Carriage prevalence of *Neisseria meningitidis* in China, 2005–2022: a systematic review and meta-analysis

Mengmeng Yue[1,2], Juan Xu[2], Jianxing Yu[2] and Zhujun Shao[1,2*]

Abstract

Introduction: *Neisseria meningitidis* (*Nm*) is a major cause of meningitis and septicemia. Most people are infected with latent infections or are carriers. We aimed to estimate the carriage prevalence of *Nm* in China.

Methods: We did a systematic review of published work to assess the prevalence of meningococcal carriage in China. The quality assessment was conducted by the risk of bias tool according to Damian Hoy's study. We estimated pooled proportions of carriage and its 95% confidence interval (95% CI) using fixed effect model for studies with low heterogeneity and random effect model for studies with moderate or high heterogeneity. Subgroup analyses were also conducted by region and age group.

Results: In total, 115 studies were included. The quality evaluation grades of all included documents were medium or high grade. The weighted proportion of carriage was 2.86% (95% CI: 2.25–3.47%, I^2: 97.7%, $p = 0$). The carriage prevalence of *Nm* varied between provinces, ranged from 0.00% (95% CI: 0.00–0.66%) to 15.50% (95% CI: 14.01–16.99%). Persons aged 15 years and older had the highest carriage 4.38% (95% CI: 3.15–5.62%, $I2$: 95.4%, $p < 0.0001$), and children under 6 years of age had the lowest carriage 1.01% (95% CI: 0.59–1.43%, $I2$: 74.4%, $p < 0.0001$). In positive carriers, serogroup B (41.62%, 95% CI: 35.25–48.00%, I^2: 98.6%, $p = 0$) took up the highest proportion, and serogroup X (0.02%, 95% CI: 0.00–0.09%, I^2: 0.00%, $p = 1$) accounted for the lowest proportion.

Conclusion: The meningococcal carriage in China was estimated low and varied by region and age group. Understanding the epidemiology and transmission dynamics of meningococcal infection in insidious spreaders is essential for optimizing the meningococcal immunization strategies of the country.

Keywords: *Neisseria meningitidis*, Prevalence, China, Meta-analysis

Introduction

Neisseria meningitidis (*Nm*), a gram-negative bacterium that colonizes 10% of the human nasopharynx and spreads through the respiratory droplets of infected people, can cause invasive meningococcal disease (IMD), such as meningitis and septicemia [1, 2]. According to the structure and characteristics of capsular polysaccharides,

Nm strains are divided into 12 serogroups (A, B, C, W, X, Y, Z, E, H, I, K, L) and non-groupable serogroups [3]. It is generally believed that six groups (*Nm* A, B, C, W, Y and X) are the main causes of IMD and that non-groupable *Nm* is not pathogenic.

Globally, the incidence and mortality of meningococcal disease have continued to decrease since 1990, although differences in age and geographic distribution remained [4, 5]. In 2020, the incidence was 0.56 per 100,000 population in Spain and 0.17 per 100,000 population in Brazil [5]. During 2015–2019, the incidence rate

*Correspondence: shaozhujun@icdc.cn

[1] School of Public Health, Nanjing Medical University, Nanjing, China
Full list of author information is available at the end of the article

Yue *et al. BMC Infectious Diseases*   (2022) 22:594

Page 2 of 16

of meningococcal disease in China was 0.078 per million persons, and the case fatality rate was 11.82% [6]. The reported cases of meningitis in China are mainly people aged 10–19 years, accounting for 34.15% (111/325) of the total reported cases of meningococcal disease, followed by people aged 1–9 years, accounting for 29.54% (96/325) [7].

Invasive cases are relatively rare in meningococcal infected cases while most cases are asymptomatic [8]. The phenomenon of asymptomatic colonization in the upper respiratory tract mucosa is known as carriage [2]. The colonization of *Nm* in the nasopharynx is the initial step in IMD development [9]. The meningococcus of the patient is usually obtained through close contact with carriers rather than patients [10]. Estimates of carriage prevalence are important for studying the dynamics of carriage and disease and for understanding the potential effect of control programs, such as vaccination, on the transmission of meningococci.

In the African meningitis belt, the carriage prevalence of *Nm* ranged from 0.595% in infants to 1.94% at age 10 [11]. In European countries, the highest carriage prevalence was 23.7% in 19-year old [8]. In the Americas, the prevalence among adolescents and young adults, especially university students and males, was higher than that of other populations [12]. These indicate that differences exist between regions and age groups. The overall carriage prevalence of *Nm* between 2000 and 2013 in China was 2.7% (95%CI: 2.0–3.5%), but the regional distribution and age distribution was unclear [13]. Understanding the distribution of meningococcal carriage in regions and age groups is critical to understanding the spread of *Neisseria meningitidis.*

Knowing the carriage prevalence can understand the dynamics of the spread of bacteria in the population, which is the important evidence for evaluating, planning, and implementing intervention measures, such as vaccine immunization. Currently, the meningococcal vaccines marketed in China include Group A meningococcal polysaccharide vaccine (MPV-A), Group A and group C meningococcal polysaccharide vaccine (MPV-AC), Group A, C, Y, and W135 meningococcal polysaccharide vaccine (MPV-ACWY), Group A and group C meningococcal polysaccharide conjugate vaccine (MPCV-AC), Group A and group C meningococcal polysaccharide conjugate and Haemophilus type b conjugate combined vaccine (MPCV-AC-Hib) [14, 15]. There is evidence that meningococcal polysaccharide conjugate vaccines (MPCVs) can reduce nasopharyngeal meningococcal bacteria carriage and have the ability to induce herd protection [16, 17]. There is no group B meningococcal vaccine in China. American CDC's Advisory Committee on Immunization Practices (ACIP) recommends to vaccinate the quadrivalent meningococcal conjugate vaccine (MenACWY) for teenagers aged 11 or 12 years, and to boost immunization at the age of 16 [18]. Knowing the carriage prevalence of *Nm* can indirectly indicate the IMD prevalence. Meanwhile, understanding the difference in the carriage prevalence of different age groups can help to adjust the immunization strategy.

We conducted this systematic review and meta-analysis to evaluate the meningococcal carriage prevalence in China and to learn the distribution of *Nm* and serogroup proportions in positive carriers. Learning the regions and age groups with high level of carriage is important for understanding the transmission dynamics and determination of target population for vaccination. It is of significance for the development of new vaccines, such us serogroup B vaccines, to find out the serogroup with the highest proportion in positive carriers.

Methods
Search strategy and data sources
This review was conducted in accordance with the PRISMA 2020 statement [19] (Additional file 1: Table S1) to identify articles reporting the carriage of *Nm* in different provinces in China published between 1st January 2005 and 30th April 2022. We searched five databases [China national knowledge infrastructure (CNKI), Wanfang Data Knowledge Service Platform (Wanfang), China Science and Technology Journal Database (VIP), China Biology Medicine disc (CBMdisc) and PubMed] using the following medical subject headings (MeSH) and text words: "Cerebrospinal meningitis", "Meningococcal meningitis", "Meningococcal Infections", "Meningitis", "*Neisseria meningitidis*", "Neisseria", "Meningococcal", and "carriage".

Inclusion and exclusion criteria
Studies were considered for inclusion if they met the following criteria: (1) the studies reported pharyngeal carriage of all meningococcal serogroups from different provinces in China; (2) the subjects of these studies must be healthy populations; (3) the studies were peer-reviewed and published between 1st January 2005 (when MPV-AC was included in the national immunization program) and 30th April 2022; (4) the studies were published in English or Chinese.

Studies were ineligible for inclusion if they met the following items: (1) case reports, case–control reports, outbreak investigations, reviews and other meta-analyses; (2) Studies that reported carriage among cases or close contacts of cases; (3) Studies that only reported the carriage prevalence of a single serogroup of meningococci; (4) studies with incomplete data; (5). Studies that reported the evaluation of the effect of antibiotics or

Yue *et al. BMC Infectious Diseases*　　(2022) 22:594

Page 3 of 16

post-chemical prophylaxis research results; (6) Duplicate studies including the same samples.

Data extraction and classification

Study selection (including screening titles and abstracts and assessment through full text review) and data collection were independently conducted by two authors (YMM and XJ). If disagreement occurred, we sought for the recommendation of the third researcher (SZJ). The data extracted from eligible studies included the following aspects: title, first author, publication year, region, research time, sampling methods, lab methods, the number of age groups, the number of carriers and sample size. Provinces were classified into seven geographical regions [20], i.e. northeast (Heilongjiang, Jilin and Liaoning), north (Beijing, Hebei, Inner Mongolia and Shanxi), east (Anhui, Fujian, Jiangsu, Jiangxi and Shandong), south (Guangdong, Guangxi and Hainan), central (Henan, Hubei and Hunan), northwest (Gansu, Ningxia, Qinghai, Shaanxi and Xinjiang), and southwest (Guizhou, Sichuan and Yunnan). Due to the different methods of age groupings reported in different literatures, the median age of each age group in the literature was used for the age grouping of subgroup analysis. The reported age groups of study participants were divided into three groups, i.e. 0–6 years, 7–14 years, and ≥ 15 years, since children aged 0–6 years are required to be vaccinated in the National Immunization Schedule.

Quality assessment

The quality assessment of the included studies was independently conducted by two reviewers (YMM and XJ). The risk of bias tool was used to assess the quality of selected studies according to Damian Hoy's study, including external validity (Items 1 to 4) and internal validity (Items 6 to 10) [21]. Items included the sampling frame of the sample, the sampling methods, the nonresponse bias, the case definition, the data collected, lab method, and data source. Each question answered "yes" received one point, while the "no" answer for each question received zero. In addition, each question answered "unknown" got 0.5 points. The risk of bias was classified as high (0–5 score), medium (5.5–8 score) and low (8.5–10 score).

Statistical analyses

All statistical analyses were performed in R software (version 4.1.2, Auckland University, USA). We used the metaprop function in the meta package to pool proportions of included studies. Subgroup analyses were conducted by province, region and age group. The Higgins I^2 test was used to measure heterogeneity between studies. Heterogeneity was classified as low ($0 < I^2 \le 50\%$), moderate ($50\% < I^2 \le 75\%$) and high ($75\% < I^2 \le 100\%$). A fixed

effect model was performed for studies with low heterogeneity, while a random effect model was used for studies with moderate or high heterogeneity. Funnel plots and Egger's test were used to evaluate possible publication bias. If publication bias exists, the trim-and-fill method was performed to evaluate the impact of publication bias on the results. Sensitivity analysis was performed to assess the stability of the results by calculating the combined carriages and 95% CIs after excluding each selected study.

Results

Study screening

Overall, 2845 records were identified from five databases based on the search strategy. After removing 1370 duplicated records, 1475 studies remained. 1316 records were excluded after screening the titles and abstracts, i.e., 293 records not relevant to *Nm*, 2 duplicated studies, and 1021 studies associated with *Nm* but not carriage. In the full text screening process, 159 studies were screened, and 44 studies excluded, i.e., 25 duplicated studies, 4 studies published before 2005, and 15 studies carriage data not reportable. Overall, 115 studies reporting the carriage of *Nm* in different provinces of China were included in the systematic review and meta-analysis (Fig. 1).

