Title: Public health management of Invasive Meningococcal Disease

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Thesis Declaration

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission in my name for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint award of this degree.

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Abstract

Introduction:

Invasive Meningococcal Disease (IMD) is a rare, but life-threatening, complication of infection with *Neisseria meningitidis* (*N. meningitidis*) bacteria. The most common clinical presentations of IMD are sepsis and meningitis, and even with rapid treatment survivors often suffer serious long-term sequelae.

Public health management of IMD is focussed on limiting transmission within a population, thus reducing the risk of outbreak development. National and international guidelines have been developed to facilitate activities by staff in public health departments to identify and respond to IMD cases as they occur. There is limited understanding on how public health management of IMD has developed over time or differs between jurisdictions.

The aims of this research study were to:

1. Assess national and international guidelines for the public health management of IMD, with a focus on their recommendations for identification and management of close contacts; and
2. Gain insight into changes across time in the public health management of IMD outbreaks through identifying and describing similarities and differences in responses according to outbreak characteristics and setting.

Methods:

English language guidelines from national and international public health agencies were assessed using a modified version of the Appraisal of Guidelines, Research and Evaluation (AGREE II) Instrument. Each guideline was scored in four key domains – stakeholder involvement, applicability, clarity of presentation, and rigour of development. The wording used in recommendations for identification and management of IMD close contacts was also compared.

To address the second aim, a systematic review was conducted to assess any changes over time in public health responses to IMD outbreaks. Pubmed and Embase were searched for studies that described IMD outbreaks and their associated response. Outbreaks were grouped by *N. meningitidis* serogroup, location and time; and assessed by size, duration, setting and public health management strategies.

Results:

Public health guidelines with higher scores using AGREE II had clear, concise recommendations, were well supported by the available evidence, and included information on the risks and benefits of each recommendation. Guidelines that scored poorly showed no clear link between evidence and recommendations, were not explicit in their guidance, or did not detail potential barriers or facilitators to implementation of guidelines. Recommendations for contact management were largely consistent across the included guidelines, with some variation in recommendations for vaccination. The operational definition of a close contact varied between countries – from household and household-like contacts alone to household, household-like, sexual, child-care, co-passengers and healthcare contacts.

Outbreak management has evolved over time, with reporting on earlier outbreaks informing responses to subsequent outbreaks. However, the detail included in reports on outbreaks was inconsistent, with many studies missing key contextual information regarding time, person, or place.

Discussion:

Clear, consistent guidance is necessary to facilitate effective public health management of IMD. Guideline development should prioritise consistency between jurisdictions in recommendations for the public health management of IMD cases and their contacts. Better reporting of IMD outbreaks and their response may also support the development of more consistent public health guidance.

Abbreviations

4CMenB	Meningococcal B vaccine (Bexsero®)
ACT	Australian Capital Territory
AGREE II	Appraisal of Guidelines for Research and Evaluation Instrument II
AR	Attack Rate
CDC	Centers for Disease Control and Prevention (United States)
CDNA	Communicable Diseases Network Australia
CI	Confidence Interval
COVID-19	Coronavirus Disease
ECDC	European Center for Disease Prevention and Control
EU	European Union
HREC	Human Research Ethics Committee
IMD	Invasive Meningococcal Disease
IQR	Interquartile Range
KAP	Knowledge, Attitudes and Practices
MenA	Meningococcal serogroup A
MenACWY	Quadrivalent meningococcal conjugate vaccine (Nimenrix®)
MenB	Meningococcal serogroup B
MenC	Meningococcal serogroup C
NGO	Non-Governmental Organisations
NMA	National Mutual Acceptance Scheme

NSW	New South Wales
NT	Northern Territory
ORION	Outbreak Reports and Intervention Studies of Nosocomial infection
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
QLD	Queensland
SA	South Australia
SSA	Site-Specific Approval
STROBE	Strengthening the Reporting of Observational Studies within Epidemiology
TAS	Tasmania
UK	United Kingdom
US	United States
VIC	Victoria
WA	Western Australia
WHO	World Health Organization
WSJ	World Scout Jamboree

Chapter 1 – Introduction

1.1 Background

1.1.1 Communicable diseases

Infectious diseases are illnesses caused by infectious agents, otherwise known as pathogens. These pathogens can be bacterial, viral, parasitic, conformational, or fungal in nature (Noah 2006; van Seventer & Hochberg 2017). Infectious diseases that can be transmitted between one person or animal to another are known as communicable diseases. Transmission can occur directly (e.g. contact with bodily fluids), indirectly (e.g. droplets, contaminated water or surfaces), or through a vector (e.g. mosquito or flea bites) (Noah 2006). Most individuals will experience multiple infections with communicable diseases over their lifetime (Australian Institute of Health and Welfare 2021).

There is wide variability between communicable diseases in their severity, risk of long-term complications or mortality, and transmissibility (Noah 2006). When a potential host is exposed to an infectious agent, there is a complex interplay of agent, host, and environmental determinants that to influence the outcome of exposure. Different pathogens vary in their infectivity (proportion of individuals who become infected following exposure), pathogenicity (likelihood of disease symptoms developing once infected) and virulence (risk of severe disease) (van Seventer & Hochberg 2017). Hosts vary in their susceptibility, or ability to resist infection. Environmental factors such as physical structures, social behaviours, overall prevalence of disease, cultural practices and political factors may also influence host vulnerability to communicable disease infection (van Seventer & Hochberg 2017). Understanding the determinants which influence disease outcomes is necessary for effective public health management.

While the majority of communicable diseases are typically mild, requiring little to no medical attention, diseases with high infectivity and virulence are considered major concerns to public health and wellbeing (Abat et al. 2016). The burden of communicable disease within a

population can fluctuate over time or between jurisdictions, requiring ongoing surveillance and public health management to reduce the overall burden of disease (Abat et al. 2016; Doherty 2000).

1.1.2 Burden of communicable diseases

While there has been a significant reduction in the overall burden of communicable diseases over the past century, they continue to have substantial societal, financial, and personal impacts (Constenla, Carvalho & Alvis Guzman 2015; Ozawa et al. 2016; Whitesell, Yaskin & Chaudhari 2009). In 2019, the World Health Organization (WHO) reported that almost a fifth (18%) of the global burden of mortality was attributable to communicable diseases (World Health Organization 2021). The majority of this burden rests on low-income countries, where communicable disease is responsible for 46.4% of overall mortality (World Health Organization 2021). Less than two years after the beginning of the Coronavirus disease (COVID-19) pandemic, it is already one of the leading causes of death worldwide (World Health Organization 2021). At an individual level, many communicable diseases can have significant impacts on a person's ongoing quality of life (Bynum 2012; Olbrich et al. 2018; Rota et al. 2016).

Efforts to prevent and manage communicable diseases are a major priority for public health agencies or departments around the world. The majority of reductions in the incidence and burden of communicable diseases can be attributed to massive improvements in sanitation, prevention, and treatment strategies (Barrett et al. 1998; Murray & Lopez 2013; Goodman, Buehler & Mott 2019). An improved understanding of the causes of communicable disease and their mechanisms for transmission has also contributed to this reduction (Murray & Lopez 2013). Formerly common causes of death or permanent disability such as tuberculosis, chickenpox, polio or measles are now wholly preventable through community-wide vaccination programs (Bynum 2012; Honigsbaum 2020). While significant progress has been made in reducing the impacts of disease (World Health Organization 2021), communicable diseases

still require constant surveillance and management to mitigate the ongoing risk presented by a changing landscape of disease (Abat et al. 2016).

1.1.3 Prevention and management

The primary aim of communicable disease management is to prevent the spread or reduce the burden of diseases within a population. Since the pathogens that can cause communicable diseases are so varied, and have differing modes of transmission, the public health response is specific to the disease and infectious agent in question (Noah 2006). Prior to the implementation of any specific management strategies, public health agencies need to be able to identify instances of disease as they occur (Abat et al. 2016). Communicable disease surveillance typically focusses on diseases identified as having a high risk of transmission, severe illness, or mortality (Balabanova et al. 2011; Doherty 2000) and is a key component of any public health system.

Surveillance systems can identify single instances of disease, otherwise known as a 'case', or detect changes in the overall burden of disease. Because of the nature of communicable diseases, there is an ever-present risk of spread within a population, resulting in multiple cases of the same disease linked by time, person, or place, otherwise known as an 'outbreak' (Centers for Disease Control and Prevention 2017). Communicable disease outbreaks consist of multiple linked cases of disease beyond what is expected for a given population, time or geographic area (Ward 2020). Large outbreaks occurring across a wide geographic area or affecting a significant proportion of the population can be classified as 'epidemics' (Ward 2020).

Communicable disease management strategies can limit the spread of disease through a range of interventions, depending on the disease in question. Vaccine-preventable diseases can be prevented by reducing the number of susceptible people within a population through vaccination programs (van Seventer & Hochberg 2017). For diseases without available vaccines, various public health interventions that limit disease transmissibility can be employed (Noah 2006; van Seventer & Hochberg 2017). Interventions that reduce transmission can

range from whole-population approaches which reduce the likelihood or duration of exposures (e.g. mask wearing or social distancing) to targeted approaches (e.g. isolation of suspected or confirmed cases) (Hadler et al. 2019; Noah 2006). All public health management of communicable disease requires accurate, up-to-date information on both the infectious agent and the individuals or population affected in order to provide the most effective intervention (Hadler et al. 2019).

Occasionally, initial public health interventions are not successful at preventing further cases from occurring, signalling the beginning of an outbreak (Hamilton 2020). Cases of disease within an outbreak are linked, through a combination of shared exposure or social interactions. Public health responses to outbreaks focus on identifying the links between cases or groups of cases to define the exposure and the population most at risk of transmission (Hamilton 2020; Noah 2006). Interventions are then targeted towards the population at risk, in an effort to halt or slow outbreak progression (Hamilton 2020). Management for outbreaks of communicable diseases is much more resource-intensive than for individual cases (Constenla, Carvalho & Alvis Guzman 2015; Ozawa et al. 2016). Outbreak responses can also incur additional costs by disrupting other public health activities through the rapid redistribution of personnel and resources required to address an active outbreak (Goodman, Buehler & Mott 2019). Since outbreak management is so costly, good quality reporting on the underlying cause of the outbreak, along with the effectiveness of any management strategies applied, is necessary to inform future outbreak responses (Hadler et al. 2019)

Public health management of communicable disease is supported by disease-specific ‘guideline’ documents, which provide information and recommendations for prevention and management (Centers for Disease Control and Prevention 2020). These guidelines are informed by current evidence around a given pathogen, including its mode of transmission, treatment options, prevention measures and prior reporting on public health management of the pathogen (Hanquet et al. 2015). Comprehensive surveillance and reporting is necessary to provide the evidence which informs public health recommendations. The process of

guideline development is complex (Rehfuess et al. 2019), necessitating a range of expertise and highly experienced personnel to produce (Noyes et al. 2019). Middle-income and low-income countries have some of the highest burdens of communicable disease (World Health Organisation 2021), and as a result are least likely to be able to redirect staff with necessary expertise to guideline development (Goodman, Buehler & Mott 2019).

They are designed to support a consistent and effective public health response in managing cases and outbreaks of communicable disease (Centers for Disease Control and Prevention 2020). However, since guidelines are reliant on existing evidence, they can be limited in their effectiveness if the evidence is scarce (Norris 2018) or are developed in the face of rapidly changing circumstances (Schünemann et al. 2007).

Of major public health concern are diseases which change in aetiology and epidemiology over time or have currently undescribed mechanisms of transmission (Jackson et al. 1995; Morens & Fauci 2013; Yezli 2018). These pose a major challenge to public health departments as it can be difficult to identify and describe the risks of transmission between individuals in order to identify the most effective methods of prevention or control. One such example is Invasive Meningococcal Disease (IMD), which is a rare but severe outcome of infection with *Neisseria meningitidis* (*N. meningitidis*) bacteria.

1.1.4 Invasive Meningococcal Disease

IMD is a life-threatening condition with an especially fulminant course. The most common clinical presentations are meningitis, septicaemia, or both (Pace & Pollard 2012). Case fatality rates range between 5-15%, and even with swift identification and antibiotic treatment, survivors often suffer from serious long-term sequelae (Olbrich et al. 2018; Pace & Pollard 2012). The most common age groups affected are infants (<1 year), adolescents, and young adults (Martinon-Torres 2016). While relatively uncommon in most high-income countries (age standardized incidence of 0 to <20 cases per 100,000 in 2016), IMD is endemic in low-income countries, which can have annual incidence rates ranging from 80 to over 200 cases per 100,000 population (Acevedo et al. 2019; Zunt et al. 2018). Due to the high case fatality rate,

IMD represents a disproportionate burden of death associated with communicable disease despite the relatively low incidence (Martinon-Torres 2016).

N. meningitidis bacteria inhabit the mucosal lining of the human oropharynx, typically without resulting in symptoms of IMD. The bacteria can be carried and transmitted asymptomatically through close, sustained contact between individuals, referred to as 'carriage' (Caugant & Maiden 2009). It is possible to have ongoing circulation of one or more strains of *N. meningitidis* within a population without necessarily observing any cases of IMD (Caugant, Tzanakaki & Kriz 2007). Currently, the mechanisms behind the transition from asymptomatic carriage to disease-state are largely unknown (Caugant & Maiden 2009; Martinon-Torres 2016). Current estimates of asymptomatic carriage range between 5-10% of the general population (Marshall, McMillan, et al. 2020; Peterson et al. 2018). Factors known to increase the risk of carriage are an increase in the size and density of social networks, smoking, being aged between 20-24 years, and inhabiting shared living environments (Caugant & Maiden 2009; Marshall, McMillan, et al. 2020; Peterson et al. 2018). Studies on the prevalence of asymptomatic carriage in high-income countries have observed the highest rates (>15%) in shared living accommodation such as military barracks or dormitory accommodation (Peterson et al. 2018; Soeters et al. 2015).

There are 12 identified serogroups of *N. meningitidis*, with six (A, B, C, W, X, Y) responsible for the majority of disease worldwide (Batista et al. 2017). Vaccine coverage is possible for all common disease-causing serogroups. However, this is achieved through a combination of vaccines, as there is no single universal vaccine to prevent IMD (Dretler, Rouphael & Stephens 2018). Not all vaccines prevent carriage (Kristiansen et al. 2014; Marshall, McMillan, et al. 2020), and can have variable durations of protection (Ohm et al. 2020).

The population predominant serogroup has been observed to vary by geographic regions (Acevedo et al. 2019). Meningococcal serogroup B (MenB) is the most prevalent serogroup in North America, South America, Europe, Australia, and North Africa, whereas meningococcal serogroup C (MenC) is the most prevalent serogroup in Brazil, China, Russia, India, and

Nigeria (Zunt et al. 2018). Shifts in the predominant serogroup within regions have also been observed over time (Mustapha & Harrison 2018). Following widespread Meningococcal serogroup A (MenA) vaccination campaigns in 2010 within Sub-Saharan Africa, the predominant disease-causing serogroup has shifted from MenA to serogroups C, X, and W (Kristiansen et al. 2014; Pizza, Bekkat-Berkani & Rappuoli 2020, Mustapha & Harrison 2018). Similar shifts in seroprevalence were observed following large-scale vaccination programmes in other parts of the world (Kaczmarski 2002; Salleras et al. 2001). As previously discussed in Section 1.1.3, changes in the epidemiology of communicable disease over time pose a challenge to the development of public health guidance for prevention and control.

1.1.5 Public health management of IMD

Robust disease surveillance and notification systems are required to detect and respond to IMD cases as they occur. Due to the risk of asymptomatic carriage, public health management of IMD is focussed on the prompt recognition of cases and anyone they may have come into contact with, henceforth described as their 'contacts', to coordinate an effective response (European Centre for Disease Prevention and Control 2010). Staff in public health departments are tasked with rapid investigation of IMD cases and their contacts so as to identify and interrupt the chain of transmission (Public Health Agency of Canada 2006). Contacts are assessed based on the risk of *N. meningitidis* transmission, which can be affected by the type, duration, and timing of contact with the case and other individuals (Fischbacher, Lally & Black 2001; Public Health England 2018). Contacts from settings with low risk of transmission, such as sharing an open office space or university lecture hall, are typically referred to as 'casual' or 'low risk' contacts and are offered information regarding IMD symptoms and contact information for local health authorities (New Zealand Ministry of Health 2018). 'Close' contacts are individuals whose contact occurred within settings at a higher risk of *N. meningitidis* transmission, such as those sharing a household or sleeping space with the case. Close contacts are typically offered clearance antibiotics to eliminate carriage and vaccination to prevent disease (Communicable Diseases Network Australia 2017).

Public health management of IMD primarily focuses on reducing host susceptibility through vaccination and timing of infectivity through clearance antibiotics. Asymptomatic carriage and transmission of *N. meningitidis* poses a significant challenge to disease management (van Seventer & Hochberg 2017). Transmission models for IMD are not clearly defined (Caro et al. 2007), however evidence suggests that case contacts are typically the source of the infection to the case, and may be at risk of either developing symptoms of IMD or futher transmitting the bacteria (Asamoah et al. 2018). Clearance antibiotics eliminate carriage of *N. meningitidis,* removing a potential source of exposure within a population. The purpose of vaccination in close contacts is to reduce the susceptibility of the host to disease development (Krause et al. 2002).

Further cases of IMD occurring within the same population can signal the beginning of an outbreak (Centers for Disease Control and Prevention 2017). Similar to the general outbreak definition given in Section 1.1.3, IMD outbreaks are defined as more cases than would be expected for a given setting at that time (Centers for Disease Control and Prevention 2017), and thus vary depending on location. Outbreaks can be small or large in scale, ranging from two or three cases to several thousand (Stuart 2001). In jurisdictions with a low incidence of IMD, outbreaks can consist of at minimum two or more cases of IMD, caused by the same serogroup, linked by time, social interactions or geographic location (Communicable Diseases Network Australia 2017; Public Health England 2018). These outbreaks are typically described as small-scale, consisting of less than a dozen cases in total (Stuart 2001). Jurisdictions with a high annual incidence of IMD are more likely to experience large-scale outbreaks with thousands or tens of thousands of cases. Instead of minimum case numbers, these jurisdictions rely on minimum thresholds of cases per 100,000 population to identify populations at risk of, or in the midst of, an outbreak of IMD (World Health Organization 2014). The most commonly used thresholds for IMD outbreaks are those recommended by the WHO, who define an alert threshold (indication to intensify epidemic preparedness) as 3-9 cases per 100,000 per week and an epidemic threshold (indication to initiate epidemic treatment and vaccination) as >10 cases per 100,000 per week (World Health Organization 2014).

A summary of the public health management process for IMD cases and small-scale outbreaks is presented in Figure 1.1. Public health management of multiple cases or potential outbreaks of IMD is a much more resource-intensive and costly endeavour than isolated cases (La et al. 2019; Letouze, Yao & Clarke 2014). Whenever a new case of IMD occurs that shares a serogroup with prior cases within the same community or organisational setting (e.g. school or workplace), it is assessed for any possible geographical or temporal associations with those prior cases (Stuart et al. 1997). Because of the potential for long-term asymptomatic carriage, cases can be considered temporally associated if they occur within a 4-week interval for organisations (e.g. attendance at the same high school), or within a 3-month interval for broader communities (e.g. a suburb or residential district) (Centers for Disease Control and Prevention 2017; European Centre for Disease Prevention and Control 2010; Public Health England 2018). If an association is present, the cases are considered 'linked' and broader social patterns are assessed to identify the potential source or cause of the outbreak, and identify subgroups within the population that may be at an increased risk of IMD transmission (Centers for Disease Control and Prevention 2017; Fischbacher, Lally & Black 2001). Large-scale outbreaks follow a similar process but focus on groupings of cases instead of singular occurrences. Groups of cases are then assessed for commonalities in geographical area or timeframe to identify possible associations. indicating the beginning of an outbreak (Carod Artal 2015).

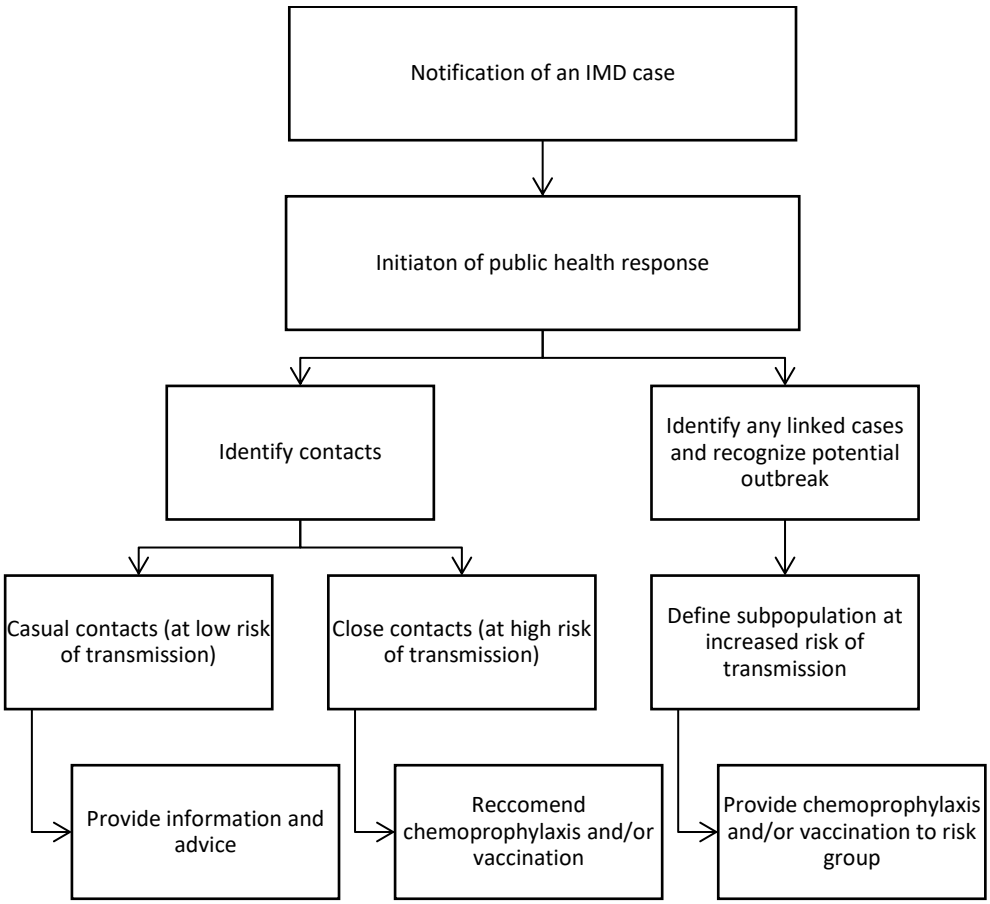

Figure 1.1: *Public health management process for IMD cases and their contacts, adapted from Fischbacher, Lally and Black (2001, p. 269)*

To aid public health staff in responding to IMD cases and their contacts, guidelines for public health management of IMD have been developed by national or international public health agencies for use within their jurisdictions. As described in Section 1.1.3, guideline documents can include clinical advice, antibiotic recommendations, examples of information for IMD contacts, and processes for contact tracing and outbreak identification (Centers for Disease Control and Prevention 2017; Communicable Diseases Network Australia 2017; European Centre for Disease Prevention and Control 2010; MacNeil & Cohn 2011; New Zealand Ministry of Health 2018; Public Health Agency of Canada 2006; Public Health England 2018).

As already noted in Section 1.1.3, the effectiveness of public health guidelines for communicable disease management is limited by the reliability of the evidence available. Discussed in Section 1.1.4 are the current gaps in knowledge around the transition between asymptomatic carriage and disease-state, alongside geographic and temporal variations in

serogroup prevalence and vaccine coverage. As a result, there is currently no clear international consensus on the definition, classification and management of close contacts to IMD cases (Burmaz, Guicciardi, et al. 2019). There also exists a similar lack of clarity around the categorisation of outbreaks (Burmaz, Selle, et al. 2019) and the most effective response by environment, setting, or population affected (Burmaz, Selle, et al. 2019). Inconsistencies in guidance may have an impact on the public health response, as staff are uncertain of how to judge conflicting evidence in a real-world situation (Burmaz, Selle, et al. 2019; Hoek et al. 2008).

A better understanding of the evidence base and decision-making processes around public health guidelines, along with their dissemination and implementation, would allow for more unified and effective management practices. Additionally, an assessment of public health management of outbreaks over time would provide insight into the effectiveness of different strategies and can provide a sound evidence base for future public health recommendations and iterations of guideline development.

1.2 Research Aims

The aims of this research project are to:

1. Assess national and international guidelines for the public health management of IMD, with a focus on their recommendations for identification and management of close contacts; and
2. Gain insight into changes across time in the public health management of IMD outbreaks by identifying and describing similarities and differences in responses by outbreak characteristics and setting.

1.3 Thesis Overview

This thesis consists of four chapters. The remainder of the thesis is organised as follows:

Chapter Two (Manuscript 1) provides a critical appraisal of current national and international English-language guidance for public health management of IMD. This manuscript was

published in the *Journal of Infection and Public Health* (see Appendix A). Chapter Two also includes a postscript, providing a brief recount of impacts due to the COVID-19 pandemic on research progress. This section includes an outline of aspects of the research project that were originally initiated across 2019, and the rationale behind the eventual shift in research focus.

Chapter Three (Manuscript 2) presents a systematic review of IMD outbreak management from the first relevant publication in 1973 onwards, focussing on the evolution of outbreak management strategies over time. The corresponding manuscript has been submitted for publication in the *Journal of Infectious Diseases.*

Chapter Four considers the results as a whole and summarises the research findings across both manuscripts. This chapter also discusses the strengths, limitations and overall implications of the research, before concluding with suggestions for future avenues of research.

Chapter 2 – An appraisal of guidance for the public health management of IMD

This chapter addresses the first aim of this research project, namely to "Assess national and international guidelines for the public health management of IMD, with a focus on their recommendations for identification and management of close contacts".

As identified previously in Sections 1.1.3 and 1.1.5, national and international health departments produce evidence-based guidelines for the public health management of IMD cases and their contacts. These guidelines are intended for use by staff within public health departments when responding to cases of IMD. It is currently unknown how the recommendations included in these guidelines compare globally across jurisdictions.

To address this gap in knowledge, a critical appraisal of English-language guidelines for public health management of IMD from countries with similar incidences of IMD is presented alongside a direct comparison of language used to describe and define close contacts to IMD cases. Processes and outcomes from this research can be used to inform a more collaborative process for guideline development and review. Research findings may also be used to highlight gaps in the literature around IMD transmission and risk of symptom development that require further study.

This chapter includes the manuscript titled "Lessons for and from the COVID-19 pandemic response – An appraisal of guidance for the public health management of Invasive Meningococcal Disease" (Morello et al. 2021), as published in the *Journal of Infection and Public Health* (see appendix A). Following the manuscript is a brief postscript (Section 2.4), outlining the impacts of the COVID-19 pandemic on the original proposed plan of research.

2.1 Author declaration

Statement of Authorship

Title of Paper	Lessons for and from the COVID-19 pandemic response — An appraisal of guidance for the public health management of Invasive Meningococcal Disease
Publication Status	☑ Published ☐ Accepted for Publication ☐ Submitted for Publication ☐ Unpublished and Unsubmitted w ork w ritten in manuscript style
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Principal Author

Name of Principal Author (Candidate)	Brianna R Morello
Contribution to the Paper	BM was first author to the manuscript, developed and carried out the appraisal strategy with guidance from all co-authors and provided first draft of the manuscript.
Overall percentage (%)	70
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.
Signature	Date: 21/SEP/2022

Co-Author Contributions

By signing the Statement of Authorship, each author certifies that:

i. the candidate's stated contribution to the publication is accurate (as detailed above);

ii. permission is granted for the candidate in include the publication in the thesis; and

iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

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Contribution to the Paper	AM provided guidance on appraisal strategy and contributed to revision and editing of the manuscript.
Signature	Date: 21/9/22

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Contribution to the Paper	HM provided guidance on appraisal strategy and contributed to revision and editing of the manuscript.
Signature	Date: 21 Sept 2022

Name of Co-Author	Lynne C Giles
Contribution to the Paper	LG provided guidance on appraisal strategy and contributed to revision and editing of the manuscript. LG was corresponding author to the manuscript.
Signature	Date: 21/9/22

2.2 Manuscript

2.2.1 Abstract

Background: COVID-19 has focussed public attention on the management of communicable disease like never before. Surveillance, contact tracing, and case management are recognised as key components of outbreak prevention. Development of guidance for COVID-19 has drawn from existing management of other communicable diseases, including Invasive Meningococcal Disease (IMD). IMD is a rare but severe outcome of Neisseria meningitidis infection that can be prevented through vaccination. Cases still occur sporadically, requiring ongoing surveillance and consistent management. To this end, national and international public health agencies have developed and published guidance for identification and management of IMD cases.

Aim: To assess national and international guidelines for the public health management of IMD, with a focus on the recommendations for identification and management of 'close contacts' to IMD cases.

Methods: Guidelines from six national and international public health agencies were assessed using a modified version of the Appraisal of Guidelines, Research and Evaluation (AGREE II) Instrument in four key domains: stakeholder involvement, developmental rigour, clarity, and applicability. A direct comparison of terminology and recommendations for identification and management of close contacts to IMD cases was also conducted.

Results: Guidelines from Europe and the United Kingdom rated most highly using the AGREE II Instrument, both presenting a clear, critical assessment of the strength of the available evidence, and the risks, costs, and benefits behind recommendations for management of close contacts. Direct comparison of guidelines identified inconsistencies in the language defining close contacts to IMD cases.

Conclusion: Discrepancies between guidelines could be due to limited evidence concerning mechanisms behind disease transmission, along with the lack of a consistent process for

development and review of guideline recommendations. COVID-19 management has demonstrated that international collaboration for development of public health guidance is possible, a practice that should be extended to management of other communicable diseases

2.2.2 Introduction

The Coronavirus Disease 2019 (COVID-19) pandemic has brought communicable disease management into the spotlight. Societal discussion around the role of public health agencies in the prevention and control of infectious disease outbreaks has never been more important. One major point of focus is the role of disease surveillance within outbreak suppression strategies. Countries that acted swiftly and decisively when setting guidance for the identification and management of COVID-19 cases and close contacts often saw greater success in supressing outbreaks and avoiding heavy case burdens. Notable examples include Australia, Taiwan, and New Zealand (Miller 2020).

The rapid development of guidelines for the management of COVID-19 in different jurisdictions across the world has, necessarily, drawn from guidelines for the management of other infectious diseases (Communicable Diseases Network Australia 2021). Differences in the public health management for other infectious diseases may help to partially explain some of the marked differences in approaches between countries.

The COVID-19 pandemic and ensuing public health measures including physical distancing, lockdowns, and contact tracing, has led to palpable reductions in the incidence of other communicable diseases (Middeldorp et al. 2021; Taha & Deghmane 2020). It is thus timely to compare guidelines for the management of other communicable diseases across a range of jurisdictions to inform the evolution of guidelines for the management of COVID-19 alongside a more unified update of guidance for other communicable diseases.

A French study investigating the effect of COVID-19 lockdowns on communicable disease identified a decrease in highly transmissible and hyperinvasive strains of Invasive Meningococcal Disease (IMD) over the same time period lockdowns were in place (Taha & Deghmane 2020). IMD is a severe disease caused by *Neisseria meningitidis* (*N. meningitidis*),

a bacteria found in the human nasopharyngeal mucosa, the cells lining the back of the nose and throat (Carbonnelle, Nassif & Boudoulous 2010). The disease has a rapid onset and cases require prompt antibiotic treatment to prevent mortality (Batista et al. 2017; Ladhani et al. 2021). Survivors of IMD often suffer from serious long-term sequalae, including – but not limited to – loss of limbs, neurological damage, hearing loss and physical or psychological scarring (Pace & Pollard 2012). Infants (<1 year old) are the most commonly affected age group, with a small increase in incidence for teenagers and the elderly (Borrow et al. 2017). While IMD is relatively rare in developed countries (age standardised incidence of 0.5–20 cases per 100,000 in 2016 (Zunt et al. 2018), *N. meningitidis* can be carried and transmitted asymptomatically throughout the general population, with carriage rates ranging between 10–20%. The mechanisms for transmission are not well understood (Kim et al. 2017), but it is known that close, sustained contact between people creates optimal conditions for spread of N. meningitidis.

IMD is preventable through vaccination, with vaccines available to cover five of the six most common disease-causing strains (A, B, C, X, Y, and W) (Batista et al. 2017; Jafri et al. 2013; Ladhani et al. 2021; Marshall, Lally, et al. 2020; Taha & Deghmane 2020). Carriage of *N. meningitidis* can be prevented through the use of clearance antibiotics (chemoprophylaxis), for contacts of cases — that is, those people who have had close and sustained interactions with cases.

As is the case with COVID-19, ongoing public health management of IMD is required to prevent the development of community outbreaks. This is achieved through two main mechanisms: vaccination of the general population to reduce overall incidence; and disease surveillance and contact tracing to prevent the spread of IMD from carriers.

