but 1 outbreak-associated case occurred at the college of attendance; 1 2014 case was associated with a 2013 outbreak at a different college.

No outbreaks due to non-B serogroups were known to have occurred among college students. However, 8 cases associated with 4 known outbreaks due to non-B serogroups among noncollege students aged 18 to 24 years were reported during this time period: 6 cases associated with 3 serogroup C outbreaks among men who have sex with men and 2 serogroup Y cases associated with a mixed serogroup C/Y outbreak among persons experiencing homelessness. Overall, 8 of 29 (27.6%) total cases due to serogroups C, W, or Y among noncollege students aged 18 to 24 years were outbreak associated.

The overall incidence of meningococcal disease due to any serogroup among persons aged 18 to 24 years was 0.17 cases per 100 000 population (Table 3). The incidences of MenB disease among persons aged 18 to 24 years were 0.17 and 0.05 cases per 100 000 population in college students and noncollege students, respectively, for an RR of 3.54 (95% CI: 2.21–5.41). By year of age, the incidence was greatest among persons aged 18 to 20 years (Fig 1A).

To assess whether this increased risk for MenB disease among college students was attributable to serogroup B college outbreaks, we limited the analysis to sporadic cases. The incidence of MenB disease in college students was 0.11 cases per 100 000 population, for an RR compared with noncollege students

TABLE 1 Characteristics of Patients with Meningococcal Disease Aged 18–24 Years by College Attendance in the United States From 2014 to 2016

Characteristic	All 18- to 24-y-Olds, *N* = 163	By College Student Status		*P*
		College Student, *N* = 83	Noncollege Student, *N* = 80	
	N (%)	*N* (%)	*N* (%)	
Sex	163 (100.0)	83 (100.0)	80 (100.0)	.05
Male	79 (48.5)	34 (41.0)	45 (56.2)	
Female	84 (51.5)	49 (59.0)	35 (43.8)	
Age, y	163 (100.0)	83 (100.0)	80 (100.0)	<.01
18	39 (23.9)	21 (25.3)	18 (22.5)	
19	34 (20.9)	29 (34.9)	5 (6.3)	
20	29 (17.8)	17 (20.5)	12 (15.0)	
21	23 (14.1)	12 (14.5)	11 (13.8)	
22	9 (5.5)	1 (1.2)	8 (10.0)	
23	16 (9.8)	0 (0.0)	16 (20.0)	
24	13 (8.0)	3 (3.6)	10 (12.5)	
Race	135 (82.8)	70 (84.3)	65 (81.3)	.24
White	103 (76.3)	57 (81.4)	46 (70.8)	
African American	25 (18.5)	9 (12.9)	16 (24.6)	
Other	7 (5.2)	4 (5.7)	3 (4.6)	
Ethnicity	134 (82.2)	66 (79.5)	68 (85.0)	.06
Hispanic	25 (18.7)	8 (12.1)	17 (25.0)	
Non-Hispanic	109 (81.3)	58 (87.9)	51 (75.0)	
Serogroup	151 (92.6)	78 (94.0)	73 (91.3)	<.01
B	88 (58.3)	60 (76.9)	28 (38.4)	
C	19 (12.6)	3 (3.9)	16 (21.9)	
W	5 (3.3)	1 (1.3)	4 (5.5)	
Y	15 (9.9)	6 (7.7)	9 (12.3)	
NG and/or other[a]	24 (15.9)	8 (10.3)	16 (21.9)	
MenACWY dose	109 (66.9)	61 (73.5)	48 (60.0)	<.01
≥1	72 (66.1)	53 (86.9)	19 (39.6)	
0	37 (33.9)	8 (13.1)	29 (60.4)	
MenB vaccine	33 (20.2)	19 (22.9)	14 (17.5)	>.99
≥1 dose	1 (3.0)	1 (5.3)	0 (0.0)	
0 doses	32 (97.0)	18 (94.7)	14 (100.0)	
Outcome	153 (93.9)	77 (92.8)	76 (95.0)	.83
Survived	134 (87.6)	67 (87.0)	67 (88.2)	
Died	19 (12.4)	10 (13.0)	9 (11.8)	

NG, nongroupable; —, not applicable.