Characterization and quality assessments of included studies

Among the 115 included studies, 114 studies reporting the carriage prevalence of *Nm* of 28 provinces in China were included regional subgroup analysis (Table 1). 66 studies were cross sectional, 48 were serial cross sectional, and one study was a combination of cross sectional and longitudinal. 57 studies reported on the carrying status of meningococci in different age groups using different grouping methods. 55 studies reported the carriage prevalence with different sampling methods: cluster sampling, cluster stratified random sampling, random sampling, multistage stratified random Sampling, simple random sampling, stratified cluster sampling and stratified random sampling. 104 studies used the isolation and culture of meningococcus as the identification standard, and 10 of them also used PCR as the identification standard.

Most (85.22%, 98/115) included studies received a medium score of the quality assessment (Additional file 1: Fig. S1). No study received a high risk-of bias score. The target population of 115 studies was not well representative of the national population. Most (97.39%, 112/115) studies did not cover a sufficient period of time (≥ 1 year) to account for seasonal variation and 58.26%
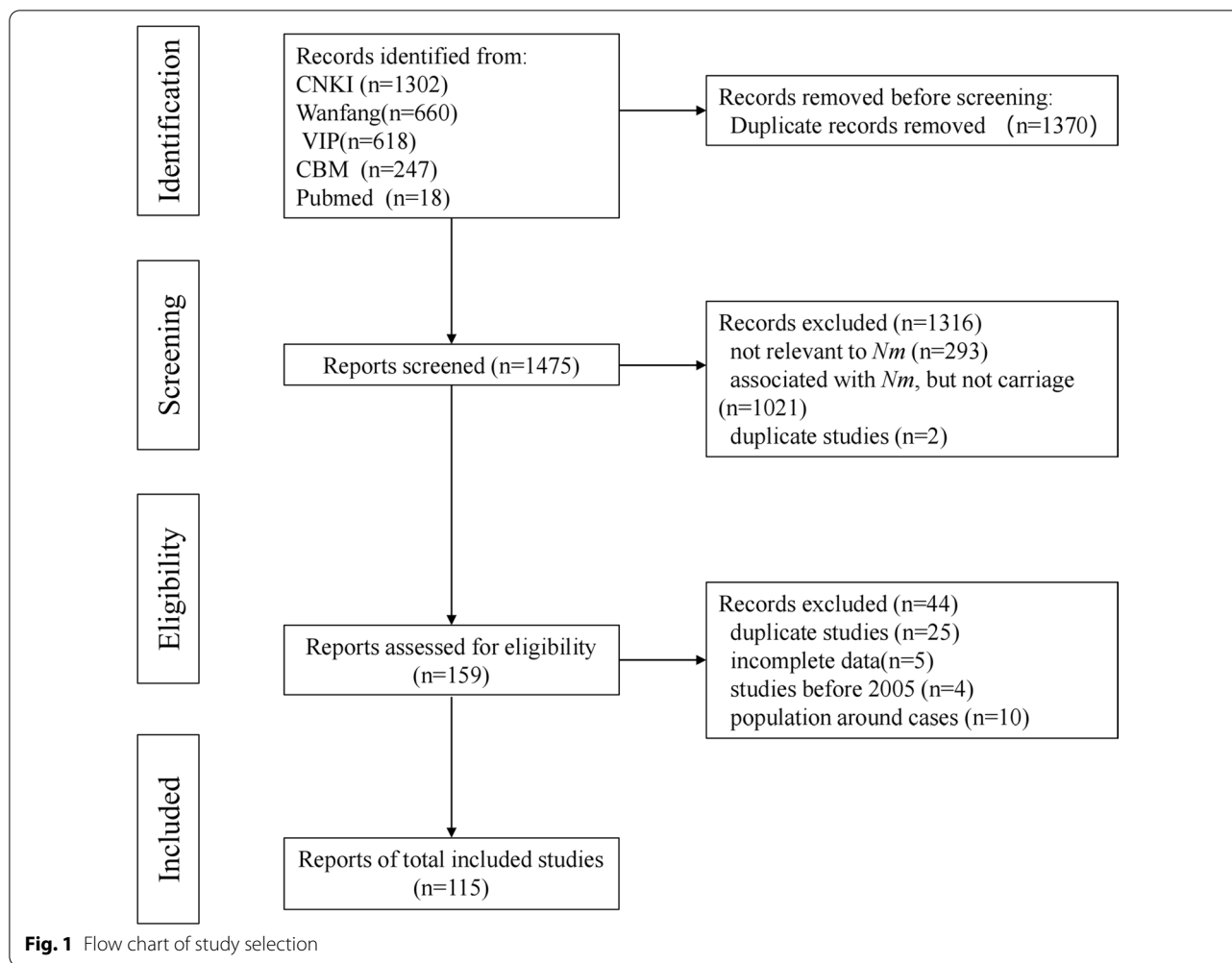
Yue *et al. BMC Infectious Diseases*   (2022) 22:594

Page 4 of 16

Fig. 1 Flow chart of study selection

(67/115) of the included studies did not report whether they used random sampling.

Carriage prevalence by region

The overall carriage prevalence of *Nm* of all 115 studies was 2.86% (95% CI: 2.25–3.47%, I^2: 97.7%, $p = 0$) with random effect model. In the results of subgroup analysis by province (Fig. 2), the meningococcal carriage rate ranged from 0.00% (95% CI: 0.00–0.66%) in Jilin in northeast China to 15.50% (95% CI: 14.01–16.99%) in Xinjiang in northwest China. In the results of subgroup analysis by region (Table 2), the meningococcal carriage prevalence ranged from 1.65% (95% CI: 1.10–2.20%) in Southwest China to 4.48% (95% CI: 0.91–8.05%) in Northwest China.

Carriage prevalence by age

The age group data were divided into 3 age groups according to the different age groupings of each study (Table 3). Random effect mode was used to generate the weighted carriage rate of each age group. As shown in Table 2, the highest carriage was 4.38% (95% CI: 3.15–5.62%) in age group ≥ 15 years old, and the lowest carriage was 1.01% (95% CI: 0.59–1.43%) in 0–6 years age group.

The proportion of *N. meningitidis* serogroups in positive cases

As shown in Table 4, random effect model was used to calculated the proportion of *Nm* serogroups, except NmX and NmY, in positive cases of carriage studies. The proportion of meningococcal serogroup in positive cases ranges from 0.02% (0.00–0.09%) of serogroup X to 41.62% (35.25–48.00%) of serogroup B.

Publication bias and sensitivity analysis

We used funnel plots and Egger's linear regression to assess the publication bias of all included studies. The result of the funnel plot, which was asymmetric (Fig. 3A), and the P value of Egger's test (Fig. 3B, P

Table 1 Characterization of included 115 studies

ID	Study	First author	Province	Publication time	Study time	Sampling method	Testing method	NO. of age groups	Cases	Sample size	Carriage prevalence
1	Yueyun Lan-2012 [22]	Yueyun Lan	Zhejiang	2012	1985–2010	UN	UN	UN	1762	7649	23.04%
2	Ruichun Ding-2013 [23]	Ruichun Ding	Hunan	2013	2011–2012	UN	Isolation and culture	7	1	442	0.23%
3	Xiumin Liang-2018 [24]	Xiumin Liang	Yunnan	2018	2014	Cluster sampling	Isolation and culture	4	16	240	6.67%
4	Hongfei Zhang-2010 [25]	Hongfei Zhang	Inner Mongolia	2010	2007	Stratified random sampling	Isolation and culture	UN	13	221	5.88%
5	Weijun Hu-2020 [26]	Weijun Hu	Shaanxi	2020	2016–2017	Cluster sampling	Isolation and culture, PCR	UN	110	1539	7.15%
6	Yueqi Wang-2017 [27]	Yueqi Wang	Shaanxi	2017	2016	Cluster sampling	Isolation and culture, PCR	6	64	998	6.42%
7	Tingting Yang-2019 [28]	Tingting Yang	Shanxi	2019	2016–2017	UN	Isolation and culture	6	25	649	3.9%
8	Honglian Lai-2011 [29]	Honglian Lai	Fujian	2011	2010	Stratified random sampling	Isolation and culture	UN	0	335	0%
9	Jialing Zhang-2019 [30]	Jialing Zhang	Jiangsu	2019	2014–2016	Random sampling	Isolation and culture	8	150	1265	11.86%
10	Xianping He-2013 [31]	Xianping He	Sichuan	2013	2010	UN	Isolation and culture	UN	2	273	0.73%
11	Zunyu Liu-2016 [32]	Zunyu Liu	Shandong	2016	2008–2015	Random sampling	Isolation and culture	7	24	2362	1.02%
12	Yingtong Wang-2015 [33]	Yingtong Wang	Hebei	2015	2006–2013	Stratified cluster sampling	Isolation and culture	7	293	28,447	1.03%
13	Zhenwu Liu-2017 [34]	Zhenwu Liu	Anhui	2017	2015	Stratified cluster sampling	Isolation and culture	6	23	1093	2.10%
14	Haiying Deng-2010 [35]	Haiying Deng	Hainan	2010	2006	Stratified random sampling	Isolation and culture	UN	9	744	1.21%
15	Min Cui-2013 [36]	Min Cui	Guangdong	2013	2009–2011	Stratified random sampling	Isolation and culture	UN	6	791	0.8%
16	Xinghua Wu-2010 [37]	Xinghua Wu	Guangxi	2010	2008	Stratified cluster sampling	Isolation and culture	UN	22	367	5.99%
17	Deshan Qiu-2016 [38]	Deshan Qiu	Shandong	2016	2013–2014	Stratified random sampling	Isolation and culture	7	8	996	0.80%
18	Weiping Jiang-2014 [39]	Weiping Jiang	Jiangsu	2014	2011–2012	UN	Isolation and culture	UN	17	703	2.42%
19	Hongna Chu-2016 [40]	Hongna Chu	Hebei	2016	2013–2014	Stratified random sampling	Isolation and culture	7	16	442	3.62%
20	Yihong Zhou-2012 [41]	Yihong Zhou	Jiangsu	2012	2011	UN	Isolation and culture	8	14	320	4.38%
21	Bin Jia-2016 [42]	Bin Jia	Beijing	2016	2009–2013	UN	Isolation and culture	9	34	1224	2.78%
22	Hengcai Niu-2018 [43]	Hengcai Niu	Beijing	2018	2016	Cluster stratified random sampling	Isolation and culture	9	11	252	4.37%

Yue *et al. BMC Infectious Diseases*   (2022) 22:594

Page 6 of 16

Table 1 (continued)

