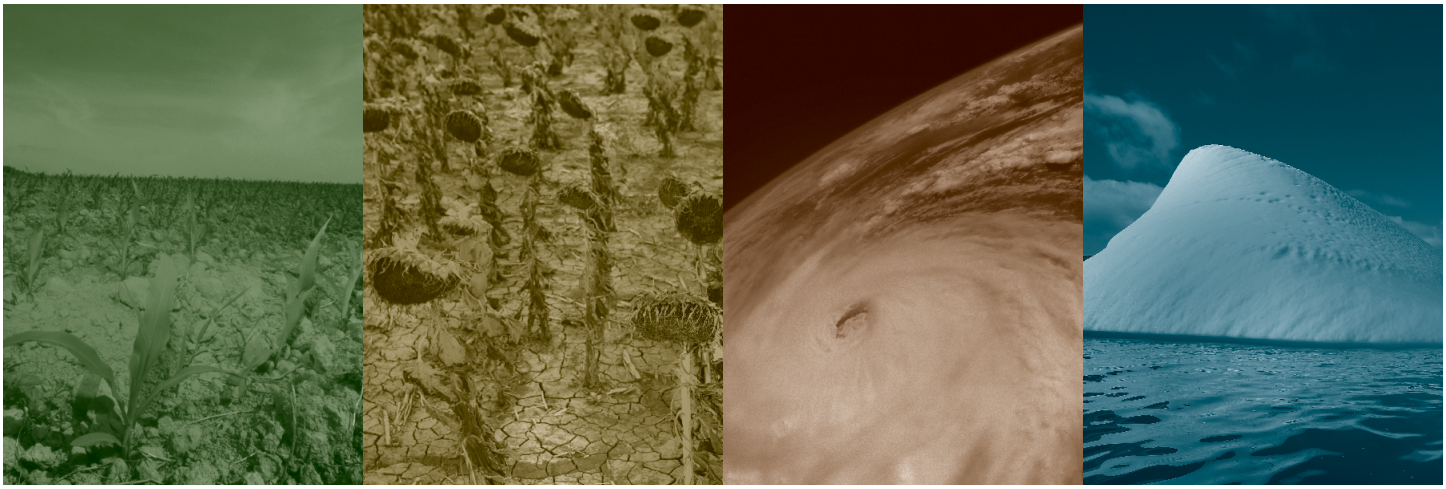
Climate and Health Intervention Assessment

Evidence on Public Health Interventions to Prevent the Negative Health Effects of Climate Change