[a] Includes 22 with nongroupable and 2 with other (not specified) serogroups.

of 2.36 (95% CI: 1.46–3.82). Among persons aged 18 to 19 years, the incidences in college students and noncollege students were 0.17 and 0.09 cases per 100 000 population, respectively, for an RR of 1.93 (95% CI: 0.94–3.95). Among persons aged 20 to 21 years, the incidences in college students and noncollege students were 0.14 and 0.04 cases per 100 000, respectively, for an RR of 3.20 (95% CI: 1.26–8.11).

For serogroups C, W, and Y combined, a similar incidence was observed among persons aged 18 to 24 years by college status: 0.03 cases per 100 000 population in college students and 0.05 cases per 100 000 population in noncollege students, for an RR of 0.56 (95% CI: 0.27–1.14). The incidence of serogroups C, W, and Y combined was highest in noncollege students aged 22 to 24 years (Table 2, Fig 1B)

TABLE 2 College-Based MenB Disease Outbreaks in the United States From 2014 to 2016

Outbreak	State	Started	Cases	ST	CC
1	Rhode Island	2015	2	ST-9069	Unassigned
2	Oregon	2015	6[a]	ST-32	CC32/ET-5
3	California	2016	2	ST-11910	CC32/ET-5
4	New Jersey	2016	2	ST-11	CC11
5	Wisconsin	2016	3	ST-11556	CC32/ET-5
6	Oregon	2016	5[b]	ST-32	CC32/ET-5

[a] One additional case in a close contact (outside of age 18–24 y).

[b] Includes 3 additional cases reported in 2017.

Genomic Characterization of *N meningitidis* Serogroup B Isolates

Among 52 serogroup B isolates from college students (*n* = 34) and noncollege students (*n* = 18), 24 STs belonging to 8 CCs were identified. The most common CCs detected among both sporadic and outbreak-associated cases were CC32/ET-5 (*n* = 22), CC41/44 Lineage 3 (*n* = 15), and CC11 (*n* = 4; Fig 2). PorA, FetA, FHbp, and NhbA rates among all 52 serogroup B isolates are described in Supplemental Table 4.

The CC32/ET-5 isolates that caused 4 college outbreaks formed 3 distinct clades, with a mean SNP difference within clades of 10 SNPs (range 19–1; Fig 2A). The 2015 and 2016 Oregon outbreaks were caused by ST-32 isolates with the same molecular typing profile that clustered into a single clade (Fig 2A, Table 2), indicating that both outbreaks may have derived from the same strain. Among 7 additional ST-32 isolates not reported as part of an outbreak, 3 from noncollege students (1 from OR and 2 from a neighboring state) clustered with the Oregon outbreak strain (Supplemental Table 4, Fig 2A). The 2016 California and Wisconsin university outbreaks were due to ST-11910 and ST-11556 isolates, respectively, which clustered into 2 phylogenetic clades (Fig 2A).

Higher genetic diversity was observed among the 15 serogroup B CC41/44 isolates, which represented 11 STs (Fig 2B). Among these, 1 2014 ST-409 isolate in a Pennsylvania college student was associated with a 2013 outbreak at a different college

TABLE 3 Incidence of Meningococcal Disease by Serogroup in Persons Aged 18–24 Years and RR by College Student Status in the United States From 2014 to 2016

Age Group	All Cases			Serogroup B			Serogroups C, W, or Y		
	Total Cases	Average Annual Incidence[a]	RR (95% CI)	Total Cases	Average Annual Incidence[a]	RR (95% CI)	Total Cases	Average Annual Incidence[a]	RR (95% CI)
All 18- to 24-year-olds	163	0.1741		88	0.0940		39	0.0416	
College student	83	0.2315	1.67 (1.23–2.27)	60	0.1673	3.54 (2.21–5.41)	10	0.0279	0.56 (0.27–1.14)
Noncollege student	80	0.1384		28	0.0485		29	0.0502	
18- to 19-year-olds	73	0.2871		48	0.1888		8	0.0315	
College student	50	0.3777	2.00 (1.22–3.28)	37	0.2795	3.10 (1.58–6.07)	6	0.0453	2.76 (0.56–13.78)
Noncollege student	23	0.1888		11	0.0903		2	0.0164	
20- to 21-year-olds	52	0.1965		28	0.1058		10	0.0378	
College student	29	0.2333	1.42 (0.82–2.46)	22	0.1770	4.14 (1.68–10.20)	3	0.0241	0.48 (0.13–1.87)
Noncollege student	23	0.1639		6	0.0428		7	0.0499	
20- to 21-year-olds	38	0.0910		12	0.0287		21	0.0503	
College student	4	0.0393	0.36 (0.13–1.03)	1	0.0098	0.28 (0.04–2.18)	1	0.0098	0.16 (0.02–1.15)
Noncollege student	34	0.1077		11	0.0348		20	0.0634	

[a] Cases per 100 000 population.