When IMD cases are identified, staff in public health units are responsible for identifying and classifying all possible contacts to the case. These contacts are then classified by the likelihood of *N. meningitidis* transmission. ‘Close contacts’ have the highest risk of transmission and are managed with chemoprophylaxis to eliminate carriage of a possible disease-causing strain of

bacteria. Depending on the disease-causing strain and availability of vaccination, close contacts may also be offered a strain-specific vaccine to reduce the risk of developing symptoms (European Centre for Disease Prevention and Control 2010).

For staff with responsibility for contact identification and classification, guidance around IMD management comes in the form of guideline documents, usually written by national public health agencies, such as the United States Centers for Disease Control (CDC) and Prevention, or the New Zealand Ministry of Health. Within Australia, these guidelines have been developed by the Communicable Diseases Network Australia (CDNA), an advisory group for the Australian Government that provides unified national guidance for the management of communicable diseases (Communicable Diseases Network Australia 2017, 2021). These guidelines outline the recommended public health response – how to identify, classify and manage contacts, what antibiotics and vaccinations to provide, and guidance on how to communicate with contacts – which is then implemented by public health staff when responding to IMD cases.

While many countries have guidelines written for the public health management of IMD, there has been no comparison or analysis of this guidance on an international level. There is limited evidence around the actual risk of transmission between cases and contacts, especially close contacts, as IMD is uncommon and epidemiology varies globally (Parikh et al. 2020).

An assessment of national and international guidelines for the public health management of IMD, accompanied by a summary of the literature around guideline development and use, will provide a better understanding of guideline implementation in public health settings, and may help to inform the evolution of guidelines for the ongoing prevention of communicable diseases, such as COVID-19. The primary purpose of this review is to assess national and international guidelines for the public health management of IMD, and, more specifically, identification and management of close contacts. A secondary purpose is to characterise and evaluate similarities and differences between guideline recommendations for the identification and management of close contacts.

2.2.3 Methods

Guidance for the public health management of IMD cases and contacts were sourced from countries with similar incidence of IMD to Australia (Zunt et al. 2018). Each national public health agency (or equivalent authority) was identified by searching the country name and "department of health" using Google. Agencies websites were then searched using the terms "meningococcal" OR "meningitis" AND "guidelines" OR "publication" to identify any publicly available resources for staff about the management of IMD cases and contacts. Any English-language guidelines identified that included recommendations for IMD case and contact management were eligible for inclusion in this review. This search was not date limited, however only the most recent published version of each agency's public health guidelines for the management of IMD cases and contacts was assessed. One international body, the European Centre for Disease Prevention and Control (ECDC), was also included as they provide overarching public health guidance to non-English-speaking European Union (EU) countries, that otherwise would not be included in this review. All screening was conducted by a single author. Any queries were discussed by the team of researchers, and disagreement resolved by consensus.

Guidelines were assessed using a modified version of the Appraisal of Guidelines, Research and Evaluation (AGREE II) Instrument. The AGREE II Instrument is a pre-verified tool, designed to 'assess the quality of practice guidelines across the spectrum of health, provide direction on guideline development, and guide what specific information ought to be reported in guidelines' (Brouwers et al. 2010). The original AGREE II consists of 23 items, organised into six quality-related domains: scope and purpose, stakeholder involvement, rigour of development, clarity of presentation, applicability, and editorial independence. Each item consists of a concept, for example, 'the recommendations are specific and unambiguous' (AGREE Next Steps Consortium 2009), which the assessor then rates on a scale of 1–7. A score of 7 indicates the concept is fully explained and articulated, and a score of 1 indicates a total absence of information. Item scores can then be grouped by domain, indicating areas where guidelines may lack clarity or purpose.

The AGREE II instrument was chosen for the present review because of its focus on assessing the methodological rigour behind the development and reporting of guidelines, rather than the validity of the recommendations themselves. It has been used in its original form to assess national and international guidelines in many specialty fields of health, such as maternal (Bazzano et al. 2016; Polus et al. 2012), cardiac (Sabharwal et al. 2013), and respiratory health (Linnemann et al. 2018). As all the guidelines being assessed were written for the same purpose (public health management of IMD) and produced by public health staff or specific government-funded working groups, the 'scope and purpose' and 'editorial independence' domains in the original instrument were omitted. This left four domains, and twelve items in the modified AGREE II instrument. The scoring system was retained, such that each item was given a score between 1 and 7, with the item scores summed according to domain. The number of items differs across the four domains, with 'stakeholder involvement' and 'applicability' each having two items (maximum possible score = 14), 'clarity of presentation' three items (maximum possible score = 21), and 'rigour of development' five items (maximum possible score = 35). Item scores were summed and presented by domain, alongside an overall score out of the maximum possible total of 84 for each set of guidelines.

In addition to the AGREE II scoring, a direct comparison of language used and recommendations for identification and management of close contacts between guidelines was conducted. This comparison included each guideline's definition of a close contact, antibiotic recommendations, and vaccination recommendations for close contacts.

2.2.4 Results

Public health guidelines from Australian (Communicable Diseases Network Australia 2017), Canadian (Public Health Agency of Canada 2006), European (European Centre for Disease Prevention and Control 2010), New Zealand (New Zealand Ministry of Health 2018), United States (US) (MacNeil & Cohn 2011), and United Kingdom (UK) (Public Health England 2018) health agencies were included (n = 6). The results from application of the modified AGREE II instrument to these six guidelines are shown in Table 2.1. All guidelines scored highly (i.e.

>75% of maximum possible domain score) in the ‘clarity of presentation’ domain. Four guidelines scored highly in ‘rigour of development’ (Canada, Europe, Australia, UK), and three scored highly in ‘applicability’ and ‘stakeholder involvement’ (Canada, Europe, UK).

Table 2.1: Modified AGREE II Instrument scores by domain and overall, for national and international guidelines (displayed in ascending order of year of publication)

		Domain Scores				**Total Score (out of 84)**
Jurisdiction	**Year**	Stakeholder involvement (out of 14)	Rigour of Development (out of 35)	Clarity of Presentation (out of 21)	Applicability (out of 14)	
Canada	2006	13	31	19	11	74
Europe (ECDC)	2010	14	35	21	12	82
Australia	2017	8	28	19	10	65
United States (US)	2017	5	25	21	9	60
New Zealand	2018	7	20	20	10	57
United Kingdom (UK)	2018	11	34	21	13	79

Overall, four guidelines – Canada, Europe, Australia, and the UK – scored above 63/84 (75%). The European guidelines scored highest overall when using the modified AGREE II criteria (82/84), followed by the United Kingdom (79/84). Both sets of guidelines clearly showed the strength of the evidence behind each recommendation, included key information summaries within each section, and addressed possible barriers and facilitators to guideline implementation. The Canadian and Australian guidelines were both clearly written with key information summaries readily available throughout the documents. However, the discussion around the strength of the evidence was more limited in each of these guidelines, and the Australian guidelines showed much less evidence of stakeholder involvement. While clearly written, the US guidelines scored 60/84, reflecting that there was little discussion in these guidelines around stakeholder involvement and applicability. The New Zealand guidelines scored lowest (57/84), with little in-depth discussion around any of the concepts that underpin the items in each domain. Notably, there was no apparent trend in scores related to their date of publication.

All guidelines emphasised the importance of prompt identification and management of close contacts to minimize the risk of additional cases of IMD. There was consistency across all guidelines regarding the exposure period – 7 days before onset of symptoms in the case to 24h on effective antibiotic treatment – and on household contacts qualifying as 'close' contacts, shown in Table 2.2.

Table 2.2: *Summary of terminology, definition of 'close contact' and recommendations for management in national and international public health guidelines*

Jurisdiction	Year	Terminology	Close contact definition	Antibiotic recommendations	Vaccination recommendations
Canada	2006	Close contacts	Household Co-sleepers Direct contamination of nose/mouth (e.g. shared cigarettes/drinks, kissing) Healthcare workers[1] Children and staff in childcare/nursery settings Co-passengers[2]	Rifampicin, Ceftriaxone, Ciprofloxacin	Yes, if the contact is unimmunised and there is a vaccine available for that strain.
Europe (ECDC)	2010	Close contacts	Household Pre-school (dependent on risk assessment)	Rifampicin, Ceftriaxone, Ciprofloxacin, Cefixime, Azithromycin	Yes, if the contact is unimmunised and there is a vaccine available for that strain.
Australia	2017	Higher risk contacts	Household/household like Intimate kissing/sexual Child-care Co-passengers Healthcare workers	Rifampicin, Ceftriaxone, Ciprofloxacin	A, C, W, Y conjugate vaccines if contact is unimmunised, 4CMenB (Bexsero®) vaccine only if there is a second case of serogroup B in the same household.
United States (US)	2017	Close contacts	Household Childcare centre contacts "Anyone directly exposed to oral secretions" (kissing, mouth-to-mouth resuscitation, intubation/tube management)	Rifampicin, Ceftriaxone, Ciprofloxacin, Azithromycin (if there is no resistance to fluoroquinolone)	Not discussed.

[1] Directly exposed to nasal secretions (e.g. mouth-to-mouth or intubation of a known IMD case)
[2] Seated directly adjacent to a known IMD case, for travel lasting longer than 8 hours on an airplane, boat, bus, train or other enclosed transport.

Table 2.2 (cont): *Summary of terminology, definition of 'close contact' and recommendations for management in national and international public health guidelines*

Jurisdiction	Year	Terminology	Close contact definition	Antibiotic recommendations	Vaccination recommendations
New Zealand	2018	Contacts	Household Bed/room sharing overnight Co-passengers Healthcare workers "Other contacts as determined on a case-by-case basis by the medical officer"	Rifampicin, Ceftriaxone, Ciprofloxacin	MenACWY conjugate vaccine if contact is unimmunised, Bexsero® (MenB) if there is a multi-occupancy outbreak
United Kingdom (UK)	2018	Close contacts	Household/household like	Rifampicin, Ceftriaxone, Ciprofloxacin, Azithromycin (for pregnant women)	MenACWY if contact cannot confirm immunisation in the preceding 12 months, MenB only if contact is at increased risk of meningococcal infection

Canada had the oldest published guidelines (2006) and the broadest definitions for close contacts, including sharing drinks and cigarettes as an indication of close contact. As seen in Table 2.2, three out of the six guidelines included co-passengers (seated directly adjacent to an IMD case on travel lasting longer than 8 h) to cases as close contacts. All of these guidelines specified an 8 -h minimum time and included any form of enclosed transport (Communicable Diseases Network Australia 2017; New Zealand Ministry of Health 2018; Public Health Agency of Canada 2006). Only Australia defined a minimum time of contact for childcare settings (two full days or 20 cumulative hours in the same care group, based on a 1981 study on secondary case rates after IMD outbreaks in Belgian children (Communicable Diseases Network Australia 2017; De Wals et al. 1981). Other guidelines left it to the discretion of the public health officer (European Centre for Disease Prevention and Control 2010) whether to include childcare contacts as close contacts or did not include childcare contacts at all (New Zealand Ministry of Health 2018; Public Health England 2018).

With the exception of the US guidelines, vaccination was recommended for all unimmunised close contacts, provided the disease-causing strain could be identified. European and Canadian guidelines recommend vaccination 'if a case of meningococcal disease is caused by a strain that is preventable by an available licenced vaccine' (European Centre for Disease Prevention and Control 2010). Australian, UK and New Zealand guidelines specify A, C, W, Y conjugate vaccines, and either do not discuss the use of meningococcal B vaccination (Australia) or limit use to multiple cases occurring in the same household (UK, New Zealand).

Each of the guidelines considered here recommended Rifampicin, Ceftriaxone, and Ciprofloxacin for the elimination of carriage (chemoprophylaxis) within close contacts. Two (US and UK) guidelines also included Azithromycin as an additional option. The European guidelines included Cefixime in addition to Rifampicin, Ceftriaxone, and Ciprofloxacin. Dosages, recommended age, duration, and cautions in usage were all identical across the guidelines.

2.2.5 Discussion

This study has shown that guidelines with higher scores based on the AGREE II Instrument clearly and critically assessed the strength of the available evidence to make recommendations for identification and management of IMD close contacts. Higher scoring guidelines also detailed the potential risks, costs and benefits of each recommendation. This is demonstrated by the European and UK guidelines, both of which clearly identified and discussed the strength of the evidence behind each recommendation. Other guidelines, such as those produced by the US and New Zealand, had lower overall scores when they showed no clear link between the evidence and recommendations given, did not provide explicit recommendations, relied on limited evidence, or did not provide information on possible barriers and facilitators to implementation of guideline recommendations.

Public health staff require clear and accurate guidance in order to effectively identify and reduce the risk of further IMD cases arising from contacts of those cases (Gobin et al. 2020). Domains within those guidelines with lower scores in the AGREE II Instrument indicate areas where public health staff lack consistent and explicit guidance on how to carry out their role concerning management of close contacts. This could in turn make it more challenging for staff to properly implement such guidelines when presented with a case of IMD.

One important point to bear in mind is that the primary purpose of the AGREE II Instrument is to assess the quality of the underlying methodology and reporting of guidelines, and not the assessment of the accuracy of any recommendations provided. Therefore, the scores from evaluation according to the AGREE II Instrument should also be considered within the context of the findings from Table 2.2. Guidelines assigned higher scores using the AGREE II Instrument may not necessarily be providing the most up-to-date or evidence-supported guidance. While recommendations for antibiotic treatment were largely consistent across the guidelines assessed in the present review, information about vaccination varied between countries. This is in part due to the publication date of some guidelines. For example, the Bexsero® meningococcal B vaccine, mentioned in Australian, UK and New Zealand

guidelines, was only licenced in the UK in 2013, and has only been included in the national immunisation programs of seven countries including Australia (Parikh et al. 2020) to date. The definition of a 'close contact' was also quite varied, and ranged from household and household-like contacts alone (Public Health England 2018) to household, household-like, sexual, child-care, co-passengers and healthcare contacts (Communicable Diseases Network Australia 2017).

In general, the development of guidance for the public health management of a given communicable disease rests on a body of evidence describing the aetiology and epidemiology of that disease. Evidence may be derived from studies investigating many different facets of the disease, including – but not limited to – causative pathogen(s), symptom progression, transmission patterns and population prevalence. In the case of IMD, the ability of researchers to study the life cycle and host interactions of N. meningitidis is limited, largely due to its adaptation to human airways (Carbonnelle, Nassif & Boudoulous 2010; Johswich & Gray-Owen 2019). While mouse models can be used to model disease symptoms and infection mechanisms, they require manual inoculation with the bacterium, and are not well-suited to studying transmission patterns (Johswich & Gray-Owen 2019). Studies on the prevalence of asymptomatic carriage have largely focussed on sub-populations already known to have higher rates of carriage, and often utilize surveys and questionnaires to identify factors that may affect an individual's risk of carriage (MacLennan et al. 2006; McMillan et al. 2019; Peterson et al. 2018). Guideline recommendations are then based on the generalised results of these population studies, in addition to public health records of previous IMD clusters (Gobin et al. 2020) and published evidence on the transmission risk of similar bacterial pathogens (e.g. tuberculosis) (MacNeil & Cohn 2011).

A 2016 study (Vygen et al. 2016) of public health guidance for the management of close contacts to IMD cases within EU countries discussed the variation between country policies for identification and management of close contacts. The study is a repeat of a 2007 survey (Hoek et al. 2008), and indicated that following the publication of the ECDC guidance in 2010,

EU countries had adopted more evidence-based public health guidance, that were better aligned with ECDC recommendations. This indicates that while there is a somewhat limited understanding of the risks affecting transmission of N. meningitidis, it has become more widely accepted that to be at a higher risk of transmission, a certain degree of close, sustained contact is required (Caugant & Maiden 2009; Gobin et al. 2020; Parikh et al. 2020; Trotter, Gay & Edmunds 2006).

While there was no clear link between AGREE II scores and date of guideline publication, definitions of close contacts did change over time. For example, Canadian guidelines had the earliest publication date (2006) and the broadest inclusion criteria for close contacts. More recent guidelines, such as those from the UK (2018) or the US (2017), have a more restricted definition of a close contact and had a stronger evidence base to support their recommendations.

The present review of guidelines was limited to high-income and predominantly English-speaking countries. While all of the included jurisdictions had a similar incidence of IMD, the disease is rare in those areas (Zunt et al. 2018). EU countries were also grouped under the ECDC guidance, as none of the individual member states had publicly available English-language guidelines. The comparisons published by Vygen et al. (2016) and Hoek et al. (2008) provided insight on the similarities and differences between EU countries with regards to their management of IMD case contacts, although a direct assessment of individual EU countries public health guidelines was not carried out in either of these studies. Another consideration in interpreting the work presented here is that the AGREE II Instrument is predominantly designed for the assessment of clinical guidance. While it provided valuable insight into the development and reporting of public health guidance around IMD prevention, there are aspects of the guidelines assessed that the AGREE II instrument does not cover. These include healthcare costs, recommendations for review of guidelines, methods for guideline dissemination to public health staff, recommendations for audit, and assessment of guideline implementation. There are also considerations for the assessment of clinical guidelines that

are not relevant to the assessment of public health guidelines. In our study, this limitation was mitigated by the removal of the ‘Scope and Purpose’ and ‘Editorial Independence’ domains from the original AGREE II Instrument.

COVID-19 management has, by necessity, streamlined the process of translating evidence into public health policy (e.g. mask wearing, hotel quarantine, lockdown strategies) (Communicable Diseases Network Australia 2021; Miller 2020). While responses to the COVID-19 pandemic have reduced the spread of IMD and other communicable diseases (Taha & Deghmane 2020; Tan et al. 2020), they have also impacted vaccination programs (Gaythorpe et al. 2021; Middeldorp et al. 2021) and may negatively impact outbreak management strategies. The current delay between increased understanding of disease transmission and actual implementation into public health guidance can have direct and immediate consequences for individual and population health.

Mechanisms for guideline development and review should prioritize the identification of areas where guidelines may lack clarity, be inconsistent, or have weak underlying evidence. This information can then be used to improve the clarity and consistency of public health recommendations. Guideline development and revision should also be considered frequently within a global context, ideally with the introduction of new vaccines or vaccination programs, as it becomes increasingly evident that inconsistent management of an infectious disease, either within or between country jurisdictions, can hinder effective disease management. Although conjugate meningococcal vaccines show evidence of reduction in transmission (Ladhani et al. 2021), they do not affect overall carriage rates (Marshall, McMillan, et al. 2020). As new vaccines are developed and implemented in population-wide programs, guidelines for management of contacts need to be reviewed to ensure they remain contemporaneous.

2.2.6 Conclusions

The present study has shown inconsistencies between higher-income countries for the public health management of IMD case contacts. Most notably, the definitions used to identify close contacts differ between countries. Limited availability of evidence surrounding the risk factors

for transmission and disease development amongst IMD case contacts, in addition to the lack of a widely accepted process for guideline development and review, may be contributing to these inconsistencies.

The facilitation of effective and multi-jurisdictional responses to communicable disease outbreaks rests on global cooperation and unified guidance. A pre-planned stage of international review within the guideline development process, so as to promote the consideration of recommendations for disease management put forth by other jurisdictions, could be adopted to achieve this. This process could be guided and implemented by internationally recognised bodies such as the World Health Organisation or the ECDC. Worldwide, responses to the COVID-19 pandemic demonstrate that public health guidance can be updated rapidly as new information is gleaned, and those changes can be quickly communicated to relevant staff and the wider public.

Response to the COVID-19 pandemic has resulted in a level of international cooperation that would have been considered unachievable previously. This singular focus on disease prevention can – and should – be carried forward into the management of IMD and other communicable diseases. International collaboration for guideline development and implementation must continue to be the cornerstone of communicable disease response and management.

2.3 Supplementary data

A full version of the modified AGREE II appraisal tool used in Manuscript 1, including minimum and maximum possible scores by domain and overall, can be viewed in Appendix B.

2.4 Postscript

2.4.1 Knowledge gap – staff implementation of guidelines

The existing guidelines reviewed in this first manuscript (Lessons for and from the COVID-19 pandemic) were designed for use by public health staff when responding to real-world cases of IMD. Within an Australian setting, while the CDNA guidelines outline an 'ideal' or 'best-practice' response, they also encourage staff to exercise their own judgement when managing IMD cases and their contacts (Communicable Diseases Network Australia 2017). This results in some expected variation in practice in accordance with individual staff's experience, knowledge and attitudes. This can be observed in prior audits of public health management of IMD cases and contacts, which have shown staff do not consistently advise vaccination or chemoprophylaxis to IMD case contacts in line with official guidelines (Murajda et al. 2015; Pearson et al. 1995). However, only relatively small-scale audits of public health responses have been conducted, either at a state (Murajda et al. 2015), regional (Pearson et al. 1995) or individual outbreak level (Burmaz, Selle, et al. 2019). There currently exists no universal tool used to assess how public health staff are recognizing and responding to IMD cases in practice (Kipping et al. 2006; Torner et al. 2011).

2.4.2 Proposed research questions and methodology

There is little knowledge surrounding the practical use of guidelines for public health management of IMD at an international level. It is also largely unknown how staff in Australian public health units are receiving information concerning guidelines and their implementation. To address this gap in knowledge, the following research questions were proposed in mid-2019, when planning for this research project commenced:

1. How are public health staff within Australia using the national Australian guidelines for prevention and control of IMD to identify and manage close contacts to IMD cases?

a. How do the knowledge and attitudes of public health staff affect their management of close contacts?
b. What, if any, are the barriers and facilitators to accessing and implementing guideline recommendations in practice?

As the proposed research questions were focussed on the dissemination and use of guidelines in real-world settings, a pragmatic approach was considered most appropriate (Albright, Gechter & Kempe 2013). Pragmatist research eschews purely qualitative/quantitative methodology (Howe 1988), instead taking a question-driven approach to research. Choosing methods based on their suitability to answer the research question at hand identified a mixed-methods approach to be most suitable (Onwuegbuzie & Leech 2005; Tashakkori & Teddlie 1998). This involved a sequential design as outlined by Creswell and Creswell (2018), consisting of two phases of data collection. The initial quantitative data from Phase 1 was intended to inform the design and implementation of the subsequent qualitative phase. Qualitative data would then be used to provide depth of understanding to the quantitative results.

Phase 1 of the proposed research was the delivery of a structured online survey to public health staff within all Australian state and territory health departments. Survey questions were designed to assess staff knowledge, attitudes, and practices (KAP) regarding implementation of CDNA guidelines for management of IMD cases and their contacts. Results from the survey would have provided an overview of participants' understandings and use of the guidelines, and informed the development of open-ended interview questions and prompts for use in Phase 2. Interview participants were to be recruited from the pool of survey respondents, and invited to identify and discuss current barriers and facilitators towards implementation of the CDNA guidelines in practice.

2.4.3 Ethics approvals and COVID-19 interruptions

Ethics approval was sought and granted in January 2020 as an amendment to an existing application titled 'Characterization of close contacts of cases diagnosed with Invasive Meningococcal Disease' (HREC number: HREC/19/SAH/8, see Appendix C). Ethics approval for interstate data collection using staff surveys and interviews was sought either under the National Mutual Acceptance (NMA) Scheme through the SA Health Human Research Ethics Committee (NSW, QLD, WA, ACT and VIC), or by seeking recognition of prior ethics approval from state and territory health departments that are not included in the NMA Scheme (TAS, NT).

In January of 2020, the first COVID-19 cases were recorded within Australia (World Health Organization 2022). While ethics approval had been granted for staff surveys and interviews, Site-Specific Approvals (SSAs) were still being sought as a necessary stage of the research governance approval process. Staff from relevant public health departments at this time were engaged with providing public health management of the COVID-19 pandemic response, and were unable to prioritise this research. The realities of the COVID-19 pandemic response within Australia necessitated the withdrawal of SSA approval for the proposed research into KAP of public health staff for management of IMD cases and their contacts, and was indefinitely paused.

2.4.3 Assessing public health management of IMD

Since it was deemed impractical to assess guideline implementation at a staff level, an alternate method of appraising real-world public health management of IMD was required. Instead, management strategies for IMD outbreaks were assessed through a review of past outbreaks and their associated public health response. This review formed the basis for Manuscript 2 (Chapter 3) and provided insight into the practicalities of public health management of IMD, without requiring input from public health staff in the midst of a global pandemic.

Chapter 3 – Public health management of IMD outbreaks, a systematic review

This chapter addresses the second aim of this research, namely to "gain insight into changes across time in the public health management of IMD outbreaks by identifying and describing similarities and differences in responses by outbreak characteristics and setting".

Following from the previous chapter, it is currently unclear how the public health guidelines assessed in the first manuscript are being applied in practice. As addressed in Section 2.4, it was not possible to assess the implementation of public health guidelines on an individual staff level due to the impacts of the COVID-19 pandemic. Instead, a global review of public health responses to IMD outbreaks was conducted. Findings from this review provide insight into the evolution of practices for outbreak response and management at a more jurisdictional level.

Assessing and describing outbreak responses and lessons learnt by setting provides a summary of the contexts in which IMD outbreaks are more likely to occur alongside recommendations for response by setting. This review also highlights key inconsistencies in outbreak reporting, and discusses the potential implications for future management of IMD and other communicable diseases.

This chapter consists of the manuscript titled "Public health management of Invasive Meningococcal Disease Outbreaks, a systematic review" as formatted for publication within the *Journal of Infectious Diseases*. Supplementary material for this manuscript is included in Appendix E – Data extract summary sheets, and Appendix F – Additional references (excluded from this manuscript due to publication reference limits).

3.1 Author declaration

Statement of Authorship

Title of Paper	Public health management of Invasive Meningococcal Disease outbreaks, a systematic review
Publication Status	☐ Published ☐ Accepted for Publication ☑ Submitted for Publication ☐ Unpublished and Unsubmitted w ork w ritten in manuscript style
Publication Details	Submitted for publication with the *Journal of Infectious Diseases*.

Principal Author

Name of Principal Author (Candidate)	Brianna R Morello
Contribution to the Paper	BM was first author to this manuscript, developed and conducted the search strategy, carried out initial title and abstract and full text screening, developed data extract tables and conducted data extraction and analysis with guidance from all co-authors. BM also provided first draft of the manuscript.
Overall percentage (%)	70
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.
Signature	Date: 21/SEP/2022

Co-Author Contributions

By signing the Statement of Authorship, each author certifies that:

i. the candidate's stated contribution to the publication is accurate (as detailed above);
ii. permission is granted for the candidate in include the publication in the thesis; and
iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

Name of Co-Author	Adriana Milazzo
Contribution to the Paper	AM provided guidance on search strategy, screening process, data extraction and analysis, cross-checked data extraction and contributed to revision and editing of the manuscript.
Signature	Date: 21/9/22

Name of Co-Author	Helen Marshall
Contribution to the Paper	HM provided guidance on search strategy, screening process, data extraction and analysis and contributed to revision and editing of the manuscript.
Signature	Date: 21 Sept 2022

Name of Co-Author	Lynne C Giles
Contribution to the Paper	LG provided guidance on search strategy, screening process, data extraction and statistical analysis, and contributed to revision and editing of the manuscript. LG was corresponding author to the manuscript.
Signature	Date: 21/9/22

3.2 Manuscript

3.2.1 Abstract

Background: Outbreaks of infectious diseases are an ongoing public health concern, requiring extensive resources to prevent and mitigate. Invasive Meningococcal Disease (IMD) is a severe outcome of infection with *Neisseria meningitidis*, which can be carried and transmitted asymptomatically between individuals. IMD is not completely vaccine-preventable, presenting an ongoing risk of outbreak occurrence. This systematic review provides a retrospective assessment of public health management strategies for IMD outbreaks.

Methods: A systematic search was performed in PubMed and Embase. Studies reporting on IMD outbreaks and associated public health response were eligible for inclusion. No publication year limits were applied. Reporting on key characteristics including outbreak size, duration, location and description of the public health response were assessed against the 'Strengthening the Reporting of Observational studies in Epidemiology' guidelines. A summary of lessons learned and author recommendations for future IMD outbreaks for each article were also extracted and discussed.

Results: A total of 39 eligible studies were identified, describing 35 discrete outbreaks in six regions worldwide. Public health responses to outbreaks were largely reactive, often involving the whole community, not just those at highest risk of transmission. In more recent publications, public health responses were more proactive – focussing on long-term preventative measures such as vaccination. Overall, outbreak reporting was inconsistent, with key characteristics often missing or incompletely described.

Conclusion: Clear, comprehensive reporting on IMD outbreaks and their associated public health management is needed to inform both policy and practice for future responses to outbreaks of IMD and other infectious diseases.

3.2.2 Introduction

Invasive Meningococcal Disease (IMD) is a severe and often life-threatening condition caused by infection with *Neisseria meningitidis* (*N. meningitidis*). The most common clinical presentations of IMD are sepsis, meningitis, or both (Pace & Pollard 2012). IMD cases require prompt recognition and treatment to reduce the risk of complications or death (Pace & Pollard 2012). The bacteria are carried in the human oropharynx and may be transmitted between individuals. Transmission requires close, sustained contact, or direct exposure to nose and/or throat secretions. Asymptomatic carriage can last for several months, and factors such as age, gender, smoker status, size and density of social networks and living space all impact the risk of carriage (Caugant, Tzanakaki & Kriz 2007; Peterson et al. 2018).

There are 12 identified serogroups of *N. meningitidis,* with six responsible for the majority of IMD worldwide (A, B, C, W, X and Y) (Borrow et al. 2017). Vaccines are available to protect against ABCWY, but there is currently no single vaccine that protects against all disease-causing serogroups. Because of the swift course of the disease, and ongoing carriage and transmission between individuals, robust disease surveillance and notification systems are required to quickly identify and respond to cases of IMD.

If the circulation of a disease-causing variant of *N. meningitidis* is not successfully prevented, subsequent linked cases of IMD can indicate the beginning of an outbreak. In jurisdictions with a relatively low incidence of IMD, an outbreak is typically defined as ‘two or more cases of the same serogroup within a shared community or organisational setting, occurring less than four weeks apart’ (Centers for Disease Control and Prevention 2017; Communicable Diseases Network Australia 2017). Jurisdictions with higher incidence of IMD often have minimum thresholds of cases per 100,000 population which are used to identify and define outbreaks (Trotter, Gay & Edmunds 2006). The World Health Organization (WHO) recommends an alert threshold (indication to intensify epidemic preparedness) as 3-9 cases per 100,000 per week and an epidemic threshold (indication to initiate epidemic treatment and vaccination) as >10 cases per 100,000 per week (World Health Organization 2014). Outbreaks require a much

more involved and costly response when compared to a single isolated case (Letouze, Yao & Clarke 2014). Outbreaks can develop within communities (social networks, town, village, or region), mass gatherings, or organisational settings (e.g. workplaces, dormitory accommodation, military barracks, childcare, or schools) (Communicable Diseases Network Australia 2017).

Public health management of IMD outbreaks is focussed on interrupting the chain of transmission, preventing further cases from occurring (Communicable Diseases Network Australia 2017). To accomplish this, public health staff are responsible for identifying the population most at risk of transmission before interventions can be implemented to prevent disease. These interventions can include enhanced surveillance to detect additional IMD cases, vaccination to prevent development of IMD within an at-risk population, or antibiotic treatment (chemoprophylaxis) to clear *N. meningitidis* from potential carriers (Stuart 2001). Outbreak responses are tailored to the population at risk, with characteristics such as causative serogroup, setting, source of exposure, timing, and availability of public health staff and resources all impacting the outbreak response.

Outbreak management is also an iterative process, with public health guidance evolving over time in response to new evidence (Morello et al. 2021; Vygen et al. 2016). Strategies for the public health management of IMD outbreaks have been developed through experience responding to the changing epidemiology of the disease. Reporting on the impact of outbreak characteristics on the public health response is scarce, and it is currently unclear how they may affect outbreak management.

3.2.3 Aims

The purpose of this research is to describe the public health management of IMD outbreaks by:

- Identifying and describing similarities and differences between jurisdictions in outbreak characteristics;

- Identifying and assessing any potential similarities and differences in public health response by outbreak setting; and
- Summarising the change in response strategies over time.

3.2.4 Methods

This review was registered with PROSPERO (Record ID: CRD42020221472). PubMed and Embase were searched using terms relating to meningococcal disease, outbreaks, and outbreak management. A list of search terms is included in Appendix D. This search was not time limited, and was initially conducted in December of 2020 and updated in September 2021.

English-language studies were considered eligible for inclusion if they reported on outbreak with at least one clinically or laboratory confirmed case of IMD, specified the region, month, and year of the outbreak, and included a detailed description of the subsequent public health response. Studies discussing or investigating sporadic cases of IMD with no epidemiological link beyond immediate household settings were excluded, along with narrative reviews, incidence/prevalence studies (in absence of an outbreak), vaccination studies (in absence of an outbreak), general carriage studies, cost-effectiveness studies and animal studies.

Reference lists of included articles were hand-searched for additional studies eligible for inclusion. Inclusion and exclusion criteria were agreed to by all authors. All screening, reference management and data extraction was conducted through Covidence systematic review software (Veritas Health Innovation n.d.).