Climate and Health Technical Report Series

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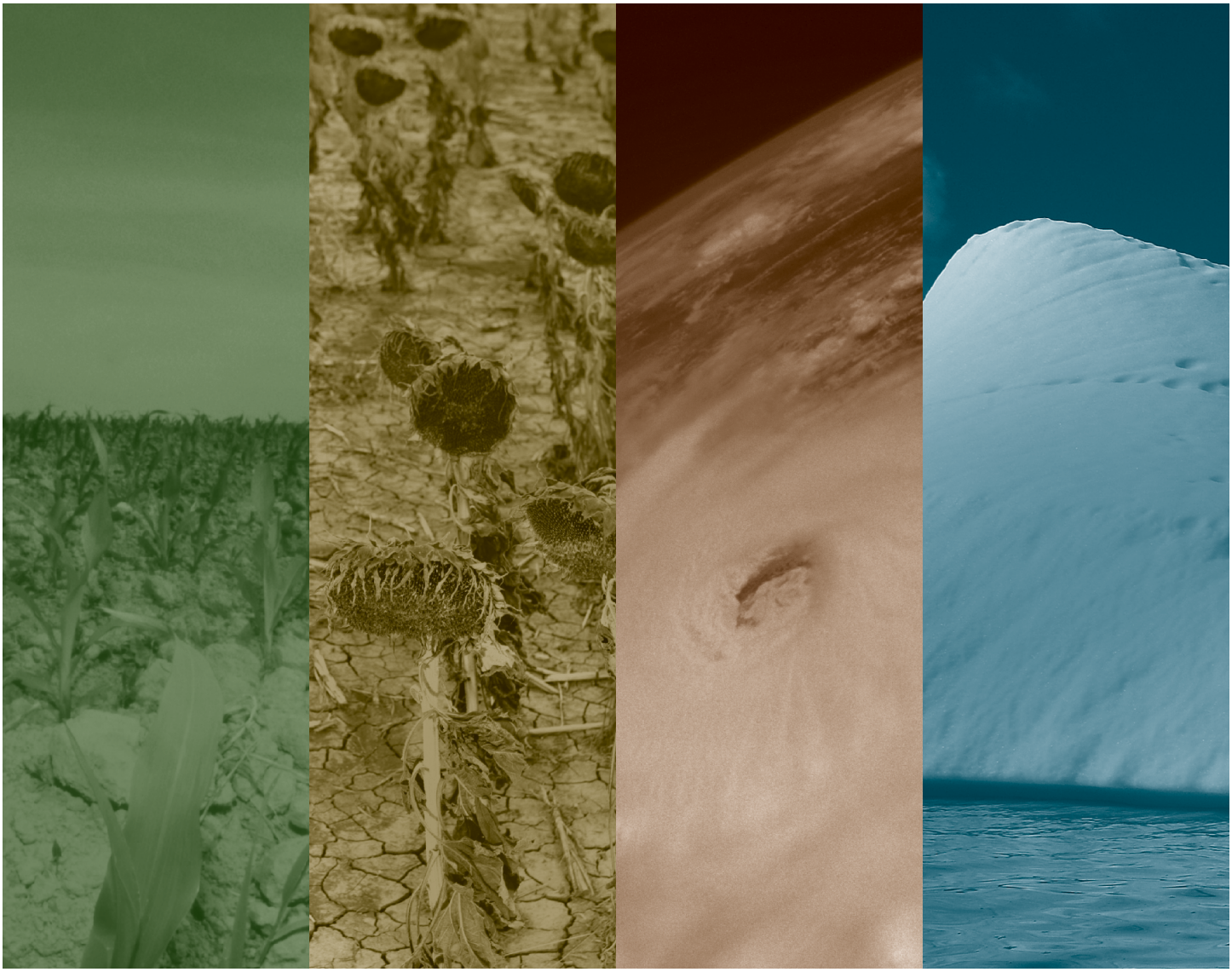

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Contents

Executive Summary

This guide outlines the findings of the Building Resilience Against Climate Effects (BRACE) Midwest/Southeast Collaborative on the evidence of effectiveness of various interventions for reducing the negative health impacts of climate change. This is not intended to be a comprehensive guide of all potential interventions; rather it outlines the evidence found for certain interventions as part of the Midwest/Southeast Collaborative's review of the literature. The findings in this document highlight a subset of potential interventions for select potential climate-related health impacts. It is intended as a general guide, and health departments are encouraged to seek out additional literature and consult with subject matter experts before implementing interventions.

Introduction

Climate change impacts human health and wellbeing. The impacts of climate change, some of which are already underway in the United States, can affect the ability of health departments to protect the population within their jurisdiction. Many potential actions are available to health departments to help to prepare for the negative health effects of climate change. This document outlines one method of assessing evidence of effectiveness regarding health interventions related to climate change adaptation and gives examples of existing evidence for selected interventions.

Evidence is fundamental to sound public health practice. While public health has always been invested in some form of evidence-based practice, commitment to a formal evidence-based approach is one of the central pillars of modern public health and this pillar has borne ever-increasing weight in recent years. Evidence confirms the suspicion of risk, clarifies the relative burden of disease, and helps prioritize needs. Evidence drives causal inference, confirms intervention effectiveness, and clarifies how interventions should be implemented in a variety of settings. Some evidence is born of experience, but increasingly evidence is intentionally developed and systematically assessed.

In the last decade, developing a public health workforce competent in evidence-based public health (EBPH) practice has become a central goal of public health education.[1] EBPH has been defined as the linkage of community preference with the systematic collection, review, and application of scientific evidence to promote population health.[2] A commitment to EBPH requires substantial investment in research and in the synthesis and assessment of this work.