ID	Study	First author	Province	Publication time	Study time	Sampling method	Testing method	NO. of age groups	Cases	Sample size	Carriage prevalence
23	Fei He-2020 [44]	Fei He	Zhejiang	2020	2013–2017	Volunteer recruiting	Isolation and culture, PCR	7	329	2807	11.72%
24	Weihua Xue-2016 [45]	Weihua Xue	Hebei	2016	2015–2015	Stratified random sampling	Isolation and culture	7	11	255	4.31%
25	Qingxiu Zheng-2019 [46]	Qingxiu Zheng	Beijing	2019	2015–2017	Cluster sampling	Isolation and culture	9	14	783	1.79%
26	Lei Geng-2017 [47]	Lei Geng	Hebei	2017	2015–2016	Stratified random sampling	Isolation and culture	7	11	215	5.12%
27	Yihong Liao-2017 [48]	Yihong Liao	Fujian	2017	2014–2016	UN	Isolation and culture	UN	0	600	0%
28	Fangqin Xie-2016 [49]	Fangqin Xie	Fujian	2016	2011	UN	Isolation and culture	UN	0	263	0%
29	Yunfeng Hu-2011 [50]	Yunfeng Hu	Fujian	2011	2009	Stratified random sampling	Isolation and culture	UN	0	188	0%
30	Shiguo Liang-2011 [51]	Shiguo Liang	Heilongjiang	2011	2009	Random sampling	Isolation and culture	UN	11	210	5.24%
31	Yongfei Yan-2018 [52]	Yongfei Yan	Hebei	2018	2009–2015	Stratified random sampling	Isolation and culture	7	100	3528	2.83%
32	Xiaolei Tang-2010 [53]	Xiaolei Tang	Qinghai	2010	2007	UN	Isolation and culture	5	11	480	2.30%
33	Maolin Wang-2011 [54]	Maolin Wang	Shandong	2011	2007–2010	Simple random sampling	Isolation and culture	7	14	1470	0.95%
34	Zhijun Wang-2010 [55]	Zhijun Wang	Henan	2010	2004–2008	UN	Isolation and culture	5	32	855	3.74%
35	Yemin Qi-2014 [56]	Yemin Qi	Hebei	2014	2000–2013	UN	Isolation and culture	UN	232	4865	4.77%
36	Lin Luan-2014 [57]	Lin Luan	Jiangsu	2014	2005–2012	Cluster sampling	Isolation and culture, PCR	UN	26	4043	0.64%
37	Caixia Hao-2010 [58]	Caixia Hao	Sichuan	2010	2008–2009	UN	Isolation and culture	7	6	212	2.83%
38	Jingzhi Gao-2019 [59]	Jingzhi Gao	Hubei	2019	2008–2018	UN	UN	UN	93	2818	3.30%
39	Rongwei Lan-2014 [60]	Rongwei Lan	Guangxi	2014	2011	Cluster stratified random sampling	Isolation and culture	5	112	1311	8.54%
40	Yafei Wang-2013 [61]	Yafei Wang	Shandong	2013	2012	UN	UN	UN	5	430	1.16%
41	Qian Liu-2013 [62]	Qian Liu	Henan	2013	2010–2012	UN	Isolation and culture	UN	99	1653	5.99%
42	Xufang Ye-2017 [63]	Xufang Ye	Guizhou	2017	2006	Stratified random sampling	Isolation and culture	UN	3	726	0.41%
43	Ling Yuan-2012 [64]	Ling Yuan	Fujian	2012	2009	UN	Isolation and culture	UN	3	727	0.4%
44	Huanzhang Yuan-2012 [65]	Huanzhang Yuan	Guangdong	2012	2008–2010	UN	Isolation and culture	7	7	737	0.95%
45	Dan Xiao-2011 [66]	Dan Xiao	Liaoning	2011	2002–2009	UN	UN	UN	8	1990	0.4%
46	Fengyun Cheng-2012 [67]	Fengyun Cheng	Anhui	2012	2009	Stratified random sampling	Isolation and culture	UN	2	80	2.5%

Yue *et al. BMC Infectious Diseases* (2022) 22:594

Page 7 of 16

Table 1 (continued)

ID	Study	First author	Province	Publication time	Study time	Sampling method	Testing method	NO. of age groups	Cases	Sample size	Carriage prevalence
47	Xiang Sun-2018 [68]	Xiang Sun	Jiangsu	2018	2014–2015	UN	Isolation and culture	UN	76	755	10.07%
48	Haitao Liu-2016 [69]	Haitao Liu	Beijing	2016	2013–2015	Stratified random sampling	Isolation and culture	UN	41	756	5.42%
49	Suxin Xu-2013 [70]	Suxin Xu	Hebei	2013	2012	Stratified random sampling	Isolation and culture	7	16	420	3.81%
50	Junrong Lu-2013 [71]	Junrong Lu	Hebei	2013	2012	Stratified random sampling	Isolation and culture	5	8	382	2.09%
51	Junhong Li-2010	Junhong Li	China	2010	2009	UN	UN	UN	92	9743	0.94%
52	Manshi Li-2010 [72]	Manshi Li	Shandong	2010	2008–2009	UN	Isolation and culture	7	13	1097	1.19%
53	Xuan Deng-2018 [73]	Xuan Deng	Zhejiang	2018	2006–2017	UN	UN	UN	4	2524	0.16%
54	Lijun Chen-2012 [74]	Lijun Chen	Guangdong	2012	2006–2008	UN	Isolation and culture	UN	1	705	0.14%
55	Xiaoping Yan-2010 [75]	Xiaoping Yan	Sichuan	2010	2006–2008	Random sampling	Isolation and culture	6	13	540	2.4%
56	Heng Yuan-2010 [76]	Heng Yuan	Sichuan	2010	2005–2008	UN	Isolation and culture	8	61	4369	1.40%
57	Jingjing Wu-2020 [77]	Jingjing Wu	Shandong	2020	2008–2018	UN	Isolation and culture	UN	34	3827	0.89%
58	Yan Wang-2016 [78]	Yan Wang	Liaoning	2016	2004–2013	UN	UN	UN	41	5197	0.79%
59	Shenxia Chen-2013 [79]	Shenxia Chen	Zhejiang	2013	2011–2013	Stratified random sampling	Isolation and culture	UN	5	152	3.29%
60	Quwen Li-2014 [80]	Quwen Li	Fujian	2014	2012	UN	Isolation and culture	UN	2	806	0.25%
61	Xiaofeng Yang-2007 [81]	Xiaofeng Yang	Hunan	2007	2006	Cluster sampling	Isolation and culture	7	10	367	2.72%
62	Xiaoqing Fu-2006 [82]	Xiaoqing Fu	Yunnan	2006	2005	UN	Isolation and culture	UN	14	979	1.43%
63	Taiping Yang-2007 [83]	Taiping Yang	Guangdong	2007	2006	Cluster sampling	Isolation and culture	5	9	352	2.56%
64	Xiaochun Li-2007 [84]	Xiaochun Li	Sichuan	2007	2005	UN	Isolation and culture	6	10	336	2.98%
65	Yushan Fan-2008 [85]	Yushan Fan	Hebei	2008	2001–2007	UN	Isolation and culture	UN	60	1792	3.35%
66	Fang Guo-2007 [86]	Fang Guo	Zhejiang	2007	2001–2006	UN	Isolation and culture	7	92	1779	5.17%
67	Sujie Shi-2006 [87]	Sujie Shi	Jiangsu	2006	2005	Random sampling	UN	9	8	470	1.70%
68	Shuxian Zhang-2009 [88]	Shuxian Zhang	Liaoning	2009	2006–2008	UN	Isolation and culture	UN	43	618	6.96%
69	Ye Chen-2007 [89]	Ye Chen	Liaoning	2007	2005	UN	UN	UN	13	229	5.68%
70	Qunwen Wen-2006 [90]	Qunwen Wen	Guangdong	2006	2005	Cluster sampling	Isolation and culture	7	10	717	1.39%
71	Changyan Ju-2008 [91]	Changyan Ju	Guangdong	2008	2005–2006	UN	Isolation and culture	7	55	1255	4.4%
72	Guohua Li-2006 [92]	Guohua Li	Shanxi	2006	2005	Random sampling	Isolation and culture	9	11	940	1.17%
73	Jianmin Zhang -2009 [93]	Jianmin Zhang	Zhejiang	2009	2003–2008	UN	Isolation and culture	3	87	1507	5.77%

Yue et al. BMC Infectious Diseases   (2022) 22:594

Page 8 of 16

Table 1 (continued)

ID	Study	First author	Province	Publication time	Study time	Sampling method	Testing method	NO. of age groups	Cases	Sample size	Carriage prevalence
74	Youju Jia-2008 [94]	Youju Jia	Qinghai	2008	2006–2007	UN	Isolation and culture	UN	11	450	2.44%
75	Yan Yang-2008 [95]	Yan Yang	Sichuan	2008	2007	UN	Isolation and culture, PCR	2	13	230	5.65%
76	Chunyuan Cao-2009 [96]	Chunyuan Cao	Fujian	2009	2006–2007	UN	Isolation and culture	UN	1	251	0.40%
77	Meng Yang-2007 [97]	Meng Yang	Jiangxi	2007	2005	UN	Isolation and culture	9	29	1441	2.01%
78	Xiaoqing Liu-2009 [98]	Xiaoqing Liu	Jiangxi	2009	2005–2007	UN	Isolation and culture	UN	55	3312	1.66%
79	Zhenglong Zhong-2008 [99]	Zhenglong Zhong	Jiangsu	2008	2005–2007	Random sampling	Isolation and culture	7	10	193	5.18%
80	Wen Lu-2008 [100]	Wen Lu	Heilongjiang	2008	2005	Random sampling	Isolation and culture	UN	3	230	1.30%
81	Jing Lv-2006 [101]	Jing Lv	Hubei	2006	2000–2005	UN	Isolation and culture	UN	213	4921	4.33%
82	Zhenyu Qian-2009 [102]	Zhenyu Qian	Hebei	2009	2007–2008	Stratified random sampling	Isolation and culture	7	163	7460	2.18%
83	Xiaoping Wang-2007 [103]	Xiaoping Wang	Anhui	2007	2005–2006	Simple random sampling	Isolation and culture	5	82	1868	4.39%
84	Xiujuan Yan-2006 [104]	Xiujuan Yan	Hainan	2006	2005	Random sampling	Isolation and culture	UN	14	617	2.27%
85	Tie Song-2007 [105]	Tie Song	Guangdong	2007	2005	UN	UN	UN	17	2413	0.70%
86	Lianfei Zhao-2007 [106]	Lianfei Zhao	Ningxia	2007	2007	Random sampling	UN	UN	0	210	0%
87	Jianying Yang-2005 [107]	Jianying Yang	Gansu	2005	2005	UN	Isolation and culture	9	2	742	0.27%
88	Ping Lin-2007 [108]	Ping Lin	Fujian	2007	2005	Random sampling	Isolation and culture	UN	1	190	0.530%
89	Huake Yang-2006 [109]	Huake Yang	Guangdong	2006	2005	UN	Isolation and culture	UN	0	226	0%
90	Shuhua Luo-2006 [110]	Shuhua Luo	Guangdong	2006	2005	UN	Isolation and culture	7	1	616	0.16%
91	Yan Teng-2009 [111]	Yan Teng	Jilin	2009	2008	Cluster sampling	Isolation and culture	7	0	210	0%
92	Yonggeng Zou-2009 [112]	Yonggeng Zou	Hunan	2009	2008	UN	Isolation and culture	7	1	240	0.42%
93	Huanying Gu-2009 [113]	Huanying Gu	Hebei	2009	2008	Stratified random sampling	Isolation and culture	UN	4	348	1.15%
94	Xinghua Wu-2009 [114]	Xinghua Wu	Guangxi	2009	2008	UN	Isolation and culture	UN	32	864	3.7%
95	Weijun Wang-2008 [115]	Weijun Wang	Chongqing	2008	2007	UN	Isolation and culture	UN	3	638	0.47%
96	Yinqi Sun-2008 [116]	Yinqi Sun	Hebei	2008	2007	UN	Isolation and culture	7	58	3618	1.60%
97	Rongna Huang-2009 [117]	Rongna Huang	Sichuan	2009	2007	Random sampling	Isolation and culture, PCR	5	11	999	1.1%