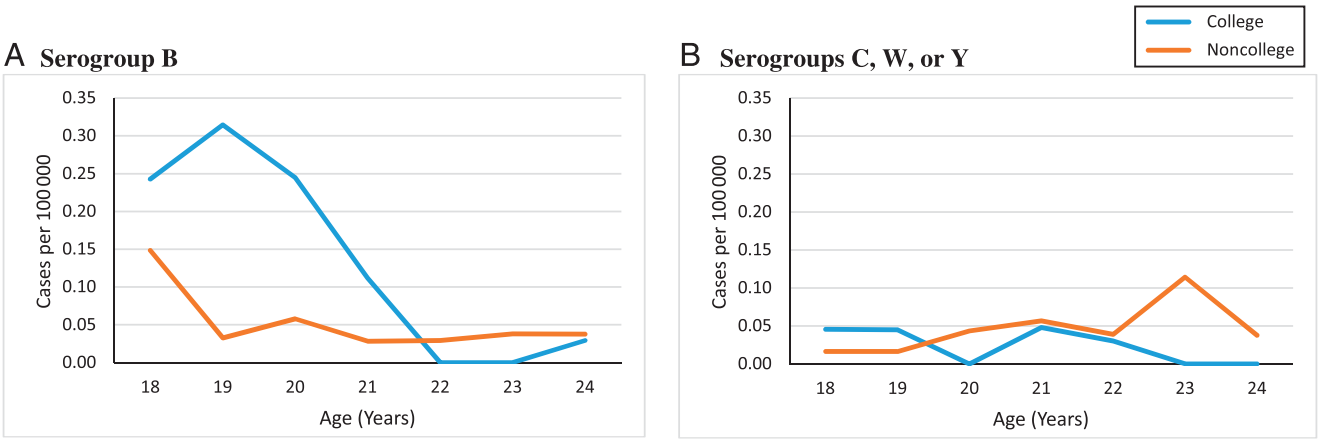

FIGURE 1
A, Estimated incidence of serogroup B among persons aged 18 to 24 years by year of life and college status in the United States from 2014 to 2016. B, Estimated incidences of serogroups C, W, and Y among persons aged 18 to 24 years by year of life and college status in the United States from 2014 to 2016.

(data not shown) and also formed a distinct phylogenetic clade with a 2016 isolate (within-clade SNP difference = 36 SNPs) from a college student in an adjacent state (Fig 2B, Supplemental Table 4).

Four serogroup B ST-11 (CC11) cases in college students reported during 2016 formed a tight phylogenetic clade (mean SNP difference of 26 SNPs [range 48–1]); 2 of these were part of a known college outbreak in New Jersey (Table 2), whereas the other 2 sporadic cases were detected by surveillance in 2 additional states. These isolates were not closely related to serogroup C, W, or nongroupable ST-11 isolates in this analysis (mean SNP difference of 237 SNPs [range 404–121]).

DISCUSSION

The incidence of meningococcal disease among US college students is low. However, college students are at an increased risk for meningococcal disease compared with noncollege students aged 18 to 24 years because of the higher incidence of MenB disease, which accounts for nearly three-fourths of all the cases in this group. Although outbreaks are an important factor accounting for >30% of serogroup B cases in college students, the risk remains elevated for college students even after the exclusion of outbreak-associated cases. In contrast, the incidence of meningococcal disease due to serogroups C, W, and Y in this age group is lower, and it is similar in college students and noncollege students.