Theorists have identified three primary types of public health evidence.[3–5] The first describes associations between exposures and disease and is used to determine that something should be done to reduce risk. The second type of evidence relates to intervention effectiveness and helps clarify what specific risk reduction measures should be pursued. The third type of evidence relates to evaluation and implementation and helps clarify how risk reduction should be pursued in various community contexts. Each type of evidence has a distinct set of standard measures and typical study designs. These evidence types can be assessed for the health effects of climate change.

Three types of public health evidence for adaptation to climate-related health effects

Type One: Evidence linking climate-sensitive exposures to health outcomes of interest[6]

Type Two: Evidence on effectiveness of interventions

Type Three: Evidence on evaluation and implementation within a community[4,5,7,8]

The discipline's commitment to an evidence-based approach is tested when public health confronts emerging threats. Perhaps more than any other major public health challenge, climate change exemplifies both the potential and the difficulties of an EBPH approach. There is sufficient evidence of harm from climate change to determine that something should be done.[9] Interventions that should be considered to facilitate adaptation in the health sector can sometimes be based on evidence from prior work not necessarily specific to climate change. There is relatively little evidence to characterize, which interventions are most effective to address specific hazards, and little evidence related to implementation. As further evidence of the negative human health impacts of climate change accumulates, the public health community is realizing that the evidence base for climate change adaptation needs considerable expansion.

In the field of climate and health, certain types of evidence are more abundant than others. Type One evidence related to climate change and health is relatively plentiful and the findings are largely consistent: climate change is very likely to have significant net adverse consequences for human health, and climate change mitigation will have significant, immediate health benefits in addition to the avoided impacts of climate change.[10,11] Type Two evidence is, unfortunately, much more scarce, as relatively few studies have evaluated the relative effectiveness of the wide range of interventions that have the potential to blunt the adverse impacts of extreme weather, climate variability, and long-term climate change. Of the three different exposures, there is more evidence related to extreme weather than climate variability or long-term change. Type Three evidence regarding interventions related to climate change is rare, though there is a growing body of evidence related to implementation of mitigation activities and to adaptation in public health broadly speaking.

Given the relative abundance and consistency of type one evidence,[12] the challenge for public health vis-à-vis climate change and health is to develop evidence of intervention effectiveness (Type Two) and implementation (Type Three). This document will focus on evaluating Type Two evidence: effectiveness of interventions.

In evaluating evidence, it is important to consider its volume, consistency and, at the level of individual studies, factors affecting internal and external validity. Internal validity refers to the likelihood that a study produces a true effect estimate, while external validity refers to the confidence with which findings from one setting can be applied to others and the likelihood of significant bias. In general, experimental evidence is considered the most helpful in supporting a causal relationship between the exposure (typically an intervention) and the observed outcome, and it is particularly important when evaluating interventions with the potential for harm. Observational evidence, which is much more common in public health, is typically invested with slightly less weight because of the potential for bias in uncontrolled studies. Ultimately, the strongest evidence of intervention effectiveness is found in systematic meta-analyses, which provide the most precise, robust estimates of effect, showing not just direction but magnitude in weighted summary estimates.[13]

Similarly, when assembling evidence—designing studies to assess levels of harm, determine intervention effectiveness, and factors affecting successful implementation—it is important to consider the same principles in order to generate strong evidence with minimal validity concerns. Comparability is also an

important consideration, starting with outcome metrics. Disability-adjusted life years (DALYs) could be used as the metric of choice for climate change health impacts, given the DALY metric's ability to capture the burden associated with both morbidity and premature mortality.[14–17] This document does not assess outcome metrics, and many of the included studies use a variety of metrics to measure the impact of a specific intervention.