In total, 1,309 studies were identified by the search strategy and imported into Covidence. After removal of duplicates (n=206) the remaining 1,103 studies were screened by title and abstract for relevance. From those, 186 full-text articles were assessed for eligibility against inclusion criteria. An additional seven eligible articles were identified from either hand-searching reference lists of included articles (n=2) or updated database search in September 2021 (n=5). Outbreaks with more than one study describing outbreak characteristics and response were grouped together for data extraction (n=8 papers detailing four distinct outbreaks). In summary,

39 articles were included, detailing 35 distinct outbreaks and their associated response (see Figure 3.1). All screening was carried out by BM, in consultation with AM, HM and LG. Any cases where article eligibility was unclear went to a consensus vote with all authors.

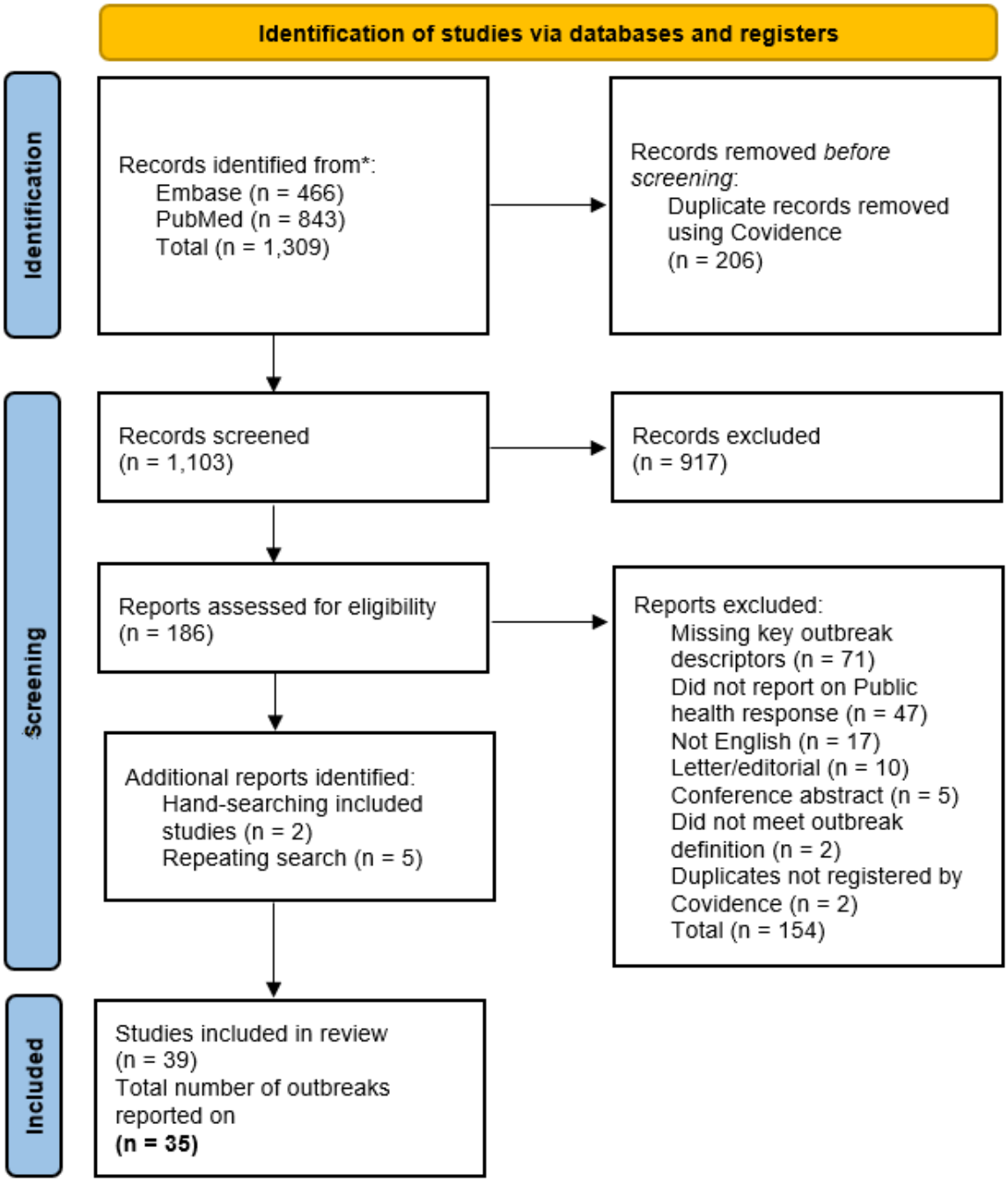

***Figure 3.1**: PRISMA diagram of literature search and screening process*

Data extraction

Included articles were grouped by decade of publication (1970-79, 1980-89, 1990-99, 2000-2009, and 2010-19). Data extraction was carried out by BM, with one article from each decade randomly selected and cross-checked by AM (n=5). Data were extracted according to three main categories: **Contextual** – information regarding the setting of the outbreak, such as date, type of study, region and author details; **Outbreak details** – information on the size and impact of the outbreak as measured by number of cases, outbreak duration (defined as number of days between first and last notified case), attack rate (cases per 100,000 population), case fatality rate (presented as a percentage), IMD complications recorded; and **Outbreak response** – information on the public health response strategies, vaccine availability (whether there was a vaccine at the time of the outbreak that protected against the given serogroup), mass vaccination or chemoprophylaxis campaigns, lessons learnt and future recommendations as summarized by authors.

Data analysis

Published attack rates were used whenever possible; when not provided, attack rates were calculated using the study-reported population size or publicly available official population estimates (e.g. university enrolment reports, census data) as the denominator. A summary of which attack rates were calculated is included in Supplement 1 (Appendix E). Exact 95% confidence intervals (95% CI) for the attack rates were calculated using the Clopper-Pearson method. All calculations were conducted in Stata version 15 (StataCorp 2017).

Quality appraisal

Included articles were assessed for quality in four domains: introduction, methods, results, and discussion. Each domain had key criteria or information that were expected, based on the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement (Von Elm et al. 2007). A single qualitative comment was added for each domain where criteria were absent or missing details. Key criteria included outbreak duration (clear start and finish

dates), summary of investigation, case summaries (time, person, place), clear summary of findings and clearly identified author recommendations. A summary of comments is included in Supplement 1 (Appendix F). Quality appraisal was carried out by BM, in consultation with AM, HM and LG.

3.2.5 Results

In total, 35 distinct outbreaks in six regions from around the world were included. A summary of outbreaks and average number of cases by region is presented in Table 3.1. The earliest outbreak occurred in Finland in 1973, and the most recently reported outbreaks occurred in early 2018. Average outbreak duration (time between first and last reported case) was 221 days, or just over 31 weeks (range=4 days – 4.5 years). Of the 28 outbreaks that reported on seasonality, the most common seasons were spring/summer (n=13) and the equatorial dry season (n=9). Seven major settings were identified: Urban Community (n=11), Rural and Remote Community (n=9), Childcare and Educational (n=7), Events (n=3), Refugee Camps (n=2), Military Barracks (n=2), and Organisational (n=1).

***Table 3.1**: Summary of outbreaks by region*

Region	No. outbreaks	Serogroups	Mean no. cases (range)	Median no. cases (1st – 3rd quartile)
Europe	13	A, B, C, W	124 (2 - 1,527)	7.5 (4.25 - 14)
Africa	10	A, C, W	12,956 (9 - 109,580)	291 (88 - 7,881)
North America	6	B, C	10 (3 - 19)	9.5 (5.5 - 15)
Asia	3	A, B, W	11 (5 - 17)	6 (5.5 - 11.5)
Oceania	2	W	13 (2 - 24)	13 (7.5 - 18.5)
South America	1	C	16 (NA)	NA

Relative size (by attack rate) and location of outbreaks can be seen in Figure 3.2. The predominant serogroup changed over time, from serogroup A or B outbreaks in 1970-1980 to A or C in 1990-early 2000s, then B or C in the mid-2000s. More recently, there has been an increase in serogroup W outbreaks since 2016. The earlier outbreaks generally had a longer duration, often occurring over months or years. More recent outbreaks have lasted less than six months on average.

***Figure 3.2**: Map of reported outbreak locations (n=32) showing relative attack rates (number of cases per 100,000 population), color-coded by serogroup.*

Outbreaks by setting

A summary of outbreak characteristics by setting is presented in Table 3.2. A full list of references for included studies can be seen in Supplement 2 (Appendix F).

***Table 3.2:** Summary of outbreak characteristics, arranged by setting*

Study	Outbreak location	Year and duration (days)	Serogroup	No. cases	Attack rate[a] (95% CI)	Case fatality rate (%)
		Urban Community				
Cartwright 1986	Gloucestershire, England	1981 1,612	B	65	21.6 (16.6-27.5)	3.00%
Chacon-Cruz 2014	Tijuana, Mexico	2013 59	C	19	1.07 (0.0664-0.167)	36.8%
Delisle 2010	Dax City, Departement Landes, Aquitaine region, France	2008 274	B	11	8.90 (4.44-15.9)	9.09%
DeSchrijver 2003	Antwerp province, Belgium	2001 334	C	74	4.50 (7.70-10.7)	9.46%

Table 3.2 (cont): *Summary of outbreak characteristics, arranged by setting*

Study	Outbreak location	Year and duration (days)	Serogroup	No. cases	Attack rate[a] (95% CI)	Case fatality rate (%)
		Urban Community (cont)				
Jacobson 1977	Mobile County, Alabama, USA	1974 396	B	16	20.0 (11.4-32.5)	31.3%
Krause 2002	Putnam County, Florida, USA	1998 395	C	12	36.4 (18.8-63.5)	16.7%
Kriz 1995	Olomuc and Bruntal, Czechia	1993 Olomouc 240 Bruntal 531	C	Olomouc 9 Bruntal 15	Olomouc 17.0 (7.77-32.3) Bruntal 23.4 (12.5-40.0)	UKN[b]
Peltola 1978	Finland, Europe	1973 1,460	A	1,527	32.5 (30.9-34.1)	UKN
Perrett 2000	Rotherham, South Yorkshire, England	1988 7	C	8	UKN	25.0%
Pivette 2020	Departement Cotes-d'Armor, Brittany Region, France	2016 121	B	5	6.40 (2.08-14.9)	NA[c]
Thabuis 2018	Beaujolais province, Auvergne-Rhone-Alpes Region, France	2016 19	B	4	22.5 (6.13-57.6)	NA
		Rural or Remote Community				
Chow 2016	Kebbi, Niger and Sokoto states, Nigeria	2015 118	C	6394	282 (275.14-288.99)	5.02%
Flood 2021	Ceduna Region, South Australia, Australia	2016 62	W	2	54.0 (6.54-195)	NA
Mohammed 2000	Nigeria	1996 182	A	109,580	UKN	10.7%
Mounkoro 2019	Kara Region, Togo, Africa (initial)	2016 176	W	1995	78.8 (75.4-82.3)	6.40%
Nnadi 2017	Zurmi Local Government Area, Zamfara State, Nigeria	2016 184	C	14,518	UKN	8.00%

Table 3.2 (cont): *Summary of outbreak characteristics, arranged by setting*

Study	Outbreak location	Year and duration (days)	Serogroup	No. cases	Attack rate[a] (95% CI)	Case fatality rate (%)
Rural or Remote Community (cont)						
Rude 2019	Foya District, Lofa County, Liberia	2017 30	W	9	679 (311-1,285)	44.4%
Sanogo 2019	Ouélessébougou district, Koulikoro Region, Mali	2010 58	C	39	18.07 (0.128-0.247)	15.4%
Sidikou 2016	Niger, Africa	2015 180	C	9,367	50.6 (49.57-51.62)	5.90%
Sudbury 2020	Alice Springs, Northern Territory, Australia	2017 153	W	24	10.9 (6.98-16.2)	NA
Childcare and Educational Settings						
Bassi 2017	Paris, Hauts-De-France, France	2017 89	W	2	200 (24.2-721)	50.0%
Capitano 2019	Eugene, Oregon, United States	2015 120	B	7	30.5 (12.3-62.8)	14.3%
Centers for Disease Control 2012	Rogers County, Oklahoma, United States	2010 21	C	5	270 (87.8-630)	40.0%
Ritscher 2019	University of Wisconsin-Madison, Madison, Wisconsin State, United States	2016 23	B	3	10.2 (2.10-29.7)	NA
Round 2001	University of Wales, Cardiff, Wales	1996 47	C	7	800 (294-1,734)	28.6%
Sekiya 2021	South-West Japan	2011 11	B	5	1,100 (358-2,546)	20.0%
Stewart 2013	West Midlands, England	2010 28	B	2	1,705 (353-4,900)	NA

Table 3.2 (cont): *Summary of outbreak characteristics, arranged by setting*

Study	Outbreak location	Year and duration (days)	Serogroup	No. cases	Attack rate[a] (95% CI)	Case fatality rate (%)
			Events			
Doedeh 2017	Greenville, Sinoe county, Liberia	2017 9	C	27	26.4 (17.4-38.4)	37.0%
Kanai 2017	Japan hosted WSJ, cases occurred in Sweden & Scotland	2015 4	W	6 (2 Scotland, 4 Sweden)	19.5 (7.16-42.4)	NA
Reintjes 2002	Belgium	1997 229	C	5	385 (125-895)	40.0%
			Refugee Camps			
Haelterman 1996	Kibumba and Katale camps, Goma Region, Zaire	1994 62	A	Kibumba 162 Katale 137	Kibumba 94.2 (81.0-109) Katale 134 (117-152)	Kibumba 8.00% Katale 3.00%
Santaniello-Newton 2000	East Moyo sub-district, Moyo District, Uganda	1994 372	A	291	300 (267-336)	14.4%
			Military			
Kushwaha 2010	Kashmir Region, India	2006 114	A	17	571 (333-913)	11.8%
Masterton 1988	Royal Air Force Base, Lincoln, England	1986 91	C	4	310 (84.4-791)	NA
			Organizational Settings			
Iser 2012	Rio Verde, Goias State, Brazil	2008 147	C	16	12 (0.0686-0.195)	31.0%

[a.] Cases per 100,000 population
[b.] Not reported.
[c.] No deaths linked to this outbreak.

Urban Community

Of the 11 outbreaks that occurred in urban community settings, eight occurred in Europe, and three occurred in North America. The European outbreaks were reported in France (n=3), the UK (n=2), Czechia (n=1), Belgium (n=1), and Finland (n=1). The Finnish outbreak had the longest recorded duration, from 1973-1976 (1,460 days) and was the earliest recorded outbreak included in this study (Peltola 1978). Excluding the Finnish outbreak, the average number of cases was 22, with a median of 12 (Interquartile range, IQR=8.5 – 17.5, range=4 – 74) and seasonality was varied.

The typical response for urban community settings differed over time, with the earliest outbreaks occurring prior to vaccine availability. In the absence of vaccination, control measures such as mass-chemoprophylaxis and heightened disease surveillance were utilised. The most recent outbreaks had more targeted responses, with an emphasis on identifying and managing only the community at risk. Author recommendations also varied over time, but increasingly focussed on the importance of restricting chemoprophylaxis use to contacts at the highest risk of transmission, and, with the exception of an outbreak in Tijuana, Mexico (Chacon-Cruz et al. 2014), promoting mass vaccination over antibiotic chemoprophylaxis when responding to the community outbreaks.

Rural or Remote Community

There were nine outbreaks that occurred in a rural or remote community setting. Two occurred in remote Australian First Nations communities, and seven occurred in Sub-Saharan Africa. All outbreaks were associated with extended periods of hot, dry weather in the form of an arid Australian spring/summer or the Sub-Saharan dry season (a period spanning December-June). Another common theme among these outbreaks was endemicity within the affected population, and occurrence over large geographic areas. As presented in Table 3.2, these outbreaks reported the highest average number of cases at 15,770 (median=1,995, IQR=24 – 9,367, range=2 – 109,580).

The typical response included an outbreak response team of public health and clinical staff to the affected regions and a strong emphasis on community engagement and education. Often febrile protocols were adopted as part of the clinical response (Haelterman et al. 1996; Sudbury et al. 2020) – meaning the immediate provision of antibiotics to any case presenting with fever or any other potential symptoms of IMD prior to laboratory confirmation. Mass vaccination was carried out in all instances. Specific to Sub-Saharan Africa were mentions of resource limitations, underreporting of cases, and an inability to determine the causative pathogen for all clinically suspected IMD cases. Responses were often reliant on the WHO (Mohammed et al. 2000; Mounkoro et al. 2019) or non-governmental organisations (NGOs), such as Médecins Sans Frontiers (Chow et al. 2016) or the Bill and Melinda Gates Foundation (Sanogo et al. 2019), for assistance with surveillance, vaccine acquisition, and distribution, resulting in decentralized and asynchronous responses. Recommendations from authors included stronger surveillance systems, gradual scaling up of response capacity to reduce reliance on NGOs, and routine vaccination of the general population with a long-lasting, multivalent conjugate vaccine.

Childcare and Educational settings

Seven outbreaks occurred in educational or childcare settings. Four of these occurred in university student accommodation, two in childcare settings, and one in a high school dormitory. The university outbreaks all either initiated in first-year cohorts or students returning from overseas travel. Outbreaks within this setting had some of the lowest case numbers presented in Table 3.2 (median=5, IQR=2.5 – 6), but also recorded some of the highest attack rates shown in Figure 3.2, with a mean of 588 cases per 100,000 population (median=270, IQR=115 – 950 per 100,000, range=10.2 – 1,705 cases per 100,000).

These outbreaks were detected rapidly and responses were targeted to easily-identifiable sub-population (residence halls, shared dining spaces, classroom). The typical response was mass-vaccination of the at-risk cohort in all cases except in the study by Sekiya et al. (2021), as there was no meningococcal B vaccine licenced in Japan at the time of the outbreak. In that

outbreak, chemoprophylaxis was limited to those in close contact with identified cases (Sekiya et al. 2021). Recommendations included proactive vaccination of incoming residents to shared accommodation settings. Vaccination was described as preferable to mass-chemoprophylaxis where the population at risk was not easily identifiable as the duration of protection is much longer, and has no associated risk of encouraging microbial resistance. Authors also stressed the importance of appropriate, comprehensive information for the population at risk.

Events

There were two international youth events with associated IMD outbreaks, namely the 2015 World Scout Jamboree held in Japan, and a European youth soccer tournament held in Belgium in 1997. There was also one local event, a funeral in Sinoe County, Liberia. All three outbreaks were linked back to the respective events, with cases occurring among attendees and/or staff. The two international events were also linked to small local outbreaks in attendees' home countries, indicating cases returning home were spreading meningococcal disease to individuals within their local communities.

The typical response to these outbreaks was increased surveillance, notification of event attendees and their contacts (with the added difficulty of cross-jurisdictional notification in the international events), and vaccination and chemoprophylaxis of at-risk contacts and communities. Response differed depending on the case jurisdiction, as did the recommendations for case management. Recommendations included facilitation of cross-jurisdictional notification of communicable disease and vaccination of incoming travellers to large international events.

The response described in the Liberian outbreak was made with no knowledge of the causal pathogen (later confirmed to be meningococcal C) (Patel et al. 2017). In the case of the Liberian outbreak, an additional recommendation was made for increased testing capabilities and more comprehensive surveillance systems to allow quicker identification of causal pathogens.

Refugee camps

Two outbreaks occurring in refugee camps were included. Both camps were located in Sub-Saharan Africa, and outbreaks occurred in the dry season, after large influxes of new refugees. Their overall health was described as poor, with widespread malnutrition and limited data on pre-existing vaccination coverage.

Responses included community education on better hygiene practices, immediate provision of antibiotics to any suspected cases, mass-vaccination campaigns and active surveillance of cases and their contacts. Recommendations included improved vaccination coverage and screening of incoming residents, use of conjugate instead of polysaccharide vaccines for increased duration of protection, and more accommodation facilities to reduce overcrowding.

Military

Two outbreaks occurred in military barracks or training camps, one in the UK and one in the Kashmir region of India. These outbreaks were characterised by shared sleeping arrangements, largely transient populations and close living quarters. The Indian outbreak also occurred during a period of overcrowding within the training camp.

The public health responses included enhanced surveillance, chemoprophylaxis of contacts at high risk of transmission (medical staff, those who shared barracks with cases) and vaccination in the case of the UK outbreak. Vaccination supply was not secured in time for the Indian outbreak, which was instead managed through isolation of cases, rearrangement of sleeping quarters to improve airflow, and strict contact-management protocols. Recommendations arising from these articles included routine vaccination of incoming recruits and better management of accommodation facilities to reduce the impact of overcrowding.

Organisational

One outbreak occurred in an organisational setting – a food preparation plant – before spreading to the wider community of Rio Verde, Brazil (Iser et al. 2012). This outbreak recorded 16 cases, 14 of which were linked to the food processing plant, which was described as a humid, enclosed work environment.

The response to this outbreak was mass-vaccination of food plant workers as the population most at risk. After this vaccination campaign, there were no further cases identified among plant workers, but four additional cases were recorded in the wider community. The authors emphasise the possibility of asymptomatic spread within a community as an ongoing challenge to outbreak prevention and management (Iser et al. 2012).

Data quality

Few of the included articles reported on outbreaks and their response in a consistent manner. At least one item of key contextual information such as outbreak setting, size, and duration were missing from the majority of studies. Almost half (n=15) of the articles did not include an overall attack rate for the outbreak described, and three of these outbreaks additionally did not have readily available population data. Sixteen articles either did not include or provided limited information regarding case demographics, number of contacts, outbreak duration or response size. Some public health responses were also not clearly described, or required close reading to identify critical details.

3.2.6 Discussion

Over time, factors of geography and human behaviour have been identified as increasing the risk of development and spread of IMD outbreaks. It was observed that rural or remote regions were at a higher risk of community outbreaks of IMD, in particular during dry seasons, or periods of reduced humidity (Koutangni, Boubacar Mainassara & Mueller 2015). These regions often spanned broad areas and when the response was not immediate, were the largest outbreaks by case numbers. A frequent point of discussion was resource limitations, in particular availability of testing, vaccination facilities and vaccination availability (Mohammed et al. 2000; Mounkoro et al. 2019; Nnadi et al. 2017). A common recommendation for people living in these areas was routine vaccination with a long-lasting, multivalent vaccine which would protect communities against the most prevalent circulating serogroups of *N. meningitidis*.

Shared accommodation settings also present an increased risk for outbreak development, in particular dormitory or barracks accommodation, or large refugee camps. Instances of overcrowding, paired with highly transient populations, are likely to lead to an increased risk of transmission given the introduction of a disease-causing serogroup. Suggested prevention measures were largely proactive, focussing on vaccination of incoming residents or attendees. This also extends to large events or gatherings, with several outbreaks associated with the Hajj and Umrah mass gatherings (Yezli 2018). Descriptions of these two outbreaks were not eligible for inclusion in this review as they did not provide any details on the associated public health response.

Some outbreaks did not have such an easily identifiable link to a high-risk setting, such as those occurring in urban communities. These outbreaks were either characterised by the emergence of a new, possibly hyper-virulent strain (Pivette et al. 2020; Thabuis et al. 2018) with rapid spread, or a steady increase in cases over several months or years (Cartwright, Stuart & Noah 1986; Peltola 1978).

A gradual evolution in public health management of outbreaks can be seen over time; increased vaccine availability and serogroup coverage has allowed some jurisdictions to be more proactive in their outbreak prevention. Most high-income countries include some form of meningococcal vaccine in their infant immunisation schedules. However, some countries, especially in Sub-Saharan Africa, are not able to fund a multi-strain vaccination program across their whole population (Sherman & Stephens 2020). These countries are not always equipped with public health systems that are able to mobilise and handle large-scale outbreaks of IMD (Obaro & Habib 2016), requiring the assistance of non-local resources to control outbreaks as they occur.

Public health responses that occurred prior to development of conjugate vaccines relied heavily on mass-chemoprophylaxis of large subgroups of the population in an attempt to reduce asymptomatic carriage (De Schrijver & Maes 2003; Jacobson, Chester & Fraser 1977; Perrett et al. 2000; Reintjes et al. 2002). However, this has limited long-term effectiveness,

especially in the case of communities where *N. meningitidis* is endemic or the population at risk cannot be clearly defined (Borrow et al. 2017; Kriz, Vlckova & Bobak 1995; Peltola 1978).

Outbreak reporting is used to inform future policy and practice, and good quality reporting is essential to inform effective, evidence-based practice (Von Elm et al. 2007). Reflections on past outbreak management can help to inform current public health management and practice. Incomplete reporting of key contextual details such as outbreak size, setting, and duration alongside a comprehensive summary of response characteristics could influence future decision-making processes. While there has been some consensus in recommendations over time (i.e. progression from chemoprophylaxis to vaccination), reporting on outbreaks is non-standardised, and key measures of outbreak size and impact within a community (as indicated by attack rate) were often not included in the studies considered here. Without clear, comprehensive reporting, a global picture of IMD outbreak management is difficult to ascertain, and so development of outbreak management strategies could be negatively impacted.

3.2.7 Conclusion

There are identifiable high-risk settings for outbreak development. Human behaviour and location can influence the risk of sporadic IMD cases spreading such that outbreaks develop. However, some low-resourced parts of the world are still limited in their capacity to detect, prevent and control IMD outbreaks. Reporting on IMD outbreaks is inconsistent, and thus decisions around outbreak prevention and management are made without a full understanding of context in some jurisdictions.

More broadly, public health management of infectious disease outbreaks has historically been reactive, with only a very recent shift in focus to proactive measures. High quality reporting is essential for effective, evidence-based policy and practice, in turn providing the evidence to support this transition. Consistent reporting would assist different parts of the world in optimising prevention and mitigation strategies for IMD outbreaks, and concurrently inform strategies to aid in the management of other infectious diseases.

Chapter 4 – Discussion

4.1 Introduction

The research presented in this thesis has identified current inconsistencies in guidelines for, and reporting on, public health management of Invasive Meningococcal Disease. Present recommendations remain insufficiently supported by evidence around risk factors for IMD transmission and disease development. Better quality evidence is needed in the form of consistent reporting on outbreaks characteristics and associated public health responses. Reporting will in turn support clear, consistent guidance, which can promote effective practice and response.

4.2 Context

Public health guidelines are developed to assist in communicable disease prevention and management. These guidelines are usually written by national public health agencies such as the Communicable Diseases Network Australia (2017), American Centers for Disease Control and Prevention (MacNeil & Cohn 2011), or European Centre for Disease Prevention and Control (2010), and outline the recommended public health response to cases or outbreaks of communicable disease. In the case of IMD, these guidelines outline evidence-based processes for identifying, classifying and managing contacts to IMD cases (Communicable Diseases Network Australia 2017) intended for implementation by public health staff when responding to IMD notifications. Prior to the current study, published reviews or appraisals of public health guidelines for the management of IMD had only been conducted within the European Union (Hanquet et al. 2015; Vygen et al. 2016) and it was unclear how global guidance was in accord with the current evidence around IMD transmission and disease prevention. This assessment of national and international guidelines for the public health management of IMD, presented alongside a summary of the literature around guideline development and use, has provided a better understanding of the processes involved with guideline development and identification of best practice.

Previous reviews of IMD outbreaks lack detail on their public health management, and have been limited by setting (Butler 2006), geography (Dogu et al. 2021; Dutta et al. 2020), or scope (Abio, Neal & Beck 2013). In addition, it was previously unknown how public health responses to IMD outbreaks may have changed globally over time, or potentially differ by jurisdiction or community affected. Settings identified as at a higher risk of outbreak development could be the focus of specific public health interventions to prevent IMD outbreaks before they can occur. This research has provided a more complete understanding of outbreaks and their associated responses.

The first published manuscript, presented in Chapter 2, sought to assess public health guidance for identification and management of close contacts to IMD cases. National and international guidelines for public health management of IMD were appraised for quality. A direct comparison of definitions for close contacts to IMD cases and recommendations for their management was also conducted. The second manuscript (submitted for publication), presented in Chapter 3, aimed to describe the evolution of public health management of IMD outbreaks over time, alongside variations in outbreak responses due to setting or geographical features.

4.3 Key findings

Overall, the findings of this research provide insight into the current state of public health management for IMD. Key areas for improvement in the development of public health recommendations for the management of IMD cases and their contacts have been suggested. Inconsistencies in outbreak management reporting were also made apparent by the review.

The first study found that higher quality guidelines according to the AGREE II instrument - including those with higher stakeholder involvement, clarity of presentation, rigorous development process, and applicability - provided clear, consistent recommendations in line with the available evidence for IMD transmission. These guidelines included concise summaries of the potential risks, costs and benefits to suggested interventions. All guidelines emphasised the importance of prompt identification and management of close contacts to IMD

cases. There was also strong consensus on the exposure period and recommendations for clearance antibiotics for close contacts. However, there were marked inconsistencies in the language and terminology used to define and describe close contacts to IMD cases. Criteria for close contacts also varied, from 'household and household-like' only to including co-passengers and intimate contacts.

The review of outbreak management strategies assessed 35 IMD outbreaks across some 50 years. Overall, there was a general decrease in outbreak size and duration over time, likely a result of increased herd immunity, reduction in susceptibility through vaccination coverage, improved disease surveillance and response times. Shifts in prevalent serogroup were also observed, from predominantly serogroup A or B in 1970-1980s to serogroup A or C in 1990-early 2000s, resulting in ongoing concerns regarding vaccine availability and serogroup coverage. Some specific regions (e.g. rural or remote communities in sub-Saharan Africa) or settings (e.g. crowded living accommodations) were observed to have an increased risk of outbreak development. Some strategies have already been implemented to mitigate this risk, such as the widespread use of MenAfriVac in Sub-Saharan Africa, or the vaccination of all incoming first-year students to American colleges with student accommodation (Butler 2007; Obaro & Habib 2016).

This second study also identified major inconsistencies in outbreak reporting, with key contextual information such as case demographics, outbreak start and end dates, or attack rate within the affected population for each outbreak often missing or incomplete. Finally, this research highlighted the limited integration between reporting on outbreak characteristics and outbreak response.

4.4 Significance

Clear, consistent reporting on communicable disease can be used to inform public health management of future cases and outbreaks. While IMD is relatively rare (Zunt et al. 2018) and the risk of transmission and ensuing disease arising from close, sustained contact between individuals appears low in comparison to other communicable diseases (Trotter, Gay &

Edmunds 2006; Zunt et al. 2018), inconsistencies were still observed in both public health recommendations and outbreak reporting. The current COVID-19 pandemic, along with previous global pandemics, has highlighted similar issues with inconsistencies in public health recommendations and reporting between jurisdictions (Hennessee et al. 2021; Lo, Mertz & Loeb 2017).

Guideline recommendations regarding identification and categorisation of close contacts to IMD cases remain inadequately justified by the available evidence. Since *N. meningitidis* can be carried and transmitted asymptomatically (Yazdankhah & Caugant 2004), it is not always immediately obvious whether a case of IMD is the first introduction of the bacteria to a community, or simply the first incidence of symptom development (Caugant et al. 1994). There also remain uncertainties around the variables that affect transmission and carriage of *N. meningitidis* (Trotter, Gay & Edmunds 2006; Yazdankhah & Caugant 2004), along with the risk of developing IMD symptoms (Caugant, Tzanakaki & Kriz 2007). Research on the impacts of vaccination suggest varying effects on carriage and duration of protection (Khatami & Pollard 2010; Pizza, Bekkat-Berkani & Rappuoli 2020). The shifting epidemiology of IMD poses an additional consideration (Norris 2018), with changes in seroprevalence and the circulation of hyper-virulent strains presenting an ongoing challenge to public health management (Borrow et al. 2017).

Routine surveillance data and outbreak reporting provide the majority of evidence around the risks of *N. meningitidis* transmission and subsequent development of IMD (Hanquet et al. 2015). The relatively low incidence of IMD in comparison with other communicable diseases (Zunt et al. 2018) severely limits opportunities to gain insight into the real-world transmission mechanisms of *N. meningitidis* between individuals. Without this knowledge, it is difficult to assess the ongoing risks of case or outbreak development within communities, or judge the impact of major events such as a global pandemic on public health management of IMD (George et al. 2022). Reporting on IMD outbreak management was assessed against criteria outlined in The Strengthening the Reporting of Observational Studies in Epidemiology

(STROBE) statement (Von Elm et al. 2007). The inconsistent and unclear reporting on outbreak characteristics and outbreak responses identified in Chapter 3 aligns with broader literature around communicable disease and outbreak reporting (Hennessee et al. 2021; Huynh, Baumann & Loeb 2019; Lo, Mertz & Loeb 2017). This supports an ongoing need for better quality reporting on communicable disease outbreaks.

Public health recommendations for prevention and control of IMD are informed by the body of evidence around IMD transmission (Hanquet et al. 2015). Reporting on clearance antibiotic use provided the necessary evidence to justify the effectiveness of clearance antibiotics among household contacts to IMD cases (McNamara et al. 2018; Telisinghe et al. 2015). Similarly, reporting on IMD outbreaks in US college dormitories was used to develop recommendations for outbreak prevention strategies among an at-risk population, and supported the country-wide implementation of vaccination campaigns for incoming students (Butler 2006, 2007). The disproportionate severity of IMD in comparison to other communicable diseases (Martinon-Torres 2016; Olbrich et al. 2018) necessitates reliable, good quality data on variables that may influence transmission and subsequent outbreak development. Such data are needed before it will be possible to achieve internationally consistent criteria for identification of close contacts to IMD cases or populations most at risk of outbreak development.