Yue *et al. BMC Infectious Diseases*   (2022) 22:594

Page 9 of 16

Table 1 (continued)

ID	Study	First author	Province	Publication time	Study time	Sampling method	Testing method	NO. of age groups	Cases	Sample size	Carriage prevalence
98	Qingmei Cong-2009 [118]	Qingmei Cong	Shandong	2009	2007–2008	UN	Isolation and culture	7	6	840	0.71%
99	Jianwen Yin-2007 [119]	Jianwen Yin	Yunnan	2007	2006	Cluster sampling	Isolation and culture	6	21	1249	1.68%
100	Lihua Ren-2008 [120]	Lihua Ren	Inner Mongolia	2008	2006	Stratified random sampling	Isolation and culture	7	8	210	3.81%
101	Yun Gong-2009 [21]	Yun Gong	Fujian	2009	2006	Stratified random sampling	Isolation and culture	UN	4	652	0.6%
102	Jun Wang-2007 [122]	Jun Wang	Ningxia	2007	2006	UN	Isolation and culture	UN	4	214	1.9%
103	Zuokui Xiao-2009 [123]	Zuokui Xiao	Shandong	2009	2007–2008	UN	Isolation and culture	UN	73	4836	1.52%
104	Xinchang Luo-2006 [124]	Xinchang Luo	Fujian	2006	2005	UN	Isolation and culture	UN	2	360	0.55%
105	Xin Li-2007 [125]	Xin Li	Inner Mongolia	2007	2005	UN	Isolation and culture	UN	27	711	3.80%
106	Hai Wang-2007 [126]	Hai Wang	Anhui	2007	2005	Random sampling	Isolation and culture	4	32	1047	3.06%
107	Lv You-2006 [127]	Lv You	Guizhou	2006	2005	UN	isolation and culture	9	17	904	1.88%
108	Meizhen Liu-2007 [128]	Meizhen Liu	Guangdong	2007	2005	UN	Isolation and culture	UN	7	1077	0.65%
109	Yan Zhang-2021 [129]	Yan Zhang	Shandong	2021	2009–2020	Recruitment	Isolation and culture, PCR	6	136	16,848	0.81%
110	Jinjun Luo-2021 [130]	Jinjun Luo	Hubei	2021	2013–2018	UN	Isolation and culture	7	370	4477	8.26%
111	Na Xie-2021 [131]	Na Xie	Xinjiang	2021	2012–2019	Cluster stratified random sampling	Isolation and culture, PCR	UN	351	2264	15.5%
112	Xiaohong Zhou-2021 [132]	Xiaohong Zhou	Jiangsu	2021	2018	UN	Isolation and culture	UN	7	411	1.70%
113	Man Jiang-2021 [133]	Man Jiang	Jiangsu	2021	2017–2018	Multistage stratified random sampling	Isolation and culture	8	15	772	1.94%
114	Chen Chen-2021 [134]	Chen Chen	Yunnan	2021	2020	Random Sampling	Isolation and culture, PCR	UN	17	1076	1.58%
115	Yunyi Zhang-2022 [135]	Yunyi Zhang	Zhejiang	2022	2015–2020	UN	Isolation and culture, PCR	UN	17	2827	0.64%

Yue *et al. BMC Infectious Diseases* (2022) 22:594

Page 10 of 16

Fig. 2 Carriage prevalence by province. The weighted mean was calculated with random effect model. Yellow diamonds represent the weighted mean, and solid black lines represent the 95% CIs
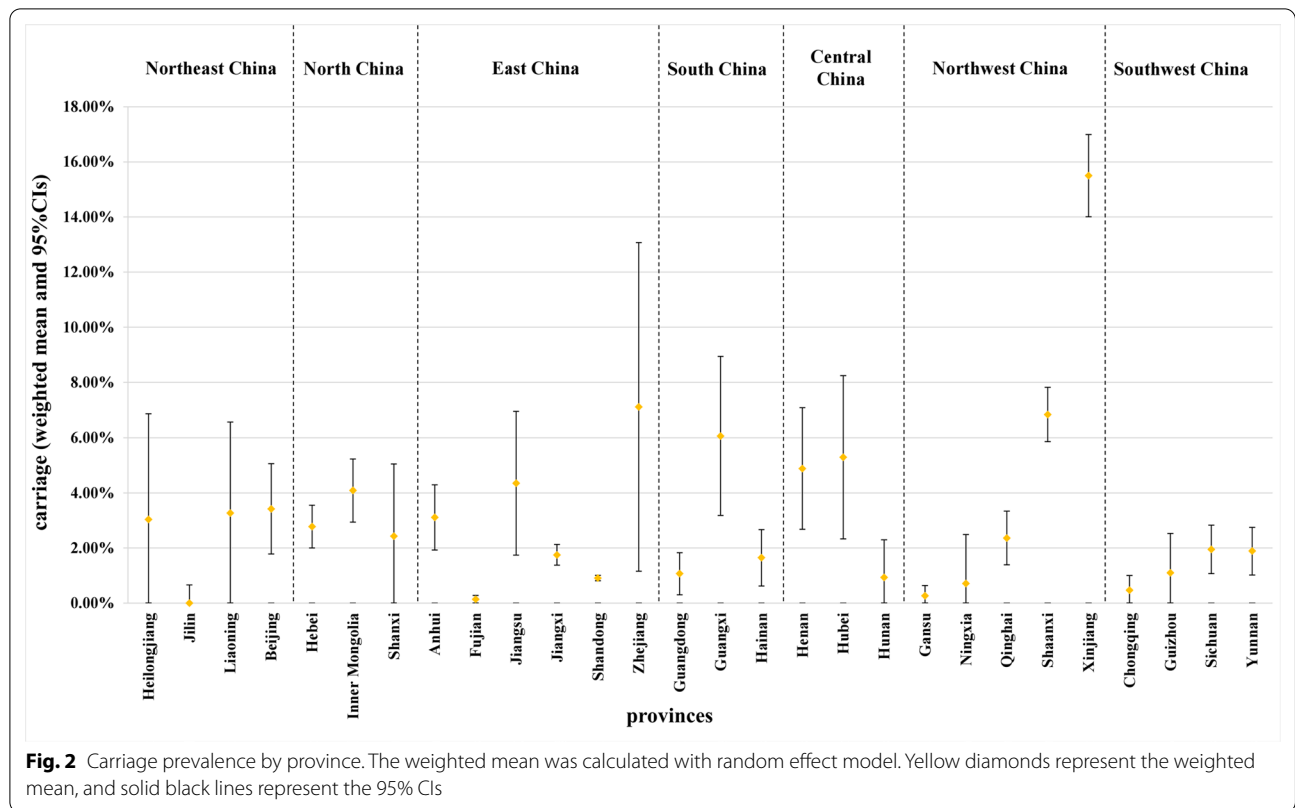
Table 2 Carriage prevalence by region

Item	Southwest China	Northeast China	South China	East China	Central China	Northwest China	North China
Studies	14	7	15	41	8	8	21
Total number of cases	207	119	302	3168	819	553	1156
Sample size	12,771	8684	12,792	74,096	15,773	6897	57,518
I^2 (P value)	76.3% ($p < 0.01$)	90.8% ($p < 0.01$)	93.7% ($p < 0.01$)	98.7% ($p = 0$)	98.3% ($p < 0.01$)	98.6% ($p < 0.01$)	93.8% ($p < 0.01$)
Model	Random	Random	Random	Random	Random	Random	Random
Weighted carriage	1.65%	2.66%	2.12%	2.82%	3.62%	4.48%	3.00%
95%CI	1.10–2.20%	0.52–4.80%	0.92–3.31%	1.48–4.16%	1.74–5.50%	0.91–8.05%	2.39–3.62%

Table 3 Carriage prevalence by age

Item	0–6 years	7–14 years	≥ 15 years
Studies	56	57	56
Total number of cases	296	667	1662
Sample size	26,491	37,763	39,633
I^2 (P value)	74.4% ($p < 0.0001$)	82.2% ($p < 0.0001$)	95.4% ($p < 0.0001$)
Model	Random	Random	Random
Weighted carriage	1.01%	1.81%	4.38%
95%CI	0.59–1.43%	1.32–2.30%	3.15–5.62%

Table 4 The proportion of *N. meningitidis* serogroups in positive cases

Item	A	B	C	W	X	Y	Others and non-groupable
Studies	95	95	95	95	95	95	95
Total number of cases	486	3124	508	195	43	116	1791
Sample size	6263	6263	6263	6263	6263	6263	6263
I^2 (P value)	86.4% ($p < 0.0001$)	98.6% ($p = 0$)	84.1% ($p < 0.0001$)	57.4% ($p < 0.0001$)	0.0% ($p = 1$)	29.8% ($p = 0.0044$)	98.1% ($p = 0$)
Model	Random	Random	Random	Random	Fixed	Fixed	Random
Weighted carriage	9.70%	41.62%	11.22%	2.13%	0.02%	0.03%	21.77%
95%CI	6.93–12.47%	35.25–48.00%	8.51–13.93%	1.16–3.09%	0.00–0.09%	0.00–0.10%	16.62–26.93%

Fig. 3 Analysis of publication bias of the 124 included studies. Panel **A** Funnel plot; Panel **B** Egger's test; Panel **C** Trim and Fill. Hallow circles show data points of added studies and filled circles show data points of included studies
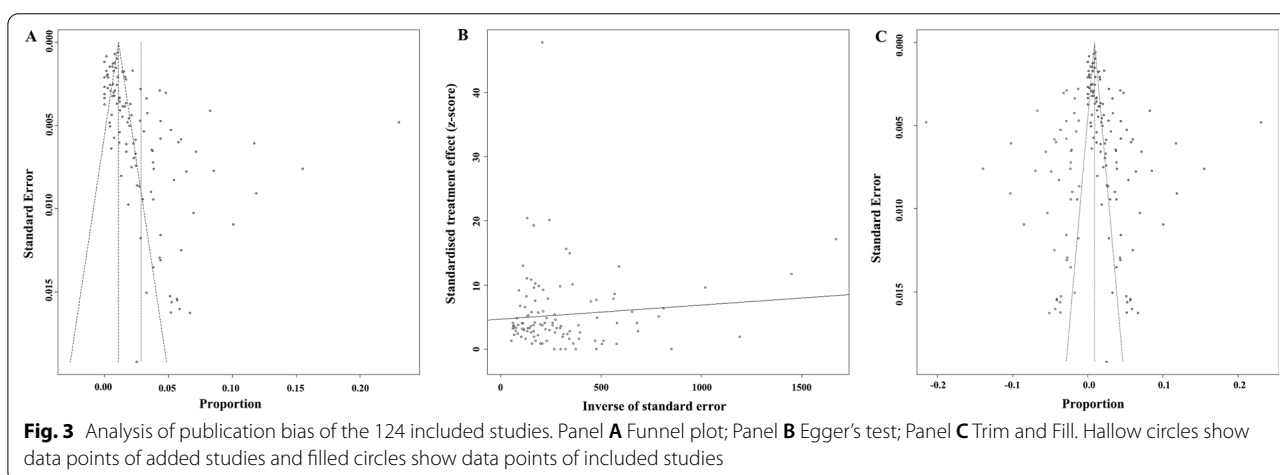
< 0.0001) illustrated the presence of publication bias. The weighted mean carriage rate was 0.91% (95%CI: 0.18–1.64%, Q = 9937.12, $p = 0$, $I^2 = 98.4$%, 95% CI of I^2: 98.3–98.5%) after adding 45 studies by the trim-and-fill method (Fig. 3C). The results of the sensitivity analysis (Additional file 1: Fig. S2) illustrated that the combined carriages and 95% CIs after excluding each selected study did not show much change. The results of the meta-analysis were stable and steady.