This guide provides an initial assessment of Type Two evidence related to some interventions in the health sector for several specific climate change impacts and health outcomes (see Table 18 in the Appendix). It starts with an overview of how the strength of evidence for each concern was assessed and then progresses to reviewing evidence for specific interventions. It is not intended to be a comprehensive literature assessment of all available interventions. Due to resource limitations, health department priorities, and timeliness of this report, some climate-related events that impact health, such as hurricanes, are not included. In addition, for climate impacts that are included in this document, not all interventions were assessed. For example, the use of asthma inhalers as an intervention to reduce the respiratory impacts of air pollution was not assessed in the "Air Quality and Respiratory Illness" section. The interventions that were assessed by the Midwest/Southeast collaborative are described in detail in the following sections. Mitigation activities (e.g., reduction of greenhouse gas emissions) were not assessed in this review.

Intervention Assessment Examples from the Midwest/Southeast Collaborative

As part of CDC's Building Resilience Against Climate Effects (BRACE) framework,[18,19] state and city health departments assess public health interventions prior to developing and implementing an adaptation plan. A group of state health departments in the Midwest and Southeast, part of the Climate-Ready States and Cities Initiative (CRSCI),[20] collaborated to develop a standard methodology for an intervention assessment and to collect and share information on various potential interventions. Initial work by the New York State Department of Health (NYSDOH) utilized guidelines from the Guide to Community Preventive Services[8] to identify and evaluate published literature on heat interventions. Implementation of the existing intervention assessment methods, which rely on empirical evidence and ample peer-reviewed literature, required more resources than were available for completing the assessment solely by NYSDOH. Thus, NYSDOH shared their initial work with CDC and other BRACE grantees in hopes of developing a more efficient collaborative inter-agency partnership for the review process.

The initial NYSDOH work served as a starting point for the Midwest/Southeast Collaborative to jointly develop a methodology employing a gridded framework to capture and rank key attributes on interventions from the literature. The collaborative consists of the Florida Department of Health, Michigan Department of Health and Human Services, Minnesota Department of Health, North Carolina Department of Health and Human Services, University of Illinois at Chicago School of Public Health, and the Wisconsin Department of Health Services. The Collaborative reviewed several methodological approaches, including an evidence-based public health (EBPH) approach,[7] the CDC's Guide to Community Preventive Services[21] as well as criteria used for the Cochrane review of heat,[22] and ultimately settled on rating guidelines developed for community-health-focused evidence-based decision making by the University of Wisconsin Public Health Institute.[23] The Collaborative applied this framework on reviews of interventions for several categories of climate-related health impacts. Articles published up to mid-2015 were included in the literature review, but additional newer evidence was assessed based on input from subject matter experts. The exposures and outcomes that were evaluated were chosen based on a variety of metrics, including agency priorities and exposures that were identified as relevant and important. Specific methodology and search terms are outlined in each section below. While an attempt was made to cover a spectrum of areas, this document is not intended to be a comprehensive assessment of all interventions for climate-related health impacts. Table 1 below outlines the criteria from What Works for Health that were utilized for this report to rate the strength of evidence for each intervention, using an EBPH framework. The appendix of this document includes a summary of interventions found to have at least some evidence (Table 17), the template used for evaluating each peer-reviewed manuscript (Table 18), and instructions for conducting the assessment and completing the summary table.

RATING	EVIDENCE CRITERIA: AMOUNT AND TYPE	EVIDENCE CRITERIA: QUALITY OF EVIDENCE

Scientifically Supported	• 1 or more systematic review(s), or at least:
	  • 3 experimental studies, or
	  • 3 quasi-experimental studies with matched concurrent comparisons
		• Studies have strong designs
		• Statistically significant positive findings

Some Evidence	• 1 or more systematic review(s), or at least:
	  • 2 experimental studies, or
	  • 2 quasi-experimental studies with matched concurrent comparisons, or
	  • 3 studies with unmatched comparisons or pre-post measures
		• Studies have statistically significant positive findings
		• Compared to 'Scientifically Supported', studies have:
		  • Less rigorous designs
		  • Limited effect(s)

Expert Opinion	• Generally no more than 1 experimental or quasi-experimental study with a matched concurrent comparison, or • 2 or fewer studies with unmatched comparisons or pre-post measures	• Expert recommendation supported by theory, but study limited • Study quality varies, but is often low • Study findings vary, but are often inconclusive
Insufficient Evidence	• Generally no more than 1 experimental or quasi-experimental study with a matched concurrent comparison, or • 2 or fewer studies with unmatched comparisons or pre-post measures	• Study quality varies, but is often low • Study findings vary, but are often inconclusive