The epidemiology of meningococcal disease has changed substantially in the United States in the past 20 years.[1] In the late 1990s, the incidences overall and among college students aged 18 to 23 years old were sevenfold and twofold,

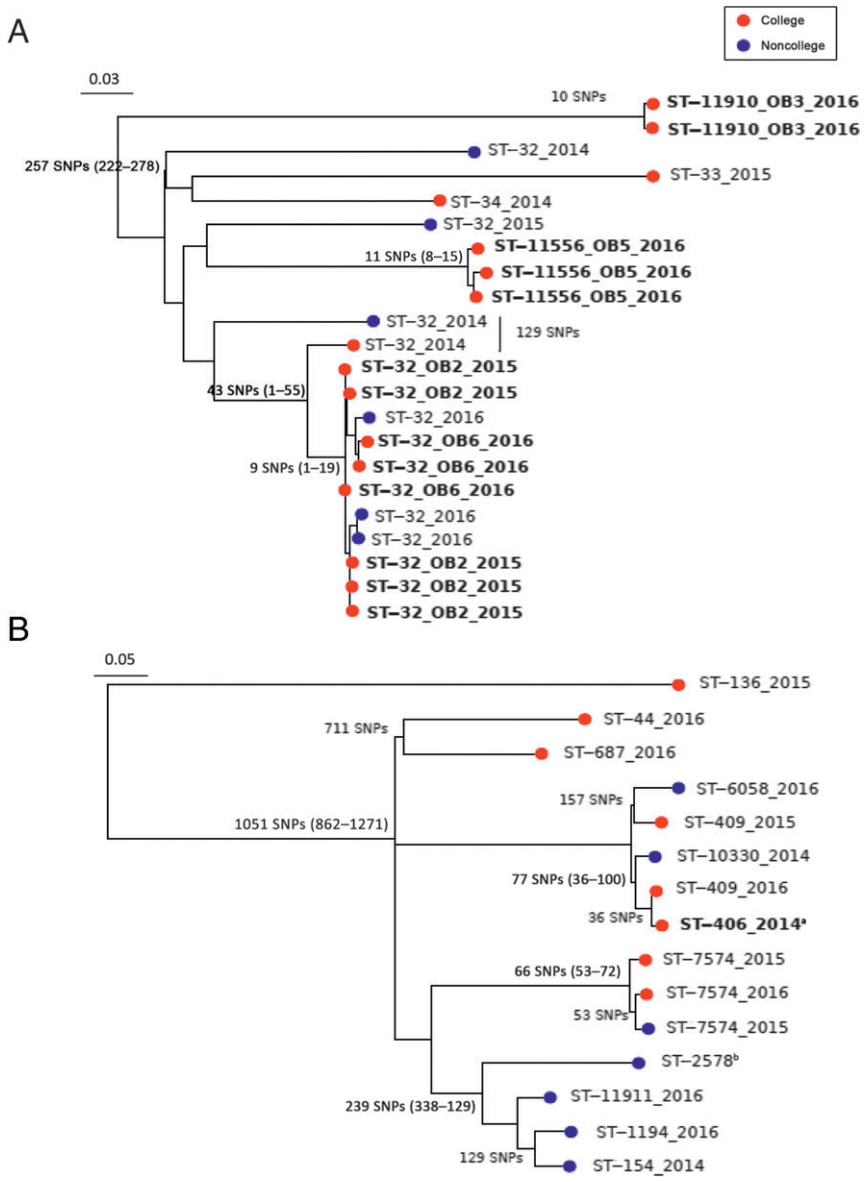

FIGURE 2

A, Phylogenetic analysis of MenB isolates CC32/ET-5 Lineage 3 among persons aged 18 to 24 years by college status in the United States from 2014 to 2016. B, Phylogenetic analysis of MenB isolates CC41/44 Lineage 3 among persons aged 18 to 24 years by college status in the United States from 2014 to 2016. The within-clade mean and range of SNP differences are shown at the internal nodes of each clade. Tip labels of the phylogenetic trees contain the ST and outbreak identification (shown in bold font and based on the identifying number in Table 2 and year). [a] Associated with a 2013 outbreak at a different college. [b] Capsule null locus.

respectively, of those observed in our analysis. Whereas nearly 70% of college student cases were due to serogroups C, W, or Y during 1998–1999, only 12% were due to these serogroups during 2014–2016.[2] Although the declines in meningococcal disease incidence began before the introduction of MenACWY vaccine and have been observed across age groups and serogroups, reductions in the incidences of serogroups C, W, and Y and the current low rates of disease due to these serogroups in both college students and noncollege students suggest an impact of the universal adolescent MenACWY program.[1]