Although the COVID-19 pandemic has led to heightened awareness of communicable diseases among the wider population, international collaboration on public health recommendations remains critical for effective cross-jurisdictional responses. Consistent reporting on case or outbreak characteristics, combined with a clear summary of any interventions and their outcomes, will provide the evidence needed to inform the development of public health recommendations for communicable disease management across a variety of settings.

It may not be possible to define a singular approach for public health management of IMD that can be applied in all contexts or settings. All guideline documents assessed included some mention of the variability in factors that impact transmission and disease development

(Communicable Diseases Network Australia 2021; European Centre for Disease Prevention and Control 2010; Public Health Agency of Canada 2006). The evidence also suggests there is some variability in severity, transmissibility, and symptom presentation between IMD serogroups (Martinon-Torres 2016). Shifts in serogroup prevalence observed over time have ongoing implications for long-term IMD management and prevention. Management of IMD outbreaks incurs significantly more costs compared to management of sporadic cases (Anonychuk et al. 2013; Constenla, Carvalho & Alvis Guzman 2015). These costs increase relative to the size of the outbreak, placing a severe burden on jurisdictions when responding to large-scale outbreaks (Anonychuk et al. 2013). Mean cost estimates for outbreak responses in high income countries range from $299,641 to $579,851 (2010 USD) for small and large-scale outbreak management strategies respectively (Anonychuk et al. 2013, Martinón-Torres 2016). Low-income countries are more likely to experience large-scale IMD outbreaks (Martinón-Torres 2016), with mean cost estimates at $3,407,590 (USD) per large-scale outbreak response (Anonychuk et al. 2013)

Resource burdens incurred by outbreak responses can also affect the ongoing ability to respond to future outbreaks, as the staff and resources required to update or develop effective public health guidance has been redirected to outbreak response (Goodman, Buehler, & Mott 2019, Martinón-Torres 2016), Use of WHO guideline development frameworks or similar standardized processes for guideline development is inherently more time and resource intensive (Refhuess 2019), thus emphasising the importance of developing proactive strategies that either limit the potential spread of outbreaks or prevent them altogether. Identifying circumstances or settings with a greater risk of outbreak development will also allow for better targeting of resources for preventative measures (Hassan et al. 2019; Stuart 2001), further underscoring the need for quality reporting on all aspects of IMD outbreaks and their management.

4.5 Strengths and limitations

4.5.1 Strengths

Both studies presented in this thesis contribute new evidence for the current body of literature around public health management of IMD, and public health management of communicable diseases in general. Strengths of this research include the use of a validated tool (Brouwers et al. 2010) in the AGREE II Instrument to critically assess national and international guidelines for the public health management of IMD, conducting a direct comparison of language used to define close contacts to IMD cases, and providing a global summary of IMD outbreak response and management.

The appraisal process outlined in the first manuscript (Chapter 2) introduces a novel process for assessing public health guidelines across jurisdictions, which can be used to assess public health guidelines for management of other communicable diseases. This process can be used to identify areas within guideline documents that may benefit from review or clarification, or indicate recommendations that require additional supporting evidence (Amer et al. 2020; Bazzano et al. 2016; Brouwers et al. 2010; Polus et al. 2012). In a similar vein, identifying inconsistencies in the language used in public health recommendations between jurisdictions supports the ongoing need for better cross-jurisdictional collaboration when developing recommendations for communicable disease control (Burmaz, Guicciardi, et al. 2019).

Summarizing outbreak management strategies across time and by location has provided new insight into the settings and circumstances where IMD outbreaks are more likely to develop. Information on the likelihood of outbreak development can be used to identify priority regions for ongoing surveillance and prevention programs (Hassan et al. 2019). Previous reviews on IMD epidemiology (Butler 2006; Dogu et al. 2021; Dutta et al. 2020) have been restricted by time or location. The current research presented here provides a new perspective to IMD outbreaks and their associated public health management. In line with previous literature, it identified the need for better integration of outbreak responses with reporting (Anonychuk et al. 2013; Butler 2006; Martinon-Torres 2016). If implemented, improved reporting would

provide the evidence needed to clearly justify public health recommendations for management of IMD cases and their contacts.

4.5.2 Limitations

No primary data collection was conducted over the course of this research, and all conclusions drawn were reliant on readily available public health guidelines for prevention and management of IMD. The guidelines assessed were also limited to high-income countries with relatively low incidence of IMD (Zunt et al. 2018). It is still unclear whether public health staff use the guidelines as written when responding to cases of IMD or if there are alternate documents for internal use that are not publicly available. While the original intent of the guideline appraisal was to lead into surveys and interviews of public health staff, the feasibility of this course of study was severely impacted by the COVID-19 pandemic. Instead, outbreak responses in the peer-reviewed literature were assessed to gain insight into some of the practical applications of public health recommendations and how they changed over time.

It was not possible to assess outbreak characteristics as presented in published literature against grey literature such as notification data for the relevant jurisdictions. It is unclear how publication bias may have affected the number of articles identified in the second manuscript. Due to changes in the nature of communicable disease surveillance over time, and differing standards of reporting between jurisdictions, it is unlikely that any global study of IMD outbreaks and their associated public health response across a similarly broad time frame would be able to present definitive data around the size and scope of previous IMD outbreaks. The heterogeneity of data presented by the included outbreaks also limited the possibility of any meta-analysis of data. Nevertheless, findings from the study are still in keeping with previously published literature on the general need for better-quality reporting on disease outbreaks (Huynh, Baumann & Loeb 2019; Stone & Cookson 2016; Wieland, Chhatwal & Vonberg 2017).

Language capabilities across the research team necessitated limiting to English-language guidelines and publications only. The search strategy for the second manuscript was limited

to two databases after discussion with a librarian who specialised in public health support regarding the scope and focus of the study.

4.6 Recommendations

International collaboration is needed when developing public health recommendations for prevention and management of communicable disease. In light of a shifting global landscape of disease, inconsistencies in definitions, especially around identification and management of close contacts, could hinder cross-jurisdictional responses to future cases or outbreaks of IMD. Some standardized process of international review should be included in the guideline development process. While management strategies and responses may differ as a result of setting or jurisdiction, the language used to describe individuals at risk of transmission (or requiring additional follow-up) should be consistent.

Consistent reporting standards for outbreaks and their associated response are also needed. There exists readily available guidance for reporting on observational studies in various settings. The STROBE Statement (Von Elm et al. 2007) provides information checklists for authors to use when reporting their observations of communicable disease outbreaks. Extensions to the STROBE Statement have been developed for use in various fields, including molecular epidemiology (Field et al. 2014; Gallo et al. 2012) and neonatal infection research (Fitchett et al. 2016). Similar guidance also exists for outbreak reports and intervention studies of nosocomial infections (ORION Statement) (Stone et al. 2007). However, guidance on reporting standards is yet to be universally adopted (Huynh, Baumann & Loeb 2019; Stone & Cookson 2016). The gaps identified in outbreak reporting need to be addressed in order to better inform the development of consistent public health recommendations for management of IMD and other communicable diseases. Better integration of disease surveillance and notification data with reporting on outbreak management is also needed for a more complete understanding of the effectiveness of public health interventions.

4.7 Future directions

There remains a gap in knowledge around the practical use of public health recommendations when responding to cases of IMD. Public health practitioners' attitudes and knowledge towards IMD could influence their adherence to public health guidance (Murajda et al. 2015), and it is currently unknown how staff in public health departments interpret or apply public health recommendations in practice (Torner et al. 2011). Assessing the barriers and facilitators to guideline implementation by public health staff will help inform the process of refining and implementing public health recommendations.

A better understanding of the factors that influence carriage and transmission of *N. meningitidis* alongside the transition between carriage and IMD symptom development will also help inform future public health recommendations. The introduction of new, hypervirulent strains of *N. meningitidis,* environmental factors, variation in the duration of protection offered by vaccination, or the impact of vaccination on carriage, can all impact the likelihood of outbreak development. New generation vaccines that reduce carriage and transmission in addition to preventing disease may play a greater role in management of future outbreaks (Pizza, Bekkat-Berkani & Rappuoli 2020). Understanding carriage rates within the general population and how they relate to the risk of outbreak development will also allow for more proactive and targeted management of IMD.

Improving the consistency of reporting on communicable disease outbreaks and associated public health responses will also help inform the development of guidance for communicable disease prevention and control. The checklist of items included in the STROBE statement was used to inform the assessment of reporting quality in this research (Von Elm et al. 2007). However, the STROBE statement and associated extensions were designed to improve reports of observational studies, and are not specific to reporting on communicable disease outbreaks (Stone et al. 2007; Von Elm et al. 2007). There is no recommended or widely accepted format for reporting on communicable disease outbreaks, which may have contributed to the inconsistencies identified by this research.

Reporting on communicable disease outbreaks should include key characteristics such as time, person, place, as part of the descriptive epidemiology, alongside a clear description of any public health responses made. Greater consistency in reporting will provide the evidence base necessary to inform future public health actions for the prevention and management of communicable disease. Establishing a formal surveillance program, with regular audits of data to ensure quality and consistency of reporting, is recommended.

4.8 Conclusion

Public health management of communicable disease is an ongoing global concern. Rapid shifts in factors that influence disease development and spread require dynamic, specific responses that are well-supported by evidence. The focus of this thesis was on the public health management of IMD, and this research has identified inconsistencies in recommendations for, and reporting on, public health responses to IMD cases and outbreaks. Incomplete or inconsistent reporting on IMD outbreak management does not provide adequate evidence to clearly justify public health recommendations for management of IMD cases and their contacts.

Promoting more complete reporting of public health responses may improve understanding of the factors impacting IMD transmission and outbreak development, and support the development of more consistent public health recommendations. Better quality reporting and greater consistency of guideline recommendations for IMD may also ultimately inform and improve the public health management of other communicable diseases.

References

Abat, C, Chaudet, H, Rolain, JM, Colson, P & Raoult, D 2016, 'Traditional and syndromic surveillance of infectious diseases and pathogens', *Int J Infect Dis*, vol. 48, Jul, pp. 22-28.

Abio, A, Neal, KR & Beck, CR 2013, 'An epidemiological review of changes in meningococcal biology during the last 100 years', *Pathog Glob Health*, vol. 107, no. 7, Oct, pp. 373-380.

Acevedo, R, Bai, X, Borrow, R, Caugant, DA, Carlos, J, Ceyhan, M, Christensen, H, Climent, Y, De Wals, P, Dinleyici, EC, Echaniz-Aviles, G, Hakawi, A, Kamiya, H, Karachaliou, A, Lucidarme, J, Meiring, S, Mironov, K, Safadi, MAP, Shao, Z, Smith, V, Steffen, R, Stenmark, B, Taha, MK, Trotter, C, Vazquez, JA & Zhu, B 2019, 'The Global Meningococcal Initiative meeting on prevention of meningococcal disease worldwide: Epidemiology, surveillance, hypervirulent strains, antibiotic resistance and high-risk populations', *Expert Rev Vaccines*, vol. 18, no. 1, Jan, pp. 15-30.

AGREE Next Steps Consortium 2009, *The AGREE II Instrument [Electronic version]*, viewed 1st May 2019, <http://www.agreetrust.org>.

Albright, K, Gechter, K & Kempe, A 2013, 'Importance of mixed methods in pragmatic trials and dissemination and implementation research', *Acad Pediatr*, vol. 13, no. 5, Sep-Oct, pp. 400-407.

Amer, YS, Sabr, Y, ElGohary, GM, Altaki, AM, Khojah, OT, El-Malky, A & Alzahrani, MF 2020, 'Quality assessment of evidence-based clinical practice guidelines for the management of pregnant women with sickle cell disease using the AGREE II instrument: a systematic review', *BMC Pregnancy Childbirth*, vol. 20, no. 1, Oct 7, p. 595.

Anonychuk, A, Woo, G, Vyse, A, Demarteau, N & Tricco, AC 2013, 'The cost and public health burden of invasive meningococcal disease outbreaks: a systematic review', *Pharmacoeconomics*, vol. 31, no. 7, Jul, pp. 563-576.

Asamoah, JKK, Nyabadza, F, Seidu, B, Chand, M & Dutta, H 2018, 'Mathematical Modelling of Bacterial Meningitis Transmission Dynamics with Control Measures', *Comp Math Methods Med*, vol. 2018, 2018/03/27, p. 2657461.

Australian Institute of Health and Welfare 2021, *Infectious diseases*, AIHW, Canberra, viewed 28 Aug 2022, <https://www.aihw.gov.au/reports/children-youth/infectious-diseases>.

Balabanova, Y, Gilsdorf, A, Buda, S, Burger, R, Eckmanns, T, Gartner, B, Gross, U, Haas, W, Hamouda, O, Hubner, J, Janisch, T, Kist, M, Kramer, MH, Ledig, T, Mielke, M, Pulz, M, Stark, K, Suttorp, N, Ulbrich, U, Wichmann, O & Krause, G 2011, 'Communicable diseases prioritized for surveillance and epidemiological research: results of a standardized prioritization procedure in Germany, 2011', *PLoS One*, vol. 6, no. 10, p. e25691.

Barrett, R, Kuzawa, CW, McDade, T & Armelagos, GJ 1998, 'Emerging and re-emerging infectious diseases: The third epidemiologic transition', *Annu Rev Anthropol*, vol. 27, no. 1, pp. 247-271.

Batista, RS, Gomes, AP, Dutra Gazineo, JL, Balbino Miguel, PS, Santana, LA, Oliveira, L & Geller, M 2017, 'Meningococcal disease, a clinical and epidemiological review', *Asian Pac J Trop Med*, vol. 10, no. 11, Nov, pp. 1019-1029.

Bazzano, AN, Green, E, Madison, A, Barton, A, Gillispie, V & Bazzano, LA 2016, 'Assessment of the quality and content of national and international guidelines on hypertensive disorders of pregnancy using the AGREE II instrument', *BMJ open*, vol. 6, no. 1, Jan 18, p. e009189.

Bianucci, R, Benedictow, OJ, Fornaciari, G & Giuffra, V 2013, 'Quinto Tiberio Angelerio and new measures for controlling plague in 16th-century Alghero, Sardinia', *Emerg Infect Dis*, vol. 19, no. 9, pp. 1478-1483.

Borrow, R, Alarcon, P, Carlos, J, Caugant, DA, Christensen, H, Debbag, R, De Wals, P, Echaniz-Aviles, G, Findlow, J, Head, C, Holt, D, Kamiya, H, Saha, SK, Sidorenko, S, Taha, MK, Trotter, C, Vazquez Moreno, JA, von Gottberg, A, Safadi, MA & Global Meningococcal, I

2017, 'The Global Meningococcal Initiative: global epidemiology, the impact of vaccines on meningococcal disease and the importance of herd protection', *Expert Rev Vaccines*, vol. 16, no. 4, Apr, pp. 313-328.

Brouwers, MC, Kho, ME, Browman, GP, Burgers, JS, Cluzeau, F, Feder, G, Fervers, B, Graham, ID, Grimshaw, J & Hanna, SE 2010, 'AGREE II: advancing guideline development, reporting and evaluation in health care', *CMAJ*, vol. 182, no. 18, pp. 839-842.

Burmaz, T, Guicciardi, S, Selle, V, Lopalco, PL, Baldo, V & Fantini, MP 2019, 'Management of meningococcal outbreaks: are we using the same language? Comparison of the public health policies between high-income countries with low incidence of meningococcal disease', *Expert Rev Vaccines*, vol. 18, no. 5, May, pp. 559-574.

Burmaz, T, Selle, V, Baldo, V & Savoia, E 2019, 'Organization or Community-Based Outbreak? Responding to Cases of Meningitis Under Epidemiologic Uncertainty', *Disaster Med Public Health Prep*, vol. 13, no. 2, Apr, pp. 368-371.

Butler, KM 2006, 'Meningococcal meningitis prevention programs for college students: a review of the literature', *Worldviews Evid Based Nurs*, vol. 3, no. 4, pp. 185-193.

Butler, KM 2007, 'The development of an evidence-based toolkit to prevent meningococcal disease in college students', *Fam Community Health*, vol. 30, no. 2, Apr-Jun, pp. 93-111.

Bynum, H 2012, *Spitting blood: the history of tuberculosis*, OUP Oxford.

Carbonnelle, E, Nassif, X & Boudoulous, S 2010, 'Mechanisms of Cellular Invasion of Neisseria meningitidis', in C Attardo Genco & L Wetzler (eds), *Neisseria*, Caister Academic Press, Norfolk, UK.

Caro, JJ, Möller, J, Getsios, D, Coudeville, L, El-Hadi, W, Chevat, C, Nguyen, VH & Caro, I 2007, 'Invasive meningococcal disease epidemiology and control measures: a framework for evaluation', *BMC Public Health*, vol. 7, no. 1, Jun, p. 130.

Carod Artal, FJ 2015, 'Meningococcal meningitis: vaccination outbreak response and epidemiological changes in the African meningitis belt', *Int Health*, vol. 7, no. 4, Jul, pp. 226-227.

Cartwright, KA, Stuart, JM & Noah, ND 1986, 'An outbreak of meningococcal disease in Gloucestershire', *Lancet*, vol. 2, no. 8506, Sep 6, pp. 558-561.

Caugant, DA, Hoiby, EA, Magnus, P, Scheel, O, Hoel, T, Bjune, G, Wedege, E, Eng, J & Froholm, LO 1994, 'Asymptomatic carriage of Neisseria meningitidis in a randomly sampled population', *J Clin Microbiol*, vol. 32, no. 2, Feb, pp. 323-330.

Caugant, DA & Maiden, MC 2009, 'Meningococcal carriage and disease--population biology and evolution', *Vaccine*, vol. 27 Suppl 2, Jun 24, pp. B64-70.

Caugant, DA, Tzanakaki, G & Kriz, P 2007, 'Lessons from meningococcal carriage studies', *FEMS Microbiol Rev*, vol. 31, no. 1, Jan, pp. 52-63.

Centers for Disease Control and Prevention 2017, *Guidance for the Evaluation and Public Health Management of Suspected Outbreaks of Meningococcal Disease*, United States Government, USA.

Centers for Disease Control and Prevention 2020, 'Introduction', in SW Roush, LM Baldy & MAK Hall (eds), *Manual for the Surveillance of Vaccine-Preventable Diseases*, National Center for Immunization and Respiratory Diseases, viewed 29 Aug 2022, pp. 1-10, <https://www.cdc.gov/vaccines/pubs/surv-manual/front-portion.html>.

Chacon-Cruz, E, Espinosa-De Los Monteros, LE, Navarro-Alvarez, S, Aranda-Lozano, JL, Volker-Soberanes, ML, Rivas-Landeros, RM, Alvelais-Arzamendi, AA & Vazquez, JA 2014, 'An outbreak of serogroup C (ST-11) meningococcal disease in Tijuana, Mexico', *Ther Adv Vaccines*, vol. 2, no. 3, May, pp. 71-76.

Chow, J, Uadiale, K, Bestman, A, Kamau, C, Caugant, DA, Shehu, A & Greig, J 2016, 'Invasive Meningococcal Meningitis Serogroup C Outbreak in Northwest Nigeria, 2015 - Third Consecutive Outbreak of a New Strain', *PLoS currents*, vol. 8, Jul 7.

Communicable Diseases Network Australia 2017, *Invasive Meningococcal Disease CDNA Guidance for Public Health Units*, Australian Government Department of Health, Canberra.

Communicable Diseases Network Australia 2021, *Coronavirus Disease 2019 (COVID-19) CDNA National Guidelines for Public Health Units*, vol. 4.3, Australian Government Department of Health, Canberra.

Constenla, D, Carvalho, A & Alvis Guzman, N 2015, 'Economic Impact of Meningococcal Outbreaks in Brazil and Colombia', *Open Forum Infect Dis*, vol. 2, no. 4, Dec, p. ofv167.

Creswell, JW & Creswell, JD 2018, *Research design: Qualitative, quantitative, and mixed methods approaches*, 5th edn, SAGE publications, California.

De Schrijver, K & Maes, I 2003, 'An outbreak of serogroup C meningococcal disease in the province of Antwerp (Belgium) in 2001-2002', *Eur J Epidemiol*, vol. 18, no. 11, pp. 1073-1077.

De Wals, P, Hertoghe, L, Borlee-Grimee, I, De Maeyer-Cleempoel, S, Reginster-Haneuse, G, Dachy, A, Bouckaert, A & Lechat, M 1981, 'Meningococcal disease in Belgium. Secondary attack rate among household, day-care nursery and pre-elementary school contacts', *J Infect*, vol. 3, pp. 53-61.

Dogu, AG, Oordt-Speets, AM, van Kessel-de Bruijn, F, Ceyhan, M & Amiche, A 2021, 'Systematic review of invasive meningococcal disease epidemiology in the Eastern Mediterranean and North Africa region', *BMC Infect Dis*, vol. 21, no. 1, Oct 22, p. 1088.

Doherty, JA 2000, 'Establishing priorities for national communicable disease surveillance', *Can J Infect Dis*, vol. 11, no. 1, Jan, pp. 21-24.

Dretler, AW, Rouphael, NG & Stephens, DS 2018, 'Progress toward the global control of Neisseria meningitidis: 21st century vaccines, current guidelines, and challenges for future vaccine development', *Hum Vaccin Immunother*, vol. 14, no. 5, May 4, pp. 1146-1160.

Dutta, AK, Swaminathan, S, Abitbol, V, Kolhapure, S & Sathyanarayanan, S 2020, 'A Comprehensive Review of Meningococcal Disease Burden in India', *Infect Dis Ther*, vol. 9, no. 3, Sep, pp. 537-559.

European Centre for Disease Prevention and Control 2010, *Public health management of sporadic cases of invasive meningococcal disease and their contacts*, European Union, Stockholm.

Field, N, Cohen, T, Struelens, MJ, Palm, D, Cookson, B, Glynn, JR, Gallo, V, Ramsay, M, Sonnenberg, P, Maccannell, D, Charlett, A, Egger, M, Green, J, Vineis, P & Abubakar, I 2014, 'Strengthening the Reporting of Molecular Epidemiology for Infectious Diseases (STROME-ID): an extension of the STROBE statement', *Lancet Infect Dis*, vol. 14, no. 4, Apr, pp. 341-352.

Fischbacher, CM, Lally, JE & Black, NM 2001, 'Improving the quality of communicable disease control: the example of meningococcal disease', *Commun Dis Public Health*, vol. 4, no. 4, Dec, pp. 268-272.

Fitchett, EJA, Seale, AC, Vergnano, S, Sharland, M, Heath, PT, Saha, SK, Agarwal, R, Ayede, AI, Bhutta, ZA, Black, R, Bojang, K, Campbell, H, Cousens, S, Darmstadt, GL, Madhi, SA, Meulen, AS, Modi, N, Patterson, J, Qazi, S, Schrag, SJ, Stoll, BJ, Wall, SN, Wammanda, RD & Lawn, JE 2016, 'Strengthening the Reporting of Observational Studies in Epidemiology for Newborn Infection (STROBE-NI): an extension of the STROBE statement for neonatal infection research', *Lancet Infect Dis*, vol. 16, no. 10, Oct, pp. e202-e213.

Gallo, V, Egger, M, McCormack, V, Farmer, PB, Ioannidis, JP, Kirsch-Volders, M, Matullo, G, Phillips, DH, Schoket, B, Stromberg, U, Vermeulen, R, Wild, C, Porta, M & Vineis, P 2012, 'STrengthening the Reporting of OBservational studies in Epidemiology - Molecular

Epidemiology (STROBE-ME): an extension of the STROBE statement', *Eur J Clin Invest*, vol. 42, no. 1, Jan, pp. 1-16.

Gaythorpe, KA, Abbas, K, Huber, J, Karachaliou, A, Thakkar, N, Woodruff, K, Li, X, Echeverria-Londono, S, Vimc Working Group on COVID-19 Impact on Vaccine Preventable Disease, Ferrari, M, Jackson, ML, McCarthy, K, Perkins, TA, Trotter, C & Jit, M 2021, 'Impact of COVID-19-related disruptions to measles, meningococcal A, and yellow fever vaccination in 10 countries', *Elife*, vol. 10, Jun 24.

George, CR, Booy, R, Nissen, MD & Lahra, MM 2022, 'The decline of invasive meningococcal disease and influenza in the time of COVID-19: the silver linings of the pandemic playbook', *Med J Aust*.

Gobin, M, Hughes, G, Foulkes, S, Bagnall, H, Trindall, A, Decraene, V, Edeghere, O, Balasegaram, S, Cummins, A & Coole, L 2020, 'The epidemiology and management of clusters of invasive meningococcal disease in England, 2010-15', *J Public Health (Oxf), England)*, vol. 42, no. 1, Feb 28, pp. e58-e65.

Goodman, RA, Buehler, JW & Mott, JA 2019, 'Defining Field Epidemiology', in SA Rasmussen & RA Goodman (eds), *The CDC Field Epidemiology Manual*, 4th edn, Oxford University Press, New York.

Hadler, JL, Varma, JK, Vugia, DJ & Goodman, RA 2019, 'Developing Interventions', in SA Rasmussen & RA Goodman (eds), *The CDC Field Epidemiology Manual*, 4th edn, Oxford University Press, New York.

Haelterman, E, Boelaert, M, Suetens, C, Blok, L, Henkens, M & Toole, MJ 1996, 'Impact of a mass vaccination campaign against a meningitis epidemic in a refugee camp', *Trop Med Int Health*, vol. 1, no. 3, Jun, pp. 385-392.

Hamilton, JL 2020, 'Recognizing Vaccine-Preventable Diseases and Managing Outbreaks', *Prim Care*, vol. 47, no. 3, Sep, pp. 467-481.

Hanquet, G, Stefanoff, P, Hellenbrand, W, Heuberger, S, Lopalco, P & Stuart, JM 2015, 'Strong Public Health Recommendations from Weak Evidence? Lessons Learned in Developing Guidance on the Public Health Management of Meningococcal Disease', *BioMed Res Int*, pp. 1-10.

Hassan, A, Balogun, M, Dalhat, M & Ihekweazu, C 2019, 'Improving epidemiological response: lessons learnt from successive outbreaks in Nigeria', *Int J Epidemiol*, vol. 48, no. 4, Aug 1, pp. 1029-1031.

Hennessee, I, Clennon, JA, Waller, LA, Kitron, U & Bryan, JM 2021, 'Considerations for Improving Reporting and Analysis of Date-Based COVID-19 Surveillance Data by Public Health Agencies', *Am J Public Health*, vol. 111, no. 12, Dec, pp. 2127-2132.

Hoek, M, Hanquet, G, Heuberger, S, Stefanoff, P, Zucs, P, Ramsay, M, Stuart, J & European Union Invasive Bacterial Infections Surveillance, N 2008, 'A European survey on public health policies for managing cases of meningococcal disease and their contacts', *Euro Surveill*, vol. 13, no. 10, Mar 6.

Honigsbaum, M 2020, *The pandemic century: A history of global contagion from the Spanish flu to Covid-19*, Random House, New York City.

Howe, KR 1988, 'Against the quantitative-qualitative incompatibility thesis or dogmas die hard', *Educ Res*, vol. 17, no. 8, pp. 10-16.

Huynh, N, Baumann, A & Loeb, M 2019, 'Reporting quality of the 2014 Ebola outbreak in Africa: A systematic analysis', *PLoS One*, vol. 14, no. 6, p. e0218170.

Isaacs, D 2019, *Defeating the Ministers of Death: The compelling story of vaccination, one of medicine's greatest triumphs*, HarperCollins, Sydney.

Iser, BP, Lima, HC, de Moraes, C, de Almeida, RP, Watanabe, LT, Alves, SL, Lemos, AP, Gorla, MC, Goncalves, MG, Dos Santos, DA & Sobel, J 2012, 'Outbreak of Neisseria

meningitidis C in workers at a large food-processing plant in Brazil: challenges of controlling disease spread to the larger community', *Epidemiol Infect*, vol. 140, no. 5, May, pp. 906-915.

Jackson, LA, Schuchat, A, Reeves, MW & Wenger, JD 1995, 'Serogroup C meningococcal outbreaks in the United States. An emerging threat', *JAMA*, vol. 273, no. 5, Feb 1, pp. 383-389.

Jacobson, JA, Chester, TJ & Fraser, DW 1977, 'An epidemic of disease due to serogroup B Neisseria meningitidis in Alabama: report of an investigation and community-wide prophylaxis with a sulfonamide', *J Infect Dis*, vol. 136, no. 1, Jul, pp. 104-108.

Jafri, RZ, Ali, A, Messonnier, NE, Tevi-Benissan, C, Durrheim, D, Eskola, J, Fermon, F, Klugman, KP, Ramsay, M, Sow, S, Zhujun, S, Bhutta, ZA & Abramson, J 2013, 'Global epidemiology of invasive meningococcal disease', *Popul Health Metr*, vol. 11, no. 1, Sep 10, p. 17.

Johswich, KO & Gray-Owen, SD 2019, 'Modeling Neisseria meningitidis Infection in Mice: Methods and Logistical Considerations for Nasal Colonization and Invasive Disease', in KL Seib & IR Peak (eds), *Neisseria meningitidis: Methods and Protocols*, Springer New York, New York, NY, pp. 149-168.

Kaczmarski, E 2002, 'Serogroup c meningococcal immunization campaign in the United Kingdom', *Curr Ther Res Clin Exp*, vol. 63, no. SUPPL. A, pp. A30-A37.

Khatami, A & Pollard, AJ 2010, 'The epidemiology of meningococcal disease and the impact of vaccines', *Expert Rev Vaccines*, vol. 9, no. 3, Mar, pp. 285-298.

Kim, HW, Lee, S, Kwon, D, Cha, J, Ahn, JG & Kim, KH 2017, 'Characterization of Oropharyngeal Carriage Isolates of Neisseria meningitidis in Healthy Korean Adolescents in 2015', *J Korean Med Sci*, vol. 32, no. 7, Jul, pp. 1111-1117.

Kipping, RR, Hamilton, S, Roderick, M & Alexander, K 2006, 'Developing audit standards required for outbreaks of communicable diseases-lessons from a mumps outbreak', *J Public Health (Oxf)*, vol. 28, no. 4, Dec, pp. 347-350.

Koutangni, T, Boubacar Mainassara, H & Mueller, JE 2015, 'Incidence, carriage and case-carrier ratios for meningococcal meningitis in the African meningitis belt: a systematic review and meta-analysis', *PLoS One*, vol. 10, no. 2, p. e0116725.

Kristiansen, PA, Ba, AK, Ouedraogo, AS, Sanou, I, Ouedraogo, R, Sangare, L, Diomande, F, Kandolo, D, Saga, IM, Misegades, L, Clark, TA, Preziosi, MP & Caugant, DA 2014, 'Persistent low carriage of serogroup A Neisseria meningitidis two years after mass vaccination with the meningococcal conjugate vaccine, MenAfriVac', *BMC Infect Dis*, vol. 14, Dec 4, p. 663.

Kriz, P, Vlckova, J & Bobak, M 1995, 'Targeted vaccination with meningococcal polysaccharide vaccine in one district of the Czech Republic', *Epidemiol Infect*, vol. 115, no. 3, Dec, pp. 411-418.

La, EM, Talbird, SE, Kanadanian, KV, Huang, L, Fain, J & Srivastava, A 2019, 'Cost calculator for mass vaccination response to a US college campus outbreak of serogroup B meningococcal disease', *Hum Vaccin Immunother*, vol. 15, no. 4, pp. 978-986.

Ladhani, SN, Campbell, H, Andrews, N, Parikh, SR, White, J, Edelstein, M, Clark, SA, Lucidarme, J, Borrow, R & Ramsay, ME 2021, 'First Real-world Evidence of Meningococcal Group B Vaccine, 4CMenB, Protection Against Meningococcal Group W Disease: Prospective Enhanced National Surveillance, England', *Clin Infect Dis*, vol. 73, no. 7, Oct 5, pp. e1661-e1668.

Letouze, D, Yao, G & Clarke, SC 2014, 'The costs associated with the public health management of a cluster of meningococcal infection in England', *Vaccine*, vol. 32, no. 43, Sep 29, pp. 5549-5551.

Linnemann, DEL, Vega, MF, Pech, JAL, Rosas, JV, Martell, JAO, del Río Navarro, BE, Salas, MdCC, Lombard, JR, Estrada, EdCL & Rodriguez-González, M 2018, 'Pediatric asthma treatment: What to do when international guideline recommendations do not agree', *Ann Allergy Asthma Immunol*, vol. 121, no. 1, pp. 7-13. e14.

Lo, C, Mertz, D & Loeb, M 2017, 'Assessing the reporting quality of influenza outbreaks in the community', *Influenza Other Respir Viruses*, vol. 11, no. 6, Nov, pp. 556-563.

MacLennan, J, Kafatos, G, Neal, K, Andrews, N, Cameron, JC, Roberts, R, Evans, MR, Cann, K, Baxter, DN, Maiden, MC, Stuart, JM & United Kingdom Meningococcal Carriage, G 2006, 'Social behavior and meningococcal carriage in British teenagers', *Emerg Infect Dis*, vol. 12, no. 6, Jun, pp. 950-957.