Mixed Evidence	• 1 or more systematic review(s), or at least:
	  • 2 experimental studies, or
	  • 2 quasi-experimental studies with matched concurrent comparisons, or
	  • 3 studies with unmatched comparisons or pre-post measures
		• Studies have statistically significant findings
		• Body of evidence inconclusive, or
		• Body of evidence mixed leaning negative

Evidence of Ineffectiveness	• 1 or more systematic review(s), or at least:
	  • 3 experimental studies, or
	  • 3 quasi-experimental studies with matched concurrent comparisons
		• Studies have:
		  • Strong designs
		  • Significant negative or ineffective findings, or
		  • Strong evidence of harm

Table 1: Guidelines for strength of evidence[23]

The results from 14 categories of climate-related health impacts are summarized in this document. Each of these assessments includes background information on the health impact, search methods used, a summary of categories of interventions that were assessed, a description of the evidence base for each type of intervention, and a summary table classifying the effectiveness of the intervention.

1. Air Quality and Respiratory Illness

Asthma is one of the most common chronic disease among children in the US. Millions of children—9.9% of all people under age 15 in the U.S—suffer from asthma.[24] Asthma is a disease that affects your lungs and causes repeated episodes of wheezing, breathlessness, chest tightness, and nighttime or early morning coughing. Asthma is a common reason that children with the condition miss school. Asthma also affects about 7% of all adults in the US. Chronic obstructive pulmonary disease (COPD), which includes emphysema and chronic bronchitis, is the third most common cause of death in US adults, and usually is the result of smoking cigarettes for many years. The symptoms of COPD are similar to those of asthma, but when COPD becomes severe, people who suffer from the condition may require extra oxygen just to walk around.

Both asthma and COPD are worsened by "triggers" that irritate the lungs and cause cough, wheezing, and shortness of breath.[25,26] Ground-level ozone pollution is one of those triggers. On days that ozone levels are higher, more people seek emergency department treatment for asthma and COPD attacks compared to days when ozone levels are lower.[27,28] Ground-level ozone levels are higher on days that are hot and sunny. As our climate gets warmer, ozone levels are expected to increase.[29] This is a very serious concern, since higher ozone means more difficulty breathing for the millions of Americans with asthma, COPD, and other respiratory illnesses.

Many aspects of air pollution can be impacted by climate change. For example, in some regions of the US, wildfires are expected to increase in frequency and magnitude as climate continues to change. Smoke from wildfires increase the number of fine particles in the air, also known as PM2.5 pollution. These very small particles, like ozone, can cause breathing difficulty for people with respiratory disease.[30]

Methods

A systematic literature review was conducted for evidence-based heat interventions to identify relevant literature on preventing asthma attacks that are triggered by air quality. PubMed clinical trials studies were searched using the terms ("asthma" AND "air pollution" AND "prevention") and ("asthma" AND "ozone" AND "prevention"). General searches (as opposed to clinical trial searches) were also conducted using the search terms ("ozone" AND "asthma" AND "prevention"), ("air quality index" AND "asthma" AND "prevention"). After relevant studies were identified, their lists of references were reviewed. Studies of medication treatment trials, tobacco smoke exposure, or those that had as an endpoint the development of sensitization to indoor allergens (such as dust mite, cockroach, dog, or cat allergens) were excluded from subsequent review.

Summary of Interventions

Several interventions that are designed to reduce the impacts of air pollution on respiratory health were reviewed. The interventions assessed in this review can be grouped into three categories:

1. Air quality education and media reporting
2. Local vehicle traffic reduction systems
3. Antioxidant dietary supplementation

This review did not include evaluations of the use of prescription medications (such as asthma inhalers) to reduce the impacts of air pollution. As noted in the list of interventions in Table 2 below, there is evidence that suggests public health benefits of these interventions. The evidence is limited, however because of the small number of studies that have been conducted, and to a lesser degree, inconsistencies in study findings.