Although not routinely recommended for all adolescents, ACIP recommends that adolescents and young adults aged 16 to 23 years may be vaccinated with a MenB vaccine, preferentially at age 16 to 18 years, on the basis of clinical decision-making.[7] However, there are currently gaps in awareness of MenB vaccines among parents of adolescents and providers; in 1 survey, less than half of the parents of 16- to 19-year-olds were aware of MenB availability, and in another survey, only 70% of pediatricians and 21% of family practitioners report being "very aware" of MenB vaccines.[8] Thus, improved guidance around MenB vaccine clinical decision-making during precollege health visits may be helpful for students, parents, and providers in making an informed decision.

Although risk factors for meningococcal disease among college students have been previously described,[2] there are limited data in the current epidemiologic context of low incidence of disease primarily caused by serogroup B. Although no additional data on college student cases are available in our analysis, the uniformly elevated incidence among students aged 18 to 20 years suggests that students across multiple years in school and not specifically freshmen may be at an increased risk. In the absence of data on invasive disease cases, risk factors for meningococcal carriage identified through 3 evaluations conducted at US universities during 2015–2016 may be informative.[16,23,24] In these evaluations, meningococcal carriage in college students was associated with male sex, smoking, and visiting bars or clubs at least once a week. However, carriage was not associated with freshman student status or residence in dormitories. Additional evaluations in which researchers identify risk factors for MenB disease and outbreaks among college

students will be useful in guiding future public health interventions.

Overall, MenB strains in college students were genetically diverse. Although CC32/ET-5 was the predominant cause of college outbreaks, this CC is also a common cause of sporadic MenB disease of all age groups in the United States, and thus is not specific to the college student population. Among other CCs, only CC11 (ST-11) was found to cause MenB disease solely in college students in this evaluation. CC11 is more commonly associated with serogroups C and W and rarely associated with serogroup B in the United States. Continued monitoring of hyperinvasive lineages in college student populations will be important. In addition, isolates from a few sporadic college and noncollege cases were retrospectively found through this evaluation to be related to college outbreak strains, highlighting the role that routine whole genome sequencing could play in early outbreak detection.

MenB vaccines are expected to provide at least short-term protection against a wide variety of circulating strains in the United States, although they will not prevent all cases. We were unable to assess the expected strain coverage of MenB vaccines in this population because we did not evaluate levels of gene expression and isolate susceptibility to antibodies induced by vaccine antigens. However, 47% of serogroup B isolates in college students and 67% in noncollege students possessed ≥1 MenB vaccine subvariants included in MenB-4C or MenB-FHbp, and others may still be covered through cross-reactivity. Assessments of MenB vaccine strain coverage, along with additional evaluations of MenB vaccine uptake and effectiveness, may be useful in evaluating the MenB vaccine program and in guiding future outbreak response.

Meningococcal disease and outbreaks in college students are important public health concerns. However, because enhanced meningococcal disease surveillance activities began in 2014, our analysis is limited by the relatively small number of cases and by an inability to evaluate trends in meningococcal disease incidence among college students. Although the incidence is low in the United States, continued improvements in surveillance will be important for monitoring the epidemiology of meningococcal disease in college students.

CONCLUSIONS

Although the incidence is low, college students are at an increased risk for sporadic and outbreak-associated MenB disease compared with noncollege students. Providers, college students, and parents should be aware of the availability of MenB vaccines. Additionally, with growing evidence of the impact of MenACWY vaccines on meningococcal disease in US adolescents, all adolescents should receive this vaccine according to ACIP recommendations regardless of college attendance. Finally, continued surveillance for meningococcal disease will be critical for monitoring the epidemiology of meningococcal disease in college students and informing public health prevention and response strategies.