MacNeil, JR & Cohn, AC 2011, *Meningococcal disease*, Manual for the surveillance of vaccine-preventable diseases., viewed 1st Oct 2019, <https://www.cdc.gov/vaccines/pubs/surv-manual/chpt08-mening.html#>.

Marshall, HS, Lally, N, Flood, L & Phillips, P 2020, 'First statewide meningococcal B vaccine program in infants, children and adolescents: evidence for implementation in South Australia', *Med J Aust*, vol. 212, no. 2, Feb, pp. 89-93.

Marshall, HS, McMillan, M, Koehler, AP, Lawrence, A, Sullivan, TR, MacLennan, JM, Maiden, MCJ, Ladhani, SN, Ramsay, ME, Trotter, C, Borrow, R, Finn, A, Kahler, CM, Whelan, J, Vadivelu, K & Richmond, P 2020, 'Meningococcal B Vaccine and Meningococcal Carriage in Adolescents in Australia', *N Engl J Med*, vol. 382, no. 4, Jan 23, pp. 318-327.

Martinon-Torres, F 2016, 'Deciphering the Burden of Meningococcal Disease: Conventional and Under-recognized Elements', *J Adolesc Health*, vol. 59, no. 2 Suppl, Aug, pp. S12-20.

McMillan, M, Walters, L, Mark, T, Lawrence, A, Leong, LEX, Sullivan, T, Rogers, GB, Andrews, RM & Marshall, HS 2019, 'B Part of It study: a longitudinal study to assess carriage of Neisseria meningitidis in first year university students in South Australia', *Hum Vaccin Immunother*, vol. 15, no. 4, 2019/04/03, pp. 987-994.

McNamara, LA, MacNeil, JR, Cohn, AC & Stephens, DS 2018, 'Mass chemoprophylaxis for control of outbreaks of meningococcal disease', *Lancet Infect Dis*, vol. 18, no. 9, Sep, pp. e272-e281.

Middeldorp, M, van Lier, A, van der Maas, N, Veldhuijzen, I, Freudenburg, W, van Sorge, NM, Sanders, EAM, Knol, MJ & de Melker, HE 2021, 'Short term impact of the COVID-19 pandemic on incidence of vaccine preventable diseases and participation in routine infant vaccinations in the Netherlands in the period March-September 2020', *Vaccine*, vol. 39, no. 7, Feb 12, pp. 1039-1043.

Miller, C 2020, *International exemplars of effective COVID-19 control*, COVID-19 Evidence Update, SAHMRI, Health Translation SA and the Commission on Excellence and Innovation in Health.

Mohammed, I, Nasidi, A, Alkali, AS, Garbati, MA, Ajayi-Obe, EK, Audu, KA, Usman, A & Abdullahi, S 2000, 'A severe epidemic of meningococcal meningitis in Nigeria, 1996', *Trans R Soc Trop Med Hyg*, vol. 94, no. 3, May-Jun, pp. 265-270.

Morello, BR, Milazzo, A, Marshall, HS & Giles, LC 2021, 'Lessons for and from the COVID-19 pandemic response - An appraisal of guidance for the public health management of Invasive Meningococcal Disease', *J Infect Public Health*, vol. 14, no. 8, Aug, pp. 1069-1074.

Morens, DM & Fauci, AS 2013, 'Emerging infectious diseases: threats to human health and global stability', *PLoS Pathog*, vol. 9, no. 7, p. e1003467.

Mounkoro, D, Nikiema, CS, Maman, I, Sakande, S, Bozio, CH, Tall, H, Sadji, AY, Njanpop-Lafourcade, BM, Sibabe, A, Landoh, DE, Abodji, EO, Kodjo, A, Tamekloe, TA, Essoh, TA, Maba, DW, Gessner, BD & Moisi, JC 2019, 'Neisseria meningitidis Serogroup W Meningitis Epidemic in Togo, 2016', *J Infect Dis*, vol. 220, no. 220 Suppl 4, Oct 31, pp. S216-S224.

Murajda, L, Aichinger, E, Pfaff, G & Hellenbrand, W 2015, 'Public health management of invasive meningococcal disease in Baden-Wuerttemberg, Germany, 2012: adherence to

guidance and estimation of resources required as determined in a survey of local health authorities', *BMC Public Health*, vol. 15, Apr 12, p. 371.

Murray, CJ & Lopez, AD 2013, 'Measuring the global burden of disease', *N Engl J Med*, vol. 369, no. 5, Aug 1, pp. 448-457.

Mustapha, MM & Harrison, LH 2018, 'Vaccine prevention of meningococcal disease in Africa: Major advances, remaining challenges', *Hum Vacc Immun*, vol. 14, no. 5, 2018/05/04, pp. 1107-1115.

New Zealand Ministry of Health 2018, *Neisseria meningitidis invasive disease*, New Zealand Government, NZ, <https://www.health.govt.nz/our-work/diseases-and-conditions/communicable-disease-control-manual/neisseria-meningitidis-invasive-disease>.

Nnadi, C, Oladejo, J, Yennan, S, Ogunleye, A, Agbai, C, Bakare, L, Abdulaziz, M, Mohammed, A, Stephens, M, Sumaili, K, Ronveaux, O, Maguire, H, Karch, D, Dalhat, M, Antonio, M, Bita, A, Okudo, I, Nguku, P, Novak, R, Bolu, O, Shuaib, F & Ihekweazu, C 2017, 'Large Outbreak of Neisseria meningitidis Serogroup C - Nigeria, December 2016-June 2017', *MMWR Morb Mortal Wkly Rep*, vol. 66, no. 49, Dec 15, pp. 1352-1356.

Noah, ND 2006, *Controlling communicable disease*, Understanding public health, Open University Press, Maidenhead, England.

Norris, SL 2018, 'Meeting public health needs in emergencies–World Health Organization guidelines', *J Evid Based Med*, vol. 11, no. 3, pp. 133-135.

Noyes, J, Booth, A, Moore, G, Flemming, K, Tunçalp, Ö & Shakibazadeh, E 2019, 'Synthesising quantitative and qualitative evidence to inform guidelines on complex interventions: clarifying the purposes, designs and outlining some methods', *BMJ Global Health*, vol. 4, no. Suppl 1, p. e000893.

Obaro, SK & Habib, AG 2016, 'Control of meningitis outbreaks in the African meningitis belt', *Lancet Infect Dis*, vol. 16, no. 4, Apr, pp. 400-402.

Ohm, M, van Rooijen, DM, Bonacic Marinovic, AA, van Ravenhorst, MB, van der Heiden, M, Buisman, AM, Sanders, EAM & Berbers, GAM 2020, 'Different Long-Term Duration of Seroprotection against Neisseria meningitidis in Adolescents and Middle-Aged Adults after a Single Meningococcal ACWY Conjugate Vaccination in The Netherlands', *Vaccines (Basel)*, vol. 8, no. 4, Oct 25, p. 624.

Olbrich, KJ, Muller, D, Schumacher, S, Beck, E, Meszaros, K & Koerber, F 2018, 'Systematic Review of Invasive Meningococcal Disease: Sequelae and Quality of Life Impact on Patients and Their Caregivers', *Infectious Dis Ther*, vol. 7, no. 4, Dec, pp. 421-438.

Onwuegbuzie, AJ & Leech, NL 2005, 'On becoming a pragmatic researcher: The importance of combining quantitative and qualitative research methodologies', *Int J Soc Res Methodol*, vol. 8, no. 5, pp. 375-387.

Ozawa, S, Portnoy, A, Getaneh, H, Clark, S, Knoll, M, Bishai, D, Yang, HK & Patwardhan, PD 2016, 'Modeling The Economic Burden Of Adult Vaccine-Preventable Diseases In The United States', *Health Aff (Millwood)*, vol. 35, no. 11, Nov 1, pp. 2124-2132.

Pace, D & Pollard, AJ 2012, 'Meningococcal disease: clinical presentation and sequelae', *Vaccine*, vol. 30 Suppl 2, no. suppl. 2, May 30, pp. B3-9.

Parikh, SR, Campbell, H, Bettinger, JA, Harrison, LH, Marshall, HS, Martinon-Torres, F, Safadi, MA, Shao, ZJ, Zhu, BQ, von Gottberg, A, Borrow, R, Ramsay, ME & Ladhani, SN 2020, 'The everchanging epidemiology of meningococcal disease worldwide and the potential for prevention through vaccination', *J Infect*, vol. 81, no. 4, Oct, pp. 483-498.

Patel, JC, George, J, Vuong, J, Potts, CC, Bozio, C, Clark, TA, Thomas, J, Schier, J, Chang, A & Waller, JL 2017, 'Rapid laboratory identification of Neisseria meningitidis serogroup C as the cause of an outbreak—Liberia, 2017', *MMWR Morb Mortal Wkly Rep*, vol. 66, no. 42, p. 1144.

Pearson, N, Gunnell, DJ, Dunn, C, Beswick, T, Hill, A & Ley, B 1995, 'Antibiotic prophylaxis for bacterial meningitis: overuse and uncertain efficacy', *J Public Health Med*, vol. 17, no. 4, Dec, pp. 455-458.

Peltola, H 1978, 'Group A meningococcal polysaccharide vaccine and course of the group A meningococcal epidemic in Finland', *Scand J Infect Dis*, vol. 10, no. 1, pp. 41-44.

Perrett, K, al-Wali, W, Read, C, Redgrave, P & Trend, U 2000, 'Outbreak of meningococcal disease in Rotherham illustrates the value of coordination, communication, and collaboration in management', *Commun Dis Public Health*, vol. 3, no. 3, Sep, pp. 168-171.

Peterson, ME, Mile, R, Li, Y, Nair, H & Kyaw, MH 2018, 'Meningococcal carriage in high-risk settings: A systematic review', *Int J Infect Dis*, vol. 73, Aug, pp. 109-117.

Pivette, M, Taha, MK, Barret, AS, Polard, E, Hautier, MB, Dufour, JB, Faisant, M, King, LA, Antona, D, Levy-Bruhl, D, Tillaut, H, Scanff, A, Morival, C, Aranda Grau, JH, Guillaumot, P & Gagniere, B 2020, 'Targeted vaccination campaigns of teenagers after two clusters of B invasive meningococcal disease in Brittany, France, 2017', *BMC Public Health*, vol. 20, no. 1, Sep 10, p. 1382.

Pizza, M, Bekkat-Berkani, R & Rappuoli, R 2020, 'Vaccines against Meningococcal Diseases', *Microorganisms*, vol. 8, no. 10, Oct 3.

Polus, S, Lerberg, P, Vogel, J, Watananirun, K, Souza, JP, Mathai, M & Gulmezoglu, AM 2012, 'Appraisal of WHO guidelines in maternal health using the AGREE II assessment tool', *PLoS One*, vol. 7, no. 8, p. e38891.

Public Health Agency of Canada 2006, *Guidelines for the Prevention and Control of Meningococcal Disease*, Government of Canada, Canada.

Public Health England 2018, *Guidance for Public Health Management of Meningococcal Disease in the UK: Updated February 2018*, Department of Health and Social Care, London.

Rehfuess, EA, Stratil, JM, Scheel, IB, Portela, A, Norris, SL & Baltussen, R 2019, 'The WHO-INTEGRATE evidence to decision framework version 1.0: integrating WHO norms and values and a complexity perspective', *BMJ Global Health*, vol. 4, no. Suppl 1, p. e000844.

Reintjes, R, Kistemann, T, MacLehose, L, McKee, M, Gill, N, Weinberg, J, Schaefer, O, Camaroni, I, Fulop, N & Brand, H 2002, 'Detection and response to a meningococcal disease outbreak following a youth football tournament with teams from four European countries', *Int J Hyg Environ Health*, vol. 205, no. 4, May, pp. 291-296.

Rota, PA, Moss, WJ, Takeda, M, de Swart, RL, Thompson, KM & Goodson, JL 2016, 'Measles', *Nat Rev Dis Primers*, vol. 2, no. 1, Jul 14, p. 16049.

Sabharwal, S, Patel, V, Nijjer, SS, Kirresh, A, Darzi, A, Chambers, JC, Malik, I, Kooner, JS & Athanasiou, T 2013, 'Guidelines in cardiac clinical practice: evaluation of their methodological quality using the AGREE II instrument', *J R Soc Med*, vol. 106, no. 8, Aug, pp. 315-322.

Salleras, L, Dominguez, A, Prats, G, Parron, I & Munoz, P 2001, 'Dramatic decline of serogroup C meningococcal disease incidence in Catalonia (Spain) 24 months after a mass vaccination programme of children and young people', *J Epidemiol Community Health*, vol. 55, no. 4, Apr, pp. 283-287.

Sanogo, YO, Guindo, I, Diarra, S, Retchless, AC, Abdou, M, Coulibaly, S, Maiga, MF, Coumare, M, Diarra, B, Chen, A, Chang, HY, Vuong, JT, Acosta, AM, Sow, S, Novak, RT & Wang, X 2019, 'A New Sequence Type of Neisseria meningitidis Serogroup C Associated With a 2016 Meningitis Outbreak in Mali', *J Infect Dis*, vol. 220, no. 220 Suppl 4, Oct 31, pp. S190-S197.

Schünemann, HJ, Hill, SR, Kakad, M, Vist, GE, Bellamy, R, Stockman, L, Wisløff, TF, Mar, CD, Hayden, F, Uyeki, TM, Farrar, J, Yazdanpanah, Y, Zucker, H, Beigel, J, Chotpitayasunondh, T, Hien, TT, Özbay, B, Sugaya, N & Oxman, AD 2007, 'Transparent Development of the WHO Rapid Advice Guidelines', *PLoS Med*, vol. 4, no. 5, p. e119.

Sekiya, N, Sunagawa, T, Takahashi, H, Kamiya, H, Yoshino, S, Ohnishi, M, Okabe, N & Taniguchi, K 2021, 'Serogroup B invasive meningococcal disease (IMD) outbreak at a Japanese high school dormitory: An outbreak investigation report from the first IMD outbreak in decades', *Vaccine*, vol. 39, no. 15, Apr 8, pp. 2177-2182.

Shah, S 2016, *Pandemic: Tracking contagions, from cholera to Ebola and beyond*, Macmillan.

Sherman, AC & Stephens, DS 2020, 'Serogroup A meningococcal conjugate vaccines: building sustainable and equitable vaccine strategies', *Expert Rev Vaccines*, vol. 19, no. 5, May, pp. 455-463.

Soeters, HM, McNamara, LA, Whaley, M, Wang, X, Alexander-Scott, N, Kanadanian, KV, Kelleher, CM, MacNeil, J, Martin, SW, Raines, N, Sears, S, Vanner, C, Vuong, J, Bandy, U, Sicard, K, Patel, M & Centers for Disease, C 2015, 'Serogroup B Meningococcal Disease Outbreak and Carriage Evaluation at a College - Rhode Island, 2015', *MMWR Morb Mortal Wkly Rep*, vol. 64, no. 22, Jun 12, pp. 606-607.

StataCorp, 2017, *Stata Statistical Software: Release 15*, Statacorp LLC, College Station, TX.

Stone, SP & Cookson, BD 2016, 'Endorsing reporting guidelines: Infection control literature gets ahead of the game', *Am J Infect Control*, vol. 44, no. 12, Dec 1, pp. 1446-1448.

Stone, SP, Cooper, BS, Kibbler, CC, Cookson, BD, Roberts, JA, Medley, GF, Duckworth, G, Lai, R, Ebrahim, S, Brown, EM, Wiffen, PJ & Davey, PG 2007, 'The ORION statement: guidelines for transparent reporting of outbreak reports and intervention studies of nosocomial infection', *J Antimicrob Chemother*, vol. 59, no. 5, May, pp. 833-840.

Stuart, JM 2001, 'Managing outbreaks : the public health response', *Methods Mol Med*, vol. 67, pp. 257-272.

Stuart, JM, Monk, PN, Lewis, DA, Constantine, C, Kaczmarski, EB & Cartwright, KA 1997, 'Management of clusters of meningococcal disease. PHIS Meningococcus Working Group

and Public Health Medicine Environmental Group', *Commun Dis Rep CDR Rev*, vol. 7, no. 1, Jan 10, pp. R3-5.

Sudbury, EL, O'Sullivan, S, Lister, D, Varghese, D & Satharasinghe, K 2020, 'Case Manifestations and Public Health Response for Outbreak of Meningococcal W Disease, Central Australia, 2017', *Emerg Infect Dis*, vol. 26, no. 7, Jul, pp. 1355-1363.

Taha, MK & Deghmane, AE 2020, 'Impact of COVID-19 pandemic and the lockdown on invasive meningococcal disease', *BMC Res Notes*, vol. 13, no. 1, Aug 27, p. 399.

Tan, JY, Conceicao, EP, Sim, XYJ, Wee, LEI, Aung, MK & Venkatachalam, I 2020, 'Public health measures during COVID-19 pandemic reduced hospital admissions for community respiratory viral infections', *J Hosp Infect*, vol. 106, no. 2, Oct, pp. 387-389.

Tashakkori, A & Teddlie, C 1998, *Mixed methodology: Combining qualitative and quantitative approaches*, Applied social research methods series, vol. 46, Thousand Oaks : Sage, California.

Telisinghe, L, Waite, TD, Gobin, M, Ronveaux, O, Fernandez, K, Stuart, JM & Scholten, RJ 2015, 'Chemoprophylaxis and vaccination in preventing subsequent cases of meningococcal disease in household contacts of a case of meningococcal disease: a systematic review', *Epidemiol Infect*, vol. 143, no. 11, Aug, pp. 2259-2268.

Thabuis, A, Tararbit, K, Taha, MK, Dejour-Salamanca, D, Ronin, V, Parent du Chatelet, I & Spaccaferri, G 2018, 'Community outbreak of serogroup B invasive meningococcal disease in Beaujolais, France, February to June 2016: from alert to targeted vaccination', *Euro Surveill*, vol. 23, no. 28, Jul.

Torner, N, Carnicer-Pont, D, Castilla, J, Cayla, J, Godoy, P, Dominguez, A, Epidemiological Surveillance Working Group of, C & Navarre, S 2011, 'Auditing the management of vaccine-preventable disease outbreaks: the need for a tool', *PLoS One*, vol. 6, no. 1, Jan 13, p. e15699.

Trotter, CL, Gay, NJ & Edmunds, WJ 2006, 'The natural history of meningococcal carriage and disease', *Epidemiol Infect*, vol. 134, no. 3, Jun, pp. 556-566.

van Seventer, JM & Hochberg, NS 2017, 'Principles of Infectious Diseases: Transmission, Diagnosis, Prevention, and Control', *Intl Encyclopedia Public Health*, pp. 22-39.

Veritas Health Innovation n.d., *Covidence systematic review software*, Melbourne, Australia, <www.covidence.org>.

Von Elm, E, Altman, DG, Egger, M, Pocock, SJ, Gøtzsche, PC & Vandenbroucke, JP 2007, 'The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies', *Bull World Health Org*, vol. 85, pp. 867-872.

Vygen, S, Hellenbrand, W, Stefanoff, P, Hanquet, G, Heuberger, S & Stuart, J 2016, 'European public health policies for managing contacts of invasive meningococcal disease cases better harmonised in 2013 than in 2007', *Euro Surveill*, vol. 21, no. 5, pp. 23-31.

Ward, JE 2020, 'Communicable disease outbreaks: Describing an epidemic', *Aust J Gen Pract*, vol. 49, Apr 23, pp. 0-0.

Whitesell, E, Yaskin, J & Chaudhari, P 2009, 'The Economics and Epidemiology of Meningococcal Infection: A Systematic Literature Review', *Value Health*, vol. 12, no. 3, May, pp. A115-A115.

Wieland, K, Chhatwal, P & Vonberg, R-P 2017, 'Outbreak reporting a decade after ORION: where do we stand?', *Lancet Infect Dis*, vol. 17, no. 5, 2017/05/01/, p. 476.

World Health Organization 2014, *Meningitis outbreak response in sub-Saharan Africa: WHO guideline*, World Health Organization.

World Health Organization 2021, *World health statistics 2021: monitoring health for the SDGs, sustainable developement goals*, Geneva.

World Health Organization 2022, *WHO Coronavirus (COVID-19) Dashboard*, viewed 18 Feb 2022, <https://covid19.who.int/>.

Yazdankhah, SP & Caugant, DA 2004, 'Neisseria meningitidis: an overview of the carriage state', *J Med Microbiol*, vol. 53, no. Pt 9, Sep, pp. 821-832.

Yezli, S 2018, 'The threat of meningococcal disease during the Hajj and Umrah mass gatherings: A comprehensive review', *Travel Med Infect Dis*, vol. 24, Jul - Aug, pp. 51-58.

Zunt, JR, Kassebaum, NJ, Blake, N, Glennie, L, Wright, C, Nichols, E, Abd-Allah, F, Abdela, J, Abdelalim, A, Adamu, et al. 2018, 'Global, regional, and national burden of meningitis, 1990-2016: a systematic analysis for the Global Burden of Disease Study 2016', *Lancet Neurol*, vol. 17, no. 12, Dec, pp. 1061-1082.

Appendices

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APPENDIX A – Manuscript 1 published in Journal of Infection and Public Health

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Lessons for and from the COVID-19 pandemic response — An appraisal of guidance for the public health management of Invasive Meningococcal Disease

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ABSTRACT

Background: COVID-19 has focussed public attention on the management of communicable disease like never before. Surveillance, contact tracing, and case management are recognised as key components of outbreak prevention. Development of guidance for COVID-19 has drawn from existing management of other communicable diseases, including Invasive Meningococcal Disease (IMD). IMD is a rare but severe outcome of *Neisseria meningitidis* infection that can be prevented through vaccination. Cases still occur sporadically, requiring ongoing surveillance and consistent management. To this end, national and international public health agencies have developed and published guidance for identification and management of IMD cases.
Aim: To assess national and international guidelines for the public health management of IMD, with a focus on the recommendations for identification and management of "close contacts" to IMD cases.
Methods: Guidelines from six national and international public health agencies were assessed using a modified version of the Appraisal of Guidelines, Research and Evaluation (AGREE II) Instrument in four key domains: stakeholder involvement, developmental rigour, clarity, and applicability. A direct comparison of terminology and recommendations for identification and management of close contacts to IMD cases was also conducted.
Results: Guidelines from Europe and the United Kingdom rated most highly using the AGREE II Instrument, both presenting a clear, critical assessment of the strength of the available evidence, and the risks, costs, and benefits behind recommendations for management of close contacts. Direct comparison of guidelines identified inconsistencies in the language defining close contacts to IMD cases.
Conclusion: Discrepancies between guidelines could be due to limited evidence concerning mechanisms behind disease transmission, along with the lack of a consistent process for development and review of guideline recommendations. COVID-19 management has demonstrated that international collaboration for development of public health guidance is possible, a practice that should be extended to management of other communicable diseases.

Introduction

The Coronavirus Disease 2019 (COVID-19) pandemic has brought communicable disease management into the spotlight. Societal discussion around the role of public health agencies in the prevention and control of infectious disease outbreaks has never been more important. One major point of focus is the role of disease surveillance within outbreak suppression strategies. Countries that acted swiftly and decisively when setting guidance for the identification and management of COVID-19 cases and close contacts often saw greater success in supressing outbreaks and avoiding heavy case burdens. Notable examples include Australia, Taiwan and New Zealand [1].

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The rapid development of guidelines for the management of COVID-19 in different jurisdictions across the world has, necessarily, drawn from guidelines for the management of other infectious diseases [2]. Differences in the public health management for other infectious diseases may help to partially explain some of the marked differences in approaches between countries.

The COVID-19 pandemic and ensuing public health measures including physical distancing, lockdowns, and contact tracing, has led to palpable reductions in the incidence of other communicable diseases [3,4]. It is thus timely to compare guidelines for the management of other communicable diseases across a range of jurisdictions to inform the evolution of guidelines for the management of COVID-19 alongside a more unified update of guidance for other communicable diseases.

A French study investigating the effect of COVID-19 lockdowns on communicable disease identified a decrease in highly transmissible and hyperinvasive strains of Invasive Meningococcal Disease (IMD) over the same time period lockdowns were in place [4]. IMD is a severe disease caused by *Neisseria meningitidis* (*N. meningitidis*), a bacteria found in the human nasopharyngeal mucosa, the cells lining the back of the nose and throat [5]. The disease has a rapid onset and cases require prompt antibiotic treatment to prevent mortality [12,13]. Survivors of IMD often suffer from serious long-term sequalae, including – but not limited to – loss of limbs, neurological damage, hearing loss and physical or psychological scarring [6]. Infants (<1 year old) are the most commonly affected age group, with a small increase in incidence for teenagers and the elderly [7]. While IMD is relatively rare in developed countries (age standardised incidence of 0.5–20 cases per 100,000 in 2016 [8]), *N. meningitidis* can be carried and transmitted asymptomatically throughout the general population, with carriage rates ranging between 10–20%. The mechanisms for transmission are not well understood [9], but it is known that close, sustained contact between people creates optimal conditions for spread of *N. meningitidis*.

IMD is preventable through vaccination, with vaccines available to cover five of the six most common disease-causing strains (A, B, C, X, Y, and W) [4,10–13]. Carriage of *N. meningitidis* can be prevented through the use of clearance antibiotics (chemoprophylaxis), for contacts of cases — that is, those people who have had close and sustained interactions with cases.

As is the case with COVID-19, ongoing public health management of IMD is required to prevent the development of community outbreaks. This is achieved through two main mechanisms: vaccination of the general population to reduce overall incidence; and disease surveillance and contact tracing to prevent the spread of IMD from carriers.

When IMD cases are identified, staff in public health units are responsible for identifying and classifying all possible contacts to the case. These contacts are then classified by the likelihood of *N. meningitidis* transmission. "Close contacts" have the highest risk of transmission and are managed with chemoprophylaxis to eliminate carriage of a possible disease-causing strain of bacteria. Depending on the disease-causing strain and availability of vaccination, close contacts may also be offered a strain-specific vaccine to reduce the risk of developing symptoms [14].

For staff with responsibility for contact identification and classification, guidance around IMD management comes in the form of guideline documents, usually written by national public health agencies, such as the United States Centers for Disease Control (CDC) and Prevention, or the New Zealand Ministry of Health. Within Australia, these guidelines have been developed by the Communicable Diseases Network Australia (CDNA), an advisory group for the Australian Government that provides unified national guidance for the management of communicable diseases [2,15]. These guidelines outline the recommended public health response – how to identify, classify and manage contacts, what antibiotics and vaccinations to provide, and guidance on how to communicate with contacts – which is then implemented by public health staff when responding to IMD cases.

While many countries have guidelines written for the public health management of IMD, there has been no comparison or analysis of this guidance on an international level. There is limited evidence around the actual risk of transmission between cases and contacts, especially close contacts, as IMD is uncommon and epidemiology varies globally [16].

An assessment of national and international guidelines for the public health management of IMD, accompanied by a summary of the literature around guideline development and use, will provide a better understanding of guideline implementation in public health settings, and may help to inform the evolution of guidelines for the ongoing prevention of communicable diseases, such as COVID-19. The primary purpose of this review is to assess national and international guidelines for the public health management of IMD, and, more specifically, identification and management of close contacts. A secondary purpose is to characterise and evaluate similarities and differences between guideline recommendations for the identification and management of close contacts.

Methods

Guidance for the public health management of IMD cases and contacts were sourced from countries with similar incidence of IMD to Australia [8]. Each national public health agency (or equivalent authority) was identified by searching the country name and "department of health" using Google. Agencies websites were then searched using the terms "meningococcal" OR "meningitis" AND "guidelines" OR "publication" to identify any publicly available resources for staff about the management of IMD cases and contacts. Any English-language guidelines identified that included recommendations for IMD case and contact management were eligible for inclusion in this review. This search was not date limited, however only the most recent published version of each agency's public health guidelines for the management of IMD cases and contacts was assessed. One international body, the European Centre for Disease Prevention and Control (ECDC), was also included as they provide overarching public health guidance to non-English-speaking European Union (EU) countries, that otherwise would not be included in this review. All screening was conducted by a single author. Any queries were discussed by the team of researchers, and disagreement resolved by consensus.

Guidelines were assessed using a modified version of the Appraisal of Guidelines, Research and Evaluation (AGREE II) Instrument. The AGREE II Instrument is a pre-verified tool, designed to 'assess the quality of practice guidelines across the spectrum of health, provide direction on guideline development, and guide what specific information ought to be reported in guidelines' [17]. The original AGREE II consists of 23 items, organised into six quality-related domains: scope and purpose, stakeholder involvement, rigour of development, clarity of presentation, applicability, and editorial independence. Each item consists of a concept, for example, 'the recommendations are specific and unambiguous' [18], which the assessor then rates on a scale of 1–7. A score of 7 indicates the concept is fully explained and articulated, and a score of 1 indicates a total absence of information. Item scores can then be grouped by domain, indicating areas where guidelines may lack clarity or purpose.

The AGREE II instrument was chosen for the present review because of its focus on assessing the methodological rigour behind the development and reporting of guidelines, rather than the validity of the recommendations themselves. It has been used in its

Table 1
Modified AGREE II Instrument scores by domain and overall, for national and international guidelines (displayed in ascending order of year of publication).

Jurisdiction	Year	Domain scores				Total score (out of 84)
		Stakeholder involvement (out of 14)	Rigour of development (out of 35)	Clarity of presentation (out of 21)	Applicability (out of 14)	
Canada	2006	13	31	19	11	74
Europe (ECDC)	2010	14	35	21	12	82
Australia	2017	8	28	19	10	65
United States (US)	2011	5	25	21	9	60
New Zealand	2018	7	20	20	10	57
United Kingdom (UK)	2018	11	34	21	13	79

original form to assess national and international guidelines in many specialty fields of health, such as maternal [19,20], cardiac [21], and respiratory health [22]. As all the guidelines being assessed were written for the same purpose (public health management of IMD) and produced by public health staff or specific government-funded working groups, the 'scope and purpose' and 'editorial independence' domains in the original instrument were omitted. This left four domains, and twelve items in the modified AGREE II instrument. The scoring system was retained, such that each item was given a score between 1 and 7, with the item scores summed according to domain. The number of items differs across the four domains, with 'stakeholder involvement' and 'applicability' each having two items (maximum possible score = 14), clarity of presentation' three items (maximum possible score = 21), and 'rigour of development' five items (maximum possible score = 35). Item scores were summed and presented by domain, alongside an overall score out of the maximum possible total of 84 for each set of guidelines.

In addition to the AGREE II scoring, a direct comparison of language used and recommendations for identification and management of close contacts between guidelines was conducted. This comparison included each guideline's definition of a close contact, antibiotic recommendations, and vaccination recommendations for close contacts.

Results

Public health guidelines from Australian [15], Canadian [23], European [14], New Zealand [24], United States (US) [25], and United Kingdom (UK) [26] health agencies were included (n = 6). The results from application of the modified AGREE II instrument to these six guidelines are shown in Table 1. All guidelines scored highly (i.e. >75% of maximum possible domain score) in the 'clarity of presentation' domain. Four guidelines scored highly in 'rigour of development' (Canada, Europe, Australia, UK), and three scored highly in 'applicability' and 'stakeholder involvement' (Canada, Europe, UK).

Overall, four guidelines – Canada, Europe, Australia, and the UK – scored above 63/84 (75%). The European guidelines scored highest overall when using the modified AGREE II criteria (82/84), followed by the United Kingdom (79/84). Both sets of guidelines clearly showed the strength of the evidence behind each recommendation, included key information summaries within each section, and addressed possible barriers and facilitators to guideline implementation. The Canadian and Australian guidelines were both clearly written with key information summaries readily available throughout the documents. However, the discussion around the strength of the evidence was more limited in each of these guidelines, and the Australian guidelines showed much less evidence of stakeholder involvement. While clearly written, the US guidelines scored 60/84, reflecting that there was little discussion in these guidelines around stakeholder involvement and applicability. The New Zealand guidelines scored lowest (57/84), with little in-depth discussion around any of the concepts that underpin the items in each domain. Notably, there was no apparent trend in scores related to their date of publication.

All guidelines emphasised the importance of prompt identification and management of close contacts to minimize the risk of additional cases of IMD. There was consistency across all guidelines regarding the exposure period – 7 days before onset of symptoms in the case to 24 h on effective antibiotic treatment – and on household contacts qualifying as 'close' contacts, shown in Table 2.

Canada had the oldest published guidelines (2006) and the broadest definitions for close contacts, including sharing drinks and cigarettes as an indication of close contact. As seen in Table 2, three out of the six guidelines included co-passengers (seated directly adjacent to an IMD case on travel lasting longer than 8 h) to cases as close contacts. All of these guidelines specified an 8 -h minimum time and included any form of enclosed transport [15,23,24]. Only Australia defined a minimum time of contact for childcare settings (two full days or 20 cumulative hours in the same care group, based on a 1981 study on secondary case rates after IMD outbreaks in Belgian children [27]) [15]. Other guidelines left it to the discretion of the public health officer [20] whether to include childcare contacts as close contacts, or did not include childcare contacts at all [24,26].