INTERVENTION	DESCRIPTION	EFFECTIVENESS
Air quality education and media reporting	Notification of the public via broadcast, web, and social media about elevated levels of air pollutants	Some evidence
Local vehicle traffic reduction systems	Limiting vehicle access to city centers in order to improve local air quality	Some evidence
Antioxidant dietary supplementation	Administration of vitamins C or E to reduce lung inflammation triggered by ozone.	Some evidence

Table 2: Summary of Interventions for air quality and respiratory illness

1.1 Air Quality Education and Media Reporting

Systems to notify the public about impaired air quality are in place. The best known of these is the US Environmental Protection Agency (EPA) Air Quality Index (AQI).[31] The AQI value for a location on a given day is based on local concentrations of five of the EPA's "Criteria Air Pollutants." These are ground-level ozone, particulate matter, nitrogen dioxide, sulfur dioxide, and carbon monoxide. AQI ranges from 0 (best) to 600 (worst), and is divided into six categories based on increasing values.

Each category has a descriptive "level of concern" and a color code. Each color category has associated health protection information. The AQI is often the basis for "ozone action days" and other notifications made through news media and social media. Current AQI values for a location can be found at www.airnow.gov[31] or through many online weather services.

Several studies have described the educational efforts that focus on the AQI, and in a small number of those, the impacts of AQI education. Research has evaluated objective measures of pollutant exposure for scenarios that could be considered baseline behavior (commuting by car, spending the evening outdoors) and, when air quality is poor, alternative behaviors (such as taking public transportation and spending the evening indoors). A research team[32] found that exposure to some pollutants (fine particulate matter, ultrafine particles, and volatile organic compounds) decreased during the alternative daytime behaviors, but exposure to ultrafine particles and volatile organic compounds increased substantially during the additional time spent indoors in the evening. Unfortunately, ozone-monitoring devices did not function properly during the study.

Another research team in London monitored air pollutant exposure and measures of lung inflammation among 60 people with asthma on two occasions.[33] On one

occasion, participants walked for two hours near significant diesel traffic, and on another occasion, the same people walked for two hours through a nearby park. While not directly tied to the AQI, walking along heavy traffic was linked to worsening of lung function, but this was not the case for walking through the park. This suggests that avoiding pollutant exposure—something that could be recommended as part of air quality messages—has clear health benefits. This finding is particularly climate-relevant because increasing temperatures generally result in worse air pollution.

A unique air quality monitoring system was put into place in British Columbia, Canada in order to predict hazardous levels of PM2.5 during wildfires. That system predicted PM2.5 levels well.[34] During two different fire seasons the predicted PM2.5 levels were correlated with the number of asthma medication (inhaler) prescriptions filled at local pharmacies, as well as the number of physician visits for asthma.[35,36] Information such as this could be used to craft timely health communication messages. It is not known whether use of a public early warning system about expected increases in PM2.5 during wildfires results in less frequent asthma attacks.

There is evidence to support the idea that air quality index reporting may lead individuals to change their planned activities. Telephone surveys conducted in six US states found that in the previous 12 months, 31.1% of adults who ever had been diagnosed with asthma reported reducing or changing their outdoor activities as a result of media alerts regarding poor air quality.[37] Among those whose physician had advised them to avoid outdoor activities, 57% had reduced or changed their activities following air quality alerts in the media.

This suggests that health care providers can promote behavior change by educating their patients with asthma (and likely, other lung conditions) about air quality, and that media alerts seem to promote the desired effect: avoiding or reducing outdoor activities among susceptible individuals when air quality is impaired. Individuals can sign up to receive air quality notification via email and text messaging through a partnership of the US EPA and local air quality organizations called Enviroflash, available at www.enviroflash.info.[38]

Evidence

Some evidence: This includes one or more systematic review(s), or at least: two experimental studies, or two quasi-experimental studies with matched concurrent comparisons, or three studies with unmatched comparisons or pre-post measures.