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ABBREVIATIONS

ACIP: Advisory Committee on Immunization Practices
CC: clonal complex
CDC: Centers for Disease Control and Prevention
CI: confidence interval
MenACWY: quadrivalent meningococcal conjugate
MenB: serogroup B meningococcal
NNDSS: National Notifiable Diseases Surveillance System
RR: relative risk
SNP: single nucleotide polymorphism
ST: sequence type

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Supplemental Information

SUPPLEMENTAL TABLE 4 Molecular Typing Profile of MenB Isolates (n = 52) Among College Students and Noncollege Students Aged 18–24 Years in the United States From 2014 to 2016

CC	ST	No. Isolates	College Student	PorA	FetA	FHbp		NhbA	NadA
						Oxford Peptide ID	Subfamily or Variant		
CC11/ET-37	11	4	Yes	P1.5-1,10-1	F3-6	19	A/v2	p0020	Incomplete ORF
CC1157	1157	1	No	P1.22,14-6	F5-36	13	B/v1	p0114	NadA-2/3 frameshift
	11 580	1	No	P1.18-1,3	F5-36	13	B/v1	p0114	Incomplete ORF
CC167	1624	1	Yes	P1.5-1,10-4	F5-36	24	A/v2	p0009	Not found
	1624	1	Yes	P1.5-1,2-2	F3-4	24	A/v2	New	Not found
CC213	213	1	Yes	P1.22,14	F5-5	4	B/v1	p0018	NadA-4/5 frameshift, phase variation
CC269	269	1	Yes	P1.19-1,15-11	F5-1	15	B/v1	p0021	Not found
	3091	1	Yes	P1.19,15	F3-6	1	B/v1	p0855	Not found
CC32/ET-5	32	1	No	P1.5-1,2-2	F3-3	1	B/v1	p0005	NadA-1.1
	32	1	No	P1.7,16	F1-7	1	B/v1	p0005	NadA-1.1
	32	1	No	P1.7,16	F3-3	1	B/v1	p0003	NadA-1.1
	32	1	No	P1.7,16-20	F3-3	1	B/v1	p0005	NadA-1.1
	32	2	No	P1.7,16-20	F4-28	1	B/v1	p0005	NadA-1.1
	32	1	No	P1.7,16-21	New	110	B/v1	p0003	NadA-1.150
	32	8	Yes	P1.7,16-20	F3-3	1	B/v1	p0005	NadA-1.1
	33	1	Yes	P1.5,2-64	F5-1	144	B/v1	p0020	NadA-1.1
	34	1	Yes	P1.19,15	F5-1	903	B/v1	p0020	NadA-1.1
	11 556	2	Yes	P1.7,16	F3-3	1	B/v1	p0003	NadA-1.1
	11 556	1	Yes	P1.7,16	F3-3	978	B/v1	p0003	NadA-1.1
	11 910	1	Yes	P1.18-1,30-3	F3-3	510	B/v1	p0029	NadA-1.1
	11 910	1	Yes	P1.18-1,30-6	F3-3	510	B/v1	p0029	NadA-1.1
CC41/44/lineage 3	154	1	No	P1.7-2,4	F1-5	4	B/v1	p0002	Not found
	1194	1	No	P1.18-1,14	F1-5	4	B/v1	p0002	Not found
	7574	1	No	P1.22,14-6	F5-28	435	B/v1	p0043	Not found
	10 330	1	No	P1.18-1,34	F1-5	31	A/v3	p0002	Not found
	11 911	1	No	P1.7-2,30	F1-5	14	B/v1	p0002	Not found
	6058	1	No	P1.18-1,34-4	F1-5	984	A/v2	p0002	Not found
	2578	1	No	P1.17,9	F1-5	100	B/v1	p0002	Not found
	44	1	Yes	P1.19,13	F1-18	19	A/v2	p0029	Not found
	136	1	Yes	P1.5-2,10-1	F5-5	24	A/v2	New	Not found
	409	1	Yes	P1.18-1,34	F1-5	19	A/v2	p0002	Not found
	409	2	Yes	P1.5-1,2-2	F1-5	276	B/v1	p0002	Not found
	687	1	Yes	P1.21-2,23-6	F5-8	110	B/v1	New	Not found
	7574	1	Yes	P1.22,14-6	F1-5	435	B/v1	p0021	Not found
	7574	1	Yes	P1.22,14-6	F4-60	435	B/v1	p0043	Not found
CC461	13 033	1	No	P1.19-2,13-1	F3-9	592	B/v1	p0058	Not found
Unassigned CC 9069	9069	1	No	P1.7-2,4	F1-5	31	A/v3	p0192	Not found
	9069	2	Yes	P1.7-2,4	F1-5	1	B/v1	p0192	Not found

ID, identification; ORF, open reading frame.