With the exception of the US guidelines, vaccination was recommended for all unimmunised close contacts, provided the disease-causing strain could be identified. European and Canadian guidelines recommend vaccination 'if a case of meningococcal disease is caused by a strain that is preventable by an available licenced vaccine' [14]. Australian, UK and New Zealand guidelines specify A, C, W, Y conjugate vaccines, and either do not discuss the use of meningococcal B vaccination (Australia) or limit use to multiple cases occurring in the same household (UK, New Zealand).

Each of the guidelines considered here recommended Rifampicin, Ceftriaxone, and Ciprofloxacin for the elimination of carriage (chemoprophylaxis) within close contacts. Two (US and UK) guidelines also included Azithromycin as an additional option. The European guidelines included Cefixime in addition to Rifampicin, Ceftriaxone, and Ciprofloxacin. Dosages, recommended age, duration, and cautions in usage were all identical across the guidelines.

Discussion

This study has shown that guidelines with higher scores based on the AGREE II Instrument clearly and critically assessed the strength of the available evidence to make recommendations for identification and management of IMD close contacts. Higher scoring guidelines also detailed the potential risks, costs and benefits of each recommendation. This is demonstrated by the European and UK guidelines, both of which clearly identified and discussed the strength of the evidence behind each recommendation. Other guidelines, such as those produced by the US and New Zealand,

Table 2
Summary of terminology, definition of "close contact" and recommendations for management in national and international public health guidelines.

Jurisdiction	Year	Terminology	Close contact definition	Antibiotic recommendations	Vaccination recommendations
Canada	2006	Close contacts	Household Co-sleepers Direct contamination of nose/mouth (e.g. shared cigarettes/drinks, kissing) Healthcare workers[a] Children and staff in childcare/nursery settings Co-passengers[b]	Rifampicin, Ceftriaxone, Ciprofloxacin	Yes, if the contact is unimmunised and there is a vaccine available for that strain.
Europe (ECDC)	2010	Close contacts	Household Pre-school (dependent on risk assessment)	Rifampicin, Ceftriaxone, Ciprofloxacin, Cefixime, Azithromycin	Yes, if the contact is unimmunised and there is a vaccine available for that strain.
Australia	2017	Higher risk contacts	Household/household like Intimate kissing/sexual Child-care Co-passengers Healthcare workers	Rifampicin, Ceftriaxone, Ciprofloxacin	A, C, W, Y conjugate vaccines if contact is unimmunised, 4CMenB (Bexsero) vaccine only if there is a second case of serogroup B in the same household.
United States (US)	2011	Close contacts	Household Childcare centre contacts "Anyone directly exposed to oral secretions" (kissing, mouth-to-mouth resuscitation, intubation/tube management)	Rifampicin, Ceftriaxone, Ciprofloxacin, Azithromycin (if there is no resistance to fluoroquinolone)	Not discussed.
New Zealand	2018	Contacts	Household Bed/room sharing overnight Co-passengers Healthcare workers "Other contacts as determined on a case-by-case basis by the medical officer"	Rifampicin, Ceftriaxone, Ciprofloxacin	MenACWY conjugate vaccine if contact is unimmunised, Bexsero (meningococcal B) if there is a multi-occupancy outbreak
United Kingdom (UK)	2018	Close contacts	Household/household like	Rifampicin, Ceftriaxone, Ciprofloxacin, Azithromycin (for pregnant women)	MenACWY if contact cannot confirm immunisation in the preceding 12 months, MenB only if contact is at increased risk of meningococcal infection

[a] Directly exposed to nasal secretions (e.g. mouth-to-mouth or intubation of a known IMD case).
[b] Seated directly adjacent to a known IMD case, for travel lasting longer than 8 h on an airplane, boat, bus, train or other enclosed transport.

had lower overall scores when they showed no clear link between the evidence and recommendations given, did not provide explicit recommendations, relied on limited evidence, or did not provide information on possible barriers and facilitators to implementation of guideline recommendations.

Public health staff require clear and accurate guidance in order to effectively identify and reduce the risk of further IMD cases arising from contacts of those cases [28]. Domains within those guidelines with lower scores in the AGREE II Instrument indicate areas where public health staff lack consistent and explicit guidance on how to carry out their role concerning management of close contacts. This could in turn make it more challenging for staff to properly implement such guidelines when presented with a case of IMD.

One important point to bear in mind is that the primary purpose of the AGREE II Instrument is to assess the quality of the underlying methodology and reporting of guidelines, and not the assessment of the accuracy of any recommendations provided. Therefore, the scores from evaluation according to the AGREE II Instrument should also be considered within the context of the findings from Table 2. Guidelines assigned higher scores using the AGREE II Instrument may not necessarily be providing the most up-to-date or evidence-supported guidance. While recommendations for antibiotic treatment were largely consistent across the guidelines assessed in the present review, information about vaccination varied between countries. This is in part due to the publication date of some guidelines. For example, the Bexsero meningococcal B vaccine, mentioned in Australian, UK and New Zealand guidelines, was

only licenced in the UK in 2013, and has only been included in the national immunisation programs of seven countries including Australia [16] to date. The definition of a "close contact" was also quite varied, and ranged from household and household-like contacts alone [26] to household, household-like, sexual, child-care, co-passengers and healthcare contacts [15].

In general, the development of guidance for the public health management of a given communicable disease rests on a body of evidence describing the aetiology and epidemiology of that disease. Evidence may be derived from studies investigating many different facets of the disease, including – but not limited to – causative pathogen(s), symptom progression, transmission patterns and population prevalence. In the case of IMD, the ability of researchers to study the life cycle and host interactions of *N. meningitidis* is limited, largely due to its adaptation to human airways [5,29]. While mouse models can be used to model disease symptoms and infection mechanisms, they require manual inoculation with the bacterium, and are not well-suited to studying transmission patterns [29]. Studies on the prevalence of asymptomatic carriage have largely focussed on sub-populations already known to have higher rates of carriage, and often utilize surveys and questionnaires to identify factors that may affect an individual's risk of carriage [30–32]. Guideline recommendations are then based on the generalised results of these population studies, in addition to public health records of previous IMD clusters [28] and published evidence on the transmission risk of similar bacterial pathogens (e.g. tuberculosis) [33].

A 2016 study [34] of public health guidance for the management of close contacts to IMD cases within EU countries discussed the variation between country policies for identification and management of close contacts. The study is a repeat of a 2007 survey [35], and indicated that following the publication of the ECDC guidance in 2010, EU countries had adopted more evidence-based public health guidance, that were better aligned with ECDC recommendations. This indicates that while there is a somewhat limited understanding of the risks affecting transmission of *N. meningitidis*, it has become more widely accepted that to be at a higher risk of transmission, a certain degree of close, sustained contact is required [16,28,36,37].

While there was no clear link between AGREE II scores and date of guideline publication, definitions of close contacts did change over time. For example, Canadian guidelines had the earliest publication date (2006) and the broadest inclusion criteria for close contacts. More recent guidelines, such as those from the UK (2018) or the US (2017), have a more restricted definition of a close contact and had a stronger evidence base to support their recommendations.

The present review of guidelines was limited to high-income and predominantly English-speaking countries. While all of the included jurisdictions had a similar incidence of IMD, the disease is rare in those areas [8]. EU countries were also grouped under the ECDC guidance, as none of the individual member states had publicly available English-language guidelines. The comparisons published by Vygen et al. [34] and Hoek et al. [35] provided insight on the similarities and differences between EU countries with regards to their management of IMD case contacts, although a direct assessment of individual EU countries public health guidelines was not carried out in either of these studies. Another consideration in interpreting the work presented here is that the AGREE II Instrument is predominantly designed for the assessment of clinical guidance. While it provided valuable insight into the development and reporting of public health guidance around IMD prevention, there are aspects of the guidelines assessed that the AGREE II instrument does not cover. These include healthcare costs, recommendations for review of guidelines, methods for guideline dissemination to public health staff, recommendations for audit, and assessment of guideline implementation. There are also considerations for the assessment of clinical guidelines that are not relevant to the assessment of public health guidelines. In our study, this limitation was mitigated by the removal of the 'Scope and Purpose' and 'Editorial Independence' domains from the original AGREE II Instrument.

COVID-19 management has, by necessity, streamlined the process of translating evidence into public health policy (e.g. mask wearing, hotel quarantine, lockdown strategies) [1,2]. While responses to the COVID-19 pandemic have reduced the spread of IMD and other communicable diseases [4,38], they have also impacted vaccination programs [3,39] and may negatively impact outbreak management strategies. The current delay between increased understanding of disease transmission and actual implementation into public health guidance can have direct and immediate consequences for individual and population health.

Mechanisms for guideline development and review should prioritize the identification of areas where guidelines may lack clarity, be inconsistent, or have weak underlying evidence. This information can then be used to improve the clarity and consistency of public health recommendations. Guideline development and revision should also be considered frequently within a global context, ideally with the introduction of new vaccines or vaccination programs, as it becomes increasingly evident that inconsistent management of an infectious disease, either within or between country jurisdictions, can hinder effective disease management. Although conjugate meningococcal vaccines show evidence of reduction in transmission [13], they do not affect overall carriage rates [40]. As new vaccines are developed and implemented in population-wide programs, guidelines for management of contacts need to be reviewed to ensure they remain contemporaneous.

Conclusions

The present study has shown inconsistencies between higher-income countries for the public health management of IMD case contacts. Most notably, the definitions used to identify close contacts differ between countries. Limited availability of evidence surrounding the risk factors for transmission and disease development amongst IMD case contacts, in addition to the lack of a widely accepted process for guideline development and review, may be contributing to these inconsistencies.

The facilitation of effective and multi-jurisdictional responses to communicable disease outbreaks rests on global cooperation and unified guidance. A pre-planned stage of international review within the guideline development process, so as to promote the consideration of recommendations for disease management put forth by other jurisdictions, could be adopted to achieve this. This process could be guided and implemented by internationally recognised bodies such as the World Health Organisation or the ECDC. Worldwide, responses to the COVID-19 pandemic demonstrate that public health guidance can be updated rapidly as new information is gleaned, and those changes can be quickly communicated to relevant staff and the wider public.

Response to the COVID-19 pandemic has resulted in a level of international cooperation that would have been considered unachievable previously. This singular focus on disease prevention can – and should – be carried forward into the management of IMD and other communicable diseases. International collaboration for guideline development and implementation must continue to be the cornerstone of communicable disease response and management.

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Competing interests

None declared.

Ethical approval

Not required.

References

[1] Miller C. International exemplars of effective COVID-19 control. SAHMRI, Health Translation SA and the Commission on Excellence and Innovation in Health; 2020.
[2] Communicable Diseases Network Australia. In: Department of Health, editor. Coronavirus disease 2019 (COVID-19) CDNA national guidelines for public health units. Canberra: Australian Government Department of Health; 2021.
[3] Middeldorp M, van Lier A, van der Maas N, Veldhuijzen I, Freudenburg W, van Sorge NM, et al. Short term impact of the COVID-19 pandemic on incidence of vaccine preventable diseases and participation in routine infant vaccinations in the Netherlands in the period March–September 2020. Vaccine 2021;39(7):1039–43.
[4] Taha M-K, Deghmane A-E. Impact of COVID-19 pandemic and the lockdown on invasive meningococcal disease. BMC Res Notes 2020;13(1):1–6.
[5] Carbonnelle E, Nassif X, Boudoulous S. Mechanisms of cellular invasion of *Neisseria meningitidis*. In: Attardo Genco C, Wetzler L, editors. Neisseria. Norfolk, UK: Caister Academic Press; 2010.
[6] Pace D, Pollard AJ. Meningococcal disease: clinical presentation and sequelae. Vaccine 2012;30(Suppl. 2):3–9, http://dx.doi.org/10.1016/j.vaccine.2011.12.062. Epub 2012/05/25. PubMed PMID: 22607896.
[7] Borrow R, Alarcón P, Carlos J, Caugant DA, Christensen H, Debbag R, et al. The Global Meningococcal Initiative: global epidemiology, the impact of vaccines on meningococcal disease and the importance of herd protection. Expert Rev Vaccines 2017;16(4):313–28, http://dx.doi.org/10.1080/14760584.2017.1258308.
[8] Zunt JR, Kassebaum NJ, Blake N, Glennie L, Wright C, Nichols E, et al. 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.
[9] Kim HW, Lee S, Kwon D, Cha J, Ahn JG, Kim K-H. Characterization of oropharyngeal carriage isolates of *Neisseria meningitidis* in healthy Korean adolescents in 2015. JKMS 2017;32(7):1111–7, http://dx.doi.org/10.3346/jkms.2017.32.7.1111.
[10] Jafri RZ, Ali A, Messonnier NE, Tevi-Benissan C, Durrheim D, Eskola J, et al. Global epidemiology of invasive meningococcal disease. Popul Health Metr 2013;11(1):17.
[11] Marshall HS, Lally N, Flood L, Phillips P. First statewide meningococcal B vaccine program in infants, children and adolescents: evidence for implementation in South Australia. Med J Aust 2020;212(2):89–93.
[12] Batista RS, Gomes AP, Gazineo JLD, Miguel PSB, Santana LA, Oliveira L, et al. Meningococcal disease, a clinical and epidemiological review. Asian Pac J Trop Med 2017;10(11):1019–29.
[13] Ladhani SN, Campbell H, Andrews N, Parikh SR, White J, Edelstein M, et al. First real world evidence of meningococcal group B vaccine, 4CMenB, protection against meningococcal group W disease; prospective enhanced national surveillance, England. Clin Infect Dis 2020:ciaa1244, http://dx.doi.org/10.1093/cid/ciaa1244.
[14] European Centre for Disease Prevention and Control. Public health management of sporadic cases of invasive meningococcal disease and their contacts. Stockholm: European Union; 2010.
[15] Communicable Diseases Network Australia. In: Department of Health, editor. Invasive meningococcal disease CDNA guidance for public health units. Canberra: Australian Government Department of Health; 2017.
[16] Parikh S, Campbell H, Bettinger JA, Harrison LH, Marshall HS, Martinon-Torres F, et al. The everchanging epidemiology of meningococcal disease worldwide and the potential for prevention through vaccination. J Infect 2020;81(4):483–98, http://dx.doi.org/10.1016/j.jinf.2020.05.079.
[17] Brouwers MC, Kho ME, Browman GP, Burgers JS, Cluzeau F, Feder G, et al. AGREE II: advancing guideline development, reporting and evaluation in health care. CMAJ 2010;182(18):839–42.
[18] AGREE Next Steps Consortium [cited 2019 1st May]. Available from: The AGREE II instrument [electronic version]; 2009 http://www.agreetrust.org.
[19] Polus S, Lerberg P, Vogel J, Watananirun K, Souza JP, Mathai M, et al. Appraisal of WHO guidelines in maternal health using the AGREE II assessment tool. PLoS One 2012;7(8):e38891, http://dx.doi.org/10.1371/journal.pone.0038891.
[20] Bazzano AN, Green E, Madison A, Barton A, Gillispie V, Bazzano LA. Assessment of the quality and content of national and international guidelines on hypertensive disorders of pregnancy using the AGREE II instrument. BMJ Open 2016;6(1):e009189.
[21] Sabharwal S, Patel V, Nijjer SS, Kirresh A, Darzi A, Chambers JC, et al. Guidelines in cardiac clinical practice: evaluation of their methodological quality using the AGREE II instrument. J R Soc Med 2013;106(8):315–22.
[22] Linnemann DEL, Vega MF, Pech JAL, Rosas JV, Martell JAO, del Río Navarro BE, et al. Pediatric asthma treatment: what to do when international guideline recommendations do not agree. Ann Allergy Asthma Immunol 2018;121(1),7–13.e4.
[23] Public Health Agency of Canada. Guidelines for the prevention and control of meningococcal disease. Canada: Government of Canada; 2006.
[24] New Zealand Ministry of Health. *Neisseria meningitidis* invasive disease. NZ: New Zealand Government; 2018.
[25] MacNeil JR, Cohn AC. Meningococcal disease. In: Manual for the surveillance of vaccine-preventable diseases; 2011 [cited 2019 1st Oct]. Available from: https://www.cdc.gov/vaccines/pubs/surv-manual/chpt08-mening.html#.
[26] Public Health England. In: Department of Health and Social Care, editor. Guidance for public health management of meningococcal disease in the UK: updated February 2018. London: Department of Health and Social Care; 2018.
[27] De Wals P, Hertoghe L, Borlee-Grimee I, De Maeyer-Cleempoel S, Reginster-Haneuse G, Dachy A, et al. Meningococcal disease in Belgium. Secondary attack rate among household, day-care nursery and pre-elementary school contacts. J Infect 1981;3:53–61.
[28] Gobin M, Hughes G, Foulkes S, Bagnall H, Trindall A, Decraene V, et al. The epidemiology and management of clusters of invasive meningococcal disease in England, 2010–15. J Public Health (Oxf) 2020;42(1):e58–65.
[29] Johswich KO, Gray-Owen SD. Modeling *Neisseria meningitidis* infection in mice: methods and logistical considerations for nasal colonization and invasive disease. In: Seib KL, Peak IR, editors. *Neisseria meningitidis*: methods and protocols. New York, NY: Springer New York; 2019. p. 149–68.
[30] Peterson ME, Mile R, Li Y, Nair H, Kyaw MH. Meningococcal carriage in high-risk settings: a systematic review. Int J Infect Dis 2018;73:109–17, http://dx.doi.org/10.1016/j.ijid.2018.05.022. Epub 2018/07/13. PubMed PMID: 29997031.
[31] McMillan M, Walters L, Mark T, Lawrence A, Leong LEX, Sullivan T, et al. B Part of it study: a longitudinal study to assess carriage of *Neisseria meningitidis* in first year university students in South Australia. Hum Vaccin Immunother 2019;15(4):987–94, http://dx.doi.org/10.1080/21645515.2018.1551672.
[32] Maclennan J, Kafatos G, Neal K, Andrews N, Cameron JC, Roberts R, et al. Social behavior and meningococcal carriage in British teenagers. Emerg Infect Dis 2006;12(6):950–7, http://dx.doi.org/10.3201/eid1206.051297.
[33] MacNeil JR, Rubin LG, Patton M, Ortega-Sanchez IR, Martin SW. Recommendations for use of meningococcal conjugate vaccines in HIV-infected persons—Advisory Committee on Immunization Practices, 2016. MMWR Morb Mortal Wkly Rep 2016;65(43):1189–94, http://dx.doi.org/10.15585/mmwr.mm6543a3.
[34] Vygen S, Hellenbrand W, Stefanoff P, Hanquet G, Heuberger S, Stuart J. European public health policies for managing contacts of invasive meningococcal disease cases better harmonised in 2013 than in 2007. Euro Surveill 2016;21(5):23–31, http://dx.doi.org/10.2807/1560-7917.ES.2016.21.5.30125. Epub 2016/02/16. PubMed PMID: 26875517.
[35] Hoek M, Hanquet G, Heuberger S, Stefanoff P, Zucs P, Ramsay M, et al. A European survey on public health policies for managing cases of meningococcal disease and their contacts. Eurosurveillance 2008;13(10):7–8.
[36] Caugant DA, Maiden MCJ. Meningococcal carriage and disease—population biology and evolution. Vaccine 2009;27:64–70, http://dx.doi.org/10.1016/j.vaccine.2009.04.061.
[37] Trotter CL, Gay NJ, Edmunds WJ. The natural history of meningococcal carriage and disease. Epidemiol Infect 2006;134(3):556–66, http://dx.doi.org/10.1017/S0950268805005339. Epub 2005/10/20.
[38] Tan J, Conceicao E, Sim X, Wee L, Aung M, Venkatachalam I. Public health measures during COVID-19 pandemic reduced hospital admissions for community respiratory viral infections. J Hosp Infect 2020;106(2):387–9, http://dx.doi.org/10.1016/j.jhin.2020.07.023.
[39] Gaythorpe K, Abbas K, Huber J, Karachaliou A, Thakkar N, Woodruff K, et al. Impact of COVID-19-related disruptions to measles, meningococcal A, and yellow fever vaccination in 10 countries. medRxiv 2021;10:e67023, http://dx.doi.org/10.7554/eLife.67023.
[40] Marshall HS, McMillan M, Koehler AP, Lawrence A, Sullivan TR, MacLennan JM, et al. Meningococcal B vaccine and meningococcal carriage in adolescents in Australia. N Engl J Med 2020;382(4):318–27.

APPENDIX B – Modified AGREE II appraisal tool

Guidelines were assessed against each of the 12 items listed below on a 7-point Likert scale (1 = strongly disagree, 7 = strongly agree) as described by Brouwers et al. (2010)

Domain 1 – Stakeholder involvement

1. *The views and preferences of the target population have been sought*
    a. statement of type of strategy used to capture patients'/public's' views and preferences (e.g., participation in the guideline development group, literature review of values and preferences)
    b. methods by which preferences and views were sought (e.g., evidence from literature, surveys, focus groups)
    c. outcomes/information gathered on patient/public information
    d. description of how the information gathered was used to inform the guideline development process and/or formation of the recommendations
2. *The target users of the guideline are clearly defined*
    a. clear description of intended guideline audience (e.g. specialists, family physicians, patients, clinical or institutional leaders/administrators)
    b. description of how the guideline may be used by its target audience (e.g., to inform clinical decisions, to inform policy, to inform standards of care)

Minimum score = 2

Maximum score = 14

Domain 2 – Rigour of development

3. *The guideline uses a range of sources as a foundation for recommendations*
4. *The strengths and limitations of the body of evidence are clearly described (e.g. evidence rating, discussion in body text)*
    a. descriptions of how the body of evidence was evaluated for bias and how it was interpreted by members of the guideline development group
    b. aspects upon which to frame descriptions include:

i. study design(s) included in body of evidence s
ii. study methodology limitations (sampling, blinding, allocation concealment, analytical methods)
iii. appropriateness/relevance of primary and secondary outcomes considered
iv. consistency of results across studies
v. direction of results across studies
vi. magnitude of benefit versus magnitude of harm
vii. applicability to practice context

5. *The methods for formulating the recommendations are clearly described*
6. *The health benefits, side effects, and risks have been considered in formulating the recommendations*
    a. supporting data and report of benefits
    b. supporting data and report of harms/side effects/risks
    c. reporting of the balance/trade-off between benefits and harms/side effects/risks
    d. recommendations reflect considerations of both benefits and harms/side effects/risks
7. *There is an explicit link between the recommendations and the supporting evidence (e.g. citations in text, quoting specific articles)*
    a. the guideline describes how the guideline development group linked and used the evidence to inform recommendations
    b. each recommendation is linked to a key evidence description/paragraph and/or reference list
    c. recommendations linked to evidence summaries, evidence tables in the results section of the guideline

Minimum score = 5

Maximum score = 35

Domain 3 – Clarity of presentation

8. *The recommendations are specific and unambiguous*
    a. statement of the recommended action
    b. identification of the intent or purpose of the recommended action (e.g., to improve quality of life, to decrease side effects)
    c. identification of the relevant population (e.g., patients, public)
    d. caveats or qualifying statements, if relevant (e.g., patients or conditions for whom the recommendations would not apply)
9. *The different options for management of the condition or health issue are clearly presented*
    a. description of options
    b. description of population or clinical situation most appropriate to each option
10. *Key recommendations are easily identifiable*
    a. description of recommendations in a summarized box, typed in bold, underlined, or presented as flow charts or algorithms
    b. specific recommendations are grouped together in one section

Minimum score = 3

Maximum score = 21

Domain 4 – Applicability

11. *The guideline describes facilitators and barriers to its application*
    a. identification of the types of facilitators and barriers that were considered
    b. methods by which information regarding the facilitators and barriers to implementing recommendations were sought (e.g., feedback from key stakeholders, pilot testing of guidelines before widespread implementation)
    c. information/description of the types of facilitators and barriers that emerged from the inquiry (e.g., practitioners have the skills to deliver the recommended care,

sufficient equipment is not available to ensure all eligible members of the population receive mammography)

d. description of how the information influenced the guideline development process and/or formation of the recommendations

12. The guideline provides advice and/or tools on how the recommendations can be put into practice

a. an implementation section in the guideline
b. tools and resources to facilitate application:
    i. guideline summary documents
    ii. links to check lists, algorithms
    iii. links to how-to manuals
    iv. solutions linked to barrier analysis (see Item 11)
    v. tools to capitalize on guideline facilitators (see Item 11)
    vi. outcome of pilot test and lessons learned
c. directions on how users can access tools and resources

Minimum score = 2

Maximum score = 14

Total minimum score = 12

Total maximum score = 84

APPENDIX C - SA Health ethics approval letter

Government of South Australia
Health
Department for Health and Wellbeing

SA Department for Health and Wellbeing
Human Research Ethics Committee

Citi Centre Building
Level 5, 11 Hindmarsh Square
Adelaide SA 5000

PO Box 287, Rundle Mall
Adelaide SA 5000
DX 243

Tel 08 8226 7702
health.humanresearchethicscommittee@sa.gov.au

22 January 2020

Dr Adriana Milazzo
Discipline of Public Health
L7 Terrace Towers
178 North Tce
Adelaide SA 5000

HREC study number: *HREC/19/SAH/8*
Amendment reference number: *HREC/19/SAH/8-AM02*
Project title: *Characterization of close contacts of cases diagnosed with Invasive Meningococcal Disease*

Dear Dr Milazzo

RE: HREC/19/SAH/8-AM02 - Project Amendment - Approval

Thank you for submitting an amendment request on 16th December 2019 in relation to the above project for ethical and scientific review.

This information was considered by a sub-committee of the SA Department for Health and Wellbeing Human Research Ethics Committee (HREC) on 13th January 2020.

The additional information received 17 January 2020 was then considered by the chair of the SA Department for Health and Wellbeing Human Research Ethics Committee (HREC) on 20th January 2020.

I am pleased to advise that your submission has been granted full ethics approval and meets the requirements of the *NHMRC National Statement on Ethical Conduct in Human Research* and the *Australian Code for the Responsible Conduct of Research*.

The documents reviewed and approved include:

Document	*Version*	*Date*
Notification of Amendment: Request to (1) Add New Investigators, (2) Add NMA Study Sites, (3) Change Focus Groups to Interviews, (4) Revise Survey	-	16 December 2019
Protocol	5.0	16 December 2019
Appendix G - Invitation Email: Survey	2	16 December 2019
Appendix H - Participant Information Sheet & Consent Form: Survey	3	
Appendix I - Invitation Email: Interview	2	16 December 2019
Apendix J - Participant Information Sheet & Consent Form: Interview	3	16 December 2019
Appendix L - Follow-up Email: Survey	2	16 December 2019
Appendix M - Follow-up Email: Interviews	2	16 December 2019
Appendix O - Survey	2	16 December 2019

Appendix P - Interview Schedule	2	16 December 2019
Response to Request for Further Information: Cover letter	-	17 January 2020

Next Annual Progress Report Due: 10 July 2020

Site(s) covered by this Ethics Approval:

- SA Department for Health and Wellbeing
- NSW Ministry of Health
- QLD Department of Health
- VIC Department of Health and Human Services
- WA Department of Health

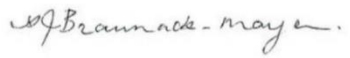
You are reminded of the terms under which Ethical approval is granted:

- It is noted that the SA Aboriginal Health Research Ethics Committee (AHREC) has not reviewed this study as the researchers have indicated analysis on indigeneity will not occur for this study. Should this change, the DHW HREC must be notified prior to this occurring, and the AHREC must be contacted to discuss ethical review requirements.
- The research must be conducted in accordance with the NHMRC *National Statement on Ethical Conduct in Human Research.*
- Confidentiality of the research subjects shall be maintained at all times as required by law.
- A progress report, at least annually, must be provided to the HREC.
- Researchers are required to immediately report to the HREC anything which might warrant review of ethical approval of the protocol, including:
    a. serious or unexpected adverse events;
    b. formal complaints from participants;
    c. protocol deviations or violations;
    d. proposed changes to the protocol or study documentation before they are implemented;
    e. proposed changes to the study investigators;
    f. new study documentation; and
    g. unforeseen events that might affect continued ethical acceptability of the project.
- Any proposed changes to the original proposal must be submitted to and approved by the HREC before they are implemented.
- If the project is discontinued before its completion, the HREC must be advised immediately and provided with reasons for discontinuing the project.
- A report and a copy of any published material should be forwarded to the HREC at the completion of the project.
- Study data is to be retained in accordance with the State Records Act 1997.

Site Specific/Governance Approval:
Your amendment request may also require modification to your Site Specific Assessment (SSA) approval, please contact the relevant Research Governance Officers for the institutions of which are covered by this HREC approval (listed above) to discuss whether this amendment needs their review before being implemented.

Should you have any queries about the HREC's consideration of your project please contact the HREC Executive Officer on phone 08 82267702 or email HealthHumanResearchEthicsCommittee@sa.gov.au

Yours sincerely



Prof Annette Braunack-Mayer
Chair, Human Research Ethics Committee
SA Department for Health and Wellbeing
ABM:psb

cc Research Governance Officer, SA Department for Health and Wellbeing (DHW)
NSW Ministry of Health
QLD Department of Health
VIC Department of Health and Human Services
WA Department of Health

APPENDIX D – Supplement 1: Search Terms

PUBMED

Meningitis, Meningococcal [mh:noexp] OR Meningococcal [tiab] OR IMD [tiab]	Disease Outbreaks [mh] OR Disease Outbreak* [tiab] OR Outbreak* [tiab] OR Cluster* [tiab] OR Community outbreak* [tiab] OR Organisational outbreak* [tiab] OR Organizational outbreak* [tiab] OR Management Case Stud* [tiab] OR Organizational Case Studies [mh] OR Organizational Case Stud* [tiab] OR Organisational Case Stud* [tiab] OR Epidemics [mh:noexp] OR Epidemic* [tiab]	Contact Tracing [mh] OR Contact Tracing [tiab] OR Tracing, Contact [tiab] OR Communicable Disease Control [mh] OR Communicable Disease Control [tiab] OR Disease response [tiab] OR Outbreak response [tiab] OR Public Health Practice [mh:noexp] OR Public Health Surveillance [mh] OR Public Health Surveillance [tiab] OR Surveillance [tiab]

EMBASE

IMD	Outbreaks	Response
‘Meningococcosis’/exp OR ‘meningococcal disease’:ti,ab OR ‘Neisseria meningitidis’/exp OR ‘neisseria meningitidis’:ti,ab OR ‘meningococcal infection*’:ti,ab OR ‘meningococcal disease*’:ti,ab	‘disease outbreak*’:ti,ab OR ‘epidemic’/exp OR ‘epidemic*’:ti,ab OR ‘Community outbreak*’:ti,ab OR ‘Organisational outbreak*’:ti,ab OR ‘Organizational outbreak*’:ti,ab OR ‘Management Case Stud*’:ti,ab OR ‘Organizational Case Stud*’:ti,ab OR ‘Organisational Case Stud*’:ti,ab	‘contact examination’/exp OR ‘contact examination’:ti,ab OR ‘contact tracing’:ti,ab OR ‘contact detection’:ti,ab OR 'communicable disease control'/exp OR ‘public health’/exp OR ‘community health’:ti,ab OR 'disease surveillance'/de OR ‘disease surveillance’:ti,ab OR 'public health service'/de OR 'public health care’:ti,ab

APPENDIX E – Supplement 2: Data extract summary sheets

Sheet 1: Study Details

STUDY ID	Title	Study details	Introduction	Methods	Results	Discussion
Bassi 2017	A cluster of invasive meningococcal disease (IMD) caused by Neisseria meningitidis serogroup W among university students, France, February to May 2017	Description of two linked cases 3 months apart, treatment, outcomes & public health response to prevent further spread	No comment	No comment	Epidemic curve, summary of complications included. Population size and age range of cases unclear	No comment
Capitano 2019	Experience implementing a university-based mass immunization program in response to a meningococcal B outbreak	Description of meningococcal B outbreak at the University of Oregon & subsequent mass vaccination campaign	No comment	Start and finish dates not included, data on case investigations not included.	Limited demographic information recorded on cases (possible identifiable data?).	Good discussion of weaknesses re. Data collection and ability to measure completion of coverage
Cartwright 1986	An outbreak of meningococcal disease in Gloucestershire	Description of outbreak in Gloucester Health District in SW England. Historic study (1981) and pre-vaccine availability.	No comment	No comment	Good summary of all important details, map, demographic table, epidemic curve etc all included	Good summary of recommendations and possible future implementation in other outbreaks.
Centers for Disease 2012	Outbreak of meningococcal disease associated with an elementary school -- Oklahoma, March 2010	Description of outbreak in a consolidated school district in North-East Oklahoma of 1,850 students	No comment	No comment	No comment	Discussion re. Lack of guidelines
Chow 2016	Invasive Meningococcal Meningitis Serogroup C Outbreak in Northwest Nigeria, 2015 - Third Consecutive Outbreak of a New Strain	Medecins sans frontieres (MSF) report on the third successive outbreak of menc in Nigeria, 2015	No comment	No comment	No comment	Not much identification/discussion of weaknesses - fairly straightforward premise though

STUDY ID	Title	Study details	Introduction	Methods	Results	Discussion
Delisle 2010	Community outbreak of group B meningococcal disease in southwest France - December 2008 to September 2009	Description of outbreak investigation and response	No comment	No comment	Good figures, include epidemic curve & summary of cases in detail.	Address limitations of only MSF data - likely under reporting outbreak size, inability to test/confirm all cases so need to rely on probable diagnosis.
DeSchrijver 2003	An outbreak of serogroup C meningococcal disease in the province of Antwerp (Belgium) in 2001-2002	Describing increase in attack rate of meningococcal C disease in 2001 in Antwerp, Belgium, by comparison with neighbouring region and years immediately before/after (2000 & 2002)	Location unclear - border between Mobile & Washington county, population size not given	No comment	No information on complications given, complete time, person, place recorded	Good discussion re. Difficulty of proving efficacy, good record of decision-making process re. Community wide chemoprophylaxis
Doedeh 2017	Rapid Field Response to a Cluster of Illnesses and Deaths - Sinoe County, Liberia, April-May, 2017	Description of response to cluster of unknown illness in Sinoe County, Liberia.	No comment	No comment	Attack rate presented in map, no overall AR given. Population summary and demographic information good but limited by data collection abilities.	Possible underreporting of cases by a factor of at least 10 - poor reporting and surveillance structures in place
Flood 2021	Lessons from a community vaccination programme to control a meningococcal disease serogroup W outbreak in remote South Australia, 2017	Description of community vaccination program in response to IMD outbreak in a regional Indigenous Australian community	No comment	No comment	Summary of cases given in table, some demographic data included, gender not reported on. Information on complications reported on in text.	Good description of response and decision-making process for defining outbreak and population at risk
Haelterman 1996	Impact of a mass vaccination campaign against a meningitis epidemic in a refugee camp	Comparison of IMD incidence between two refugee camps with differing vaccination	No comment	Good description of contacts - includes numbers and management practices	No attack rate included, details on age and gender of cases not	No comment

STUDY ID	Title	Study details	Introduction	Methods	Results	Discussion
		times in Zaire, Africa to assess the impact of vaccination of IMD prevention			included (poss identifying?)	
Jacobson 1977	An epidemic of disease due to serogroup B Neisseria meningitidis in Alabama: report of an investigation and community-wide prophylaxis with a sulfonamide	Description of outbreak identification and response, case-control studies used to identify groups at risk and to assess carriage after mass-chemoprophylaxis.		Information re. Case investigations and management not given	Time, person, place not given - no summary of case demographics given (age, gender, complications other than the one fatality) main focus is on the vaccination campaign but information there is also not well organised. Supplement figure with timeline is illegible.	Good communication of recommendations and barriers to student uptake, limited information re. Missing case information
Kanai 2017	Outbreak of Neisseria meningitidis capsular group W among scouts returning from the World Scout Jamboree, Japan, 2015	Descriptions of meningococcal W outbreaks at 2015 World Scout Jamboree (WSJ) & subsequent spread to home countries	Good description of community, region & population affected	No comment	No summary table included on cases - demographics such as age, gender etc but adequate detail given in text. Better identification of population and spread than some later published papers.	Good recommendations and summary of weaknesses re. Testing and notification.
Krause 2002	Mass vaccination campaign following community outbreak of meningococcal disease	Assessment of mass-vaccination campaign in Florida, United States, to control a community outbreak of meningococcal disease	No comment	Case definitions not clear, overall number of suspected vs confirmed cases not clear	Case summaries given with different denominators (CFR out of clinically suspect cases not actual case numbers) timeline unclear. Demographics unclear.	Limited discussion of weaknesses/missing data.