Discussion

At present, this is the first systematic review and meta-analysis to describe the regional distribution and age distribution of meningococcal carriage prevalence in healthy people in China. We estimated the overall carriage rate to be 2.85% (95% CI: 2.24–46%), which is lower than that reported in Cuba (31.9%), America (24%) and Brazil (21.5%) [12]. Limited nasopharyngeal swab sampling collection and insufficient laboratory testing capacity in different regions may contribute to the low carriage prevalence of *Nm*. The transportation of samples may also affect the carriage prevalence of *Nm*.

More than half of the studies were retrieved from East and North China, with the largest number of studies from Fujian Province of East China. A part (8.06%) of the research subjects were from rural areas [71, 83, 95, 102, 106, 113, 116, 119, 122, 136]. The majority of the study subjects included people of all ages, and only 2 were conducted on primary and middle school students [93, 95]. During 2006 and 2014, the provinces with the most cases of meningitis in China included Anhui (cases = 159) and Jiangsu (cases = 70) provinces in East China and Hebei Province (cases = 61) in North China [137]. Between 2015 and 2019, there were still many cases of meningitis reported in Hebei in North China while cases in Southwest and Northeast were fewer than that of other regions [6]. In a study analyzing the results of surveillance of meningococcal disease in China in 2009, 9743 subjects in eight provinces or cities were tested, and the carriage rate was 0.94% (92/9743), in which Hebei in North China was the province with the highest carriage rate [138].

According to the results of the age subgroup analysis, the meningococcal carriage rates of age group 7–14 and the age group ≥ 15 years old were higher than those of children (0–6 years). In the African meningitis belt, the

Yue *et al. BMC Infectious Diseases*   (2022) 22:594

Page 12 of 16

carriage prevalence of individuals aged 5–19 years were significantly higher than that of other age groups [11]. Since 2010, the meningococcal serogroup A conjugate vaccine (MenAfriVac) has been introduced in 26 countries of the African meningitis belt for individuals aged 1–29 years [139]. In European countries, the carriage prevalence increased from 4.5% in infants to a peak of 23.7% in 19-year-old adolescents and then decreased in adulthood to 7.8% in adults aged 50 [8]. This demonstrates the success of the immunization program of meningococcal serogroup C conjugate (MCC) for children under 18 in UK [140]. In China, the basic immunization population of the five meningococcal vaccines that have been marketed are children aged 0–6 [141]. It is important to improve vaccine strategies to determine whether it is necessary to booster immunization with meningococcal meningitis vaccines among people aged ≥ 7 years.

In our study, the highest and lowest proportion of *N. meningitidis* serogroups in positive meningococcal carriers was NmB with 41.62% (35.25–48.00%) and NmX with 0.02% (0.00–0.09%). Globally, serogroup B was the foremost cause of invasive meningococcal disease in America, Europe, and the western Pacific [142, 143]. At present, vaccines marked in China includes NmA, NmC, NmW and NmY vaccines except NmB vaccines [14, 15]. It is urgent for the development of serogroup B vaccines.

The results of the funnel plot and trim-and-fill method indicate that there is publication bias in this study. As 114 studies were regional and small-scale studies, the target population of these studies was not well representative of the national population (Additional file 1: Fig. S1). This review includes only published studies without unpublished literature whose results may be not significant.

A limitation of this review is that there is no unified standard on sample collection and laboratory testing methods, which can cause bias that impacts the results of meta-analysis. Inconsistent diagnostic methods and a lack of diagnostic kits may lead to underestimation or misinformation of the data reported in the study.

Understanding the carriage prevalence of *Nm* in generalizable populations contributes to providing evidence for further improvement of meningococcal vaccine and vaccination strategies. This is important for the prevention of meningitis and development of vaccines in China in the future.

Conclusion

In summary, the meningococcal carriage in China was estimated low and varied by region and age group. Based on our findings, we suggest that the surveillance on epidemic cerebrospinal meningitis among generalizable populations in each province and region in China should be enhanced.

The age distribution of meningococcal carriage highlights the importance of monitoring and booster immunization among teenagers aged ≥ 7 years.

Abbreviations

Nm: *Neisseria meningitidis*; IMD: Invasive meningococcal disease; CNKI: China national knowledge infrastructure; Wanfang: Wanfang Data Knowledge Service Platform; VIP: China Science and Technology Journal Database; CBMdisc: China Biology Medicine disc; MeSH: Medical subject headings; MPV-A: Group A meningococcal polysaccharide vaccine; MPV-AC: Group A and group C meningococcal polysaccharide vaccine; MPV-ACWY: Group A, C, Y, and W135 meningococcal polysaccharide vaccine; MPCV-AC: Group A and group C meningococcal polysaccharide conjugate vaccine; MPCV-AC-Hib: Group A and group C meningococcal polysaccharide conjugate and Haemophilus type b conjugate combined vaccine.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12879-022-07586-x.

Additional file 1: Table S1. PRISMA checklist. **Fig S1.** Quality assessment of the included studies. **Fig S2.** Forest plot of sensitivity analysis.

Author details
[1]School of Public Health, Nanjing Medical University, Nanjing, China. [2]Department of Respiratory Infectious Diseases, National Institute for Communicable Disease Control and Prevention, Chinese Center for Disease Control and Prevention, No. 155# Changbai Road, Chang Ping, Beijing, People's Republic of China.

Yue *et al. BMC Infectious Diseases*   (2022) 22:594

Page 13 of 16

References

1. Tefera Z, Mekonnen F, Tiruneh M, Belachew T. Carriage rate of *Neisseria meningitidis*, antibiotic susceptibility pattern and associated risk factors among primary school children in Gondar town, Northwest Ethiopia. BMC Infect Dis. 2020;20(1):358. https://doi.org/10.1186/s12879-020-05080-w.
2. Yazdankhah SP, Caugant DA. *Neisseria meningitidis*: an overview of the carriage state. J Med Microbiol. 2004;53(Pt 9):821–32. https://doi.org/10.1099/jmm.0.45529-0.
3. Peterson ME, Li Y, Shanks H, Mile R, Nair H, Kyaw MH, Meningococcal CG. Serogroup-specific meningococcal carriage by age group: a systematic review and meta-analysis. BMJ Open. 2019;9(4): e024343. https://doi.org/10.1136/bmjopen-2018-024343.
4. Collaborators GBDM. Global, regional, and national burden of meningitis, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. Lancet Neurol. 2018;17(12):1061–82. https://doi.org/10.1016/S1474-4422(18)30387-9.
5. Alderson MR, Arkwright PD, Bai X, Black S, Borrow R, Caugant DA, Dinleyici EC, Harrison LH, Lucidarme J, McNamara LA, et al. Surveillance and control of meningococcal disease in the COVID-19 era: a global meningococcal initiative review. J Infect. 2022;84(3):289–96. https://doi.org/10.1016/j.jinf.2021.11.016.
6. Li JH, Wu D, Wen N, Zheng H, Shi W, Xu L, Shao ZJ, Yin ZD, Li YX. Serogroup distribution of meningococcal meningitis in China, 2015–2019. Chin J Vaccines Immun. 2020;26(03):241–4.
7. Li JH, Wu D, Yin ZD, Li YX. Analysis of epidemic characteristics for meningococcal meningitis in China during 2015–2017. Chin J Prev Med. 2019;02:159–63. https://doi.org/10.3760/cma.j.issn.0253‑9624.2019.02.007.
8. 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. https://doi.org/10.1016/s1473-3099(10)70251-6.
9. Soriano-Gabarro M, Wolter J, Hogea C, Vyse A. Carriage of *Neisseria meningitidis* in Europe: a review of studies undertaken in the region. Expert Rev Anti Infect Ther. 2011;9(9):761–74. https://doi.org/10.1586/eri.11.89.
10. Serra L, Presa J, Christensen H, Trotter C. Carriage of *Neisseria meningitidis* in low and middle income countries of the Americas and Asia: a review of the literature. Infect Dis Therapy. 2020;9(2):209–40. https://doi.org/10.1007/s40121-020-00291-9.
11. Cooper LV, Kristiansen PA, Christensen H, Karachaliou A, Trotter CL. Meningococcal carriage by age in the African meningitis belt: a systematic review and meta-analysis. Epidemiol Infect. 2019;147: e228. https://doi.org/10.1017/S0950268819001134.
12. Santos-Neto JF, Ferreira VM, Feitosa CA, Martinez-Silveira MS, Campos LC. Carriage prevalence of *Neisseria meningitidis* in the Americas in the 21st century: a systematic review. Braz J Infect Dis. 2019;23(4):254–67. https://doi.org/10.1016/j.bjid.2019.06.006.
13. Zhang Y, Wei D, Guo X, Han M, Yuan L, Kyaw MH. Burden of *Neisseria meningitidis* infections in China: a systematic review and meta-analysis. J Glob Health. 2016;6(2): 020409. https://doi.org/10.7189/jogh.06.020409.
14. Association CPM. Efficacy, safety, and cost‑effectiveness of meningococcal vaccines. Chin J Prev Med. 2019;25(01):102-108+114.
15. China NHCotPsRo. Immunization schedules and instructions for vaccines of the national immunization program (2021 version). Chin J Viral Dis. 2021;2021:241–5. https://doi.org/10.16505/j.2095-0136.2021.0021.
16. Pizza M, Bekkat-Berkani R, Rappuoli R. Vaccines against meningococcal diseases. Microorganisms. 2020. https://doi.org/10.3390/microorganisms8101521.
17. McMillan M, Chandrakumar A, Wang HLR, Clarke M, Sullivan TR, Andrews RM, Ramsay M, Marshall HS. Effectiveness of meningococcal vaccines at reducing invasive meningococcal disease and pharyngeal *Neisseria meningitidis* carriage: a systematic review and meta-analysis. Clin Infect Dis. 2021;73(3):E609–19. https://doi.org/10.1093/cid/ciaa1733.
18. Mbaeyi SA, Bozio CH, Duffy J, Rubin LG, Hariri S, Stephens DS, MacNeil JR. Meningococcal vaccination: recommendations of the Advisory Committee on Immunization Practices, United States, 2020. MMWR Recomm Rep. 2020;69(9):1–41. https://doi.org/10.15585/mmwr.rr6909a1.
19. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, Shamseer L, Tetzlaff JM, Akl EA, Brennan SE, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021;372: n71. https://doi.org/10.1136/bmj.n71.
20. Ye Z, Zeng G, Yang H, Li J, Tang K, Wang G, Wang S, Yu Y, Wang Y, Zhang T, et al. The status and characteristics of urinary stone composition in China. BJU Int. 2020;125(6):801–9. https://doi.org/10.1111/bju.14765.
21. Hoy D, Brooks P, Woolf A, Blyth F, March L, Bain C, Baker P, Smith E, Buchbinder R. Assessing risk of bias in prevalence studies: modification of an existing tool and evidence of interrater agreement. J Clin Epidemiol. 2012;65(9):934–9. https://doi.org/10.1016/j.jclinepi.2011.11.014.
22. Lan YY, Jiang XC, Lu XY. Analysis on epidemiological features of patients with epidemic cerebrospinal meningitis in Quzhou from 1985 to 2010. Chin Prev Med. 2012;13(05):377–9. https://doi.org/10.16506/j.1009-6639.2012.05.018.
23. Ding RC. Investigation on the level of meningococcal immunity and bacteria-carrying status of healthy people in Yunxi District from 2011 to 2012. Chin J of PHM. 2013;29(03):374–5.
24. Liang XM, Cao JD, Luo XJ, Sun BJ. The analysis of healthy people suffering from cerebrospinal meningitis in Yi Liang County in 2014. China's Rural Health. 2018;04:34.
25. Zhang HF, Liu YY, Li SF, Chang XL, Zhang DW, Wu FY, Ren LH, Lin Z. Surveillance report of *Neisseria meningitidis* carrying and antibody levels in healthy people in Kezuozhong Banner, Tongliao City. J Dis Monit Control. 2010;4(12):658.
26. Hu WJ, Wang RZ, Wang YQ, Zhang SB. *Neisseria meningitidis* carriage prevalence and serogroup distribution among a healthy population of Shaanxi province. J Pract Med. 2020;36(06):796–800.
27. Wang YQ, Zhang SB, Wang RZ, Kou GP, Gao T, Hou TJ, Wang ZG. A carriage survey of *Neisseria meningitidis* among a healthy population in Guanzhong region, Shaanxi province. Chin J Vaccines Immun. 2017;23(04):375–8.
28. Yang TT, Wang XF, Chang SY, Guang M, Wang H, Yang HX. Analysis of epidemic cerebrospinal meningitis in healthy people in Shanxi Province from 2016 to 2017. Chin Rem Clin. 2019;19(10):1619–20.
29. Lai HL, Wang H, Hu QB, Cao CY, Liao LH. An investigation on meningococcal meningitis group A, group C antibody level and the pathogen rate of partly healthy population in Longyan City. J Dis Monit Control. 2011;5(09):521–2.
30. Zhang JL, Gu LN. Surveillance and analysis of immune level and carrier rate of epidemic meningitis in healthy population in Lianyungang City from 2014 to 2016. Pract Prev Med. 2019;26(09):1126–8.
31. He XP. Surveillance and Analysis of Antibody Level and Carrier Status of Meningococcal Healthy Population in Jiangyou City. World Health Digest Med Period. 2013;4:98–9. https://doi.org/10.3969/j.issn.1672-5085.2013.04.086.
32. Liu ZY, Nie W, Liu LZ, Hu GC, Shan XY, Bai AY. Monitoring results and analysis of Neisseria meningitides carrying status among healthy population in Jinan from 2008 to 2015. Chin J Health Lab Tec. 2016;26(23):3436–40.
33. Wang YT, Jia ZY, He BH, Ma HS, Wang Q, Jiang X, Qian ZY, Liu XL, Chen SL, Sun YQ. Analysis of Neisseria meningitidis carriage situation among healthy population in Hebei Province from 2006 to 2013. Chin J Vaccines Immun. 2015;21(05):506-510+518.
34. Liu ZW, Jin YH, Zeng Z. Investigation on immune level against epidemic cerebrospinal meningitis and carrier status among healthy population in Hefei. J Med Pest Control. 2017;33(07):726–9. https://doi.org/10.7629/yxdwfz201707005.
35. Deng HY, Sun LY, Zeng XX, Wang SL, Huang CH, Fu ZW, Yan XJ, He J, Pan TT, Li WH, et al. Survey of Neisseria meningitiis-carrying rate and detection of antibody level in Hainan in 2006. China Trop Med. 2010;10(11):1365–6. https://doi.org/10.13604/j.cnki.46-1064/r.2010.11.009.
36. Cui M, Xu JX, Cai YS, Fu CX, Li MX, Zhang CH, Li KB, Wang M. Level of immunity against epidemic cerebrospinal meningitis and the carrier status among healthy population in 2009–2011 in Guangzhou. J Trop Med. 2013;13(08):1015–7.
37. Wu XH, Lin M, Quan Y, Fang JS, Liang DB, Qin WW, Qiu XQ. Reaserch on bacteria carrying antibody level and control strategy for epidemic cerebrospinal meningitis in Guangxi. Chin J Sch Health. 2010;03:337–9. https://doi.org/10.16835/j.cnki.1000-9817.2010.03.035.

