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

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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%, *I*²: 95.4%, *p* < 0.0001), and children under 6 years of age had the lowest carriage 1.01% (95% CI: 0.59–1.43%, *I*²: 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...
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 as 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
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 ($0 < I^2 \leq 50$%), moderate ($50 < I^2 \leq 75$%) and high ($75 < I^2 \leq 100$%). 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%
(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, \( P \)
| 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 | Huiying Deng 2010 [35] | Huiying 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% |
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 | 7 | 232 | 4865 | 4.77% |
| 36 | Lin Luan-2014 [57] | Lin Luan | Jingsu | 2014 | 2005–2012 | Cluster sampling | Isolation and culture, PCR | 7 | 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 | Isolation and culture | 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 | 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 | 7 | 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 | Isolation and culture | 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% |
| 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 | Ning Yuan-2010 [76] | Ning 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 | 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 | 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 | Quwen Wen-2006 [90] | Quwen 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% |
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 | 2                  | 13    | 230         | 5.65%               |
| 76 | Chunyuan Cao-2009 [86] | 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 | Xiaoting Liu-2009 [98] | Xiaoting 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                  | Isolation and culture | 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         | 0.53%               |
| 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       | 2008             | 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   | 2007             | 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 | 5                  | 11    | 999         | 1.1%                |
| 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 [121]  | 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%                |
**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           | 533             | 1156       |
| Sample size           | 12,771          | 8684            | 12,792      | 74,096     | 15,773        | 6897            | 57,518     |
| I² (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     |
| I² (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% |
< 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 $\geq 15$ years old were higher than those of children (0–6 years). In the African meningitis belt, the
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; *Wangfang*: Wangfang 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; *MPV-AC*: Group A and group C meningococcal polysaccharide conjugate vaccine; *MPV-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.

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**Author contributions**

YM and XJ are joint first authors. YMM: studies screening and selection, data collection, data analysis and interpretation, manuscript writing. XJ: studies screening and selection, data collection. YJX: the conception and design of the study, search strategy making. SZJ: revision of the article, final approval of submitted version, guarantor of the study. All authors critically revised the article, read and approved the final manuscript.

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**Availability of data and materials**

The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

**Declarations**

**Ethics approval and consent to participate**

Not applicable.

**Consent for publication**

Not applicable.

**Competing interests**

The authors declares that there is no competing interest.

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