STUDY ID	Title	Study details	Introduction	Methods	Results	Discussion
Kriz 1995	Targeted vaccination with meningococcal polysaccharide vaccine in one district of the Czech Republic	Comparison between two neighbouring districts during a meningococcal C outbreak, one which received mass vaccination and one which didn't. Authors have also compared pre-& post vaccination case numbers to assess the effectiveness of mass vaccination.	No comment	No comment	No comment	No comment
Kushwaha 2010	Outbreak of Meningococcal Infection amongst Soldiers Deployed in Operations	Description of outbreak in army barracks during deployments	No comment	No comment	Presented as a series of individual case summaries? No overall summary of cases and demographics given	No comment
Masterton 1988	Control of an outbreak of group C meningococcal meningitis with a polysaccharide vaccine	Description of management of an outbreak in royal air force recruits at a training camp in England	No comment	No comment	AR not reported, other reporting good	Discussion of weaknesses re. Testing availability in rural areas, strong recommendations
Mohammed 2000	A severe epidemic of meningococcal meningitis in Nigeria, 1996	Description of outbreak and subsequent vaccination campaign	No comment	No comment	AR not reported for first year of outbreak	No comment
Mounkoro 2019	Neisseria meningitidis Serogroup W Meningitis Epidemic in Togo, 2016	Description of the first large menw outbreak in Togo, Africa			Timeline included but difficult to read, AR not reported, focus on description of response over outbreak	No comment
Nnadi 2017	Large Outbreak of Neisseria meningitidis Serogroup C - Nigeria, December 2016-June 2017	Description of outbreak investigation and response	No comment	No comment	Demographics reported on, transmission chain and epidemic curve included	Strong recommendations

STUDY ID	Title	Study details	Introduction	Methods	Results	Discussion
Peltola 1978	Vaccination against meningococcal group A disease in Finland 1974-75	A) epidemiology of meningococcal A epidemic in Finland from 1973-76, specifically the final years & implementation of a mass meningococcal A vaccination program B) description of vaccine effectiveness studies to assess the usefulness of meningococcal A polysaccharide vaccines to prevent mena disease	No comment	No comment	Map included, summary table included, flowchart of decision-making process included	No comment
Perrett 2000	Outbreak of meningococcal disease in Rotherham illustrates the value of coordination, communication, and collaboration in management	Description of outbreak investigation and response	No comment	Unclear that the paper is reporting specifically on a meningococcal C outbreak in 2001, compared to other serotypes/preceding/following years	No comment	No comment
Pivette 2020	Targeted vaccination campaigns of teenagers after two clusters of B invasive meningococcal disease in Brittany, France, 2017	Description of outbreak and subsequent vaccination campaign	No comment	No comment	Epidemic curve included, time, person, place details included but limited. Information on complications not included	No comment
Reintjes 2002	Detection and response to a meningococcal disease outbreak following a youth football tournament with teams from four European countries	Description and assessment of multi-country outbreak of meningococcal disease arising from a youth football tournament	No comment	No comment	No comment	No comment

STUDY ID	Title	Study details	Introduction	Methods	Results	Discussion
Ritscher 2019	Meningococcal serogroup B outbreak response University of Wisconsin-Madison	Summary of meningococcal B vaccination response to a university outbreak	No comment	Presented as pre- and post-vaccination, instead of single outbreaks assessed at diff time periods	Information given in text, no clear summary made in table/figure format	No comment
Round 2001	Public health management of an outbreak of group C meningococcal disease in university campus residents	Carriage & case/control study conducted alongside case investigation	No comment	No comment	Epidemic curve, summary tables, only didn't report on age range and complications - fair for an outbreak of this size	No comment
Rude 2019	Rapid response to meningococcal disease cluster in Foya district, Lofa County, Liberia January to February 2018	Summary of response to cluster of serogroup W disease in Liberia	No comment	No comment	No comment	Focus on operational aspects - missing from other outbreak reports, discussion of evidence re decision making process & difficulty of identifying at-risk groups etc
Santaniello-Newton 2000	Management of an outbreak of meningococcal meningitis in a Sudanese refugee camp in Northern Uganda	Description of outbreak investigation and response	No comment	No comment	Good summary of cases, demographic information included, summary of response included	Strong recommendations for future international outbreaks included
Sekiya 2021	Serogroup B invasive meningococcal disease (IMD) outbreak at a Japanese high school dormitory: An outbreak investigation report from the first IMD outbreak in decades	Epidemiological investigation and response to dormitory outbreak, includes case-control study of carriage	No comment	No comment	No comment	Comment on dearth of evidence for recommendations & need for unified guidance

STUDY ID	Title	Study details	Introduction	Methods	Results	Discussion
Stewart 2013	Public health action and mass chemoprophylaxis in response to a small meningococcal infection outbreak at a nursery in the West Midlands, England	Description of outbreak investigation and response	No comment	No comment	Epidemic curve, case demographics included, age range not reported, AR included	Clear recommendations
Sudbury 2020	Case Manifestations and Public Health Response for Outbreak of Meningococcal W Disease, Central Australia, 2017	Retrospective review of menw cases treated by the Alice Springs Hospital paediatric service during July-December 2017.	No comment	No comment	Presented as two case descriptions, no combined or overall summary of cases given. No AR reported. Good summary table of timeline	Summary of recommendations made
Thabuis 2018	Community outbreak of serogroup B invasive meningococcal disease in Beaujolais, France, February to June 2016: from alert to targeted vaccination	Description of detection and response to 2 clusters of 2 cases	Setting unclear from first read - multiple readthroughs required to ID city of Dax as affected area	No comment	Cases grouped by age, minimal information on complications and hospitalizations included	No clear recommendations made, but not really necessary. Interesting discussion re. Nightclub as shared exposure site.
Chacon-Cruz 2014	An outbreak of serogroup C (ST-11) meningococcal disease in Tijuana, Mexico	Investigation of an outbreak in Tijuana, Mexico	Good summary of setting, population and current public health management	No comment	Epidemic curve included, time, person, place details included and contact between cases reported on. Good summary of public health interventions.	No comment
Iser 2012	Outbreak of Neisseria meningitidis C in workers at a large food-processing plant in Brazil: challenges of controlling disease spread to the larger community	Retrospective description of outbreak in a food processing plant and control measures	No comment	No comment	Epidemic curve included, attack rates reported, time, person, place data recorded in detail	Discussion of limitations of response, summary of future recommendations
Sanogo 2019	A New Sequence Type of Neisseria meningitidis Serogroup C Associated	Retrospective investigation of a large-scale meningococcal C outbreak in Mali	No comment	No comment	Total number of cases difficult to identify, timing of cases unclear, epidemic curve	No comment

STUDY ID	Title	Study details	Introduction	Methods	Results	Discussion
	With a 2016 Meningitis Outbreak in Mali				included, AR not reported	
Sidikou 2016	Emergence of epidemic Neisseria meningitidis serogroup C in Niger, 2015: an analysis of national surveillance data	Description of nmc outbreak in Niger, Africa	No comment	No comment	Somewhat limited description of public health response	No comment

Sheet 2: Outbreak Details

STUDY ID	Outbreak comments	Region	Setting	Serotype	Duration (days)	Season & year	No. cases	Population size	Attack rate (per 100,000)	95% CI lower	95% CI upper	AR Given in study?	Case fatality rate
Bassi 2017		Europe	Educational - University	W	89	Spring 2017	2	1,000.0	200.0	24.23	720.58	N	50.00%
Capitano 2019		North America	Educational - University	B	120	Winter/ spring 2015	7	22,950.8	30.5	12.26	62.83	Y	14.29%
Cartwright 1986	Outbreak still continuing at time of writing - 9 additional cases and 1 fatality recorded in the second quarter of 1986 spread described as moving through discrete community groups w/in districts	Europe	Community - urban	B	1612	N/a 1981	65	301,537.0	21.6	16.64	27.47	Per year	3.00%
Centers for Disease 2012	Two additional students hospitalized with fever and rash but laboratory results cleared them of N. Meningitidis infection	North America	Educational - day-care	C	21	Spring 2010	5	1,850.0	270.3	87.81	629.58	Primary only	40.00%
Chow 2016	Highest proportion (48%) of cases in individuals aged 5-14 years	Africa	Community - rural	C	118	Dry season 2015	6394	2,267,375.9	282.0	275.14	288.99	Y	5.02%
Delisle 2010		Europe	Community - Urban	B	274	N/A 2008	11	123,595.5	8.9	4.44	15.92	Y	9.09%
DeSchrijver 2003		Europe	Community - Urban	C	334	N/A 2001	74	1,637,362.6	4.5	7.7	10.68	Y	9.46%

STUDY ID	Outbreak comments	Region	Setting	Serotype	Duration (days)	Season & year	No. cases	Population size	Attack rate (per 100,000)	95% CI lower	95% CI upper	AR Given in study?	Case fatality rate
Doedeh 2017		Africa	Event - Local	UKN	9	Spring 2017	27	102,389.1	26.4	17.38	38.36	N	37.04%
Flood 2021	2 cases of IMD serotype W, 1 case of meningococcal conjunctivitis	Oceania	Community - Remote	W	62	Summer 2016	2	3,703.7	54.0	6.54	194.91	Y	0.00%
Haelterman 1996		Africa	Refugee Camp	A	62	Dry season 1994	Kibumba: 162 Katale: 137	Kibumba 171,975 Katale 102,468	Kibumba: 94.2 Katale: 133.7	Kibumba: 81.0 Katale: 117.1	Kibumba: 108.92 Katale: 152.04	Y	Kibumba: 8% Katale: 3%
Jacobson 1977		North America	Community - Urban	B	396	N/A 1974	16	80,000.0	20.0	11.43	32.48	Y	31.25%
Kanai 2017		Asia	Event - International	W	4	Summer 2015	6 (2 Scotland, 4 Sweden)	30,769.2	19.5	7.16	42.44	Y	0.00%
Krause 2002		North America	Community - Urban	C	395	N/A 1998	12	33,000.0	36.4	18.79	63.51	Primary only	16.67%
Kriz 1995		Europe	Community - Urban	C	Olomouc: 240 days Bruntal 531 days	Spring 1993	Olomouc: 9 Bruntal: 15	Olomouc 52980 Bruntal 55556	Olomouc 16.99 Bruntal 23.40	Olomouc: 7.77 Bruntal: 12.46	Olomouc: 32.25 Bruntal: 40.01	Pre--vacc only	UKN

STUDY ID	Outbreak comments	Region	Setting	Serotype	Duration (days)	Season & year	No. cases	Population size	Attack rate (per 100,000)	95% CI lower	95% CI upper	AR Given in study?	Case fatality rate
Kushwaha 2010	Focal outbreak consisted of 10 cases over 19 days, followed by further sporadic cases up until may. Clustering observed around shared training establishment.	Asia	Army barracks	A	114	Winter 2006	17	2,976.0	571.2	333.11	913.03	N	11.76%
Masterton 1988		Europe	Army barracks	C	91	UKN 1986	4	1,292.0	309.6	84.42	790.78	N	0.00%
Mohammed 2000		Africa	Community - Rural	A	182	Dry season 1996	109,580	UKN	UKN			N	10.69%
Mounkoro 2019		Africa	Community - Rural	W	176	Dry season 2016	1995	2,531,725.9	78.8	75.38	82.33	Y	6.40%
Nnadi 2017	7,140 cases occurred in Zamfara state, 56 Local Government Areas (lgas) hit alert threshold, 36 met epidemic threshold	Africa	Community - Rural	C	184	Dry season 2016	14,518	UKN	UKN			N	8.00%
Peltola 1978		Europe	Community - Urban	A	1460	N/A 1973	1,527	4,705,091.1	32.5	30.85	34.12	N	UKN
Perrett 2000	Suspected connection of party attendance/drink sharing for initial cases, expanded to friendship group after third case	Europe	Community - urban	C	7	Winter 1998	8	Ukn	Ukn			N	25.00%

STUDY ID	Outbreak comments	Region	Setting	Serotype	Duration (days)	Season & year	No. cases	Population size	Attack rate (per 100,000)	95% CI lower	95% CI upper	AR Given in study?	Case fatality rate
Pivette 2020		Europe	Community - Urban	B	121	Winter/spring 2016	5	78,125.0	6.4	2.08	14.93	Y	0.00%
Reintjes 2002		Europe	Event - International	C	229	Summer/winter 1997	5	1,300.0	384.6	125	895.26	N	40.00%
Ritscher 2019	2 cases notified within days of each other, third case occurred after start of mass-vaccination campaign	North america	Educational - university	B	23	Autumn 2016	3	29,527.6	10.2	2.1	29.69	N	0.00%
Round 2001		Europe	Educational - University	C	47	Autumn 1996	7	750.0	800.0	294.14	1733.08	N	28.57%
Rude 2019		Africa	Community - Rural	W	30	Dry season 2017	9	1,325.2	679.1	311.05	1285.49	Y	44.40%
Santaniello-Newton 2000		Africa	Refugee Camp	A	372	N/A 1994	291	97,000.0	300.0	266.56	336.46	Y	14.43%
Sekiya 2021		Asia	Educational - HS Dorm	B	11	Spring 2011	5	454.5	1100.0	357.75	2545.72	Y	20.00%
Stewart 2013		Europe	Educational - Daycare	B	28	Summer 2010	2	176.0	1704.5	352.91	4900.37	N	0.00%
Sudbury 2020	2 additional menw cases in adults, 1 meny and one nonsubtypeable	Oceania	Community - Remote	W	153	Spring 2017	24	220,183.5	10.9	6.98	16.22	Y	0.00%
Thabuis 2018		Europe	Community - Urban	B	19	Spring 2016	4	17,777.8	22.5	6.13	57.6	Y	0.00%
Chacon-Cruz 2014		North America	Community - Urban	C	59	Winter 2013	19	1,775,700.9	1.1	0.0644	0.167	Y	36.80%

STUDY ID	Outbreak comments	Region	Setting	Serotype	Duration (days)	Season & year	No. cases	Population size	Attack rate (per 100,000)	95% CI lower	95% CI upper	AR Given in study?	Case fatality rate
Iser 2012	Majority of cases directly associated (workers at) or indirectly associated (contacts of workers) with food processing plant	South america	Organisational	C	147	Dry season 2008	16	133,333.3	12.0	0.0686	0.195	Y	31.00%
Sanogo 2019		Africa	Community - Rural	C	58	Dry season 2016	39	215,827.3	18.1	0.128	0.247	N	15.38%
Sidikou 2016		Africa	Community - Rural	C	180	Dry season 2015	9367	18,511,857.7	50.6	49.57	51.62	Y	5.90%

Sheet 3: Response Details

STUDY ID	Existing public health measures/Protection	Description of public health response	No. contacts receiving antibiotics	No. contacts vaccinated	Community vaccination	Recommendations/lessons learnt
Bassi 2017	Notifiable, contact tracing conducted immediately after notification. Vaccination and chemoprophylaxis of close contacts recommended, menacwy vaccine available in france at this time	Contact tracing, vaccination & chemoprophylaxis of close contacts, university vaccination campaign after second case regional public health authority organised wide-spread vaccination campaign after the second case. Two rounds of vaccination organised between 1-9 june, total of 186 students vaccinated (out of ~350 summer students, ~1,000 university students overall).	32 recommended	Case 1: 6/17 received vaccine who were recommended case 2: 3/8 received vaccine who were recommended (5 vaccinated previously)	186	No clear epidemiological link between cases - indicates bacteria was spread through asymptomatic carriers w/in university community despite chemoprophylaxis. Comment re. Strain lineage - appears to be highly virulent & transmissible uncommon presentation of second case (gi symptoms)

STUDY ID	Existing public health measures/Protection	Description of public health response	No. contacts receiving antibiotics	No. contacts vaccinated	Community vaccination	Recommendations/lessons learnt
Capitano 2019	Standard protocol of identification and notification of contacts, chemo prophylaxis and university-wide communication campaigns implemented for each case. Planning meetings held after case 2 met cdc threshold for outbreak after third case (3 confirmed or probable cases within the same serogroup within 3months with an attack rate of 10 cases per 100,000) but was not declared an outbreak as cases 2 &3 were close contacts outbreak declared after case 4 resulted in fatality, menb-fhbp and menb-4c recently given accelerated fda approval in response to other university outbreaks of menb but not included in any regular vaccination programs at time of outbreak advisory committee on immunization practices recently published recommendations at category b for menb vacc in all individuals aged 16-23 years	Menb-fhp chosen after consultation with local pharmacies & partnership deal to ensure vaccine could be invoiced to insurance (to reduce barriers to vaccination) university & pharmacy-based vaccination clinics run throughout year following outbreak emails sent to students, staff, faculty & parent assosc. Outlining signs & symptoms of menb alongside preventative measures food & gift incentives offered to encourage student vaccination uptake	Ukn	Ukn	14665	Recommendation for ongoing vaccination programs for incoming students (instead of a reactive campaign)

STUDY ID	Existing public health measures/Protection	Description of public health response	No. contacts receiving antibiotics	No. contacts vaccinated	Community vaccination	Recommendations/lessons learnt
Cartwright 1986	Notification at time of outbreak limited to cases with meningitis, 11% (7/65) cases presented as septicaemic without meningitis - not notifiable. Of the notifiable cases only 57% were notified no definable closed community available so mass-prophylaxis and swabbing (carriage testing) were not conducted however some swabbing showed a low carriage indicating either high virulence & low transmissibility or low virulence and high transmissibility w/ a low carriage duration, no vaccine available at time of outbreak	Informal notification system established between hospital staff, laboratory staff and advisory group kissing and household contacts for each case were given rifampicin chemoprophylaxis on confirmation of diagnosis gps recommended to give antibiotics to any suspected cases before arranging hospital admission - only recorded for 6 cases	Ukn	N/a	N/a	Recommendation that all meningococcal disease be notifiable (even in absence of meningitis) suggestion of a link between lab and public health staff to assist with ease of reporting recommendation that all isolates be serotyped to monitor epidemiology of disease
Centers for Disease 2012	Notifiable, surveillance conducted and chemoprophylaxis offered to all close contacts after 4 cases notified within 48 hours outbreak control measures were initiated, existing vaccination available for serotype C, majority of cases were between 5-7 years and not considered at risk so vaccination is not routinely recommended all five cases had not been previously vaccinated	Mass chemoprophylaxis initiated after the notification of 4 cases within 48 hours - initially targeted at 443 elementary students, 50 faculty & case close contacts intramuscular ceftriaxone chosen for ease of delivery and single-dose requirement after additional deaths and notifications eligibility for chemoprophylaxis extended to older students - 400 additional	1063		1459	Mass chemoprophylaxis effective when promptly delivered - vaccination was only recommended when cases were starting to appear outside the initial at-risk group considerations re. Funding - state funds only covered 25% of the vaccines purchased - ACIP and Vaccines For Children (VCF) funds were used to purchase the majority of the rest of the doses

STUDY ID	Existing public health measures/Protection	Description of public health response	No. contacts receiving antibiotics	No. contacts vaccinated	Community vaccination	Recommendations/lessons learnt
		contacts after notification of a case in a high-school student classes & extracurriculars were cancelled & mass vaccination recommended for all students, faculty and staff in the district				
Chow 2016	Notifiable, active surveillance, vaccination and chemoprophylaxis recommended for contacts, existing menafrivac campaign in region (meningococcal A conjugate) 104 cases (2%) recorded receiving menacwy previously during the reactive vaccination campaign	MSF-supported mass vaccination campaign held in weeks 9, 11 &16 in Kebbi; 12,13,10 in Sokoto additional vaccination round reported in Kebbi state, but not reported on here. Second round of vaccination reported on in Sokoto state, also not reported on here.	UKN	UKN	>140,000 (first round) > 82,000 (second round)	Increased prevalence of mencwyx after menafrivac rollout, needs ongoing surveillance/and similar national rollout of a menc conjugate vaccine to prevent future outbreaks. Cultural considerations to vaccine uptake - Muslim Hausa communities may have been affected by vaccinee-vaccinator gender differences and the cultural requirement for male head-of-household consent to women being vaccinated. Environmental considerations to future outbreaks - dry season peak & decline in cases with onset of rainy season - similar pattern to prev outbreaks.

STUDY ID	Existing public health measures/Protection	Description of public health response	No. contacts receiving antibiotics	No. contacts vaccinated	Community vaccination	Recommendations/lessons learnt
Delisle 2010	Notifiable, ongoing surveillance, chemoprophylaxis of close contacts recommended, no universal menb vaccine available, at the discretion of the responders to recommend, not included in routine vaccination	Enhanced surveillance in region chemoprophylaxis of contacts carried out nightclub staff (n=10) identified as a possible transmission vector & also given chemoprophylaxis vaccination decided against due to the nature of the outbreak open population meant mass-chemoprophylaxis was also not implemented gps and hospital staff in region warned, local media used to educate public	UKN	UKN	N/A	Chemoprophylaxis of nightclub workers seemed to curb the spread, but reappearance of cases afterwards suggests ongoing community transmission advanced surveillance did catch 2 more cases occurring after the epidemic period (in 2010)
DeSchrijver 2003	Notifiable, routine surveillance conducted, vaccine available but not part of routine schedule until Nov 2001	150,000 vaccinations delivered through private sector prior to Nov 2001 post-nov conjugate vaccine that offers protection against meningococcal C added to the infant & childhood vaccination program with catch-up program included	UKN	UKN	UKN	Inclusion of vaccine that offers protection against meningococcal C into infant & childhood schedules

STUDY ID	Existing public health measures/Protection	Description of public health response	No. contacts receiving antibiotics	No. contacts vaccinated	Community vaccination	Recommendations/lessons learnt
Doedeh 2017	IMD not identified until may 8 (after end of outbreak) responded to within 24 hours as a cluster of febrile illness and death, vaccination available but not offered (causative agent not known)	Active case search and contact surveillance initiated by rapid response team, contact tracing conducted and links identified. Contacts were identified and monitored daily cases managed with broad-spectrum supportive therapy as causative agent not identified social mobilization and health promotion team engaged with local community leaders to raise awareness and dispel rumours dead body management team provided safe and dignified burials for decedents	UKN	UKN	N/A	Surveillance and notification system worked as intended - allowed response within 24 hours of notification in spite of causative pathogen not being known case management likely improved survival of patients before diagnosis was known response & subsequent investigation indicate improvements in public health capacities post-ebola outbreak of 2015

STUDY ID	Existing public health measures/Protection	Description of public health response	No. contacts receiving antibiotics	No. contacts vaccinated	Community vaccination	Recommendations/lessons learnt
Flood 2021	Notifiable, epidemic cut-off of 10 cases per 100,000 population, alongside lower epidemic threshold for remote Indigenous Australian populations, NIP funded menacwy vaccine from 2019, approved for use in Australia at time of outbreak but not funded/provided as part of any routine schedule in 2016	Menveo (GSK) used for infants 2-24 months, Nimenrix (Pfizer) & menveo used interchangeably for persons aged 2 years and over. Community vaccination program implemented for all people living in the Ceduna region, communication campaign established with input from community leaders, press releases and media campaigns used to communicate vaccination information and warning symptoms program commences 6 march 2017 and ran until 30 june 207 at various locations within the community	UKN	UKN	3383	Additional cases occurred after vaccination campaign - better coverage necessary to prevent cases from reoccurring in a community setting. Did interrupt transmission in the short term, and likely prevented some further cases from occurring. Data collection on vaccination recipient addresses was poor in some areas but at least 90% of vaccines delivered were given to individuals residing in target area, residents who did not provide an address likely reside in target area regardless/move through are and interact with other residents Program also allowed opportunity for education re menw signs and symptoms, community vaccination is an effective response to an outbreak w/in a geographically confined area Local consultation necessary for success

STUDY ID	Existing public health measures/Protection	Description of public health response	No. contacts receiving antibiotics	No. contacts vaccinated	Community vaccination	Recommendations/lessons learnt
Haelterman 1996	Notifiable epidemic threshold of 15 out of 100,000 cases recommendation of mass vaccination within 4-8 weeks of meeting threshold - vaccine available but protection wanes after ~3 years - no record of previous vaccination at either camp	Home visitors trained in both camps to identify signs of meningitis and responsible for case detection and referral to hospital single dose chloramphenicol injection used to treat all suspected and confirmed cases kibumba: vaccination campaign initiated within 1 month of first case goal to vaccinate all refugees over 6 months of age & vaccine clinics established to achieve this katale: vaccination delayed to over 1 month of first case similar strategy applied	Ukn	Ukn	Kibumba: 121,588 doses (75.9% target pop) katale: 112,354 doses administered	Possible that vaccination campaign did prevent cases in katale according to analysis, however low operational effectiveness (~5.6 cases avoided per 10,000 vaccinations administered) threshold of 15 out of 100,000 cases may be too high, and vaccination needs to be delivered more swiftly active case detection and early treatment may be more effective at responding to and limiting further spread of epidemic imd possibility of routine vaccination on entry to camp worth investigating
Jacobson 1977	Notifiable, chemoprophylaxis recommended for close contacts of cases, no vaccine available for menb at time of outbreak	Case-control questionnaires delivered to case households & household opposite to identify possible risk factors and vectors of transmission after no groupings smaller than community could be identified, mass chemoprophylaxis of community carried out chemoprophylaxis of	4,454 community doses delivered	0	0	First time attempting mass-prophylaxis in an entire community, efficacy still unproven. Any protection derived is temporary, effectiveness will wane over time & will still be vulnerable to broadly circulating strains/admixing

STUDY ID	Existing public health measures/Protection	Description of public health response	No. contacts receiving antibiotics	No. contacts vaccinated	Community vaccination	Recommendations/lessons learnt
		case contacts also conducted				
Kanai 2017	Notifiable in all 3 involved countries, chemoprophylaxis and vaccination of contacts recommended, existing menacwy vaccine available UK program just initiated at time of outbreak not included in routine vaccination in japan UKN re. Sweden not included in routine travel vaccinations	Vaccination and chemoprophylaxis of contacts carried out cross-border communication btwn the three involved countries carried out Japan conducted case investigation - no clonally similar cases found, concluded that a WSJ participant brought the meningococcus with the & spread it among the camp letter sent to ~4,000 WSJ attendees across the UK chemoprophylaxis of all scouts in sweden (~1,900)	53 (scotland)	53 (scotland)	UKN	Rapid communication between countries allowed good dissemination of information & aided with decision making different decisions made re. Mass- chemoprophylaxis (UK decided against, sweden decided for), unclear what impact it had re. Preventing further spread atypical presentation of menw means HC workers need to be aware of differing signs & symptoms decision making needs to occur rapidly & be communicated clearly & quickly to all parties involved

STUDY ID	Existing public health measures/Protection	Description of public health response	No. contacts receiving antibiotics	No. contacts vaccinated	Community vaccination	Recommendations/lessons learnt
Krause 2002	Primary method of control is chemoprophylaxis of close contacts, quadrivalent polysaccharide vaccine available at the time & recommended for use to control outbreaks	Chemoprophylaxis delivered to contacts introduction of mass vaccination campaign after outbreak threshold was reached vaccination campaign initially limited to ages 2-22 in target area but expanded after public pressure	484 (306 close contacts)	Ukn	13,535	Effectiveness of chemoprophylaxis to control community outbreaks under review - limited duration of protection is an ongoing issue if the disease-causing strain persists in the community recommendation for vaccination campaign to me limited to target population to ensure high coverage in the group identified as most at risk
Kriz 1995	Notification mandatory active surveillance conducted by the National Reference Laboratory for all IMD cases chemoprophylaxis recommended for close contacts of cases, vaccination not currently part of any routine immunization scheme in any country at time of outbreak	Decision made to assess the effectiveness of vaccination in preventing further cases olomouc recieved a targeted mass-vaccination campaign (all students - either enrolled in secondary ed/apprenticeships or school/college) were included Bruntal only vaccinated close contacts & those who requested vaccination	UKN	Bruntal: 137	Olomouc: 6191 doses Bruntal: 908	In the district where the mass-vaccination campaign was carried out, the outbreak stopped (olomouc), whereas in Bruntal , the outbreak continued consistent with other findings suggesting that targeted mass-vaccination can prevent community outbreaks from spreading further
Kushwaha 2010	Epidemic threshold of 10 cases per 100,000, no vaccination program but men ACWY vaccination available at the time in the required number of doses	No vaccination offered chemoprophylaxis given to all close contacts of cases and general medical staff close contacts placed under medical surveillance for 10 days rearrangement of army	UKN	N/A	N/A	Routine vaccination of army recruits recommended overcrowding needs to be managed better to avoid increasing the risk of IMD transmission

STUDY ID	Existing public health measures/Protection	Description of public health response	No. contacts receiving antibiotics	No. contacts vaccinated	Community vaccination	Recommendations/lessons learnt
		barracks and sleeping arrangements to minimize impacts of overcrowding on spread of disease				
Masterton 1988	Chemoprophylaxis recommended for management of outbreaks, polysaccharide group A and/or C vaccines newly available at time of outbreak	Chemoprophylaxis offered broadly to dorm mates of the initial cases swabbing conducted to assess carriage of epidemic strain - swabs lost in transit made it impossible to calculate an accurate carriage rate decision to switch to mass vaccination made after the second case (week 4) and targeted at all permanent personnel, extended to all recruits in week 5, vaccination stopped after week 13 when only one carrier was found after swabbing	54		UKN	Chemoprophylaxis offered more broadly than necessary for initial cases, should be restricted to close contacts and confirmed carriers of the disease-causing strain vaccination preferable for the control of outbreaks