Yue *et al. BMC Infectious Diseases*   (2022) 22:594

Page 14 of 16

38. Qiu DS, Zhang YD, Tan CJ. Investigation and analysis of carrier rate for Neisseria meningitides among healthy population from 2013 to 2014 in Gaomi City. Chin J Hosp Stat. 2016;23(01):35–7.

39. Jiang WP, Bi C. Investigation of meningococcal antibody level and bacteria carrying situation in healthy population in Danyang City. Jiangsu J Prev Med. 2014;25(03):56–7.

40. Chu HN, Wei F, Zhao GL, Wang W, Li QL, Li Q. Surveillance on the rate of the healthy carrier from 2013 to 2014 of epidemic Neisseria meningitis (NM) in Chengde city. J Med Pest Control. 2016;32(05):494–6. https://doi.org/10.7629/yxdwfz201605008.

41. Zhou YH. Investigation on the infection rate and immune level of epidemic cerebrospinal meningitis among healthy people in Wujin District of Changzhou in 2011. Jiangsu J Prev Med. 2012;23(05):55–6.

42. Jia B, Zhang N, Shi Q, Chen TJ, Chu P. Analysis on the status of meningococcal infection among healthy people from 2009 to 2013 in Chaoyang District. Beijing Pract Prev Med. 2016;23(5):614–615+627.

43. Niu HC, Wu Y, Shu GL, Gao JX. Analysis of presence status, serotype distribution and antibiotic susceptibility of *Neisseria meningitidis* among healthy residents in Changping district of Beijing, 2016. Jiangsu J Prev Med. 2018;29(2):131–4.

44. He F, Yang HM, Li GM, Zhu BQ, Zhang Y, Jiang HL, Yuan M, Jiang Y, Lv J. *Neisseria meningitidis* carriage and risk factors among teenagers in Suizhou city in China. Epidemiol Infect. 2020;148: e227. https://doi.org/10.1017/s0950268820002113.

45. Xue WH, Pang ZL, Zhang Y, Liu ZL, Zhao MQ. Analysis of the surveillance results of meningomyelitis among healthy population in Pingshan in 2015. Chin J Health Lab Tec. 2016;26(07):1020-1021+1024.

46. Zheng QX, Zhang HT, Sun H, Gao P, Dong M. The condition of *Neisseria meningitidis* of the non-epidemic season among healthy people during 2015–2017 in Dongcheng district, Beijing. Cap J Public Health. 2019;13(04):189–91.

47. Geng L, Sun RC, He BH, Zhang HX, Jia ZY, Wang YT, Sun YQ. Analysis of *Neisseria meningitidis* carriage situation among healthy population in Hebei Xinji City from 2015 to 2016. J Med Pest Control. 2017;33(11):1182–4. https://doi.org/10.7629/yxdwfz201711019.

48. Liao YH, Lin W, Cao CY, Chen JX, Guo ZZ, He Y. Surveillance on epidemic cerebrospinal meningitis among the healthy population, Longyan city, 2014–2016. Prev Med Trib. 2017;23(07):476-558–9.

49. Xie FQ, Li QW, Luo CC, Lin ZY, Chen AP. Analysis on carrying rate of *Neisseria meningitis* and antibody level of epidemic cerebrospinal meningitis among the healthy population in epidemic period in two cities, Fujian Province, 2011. Prev Med Trib. 2016;22(04):260–2. https://doi.org/10.16406/j.pmt.issn.1672-9153.2016.04.007.

50. Hu YF, Lu YP, Zhang BQ. Investigation on carrier status of epidemic miningitis virus and immune level among healthy people in Pingnan County in 2009. Prev Med Trib. 2011;17(01):39-40+43.

51. Liang SG, Wang BY. Investigation on antibody level against epidemic cerebrospinal meningitis and carriage rate of *Neisseria meningitidis* among healthy population in Harbin in 2009. Chin Foreign Med Res. 2011;9(13):126–8. https://doi.org/10.14033/j.cnki.cfmr.2011.13.084.

52. Yan YF, Zhao LP, Guo NN, Ma YX, Li YX, Li RF, Deng J, Huang L. Germ-carrying rate of epidemic cerebrospinal meningitis and molecular typing of bacteria among healthy population in Handan City, 2009–2015. Pract Prey Med. 2018. https://doi.org/10.3969/j.issn.1006-3110.2018.02.023.

53. Tang XL. Investigation on germ-carrying situation on *Neisseria meningitidis* (Nm) of health populations in Qinghai Province in 2007. Mod Prev Med. 2010;37(03):555–6.

54. Wang ML, Qu WJ, Sai JY, Liu Y, Liu T. Analysis of Neisseria meningitidis carrier monitoring data in healthy people in Wendeng City, 2007–2010. Prev Med Trib. 2011;17(07):654+657. https://doi.org/10.16406/j.pmt.issn.1672-9153.2011.07.030.

55. Wang ZJ, Wang JT, Zheng LF, Zheng JB. Investigation and analysis of meningococcal disease in healthy people in Wen County from 2004 to 2008. Henan J Prev Med. 2010;21(04):277–8. https://doi.org/10.13515/j.cnki.hnjpm.2010.04.035.

56. Qi YM, Gao YH, Lu JR, Wang CD, Pang ZQ. Monitoring results of epidemic cerebrospinal meningitis pathogen among healthy population in Cangzhou from 2000–2013. Occup Health. 2014. https://doi.org/10.13329/j.cnki.zyyjk.2014.16.039.

57. Luan L, Zhan YH, Zhang MH, Bi C, Zhu YH, Zhang J, Zheng BF, Chen T. Epidemiological analysis of the meningococcal disease in Suzhou City during 1992–2012. Mod Prev Med. 2014;41(12):2113-2115+2118.

58. Hao CX, Yuan H, Luo LZ, Li YC, Zhu XP, Liu LG. Results of surveillance of Group A、C、Y and W135 of epidemic cerebrospinal meningitis in Hejiang County of Sichuan Province in 2008. China Trop Med. 2010;10(02):165–6. https://doi.org/10.13604/j.cnki.46-1064/r.2010.02.037.

59. Gao JZ, He F, Wu LQ, Song XJ, Liu HB, Zhang YT, Yang HM, Lv J. Epidemiological characteristics of epidemic cerebrospinal meningitis from 1971 to 2018 and trend of *Neisseria meningitidis* in Shiyan City. Int J Lab Med. 2019;40(23):2858–63. https://doi.org/10.3969/j.issn.1673-4130.2019.23.010.

60. Lan RW, Liu MZ, Deng LL, Xu L, Mao WC, Yu HF, Wen DL, Wu L, Zeng LY, Meng NX, et al. Neisseria meningitidis carriage prevalence and serogroup distribution among a healthy population. Chin J Vaccines Immun. 2014;20(05):438–41.

61. Wang YF, Zhang YY. Monitoring report of meningococcal meningitis in Jiaxiang County in 2012. Zongheyixue. 2013;10(19):154–5. https://doi.org/10.3969/j.issn.1674-4985.2013.19.075.

62. Liu Q, Seng MH, Li MY, Guo YH, Xu J. Surveillance and analysis of epidemic cerebrospinal meningitis in Henan Province from 2010 to 2011. China Health Care Nutr. 2013;23(10):6133–4. https://doi.org/10.3969/j.issn.1004-7484(x).2013.10.685.

63. Ye XF, Liu CT, Zhao ST, Zhang L, Zhu Q, Ren G. Laboratory surveillance result analysis of epidemic cerebrospinal meningitis (EMC) in Guizhou Province. Open J Nat Sci. 2017;5(01):73–8. https://doi.org/10.12677/ojns.2017.51011.

64. Yuan L, Lin ZY, Wang ZM, Wen CJ, Cao CY, Yang ZQ, Zhang BQ. The surveillance of meningococcal infection and antibody levels in Fujian Province in 2009. Strait J Prev Med. 2012;18(01):29–31.

65. Yuan HZ, Cai BL, Li YC, Liu J, Chen QY. Epidemiological analysis of epidemic cerebrospinal meningitis in Dongguan City from 2008 to 2010. South China J Prev Med. 2012;38(6):39–40, 43.

66. Xiao D, Yang SH, Han YN. Analysis of epidemiological surveillance results of epidemic cerebrospinal meningitis in Dalian from 1996 to 2010. J Dis Monit Control. 2011;5(11):655–7.

67. Cheng FY. Analysis of the incidence of meningococcal meningitis and monitoring results in Feidong County, Anhui Province in 2009. Anhui Med J. 2012;33(06):739–40.

68. Sun X, Liu YB, Xu Y, Wang ZG, Tang FY. Analysis of epidemic characteristics and antibody level of epidemic cerebrospinal meningitis in Jiangsu province during 2014–2015. Mod Prev Med. 2018;45(14):2510-2512+2520.

69. Liu HT, Zhuang GL, Wang ZY, Song JH, Zhou B. Analysis of *Neisseria meningitidis* carrier rate among healthy people during 2013–2015 in Mentougou district. Beijing Cap J Public Health. 2016;10(2):78–9.

70. Xu SX. Analysis of the carrier and antibody levels of *Neisseria meningitidis* in some healthy people in Luanping County in 2012. Prev Med Trib. 2013;19(06):447–8. https://doi.org/10.16406/j.pmt.issn.1672-9153.2013.06.033.

71. Lu LR, Wnag CD, Yang Y, Dong XJ, Li XZ, Dai GJ. Status of epidemic cerebrospinal meningitis in rural areas of Xianxian County, 2012. J Prev Med Inf. 2013;29(09):755–7.

72. Li MS, Lin XJ, Wang M, Lv JJ, Zhang Y, Fu ZY, Xiao ZK, Xu Q, Song LZ. Analysis on pathogen surveillance data of epidemic cerebrospinal meningitis in Shandong Province, 2008–2009. Prev Med Trib. 2010;16(09):835–7. https://doi.org/10.16406/j.pmt.issn.1672-9153.2010.09.028.

73. Deng X, Yao PP, He HQ, Yan R, Tang XW, Zhou Y, Fu J, Xie SY. Epidemiological characteristics of meningococcal meningitis and changing trend of serogroups of *Neisseria meningitidis* in Zhejiang, 2006–2017. Dis Surveil. 2018;33(07):547–51.

74. Chen LJ, Cui WJ, Feng JG, Xu L, Chen YM, Huang H, Tang JH. Surveillance of epidemic cerebrospinal meningitis in Shaoguan City, 2006–2008. J Occup Health Damage. 2012;27(03):160–2.

75. Yan XP, Zeng YQ, Liu GR, Li YC, Luo LZ. Carriage of *Neisseria meningitidis* and immunity level among healthy population in Jiajiang County, 2006–2008. J Prev Med Inf. 2010;26(4):276–9.

Yue *et al. BMC Infectious Diseases*   (2022) 22:594

Page 15 of 16

76. Yuan H, Luo LZ, Li YC, Hao CX, Tang XY, Lv Q, Liu LG, Zhu XP. Surveillance of epidemic cerebrospinal meningitis in Sichuan Province, 2005 to 2008. J Prev Med Inf. 2010;26(05):340–3.

77. Wu JJ, Song KJ, Zhang T, Yang H, Zhao JY, Wu CC, Zhang J. Epidemiological characteristics of meningococcal meningitis and changing trend of serogroups of Neisseria meningitidis in Jinan, 1991–2018. Mod Prev Med. 2020;47(19):3598-3601+3606.

78. Wang Y, Fu RH, Gu SY, Han Y. Analysis for surveillance on epidemic cereborspinal meningitis in Liaoning Province during 1950 to 2013. Chin J Public Health Eng. 2016;15(06):582–3.

79. Chen SX. Study on the prevalence trend of new meningococcal Y and W135 groups 2013.

80. Li QW, Yuan WH, Zheng EH, Yuan L, Lin ZY, Chen AP. Monitoring and analysis of epidemic cerebrospinal meningitis infection rate and antibody level in healthy population in Fujian province in 2012. Chin J Health Lab Tec. 2014;24(02):244–6.

81. Yang XF. Surveillance of *Neisseria meningitides* carrier incidence in Changsha population. Pract Prev Med. 2007;03:732–3.

82. Fu XQ, Yin JW, Gao Y. Analysis of survey results of meningococcal pathogens in healthy people in Yunnan Province in 2005. Pract Prev Med. 2006;13(2):341–2. https://doi.org/10.3969/j.issn.1006-3110.2006.02.052.

83. Yang TP. The monitoring analysis of groups of healthy people suffering from cerebrospinal meningitis in Wengyuan County in 2006. Chin Prim Health Care. 2007;21(7):40–1. https://doi.org/10.3969/j.issn.1001-568X.2007.07.018.

84. Li XC, Li Y, Zhang HC, Lin GK, Chen HY, Zhang LY, Hong CJ, Wang LH. Surveillance analysis of epidemic cerebrospinal meningitis in Wenzhou. Dis Surveil. 2007;06:390-391+404.

85. Fan YS, Zhang LS, Wang JH. Survey of N meningitidis carrier in healthy confluence of Tangshan. Chin J Health Lab Technol. 2008;04:690–1.

86. Guo F, Liu XH, Jiang B, Peng B, Huang XM, Wang YG, Nie SF. Analysis on the surveillanee results of epidemic cerebrospinal meningitis in the healthy people in Suizhou city from 2001 to 2006. Chin J Dis Control Prev. 2007;11(5):482–4. https://doi.org/10.3969/j.issn.1674-3679.2007.05.012.

87. Shi SJ, Xu QY, He ZQ. Surveillance of antibody levels and carrying rate of epidemic meningitis of group A and group C of healthy people in Suzhou City in 2005. J Med Pest Control. 2006;22(2):106–8. https://doi.org/10.3969/j.issn.1003-6245.2006.02.014.

88. Zhang SX. Epidemiological survey on the distribution of epidemic cerebrospinal meningitis in Shenyang. China Mod Med. 2009;07:136.

89. Chen Y, Wang YC. Surveillance and analysis of epidemic cerebrospinal meningitis in Shenyang City in 2005. Modern Preventive Medicine. 2007;34(4):855,861. https://doi.org/10.3969/j.issn.1003-8507.2007.04.080.

90. Wen QW, Duan YX, Ju CY. Situation of taking *Neisseria meningitidis* in health population in Shenzhen. J Prev Med Inf. 2006;05:527–9.

91. Ju CY, Huang WF, Yu MH, Liu HJ, Duan YX. Survey of prevalence of *Neisseria meningitidis* in heathy population in Shenzhen City in 2005 and 2006. China Trop Med. 2008;8(1):80–1. https://doi.org/10.3969/j.issn.1009-9727.2008.01.044.

92. Li GH, Gao XF, Zhang QX, Zuo SJ, Hao RE. Investigation and analysis on the status of epidemic cerebrospinal meningitis in healthy people in Shanxi Province in 2005. Chin Rem Clin. 2006;6(9):696. https://doi.org/10.3969/j.issn.1671-2560.2006.09.018.

93. Zhang JM, Jin WE, Ye CH. Situation of carrier rate of Neisseria meningitides in school healthy population in Quzhou City during 2003–2008. Chin J Health Lab Technol. 2009;19(7):1647-1648,1669.

94. Jia YJ. Investigation on the carrier and antibody levels of *Neisseria meningitidis* in healthy people in Qinghai Province. Chin J Vaccines Immun. 2008;05:460.

95. Yang Y, Liang JL, Ju CY, Su HW, Chen ZQ, Gan ZL, Liu HC. Investigation on the germ-carrying status of epidemic meningitis among health rural students in primary and middle school of Luzhou. Mod Prev Med. 2008;12:2347–9.

96. Cao CY, Chen QJ, He Y, Lin ZY, Yuan L. Analysis on the status of meningococcal bacteria and immune level in some healthy people in Longyan City in 2006 and 2007. Strait J Prev Med. 2009;03:45–6.

97. Yang M, Yuan H, Liu XQ, Ding S, Xu JM, Xu XQ, Shao ZJ, Cui ZG, Xu L, Diao BW. Investigation on carriage of *Neisseria meningitidis* and analysis of serogroup C strains by PFGE in Jiangxi Province, 2005. Chin J Vaccines Immun. 2007;03:200–2.

98. Liu XQ, Yuan H, Yang M, Xie Y, Xu XQ, Liao YJ. Prevalence of epidemic cerebrospinal meningitis in Jiangxi Province. Chin J Public Health. 2009;25(8):907–8. https://doi.org/10.3321/j.issn:1001-0580.2009.08.051.

99. Zhong ZL, Yu LG. Investigation of carrying status and immune level of meningitides in health population in Lishui County of Jiangsu Province. Occup and Health. 2008;24(16):1671–3. https://doi.org/10.3969/j.issn.1004-1257.2008.16.037.

100. Lu W. Investigation on immune level and carrier status of epidemic meningitis in healthy population. World Health Digest Med Period. 2008;5(4):521–2.

101. Lv J, Liu L, Sun J, Cheng JF, Lin FR, Wu HX. Analysis of the surveillance of epidemic cerebrospinal meningitis in Hubei, 2000–2005. J Pub Health Prev Med. 2006;17(4):41–4. https://doi.org/10.3969/j.issn.1006-2483.2006.04.015.

102. Qian ZY, Ma HS, Sun YQ, Zhen SJ, Li YP, Jiang X, Wang YT, Liu HB. Surveillance and analysis of bacteria carrying in healthy population with epidemic cerebrospinal meningitis from 2007 to 2008 in Hebei. Hebei Med J. 2009;31(14):1819–20. https://doi.org/10.3969/j.issn.1002-7386.2009.14.069.