STUDY ID	Existing public health measures/Protection	Description of public health response	No. contacts receiving antibiotics	No. contacts vaccinated	Community vaccination	Recommendations/lessons learnt
Mohammed 2000	Notifiable, surveillance protocols in place, recent epidemics in the region epidemic threshold of 15 cases per 100,000 population for two consecutive weeks, previous mass vaccination in in preceding years to outbreak, but waning vaccination levels in the 2 years immediately preceding	Task force established, treatment centres set up in every affected lga early in march oily cloramphinol used for treatment federal task force oversaw vaccine acquisition and delivery - delivered over 22 million doses to states to distribute - 'ped-o-jet' injectors used - risk of hiv/hepatitis transmission when used improperly	Ukn	Ukn	13.4 million	Changes in epidemiological pattern of imd epidemics intervention did reduce the number of cases & help end the epidemic (aided by end of the dry season) single dose oily cloraphenicol shown to be effective treatment inadequate supply of needles & syringes in affected regions - forced reliance on air injection machines, which may have spread other blood-borne illnesses - stressed importance of adequate supply waning vaccination coverage in prev 2 years may have contributed to size of this epidemic - regular country-wide vaccination is needed to prevent similar events

STUDY ID	Existing public health measures/Protection	Description of public health response	No. contacts receiving antibiotics	No. contacts vaccinated	Community vaccination	Recommendations/lessons learnt
Mounkoro 2019	Epidemic threshold = attack rate of 10 out of 100,000 population alert threshold = attack rate of 4 out of 100,000, menafrivac (MACV) phased introduction from 2010 in meningitis belt Togo introduced MACV from 2014 to all individuals ages 1-29 years	Investigation conducted in Dankpen in week 4 - identified nmw as causative agent support provided for establishment of mobile laboratories to provide surveillance & tracking Togolese ministry of health & WHO requested supply of quadrivalent meningococcal vaccine polysaccharide vaccines mass vaccination conducted in districts that crossed the epidemic threshold - target group = all persons aged 2-29 years requests could only be submitted after districts had hit epidemic thresholds, submitted multiple requests from week 6 onwards first campaign conducted from week 8 onwards	UKN	UKN	Coverage: 94% dankpen, bassar, sotouboua districts 100% doufelgou district 101% keran, binah assoli 102% cinkasse 105% kozah	Large, well co-ordinated response to one of the largest recorded nnw outbreaks in the meningitis belt preventative vaccination with a conjugate vaccine instead of reactive would have been more effective at limiting the spread of the epidemic possibly triggered by waning population immunity (prev nmw epidemic was ~10 years prior) late start to vaccination program makes it unclear how much impact vaccination had on the spread of the epidemic, some evidence in districts where the epidemic spread later that it was effective, but other districts did not receive vaccination until after cases had already started declining naturally faster response required to better respond to & control large epidemics of meningococcal disease

STUDY ID	Existing public health measures/Protection	Description of public health response	No. contacts receiving antibiotics	No. contacts vaccinated	Community vaccination	Recommendations/lessons learnt
Nnadi 2017	Alert & epidemic thresholds detailed on p1353, vaccination available, recommended within 4 weeks of crossing epidemic threshold routine mena vaccination in meningitis belt	Mass vaccination initiated in week 8 of outbreak, prioritised to most affected areas (target group = anyone aged 2-29 years) community outreach and education to warn of overcrowding risks & increase vaccine acceptance mobile rapid response teams deployed to affected regions	UKN	UKN	2.5 million doses	Outbreak identification and response hampered by lack of resources (test kits, manpower, transportation services) more rural & remote areas hard to access, less available human resources in the most affected areas outbreak response may have helped control the outbreak but large number of cases & long duration highlight need for more proactive measures evolving regional distribution of serotypes - largest recorded menc outbreak - suggests mena will not always be the most predominant serotype in the region mass vaccination is effective at preventing outbreak spread, but needs to be implemented in a timely and appropriate manner surveillance and outbreak response can only be effective when the capacity to respond is there - capacity needs to be scaled up in order to better respond to future outbreaks of this size

STUDY ID	Existing public health measures/Protection	Description of public health response	No. contacts receiving antibiotics	No. contacts vaccinated	Community vaccination	Recommendations/lessons learnt
Peltola 1978	Notifiable, no existing vaccination program, mena vaccine effectiveness in young children unknown at time of outbreak - studies conducted during outbreak to test effectiveness at preventing disease (study B)	Mass-vaccination trials conducted in young children to assess effectiveness (study B) after studies proved effectiveness of vaccine, mass vaccination programs were rolled out in nov 1975 - feb 1976 (target group = individuals aged 2.5 months-19 years) vaccination rollout repeated again at the end of 1976 no further epidemic-level of cases recorded, so vaccination program ceased (excl. Routine vaccination of armed forces recruits)	UKN	UKN	~1.2 million persons (90% of target group)	Mass vaccination of target groups effective in reducing spread, additional benefit of cost-effectiveness (only 1/4 of the whole population needed vaccination)

STUDY ID	Existing public health measures/Protection	Description of public health response	No. contacts receiving antibiotics	No. contacts vaccinated	Community vaccination	Recommendations/lessons learnt
Perrett 2000	Notifiable, vaccination and chemoprophylaxis recommended for contacts of cases, meningococcal C vaccine available at time of outbreak	Response group organised initial decision to offer chemoprophylaxis and vaccination to all children at the same school to eliminate carriage across friendship groups expanded to non-school friendship groups after the third case (defined as prolonged & social contact incl bottle/glass sharing with any of the three cases) extensive contact tracing & establishment of temporary contact tracing office required to identify & manage contacts media and community outreach conducted to ensure clear, consistent & necessary messaging were reaching the public, local helpline established to respond to general queries	224 (of first three cases)	224 (of first three cases)	UKN	Investigation was assisted by speedy recognition of cases policy decision making was difficult, no formal guidance on bottle/glass sharing in national recommendations & unclear on whether it's a true risk of transmission clear & prompt policy making required for effective PH response news media were essential in communicating message to general public (w/ exception of one factually incorrect article)

STUDY ID	Existing public health measures/Protection	Description of public health response	No. contacts receiving antibiotics	No. contacts vaccinated	Community vaccination	Recommendations/lessons learnt
Pivette 2020	Notifiable, epidemic cut-offs detailed, menb vacc available, used in outbreak response, screening of all menb cases to determine coverage of Baxsero vacc	Community vaccination offered for children and adults at school of initial cases (579 pupils and 86 adults), expanded to all individuals aged between 11-19 after emergence of following two cases (2007 students and 6298 people in the community) public meeting at HS to inform parents, GP options for non-parents. Vacc fully reimbursed by healthcare system, communication campaign established in place of individual invitations to vaccinate	UKN	UKN	3846 (43% coverage) first doses	Higher vaccination coverage in schools vs in community - identify possible issues with access/perceived risk useful summary of community vaccination for future campaigns
Reintjes 2002	Notifiable in each country, completeness of notification considered good some discrepancies in guidelines around management of cases (table 2) contact tracing, chemoprophylaxis recommended for close contacts, vaccination available, recommended in response to community outbreaks	Chemoprophylaxis and contact tracing of each case conducted by country of origin cross-country collaboration occurred largely through ad-hoc phone calls & meeting of the european monitoring group for meningococci (emgm) that happened to occur shortly after the first few cases mass vaccination conducted in one dutch town (n=6,000 residents) after further cases arose individual case	Ukn	Ukn	6,000 (dutch town)	Rapid detection and response to cases was good, aided by unified case definitions and exchange of serotype information international collaboration had no formalized process - did not occur automatically when it was revealed that cases had attended an international competition formal network for meningococcal disease management needed across all of europe, unified recommendations for case & contact management also needed

STUDY ID	Existing public health measures/Protection	Description of public health response	No. contacts receiving antibiotics	No. contacts vaccinated	Community vaccination	Recommendations/lessons learnt
		responses detailed in table 1				
Ritscher 2019	Notifiable no specified mass-vaccination plan at the university prior to outbreak but existing emergency committee students encouraged to submit vaccination history to the university, less than 3% of the student cohort had been previously vaccinated against menb, 2 meningococcal vaccines available but vaccination only recommended for high-risk groups (not included in any existing routine schedules at time of outbreak)	Mass vaccination campaign initiated targeting undergraduate students aged 25 & under vaccine provided by DOH immunization program and CDC vaccine outbreak set-aside fund	UKN	UKN	20,440 in-clinics, 496 through student health services	Removal of cost & insurance hurdles massively increased uptake 34% of students who received first dose recorded as receiving second dose as of 1 oct 2017 (Bexsero® is a 2-dose program), potential under-estimation inter-organizational cooperation essential for successful implementation of the campaign

STUDY ID	Existing public health measures/Protection	Description of public health response	No. contacts receiving antibiotics	No. contacts vaccinated	Community vaccination	Recommendations/lessons learnt
Round 2001	Notifiable, vaccination not recommended at time of outbreak chemoprophylaxis recommended for close contacts (kissing & household-like), vaccination available but no program at time of outbreak	Outbreak control team set up after case 4/7 information sent out to students and staff via email, noticeboards & student union, helpline established for communication 500mg ciprofloxacin given to all but 4 of the 750 residents of the hall, & all guests who stayed overnight in the previous 2 weeks all students and staff offered serogroup a+c vaccine carriage study conducted	Ukn	Ukn	Ukn	Need earlier recognition of cases & management of contacts - gap between first 2 cases & following was more than 4 weeks, but early intervention may have prevented later cases mass chemoprophylaxis not very effective in community based outbreaks case interviews & contact tracing recommended for all clusters to identify areas of transmission supports recent introduction of mandatory meningococcal c vaccination for all incoming university students in the uk (introduced ~1999) need to harmonize policies for vaccination and outbreak management across europe
Rude 2019	Unexplained cluster of deaths notifiable (two or more people in the same community who die suddenly of unknown or infectious cause after suffering similar symptoms) surveillance and active case search protocols well established integrated disease surveillance and response system, meningococcal W vaccine not available in this country at time of outbreak	Contact tracing and active case searching conducted chemoprophylaxis of contacts delivered vaccine not given as outbreak was small & vaccine not available mass-chemoprophylaxis conducted in some community groups (health workers & none-contact residents) outreach with local leaders & religious authorities conducted safe burials conducted after the second death	233 (+ 103 health workers & 843 none-contact community members)	0	0	Rapid response to cluster (<48 hours) led to good management earlier recognition of septicaemic type (IMD without meningitis) could have improved case outcomes lack of testing materials to confirm all cases, unable to take CSF samples better community health services & recognition of IMD could have also improved case outcomes prompt community engagement & outreach essential to limit transmission rapid prophylaxis helped prevent further spread of disease

STUDY ID	Existing public health measures/Protection	Description of public health response	No. contacts receiving antibiotics	No. contacts vaccinated	Community vaccination	Recommendations/lessons learnt
		infection control measures implemented (hand washing stations & education sessions)				
Santaniello-Newton 2000	Ongoing surveillance and epidemic threshold of more than 1 case per 100,000 population per week, vaccination program for incoming refugees covering strains A+C 129 cases knew their vaccination status, 9 had been vaccinated more than 3 years prior and 85 had been vaccinated less than three years prior	Isolation ward established mass vaccination campaign initiated second mass immunization campaign run after second wave of the epidemic	UKN	UKN	37,547 in the first round, 5,002 in the second round	Vaccine failure may be due to limited protection and/or improper administration mass vaccination campaign shown to be effective by rapid drop in incidence after the first wave of vaccination second wave likely due to mass-influx of refugees in may-june, due to famine & other epidemics & inability to vaccinate newcomers en-masse
Sekiya 2021	Notifiable, no existing country guidelines at time of outbreak, no menb vaccine licensed in japan at time of outbreak	Enhanced surveillance, contact tracing and management based on UK guidelines no vaccination campaign initiated as menb not licenced in Japan at time of outbreak	UKN	N/A	N/A	No national public health guidelines currently exist, unclear why there have been no outbreaks until now, recommend that guidelines should be developed for future outbreaks high-risk communities like dorms need more active surveillance - carriage study suggests that

STUDY ID	Existing public health measures/Protection	Description of public health response	No. contacts receiving antibiotics	No. contacts vaccinated	Community vaccination	Recommendations/lessons learnt
						proliferation of virulent strains is possible through populations
Stewart 2013	Notifiable, outbreak threshold of "two or more cases of meningococcal disease (of the same serogroup) occurring in the nursery within four weeks of disease confirmation on aug 23rd 2010" recommendation for chemoprophylaxis of close contacts & mass prophylaxis in organizational settings, no vaccine for meningococcal B at time of outbreak	Mass chemoprophylaxis of nursery staff/attendees who had attended or worked at the nursery from 10-23rd august 2010 no indication for mass vaccination (& no available vaccine) medical staff made available on-site to dispense scripts & provide counselling GP clinics in region notified	4 household contacts, 173 childcare recommended (129 scripts filled)	0	0	Prompt recognition of cases necessary to react, mass prophylaxis most effective when rapidly implemented unable to identify specific at-risk group so all staff & attendees were prescribed antibiotics suggest that mass prophylaxis did reduce carriage & prevent further cases, but research evidence is limited limited by timing - second case occurred just before a bank holiday & there was a delay in presentation & confirmation of diagnosis research suggests significant benefit from giving chemoprophylaxis to all contacts of nursery cases, even when there is only a small number of cases

STUDY ID	Existing public health measures/Protection	Description of public health response	No. contacts receiving antibiotics	No. contacts vaccinated	Community vaccination	Recommendations/lessons learnt
Sudbury 2020	Notifiable, epidemic thresholds, vaccination available but not included in schedule vaccination and chemoprophylaxis recommended for close contacts	Contact tracing, advanced surveillance community vaccination program initiated in early oct 2017, provided to all persons 1-19 years in the region. Menacyw replaced menc vacc in nt infant schedule as of dec 1 2017 febrile protocol initiated - any patients under the age of 19 with a fever managed as if they had imd until proven otherwise by pcr/culture testing - further diagnostics carried out as clinically advised (approx 649 patients managed under fever protocol)	465	Ukn	81% coverage for indigenous pop, 49% coverage non-indigenous	25% of patients had atypical manifestations (all under 7 years of age) only one patient required transfer to tertiary centre maximum length of time between detection and initial antibiotic treatment was 55hrs successful management of a rapid developing & unpredictable disease in a remote, low density & disadvantaged community fever protocol was effective at managing early cases immediately without waiting for pcr results (which would allow disease to progress) but may be more resource-intensive in a more densely populated setting

STUDY ID	Existing public health measures/Protection	Description of public health response	No. contacts receiving antibiotics	No. contacts vaccinated	Community vaccination	Recommendations/lessons learnt
Thabuis 2018	Notifiable, chemoprophylaxis and vaccination recommended for close contacts of cases epidemic threshold of at least three cases within 3 months caused by the same strain, occurring without direct contact in the same community, with an incidence rate above 10 cases per 100,000 population recommendation for mass-vaccination within community if epidemic threshold is hit, menb vaccine available but not included in any routine schedule	Close contacts received chemoprophylaxis enhanced surveillance in region for the year following the outbreak mass-vaccination initiated after epidemic threshold hit & school community was identified vaccination program targeted all people aged 2 months - 24 years who lived, worked, studied or otherwise inhabited the epidemic area initial vaccination period 5 april - june 24, second period 1 june - 30 sep local news outlets and community leader engagement used to communicate messages & co-ordinate general public	UKN	UKN	4,062 (2,222 first doses, 1,840 second doses)	First Bexsero® vaccination campaign in France recorded low vaccine uptake (47% first dose, 40% second dose) could be mitigated in future outbreaks by emphasising the threat of transmission & reassuring re. Vaccine safety and efficacy
Chacon-Cruz 2014	National case load lower than 2 cases per year. Active surveillance for imd limited to general hospital of tijuana but passive surveillance is conducted in the rest of the country. Notifiable and considered endemic in children within tijuana. Meningococcal vaccine not included in any national schedule	No vaccination offered, chemoprophylaxis offered to all identified contacts, education campaign promoting avoiding crowded spaces, not sharing drinks and not smoking	1430	0	N/a	Active surveillance within multiple hospitals, consideration of vaccination in children, especially given proven endemicity of disease in children

STUDY ID	Existing public health measures/Protection	Description of public health response	No. contacts receiving antibiotics	No. contacts vaccinated	Community vaccination	Recommendations/lessons learnt
Iser 2012	Notifiable, no existing vaccination program at time of outbreak, Brazilian ministry of health defines outbreaks as relative to prev years case numbers, CDC defines outbreak as three cases caused by the same serogroup <= 3 months apart in persons without direct contact within a defined population (OR attack rate >10 per 100,000) meningococcal polysaccharide (A+C) vaccine approved for use in outbreak situations	Household contacts offered chemoprophylaxis on 19 August decision made to vaccinate plant workers (10,012)	UKN	UKN	9,200 plant workers	No further cases occurred in plant workers post-vaccination, but additional cases (n=4) occurred within the municipality within 2 months of vaccination program. All but one had some contact with plant workers, but not all were household contacts. Authors discuss difficulty of identifying/restricting target population and concern of ongoing community transmission of disease. Routine meningococcal C vaccination adopted in brazil post-2010
Sanogo 2019	WHO epidemic threshold of 10/100,000 one of the ten initial health districts supported by bill & melinda gates foundation to reinforce case-based meningitis surveillance. Widespread vaccination (80%) coverage of population under 29 with previous polysaccharide AC vaccine in 2008	Reactive vaccination in weeks 20-11 of the epidemic (28 feb-12mar)	UKN	UKN	50998	Authors highlight need for better case finding and sampling facilities (unable to obtain samples from all suspected cases) also id limitations re. Polysaccharide vaccines wrt long term coverage and immune response in children
Sidikou 2016	Notifiable, nationwide enhanced surveillance - case level data collected and transmitted weekly through line listings. Who alert (3-9 cases per 100,000) and epidemic thresholds (>10 cases per 100,000).	Reactive vaccination campaign initiated in week 13, continued until week 16, hampered by global shortages of vaccine doses and majority of doses avaliable in june - after peak of epidemic.	Ukn	Ukn	1.4 million doses made avaliable (619,435 polysaccharide doses given, 188,129 conjugate	Authors note faster transmission/lateness of season for meningococcal outbreak, comment on incompleteness of case outcomes and difficulty of ongoing prevention given limited avaliability of affordable conjugate vaccines. Emphasise importance of case-level

STUDY ID	Existing public health measures/Protection	Description of public health response	No. contacts receiving antibiotics	No. contacts vaccinated	Community vaccination	Recommendations/lessons learnt
	Meningococcal a vaccination but not c	Vaccination limited to 2-15 or 2-19 years, instead of full age group at risk (2-29 years)			vaccine doses given)	surveillance and improving laboratory confirmation capacity for more informed response

APPENDIX F – Supplement 3: Additional references

Bassi, C, Taha, MK, Merle, C, Hong, E, Levy-Bruhl, D, Barret, AS & Mounchetrou Njoya, I 2017, 'A cluster of invasive meningococcal disease (IMD) caused by Neisseria meningitidis serogroup W among university students, France, February to May 2017', *Euro Surveill*, vol. 22, no. 28, Jul 13.

Bozio, CH, Vuong, J, Dokubo, EK, Fallah, MP, McNamara, LA, Potts, CC, Doedeh, J, Gbanya, M, Retchless, AC, Patel, JC, Clark, TA, Kohar, H, Nagbe, T, Clement, P, Katawera, V, Mahmoud, N, Djingarey, HM, Perrocheau, A, Naidoo, D, Stone, M, George, RN, Williams, D, Gasasira, A, Nyenswah, T, Wang, X, Fox, LM & Liberian Meningococcal Disease Outbreak Response Team 2018, 'Outbreak of Neisseria meningitidis serogroup C outside the meningitis belt-Liberia, 2017: an epidemiological and laboratory investigation', *Lancet Infect Dis*, vol. 18, no. 12, Dec, pp. 1360-1367.

Capitano, B, Dillon, K, LeDuc, A, Atkinson, B & Burman, C 2019, 'Experience implementing a university-based mass immunization program in response to a meningococcal B outbreak', *Hum Vaccin Immunother*, vol. 15, no. 3, pp. 717-724.

Cartwright, KA, Stuart, JM & Noah, ND 1986, 'An outbreak of meningococcal disease in Gloucestershire', *Lancet*, vol. 2, no. 8506, Sep 6, pp. 558-561.

Centers for Disease Control and Prevention 2012, 'Outbreak of meningococcal disease associated with an elementary school -- Oklahoma, March 2010', *MMWR Morb Mortal Wkly Rep*, vol. 61, no. 13, Apr 6, pp. 217-221.

Chacon-Cruz, E, Espinosa-De Los Monteros, LE, Navarro-Alvarez, S, Aranda-Lozano, JL, Volker-Soberanes, ML, Rivas-Landeros, RM, Alvelais-Arzamendi, AA & Vazquez, JA 2014, 'An outbreak of serogroup C (ST-11) meningococcal disease in Tijuana, Mexico', *Ther Adv Vaccines*, vol. 2, no. 3, May, pp. 71-76.

Chow, J, Uadiale, K, Bestman, A, Kamau, C, Caugant, DA, Shehu, A & Greig, J 2016, 'Invasive Meningococcal Meningitis Serogroup C Outbreak in Northwest Nigeria, 2015 - Third Consecutive Outbreak of a New Strain', *PLoS currents*, vol. 8, Jul 7.

De Schrijver, K & Maes, I 2003, 'An outbreak of serogroup C meningococcal disease in the province of Antwerp (Belgium) in 2001-2002', *Eur J Epidemiol*, vol. 18, no. 11, pp. 1073-1077.

Delisle, E, Larrieu, S, Simoes, J, Laylle, N, De Pommerol, M, Taha, MK, Termignon, JL & Parent du Chatelet, I 2010, 'Community outbreak of group B meningococcal disease in southwest France--December 2008 to September 2009', *Euro Surveill*, vol. 15, no. 37, Sep 16, pp. 1-5.

Doedeh, J, Frimpong, JA, Yealue, KDM, 2nd, Wilson, HW, Konway, Y, Wiah, SQ, Doedeh, V, Bao, U, Seneh, G, Gorwor, L, Toe, S, Ghartey, E, Larway, L, Gweh, D, Gonotee, P, Paasewe, T, Tamatai, G, Yarkeh, J, Smith, S, Brima-Davis, A, Dauda, G, Monger, T, Gornor-Pewu, LW, Lombeh, S, Naiene, J, Dovillie, N, Korvayan, M, George, G, Kerwillain, G, Jetoh, R, Friesen, S, Kinkade, C, Katawera, V, Amo-Addae, M, George, RN, Gbanya, MZ & Dokubo, EK 2017, 'Rapid Field Response to a Cluster of Illnesses and Deaths - Sinoe County, Liberia, April-May, 2017', *MMWR Morb Mortal Wkly Rep*, vol. 66, no. 42, Oct 27, pp. 1140-1143.

Flood, L, McConnell, M, Molchanoff, L, Dodd, Z, Sisnowski, J, Fidock, M, Miller, T, Borresen, K, Vogt, H & Lane, A 2021, 'Lessons from a community vaccination programme to control a meningococcal disease serogroup W outbreak in remote South Australia, 2017', *Western Pac Surveill Response J*, vol. 12, no. 1, Jan-Mar, pp. 26-31.

Haelterman, E, Boelaert, M, Suetens, C, Blok, L, Henkens, M & Toole, MJ 1996, 'Impact of a mass vaccination campaign against a meningitis epidemic in a refugee camp', *Trop Med Int Health*, vol. 1, no. 3, Jun, pp. 385-392.

Iser, BP, Lima, HC, de Moraes, C, de Almeida, RP, Watanabe, LT, Alves, SL, Lemos, AP, Gorla, MC, Goncalves, MG, Dos Santos, DA & Sobel, J 2012, 'Outbreak of Neisseria meningitidis C in workers at a large food-processing plant in Brazil: challenges of controlling disease spread to the larger community', *Epidemiol Infect*, vol. 140, no. 5, May, pp. 906-915.

Jacobson, JA, Chester, TJ & Fraser, DW 1977, 'An epidemic of disease due to serogroup B Neisseria meningitidis in Alabama: report of an investigation and community-wide prophylaxis with a sulfonamide', *J Infect Dis*, vol. 136, no. 1, Jul, pp. 104-108.

Kanai, M, Kamiya, H, Smith-Palmer, A, Takahashi, H, Hachisu, Y, Fukusumi, M, Saitoh, T, Ohnishi, M, Sunagawa, T, Matsui, T & Oishi, K 2017, 'Meningococcal disease outbreak related to the World Scout Jamboree in Japan, 2015', *Western Pac Surveill Response J*, vol. 8, no. 2, Apr-Jun, pp. 25-30.

Krause, G, Blackmore, C, Wiersma, S, Lesneski, C, Gauch, L & Hopkins, RS 2002, 'Mass vaccination campaign following community outbreak of meningococcal disease', *Emerg Infect Dis*, vol. 8, no. 12, Dec, pp. 1398-1403.

Kriz, P, Vlckova, J & Bobak, M 1995, 'Targeted vaccination with meningococcal polysaccharide vaccine in one district of the Czech Republic', *Epidemiol Infect*, vol. 115, no. 3, Dec, pp. 411-418.

Kushwaha, AS, Aggarwal, SK & Arora, MM 2010, 'Outbreak of Meningococcal Infection amongst Soldiers Deployed in Operations', *Med J Armed Forces India*, vol. 66, no. 1, Jan, pp. 4-8.

Masterton, RG, Youngs, ER, Wardle, JC, Croft, KF & Jones, DM 1988, 'Control of an outbreak of group C meningococcal meningitis with a polysaccharide vaccine', *J Infect*, vol. 17, no. 2, Sep, pp. 177-182.

Mohammed, I, Iliyasu, G & Habib, AG 2017, 'Emergence and control of epidemic meningococcal meningitis in sub-Saharan Africa', *Pathog Glob Health*, vol. 111, no. 1, Feb, pp. 1-6.

Mounkoro, D, Nikiema, CS, Maman, I, Sakande, S, Bozio, CH, Tall, H, Sadji, AY, Njanpop-Lafourcade, BM, Sibabe, A, Landoh, DE, Abodji, EO, Kodjo, A, Tamekloe, TA, Essoh, TA, Maba, DW, Gessner, BD & Moisi, JC 2019, 'Neisseria meningitidis Serogroup W Meningitis Epidemic in Togo, 2016', *J Infect Dis*, vol. 220, no. 220 Suppl 4, Oct 31, pp. S216-S224.

Nnadi, C, Oladejo, J, Yennan, S, Ogunleye, A, Agbai, C, Bakare, L, Abdulaziz, M, Mohammed, A, Stephens, M, Sumaili, K, Ronveaux, O, Maguire, H, Karch, D, Dalhat, M, Antonio, M, Bita, A, Okudo, I, Nguku, P, Novak, R, Bolu, O, Shuaib, F & Ihekweazu, C 2017, 'Large Outbreak of Neisseria meningitidis Serogroup C - Nigeria, December 2016-June 2017', *MMWR Morb Mortal Wkly Rep*, vol. 66, no. 49, Dec 15, pp. 1352-1356.

Peltola, H 1978, 'Group A meningococcal polysaccharide vaccine and course of the group A meningococcal epidemic in Finland', *Scand J Infect Dis*, vol. 10, no. 1, pp. 41-44.

Peltola, H, Makela, PH, Elo, O, Pettay, O, Renkonen, OV & Sivonen, A 1976, 'Vaccination against meningococcal group A disease in Finland 1974-75', *Scand J Infect Dis*, vol. 8, no. 3, pp. 169-174.

Perrett, K, al-Wali, W, Read, C, Redgrave, P & Trend, U 2000, 'Outbreak of meningococcal disease in Rotherham illustrates the value of coordination, communication, and collaboration in management', *Commun Dis Public Health*, vol. 3, no. 3, Sep, pp. 168-171.

Pivette, M, Taha, MK, Barret, AS, Polard, E, Hautier, MB, Dufour, JB, Faisant, M, King, LA, Antona, D, Levy-Bruhl, D, Tillaut, H, Scanff, A, Morival, C, Aranda Grau, JH, Guillaumot, P & Gagniere, B 2020, 'Targeted vaccination campaigns of teenagers after two clusters of B invasive meningococcal disease in Brittany, France, 2017', *BMC Public Health*, vol. 20, no. 1, Sep 10, p. 1382.

Reintjes, R, Kistemann, T, MacLehose, L, McKee, M, Gill, N, Weinberg, J, Schaefer, O, Camaroni, I, Fulop, N & Brand, H 2002, 'Detection and response to a meningococcal disease

outbreak following a youth football tournament with teams from four European countries', *Int J Hyg Environ Health*, vol. 205, no. 4, May, pp. 291-296.

Ritscher, AM, Ranum, N, Malak, JD, Ahrabi-Fard, S, Baird, J, Berti, AD, Curtis, W, Holden, M, Jones, CD, Kind, J, Kinsey, W, Koepke, R, Schauer, SL, Stein, E, Van Orman, S, Ward, BG, Zahner, SJ & Hayney, MS 2019, 'Meningococcal serogroup B outbreak response University of Wisconsin-Madison', *J Am Coll Health*, vol. 67, no. 3, Apr, pp. 191-196.

Round, A, Evans, MR, Salmon, RL, Hosein, IK, Mukerjee, AK, Smith, RW & Palmer, SR 2001, 'Public health management of an outbreak of group C meningococcal disease in university campus residents', *Eur J Public Health*, vol. 11, no. 4, Dec, pp. 431-436.

Rude, JM, Kortimai, L, Mosoka, F, April, B, Nuha, M, Katawera, V, Nagbe, T, Tamba, A, Desmound, W, Mulbah, R, Pierre, F, Onuche, EM, Chukwudi, JO, Talisuna, A, Yahaya, AA, Rajatonirina, S, Nyenswah, T, Dahn, B, Gasasira, A & Fall, IS 2019, 'Rapid response to meningococcal disease cluster in Foya district, Lofa County, Liberia January to February 2018', *Pan Afr Med J*, vol. 33, no. Suppl 2, p. 6.

Sanogo, YO, Guindo, I, Diarra, S, Retchless, AC, Abdou, M, Coulibaly, S, Maiga, MF, Coumare, M, Diarra, B, Chen, A, Chang, HY, Vuong, JT, Acosta, AM, Sow, S, Novak, RT & Wang, X 2019, 'A New Sequence Type of Neisseria meningitidis Serogroup C Associated With a 2016 Meningitis Outbreak in Mali', *J Infect Dis*, vol. 220, no. 220 Suppl 4, Oct 31, pp. S190-S197.

Santaniello-Newton, A & Hunter, PR 2000, 'Management of an outbreak of meningococcal meningitis in a Sudanese refugee camp in Northern Uganda', *Epidemiol Infect*, vol. 124, no. 1, Feb, pp. 75-81.

Sekiya, N, Sunagawa, T, Takahashi, H, Kamiya, H, Yoshino, S, Ohnishi, M, Okabe, N & Taniguchi, K 2021, 'Serogroup B invasive meningococcal disease (IMD) outbreak at a Japanese high school dormitory: An outbreak investigation report from the first IMD outbreak in decades', *Vaccine*, vol. 39, no. 15, Apr 8, pp. 2177-2182.

Sidikou, F, Zaneidou, M, Alkassoum, I, Schwartz, S, Issaka, B, Obama, R, Lingani, C, Tate, A, Ake, F, Sakande, S, Ousmane, S, Zanguina, J, Seidou, I, Nzeyimana, I, Mounkoro, D, Abodji, O, Wang, X, Taha, MK, Moulia-Pelat, JP, Pana, A, Kadade, G, Ronveaux, O, Novak, R, Oukem-Boyer, OOM, Meyer, S & MenAfriNet consortium 2016, 'Emergence of epidemic Neisseria meningitidis serogroup C in Niger, 2015: an analysis of national surveillance data', *Lancet Infect Dis*, vol. 16, no. 11, Nov, pp. 1288-1294.

Smith-Palmer, A, Oates, K, Webster, D, Taylor, S, Scott, KJ, Smith, G, Parcell, B, Lindstrand, A, Wallensten, A, Fredlund, H, Widerstrom, M, McMenamin, J & Imt and investigation team in Sweden 2016, 'Outbreak of Neisseria meningitidis capsular group W among scouts returning from the World Scout Jamboree, Japan, 2015', *Euro Surveill*, vol. 21, no. 45, Nov 10.

Stewart, A, Coetzee, N, Knapper, E, Rajanaidu, S, Iqbal, Z & Duggal, H 2013, 'Public health action and mass chemoprophylaxis in response to a small meningococcal infection outbreak at a nursery in the West Midlands, England', *Perspect Public Health*, vol. 133, no. 2, Mar, pp. 104-109.

Sudbury, EL, O'Sullivan, S, Lister, D, Varghese, D & Satharasinghe, K 2020, 'Case Manifestations and Public Health Response for Outbreak of Meningococcal W Disease, Central Australia, 2017', *Emerg Infect Dis*, vol. 26, no. 7, Jul, pp. 1355-1363.

Thabuis, A, Tararbit, K, Taha, MK, Dejour-Salamanca, D, Ronin, V, Parent du Chatelet, I & Spaccaferri, G 2018, 'Community outbreak of serogroup B invasive meningococcal disease in Beaujolais, France, February to June 2016: from alert to targeted vaccination', *Euro Surveill*, vol. 23, no. 28, Jul.