103. Wang XP, Jin YH, Wang H. Investigation of the infection rate and antibody level on epidemic cerebrospinal meningitis in the epidemic prophase and metaphase in healthy people in Hefei. Chin J Vaccines Immun. 2007;13(6):548–51. https://doi.org/10.3969/j.issn.1006-916X.2007.06.010.

104. Yan XJ, Sun LY, Zeng ZC, Fu ZW, Deng HY, Chen SM. Survey of distribution of epidemic cerebrospinal meningitis bacterium and the population immunity level in Hainan Province. China Trop Med. 2006;6(2):244–5. https://doi.org/10.3969/j.issn.1009-9727.2006.02.017.

105. Song T, He JF, Liu MZ. Epidemic analysis on meningococcal meningitis prevalence status and control effect in Guangdong Province in 2005. Chin J Vaccines Immun. 2007;03:203–5.

106. Zhao LF, Xi JL. Analysis of monitoring results of meningococcal disease and immune level among healthy people in Guyuan City Ningxia. Med J. 2007;12:1155.

107. Yang JY, Yang SM, Zhang GY, Yu DS, Yang JJ, Zhao XH. Analysis of the surveillance results of the population carrying bacteria in the peak season of meningitis in 2005. Health Vocat Educ. 2005;23(23):82–3. https://doi.org/10.3969/j.issn.1671-1246.2005.23.057.

108. Lin P, Pan ZY, Liu H. An investigation on the infection rate and immune level of epidemic cerebrospinal meningitis among healthy people in Fuzhou. Dis Surveil. 2007;08:536.

109. Yang HK, Zhang LP, Liu MZ. Analysis of surveillance results of meningococcal meningitis among healthy people in Dongguan in 2005. Chin J Health Lab Technol. 2006;01:76–7.

110. Luo SH, Zhang LP, Huang SZ, Li JQ. Analysis of surveillance results of meningococcal meningitis in Dongguan from 2004 to 2005. Chin J Health Lab Technol. 2006;06:701–2.

111. Teng Y. Analysis of serum surveillance of meningococcal meningitis among healthy people in Dehui City in 2008. Chin J Public Health Eng. 2009;S1:20–1.

112. Zou YG, Chen JW, Li TP, Luo XJ, Wu CL, Peng JJ, Dai DF. Investigation on antibody level against epidemic cerebrospinal meningitis and carriage rate of *Neisseria meningitidis* among healthy population in Qidong County in 2008. Pract Prev Med. 2009;02:410–1.

113. Gu HY, Chen BY, Chu XJ. Surveillance of epidemic cerebrospinal meningitis in Langfang City, Hebei Province in 2008. J Trop Dis Parasitol. 2009;02:103–4. https://doi.org/10.3969/j.issn.1672-2302.2009.02.017.

114. Wu XH, Lin M, Quan Y, Fang JS, Wang ML, Qin WW. Study on healthy carrier and antibody level for meningococcal meningitis in Guangxi, 2008. Appl Prev Med. 2009;06:331–4.

115. Wang WJ, Kuang SS, Han ZM, Liu YM, You CQ, Gou N, Zhou GH, Zhou S, Zhao SM. Investigation on antibody level and carriage rate of *Neisseria meningitidis* in healthy population before epidemic period in Chongqing. Prog Microbiol Immunol. 2008;03:29–33. https://doi.org/10.13309/j.cnki.pmi.2008.03.015.

116. Sun YQ, Ma HS, Zhen SJ, Jiang X, Qian ZY, Li YP, Liu HB, Wang YT. Analysis of epidemic cerebrospinal meningitis surveillance in Hebei province in 2007. Dis Surveil. 2008;23(10):634–6. https://doi.org/10.3784/j.issn.1003-9961.2008.10.015.

117. Huang RN. Analysis on *Neisseria meningitidis* carriage status of residents in health population in Chengdu District. Strait J Prev Med. 2009;04:13–5.

118. Cong QM, Tang SH, Zhang JB, Sun Q, Xiao HC. Investigation on the carrying status of Neisseria meningitidis in some healthy people in Weihai City from 2007 to 2008. Prev Med Trib. 2009;09:911. https://doi.org/10.16406/j.pmt.issn.1672-9153.2009.09.031.

119. Yin JW, Gao Y, Fu XQ, Zhou YM, Yang JB, Gu WP. Investigation on the status of meningococcal disease in healthy people in some areas of Yunnan Province in 2006. J Prev Med Inf. 2007;03:362–3.

120. Ren LH, Liu YY, Wu FY, Chang XL, Yang HM. Investigation on *Neisseria meningitidis* and the level of immune antibody among healthy population in Tongliao City in 2006. Prev Med Trib. 2008;01:57–8.

121. Gong Y, Luo XC, Zhao Q, Cai SW, Zhong GX. Investigation on the level of meningococcal antibody and the rate of infection among healthy people in Sanming City in 2006. Strait J Prev Med. 2009;15(5):33.

122. Wang J, Yan LQ. Surveillance analyses on epidemic cerebrospinal meningitis of Zhongwei city of Ningxia in 2006. Chin Health Lab Technol. 2007;03:495–6.

123. Xiao ZK, Song LZ, Li MS, Wang M, Zhang L, Xu Q, Xu AQ. Epidemiological analysis for epidemic cerebrospinal meningitis in Shandong Province from 2006 to 2008. Prev Med Trib. 2009;09:805-806+836. https://doi.org/10.16406/j.pmt.issn.1672-9153.2009.09.027.

124. Luo XC, Luo LM, Gong Y, Luo HH, Cai SW, Zhao Q. Analysis of surveillance results of epidemic cerebrospinal meningitis in Sanming City in 2005. Chin J Health Lab Technol. 2006;04:451–2.

125. Li X, Wu CP, Bai L. Investigation on antibody level and epidemic cerebrospinal meningitis in Inner Mongolia 2005. Prev Med Trib. 2007;13(10):883–4. https://doi.org/10.3969/j.issn.1672-9153.2007.10.008.

126. Wang H, Zhang XL, Yang YL. Investigation and analysis of *Neisseria meningitides* infection status of residents in Hefei District. Anhui Prev Med. 2007;13(1):17–8.

127. You L, Tian KC, Yao GH, Nie W, Zou ZT. Investigation on the status of healthy population carrying bacterial pathogens of epidemic cerebrospinal meningitis in Guizhou Province in 2005. Dis Surveil. 2006;21(3):120–2. https://doi.org/10.3784/j.issn.1003-9961.2006.03.005.

128. Liu MZ, Yang HK, Liao GD, Huang ZS, Xu L, Deng XL, Tan HL, Chen JD, Song T. Investigation on antibody level against epidemic cerebrospinal meningitis and carriage rate of neisseria meningitidis in healthy population in Guangdong Province. Chin J Health Lab Technol. 2007;17(2):325-326,338. https://doi.org/10.3969/j.issn.1004-8685.2007.02.057.

129. Zhang Y, Li MS, Liu GF, Lin XJ, Feng L, Xu AQ, Zhang L. Analysis of *Neisseria meningitidis* carriage characteristics among healthy population in Shandong province from 2008 to 2020. Chin J Prev Med. 2021;55(08):973–7. https://doi.org/10.3760/cma.j.cn112150-20210412-00358.

130. Luo JJ, Lv J, Li TT, Xiao J. Analysis of the monitoring results of Neisseria meningitidis carrier rate among healthy people in Hubei Province from 2013 to 2018. Appl Prev Med. 2021;27(02):180-182+184.

131. Xie N, Fu WH, Zhu BQ, Wang TM, Chen T, Hanaxi Z, Xu L, Shao ZJ, Cui Y. Epidemiological and etiologic characteristics of Meningococcal meningitis in Xinjiang Uygur Autonomous Region, 1960–2019. Chin J Epidemiol. 2021;42(6):1037–43.

132. Zhou XH, Zhang GQ, Fei YH. Surveillance on bacterial carrier and immune level of epidemic cerebrospinal meningitis among healthy people in Lianshui County in 2018. Anhui J Prev Med. 2021;27(3):238-240,252. https://doi.org/10.19837/j.cnki.ahyf.2021.03.017.

133. Jiang M, Zhao JJ, Cheng X, Liu JS. Investigation on antibody and carrier rate of epidemic meningitis A and C in Lianshui County. Prev Med. 2021;33(10):1053–6. https://doi.org/10.19485/j.cnki.issn2096-5087.2021.10.020.

134. Chen C, Ren Y, Guo N, Zheng Y, Li YZ, Tang C, Tan YZ, Li JC, Wang XF, Cun W, et al. Investigation on carrying status of *Neisseria meningitidis* in healthy population in Baoshan City, Yunnan Province, China. Chin J Biol. 2021;34(05):571–4. https://doi.org/10.13200/j.cnki.cjb.003337.

135. Zhang Y, Deng X, Jiang Y, Zhang J, Zhan L, Mei L, Lu H, Yao P, He H. The epidemiology of meningococcal disease and carriage, genotypic characteristics and antibiotic resistance of *Neisseria meningitidis* Isolates in Zhejiang Province, China, 2011–2021. Front Microbiol. 2021;12: 801196. https://doi.org/10.3389/fmicb.2021.801196.

136. Lu JR, Wang CD, Bi HJ, Li XZ. Test results analysis of epidemic cerebrospinal meningitis carrier in Cangzhou Area from 2008–2011. Occup Health. 2012;28(21):2–3. https://doi.org/10.13329/j.cnki.zyyjk.2012.21.041.

137. Li JH, Li YX, Wu D, Ning GJ, Shao ZJ, Yin ZD. Epidemiological characteristics of meningococcal meningitis and switching trend of serogroups of *Neisseria meningitidis* in China, 2006–2014. Chin J Vaccines Immun. 2015;21(05):481–5.

138. Li JH, Li YX, Shao ZJ, Zhou HJ, Ning GJ, Yin ZD, Luo HM, Liang XF. Surveillance of meningococcal disease in China, 2009. Dis Surveil. 2010;25(10):770-773+780.

139. Jaca A, Wiyeh AB, Sambala EZ, Wiysonge CS. The burden of meningococcal meningitis in the African Meningitis Belt, from 2009 to 2014: a trend analysis. Pan Afr Med J. 2021;39:57. https://doi.org/10.11604/pamj.2021.39.57.17629.

140. Trotter CL, Maiden MCJ. Meningococcal vaccines and herd immunity: lessons learned from serogroup C conjugate vaccination programs. Expert Rev Vaccines. 2009;8(7):851–61. https://doi.org/10.1586/Erv.09.48.

141. Chinese PMA. Experts' consensus on immunization with meningococcal vaccines in China. Chin J Vaccines Immun. 2019;25(01):96–101.

142. Purmohamad A, Abasi E, Azimi T, Hosseini S, Safari H, Nasiri MJ, Imani Fooladi AA. Global estimate of *Neisseria meningitidis* serogroups proportion in invasive meningococcal disease: a systematic review and meta-analysis. Microb Pathog. 2019;134: 103571. https://doi.org/10.1016/j.micpath.2019.103571.

143. Peterson ME, Li Y, Bita A, Moureau A, Nair H, Kyaw MH, Meningococcal Surveillance G, Abad R, Bailey F, Garcia IF, et al. Meningococcal serogroups and surveillance: a systematic review and survey. J Glob Health. 2019;9(1): 010409. https://doi.org/10.7189/jogh.09.010409.

Publisher's Note