1.2 Local Vehicle Traffic Reduction Systems

Systems can be put into place to reduce the amount of cars and trucks in cities. By reducing vehicle traffic, emissions and consequent air pollution levels should decrease, resulting in less frequent asthma attacks. This approach is appealing as it can promote climate change mitigation efforts (use of public transit and zero-emission vehicles to reduce greenhouse gases). During both the 1996 summer Olympic games in Atlanta, Georgia,[39] and the 2008 summer Olympic games in Beijing, China,[40] the use of private cars was restricted in the areas of the games. In the case of the Beijing games, banning trucks that failed emissions standards was also enforced. Air quality improved significantly compared to pre-game levels once the traffic

management programs were instituted in both Atlanta and Beijing. Importantly, the number of people treated for asthma during the games also decreased.

These studies are not definitive, however, as much of the local population left town during the games, potentially reducing the number of people at risk for asthma, and a regional reduction in ozone levels potentially related to meteorological conditions was also seen.[41] Nevertheless, both studies suggest that comprehensive traffic management programs might improve air quality and reduce the number of asthma attacks in a city. Unlike the temporary traffic reduction systems put in place during the Olympics, a standing "low emission zone" was instituted in London.

Beginning in 2008, trucks, buses, and vans (but not cars or taxis) must meet European Union air quality emissions standards or pay a fine. Since the system came on line, there has been limited improvement in air quality and limited health benefits documented (the reduction of nasal symptoms in school children).[42] Taken as a whole, it seems that aggressive efforts to improve air quality (as was done during the Atlanta and Beijing summer Olympic games) have substantial health benefits, while limited measures (as instituted in London) may not.

Evidence

Some evidence: This includes one or more systematic review(s), or at least: two experimental studies, or two quasi-experimental studies with matched concurrent comparisons, or three studies with unmatched comparisons or pre-post measures.

1.3 Antioxidant Dietary Supplementation

Ozone is a strong oxidant, and is thought to trigger worsening of asthma and COPD partly through its oxidant effects. Vitamins E and C have antioxidant properties. These vitamins alone and in combination have been evaluated in clinical trials for their potential to blunt the antioxidant effect of ozone on people with asthma.

Vitamin C supplementation appeared effective in reducing the harmful effects of ozone in one relatively large study of genetically susceptible children with asthma.[43] Vitamin E in adults was associated with limited protection against ozone on only one of multiple measures of ozone effect.[44] Combining Vitamin C and Vitamin E in adults with asthma seemed to blunt the effect of ozone exposure on susceptibility to sulfur dioxide, an air pollutant linked to the burning of coal.[45]

Evidence

Some evidence: This includes one or more systematic review(s), or at least: two experimental studies, or two quasi-experimental studies with matched concurrent comparisons, or three studies with unmatched comparisons or pre-post measures.

2. Carbon Monoxide Poisoning

Carbon monoxide (CO) is a colorless and odorless gas that results from incomplete combustion of carbon-containing fuels.[46] Exposure to CO without adequate ventilation can lead to health outcomes ranging from headache, tiredness, nausea and cognitive impairment to coma and death. When inhaled, CO binds to hemoglobin which is

responsible for transporting oxygen in blood. In so doing, it reduces the delivery of oxygen to the brain, heart, and rest of the body.

CO poisoning is relevant to climate change because increases in the frequency and intensity of severe weather events can increase the occurrence of power outages and flooding, events in which people are likely to utilize gas-powered devices such as generators and power washers. When people use these devices inappropriately (e.g., within the home), they and their families are at serious risk of CO poisoning.[47]

Methods

Studies used in the literature review were identified using a two-step process. First, the following phrase was entered into the PubMed search engine: "carbon monoxide poisoning intervention." The resulting article titles were scanned and those that appeared to be descriptions of methods to prevent CO poisoning were reviewed. Second, the references listed by each of these reviewed articles were scanned and subsequently reviewed if they appeared to be relevant studies.

Thirteen articles were reviewed and of these, six were considered evaluations of interventions to prevent unintentional carbon monoxide poisoning. Three evaluated the use of carbon monoxide detectors and three examined educational campaigns. The relevant findings from the articles are described in the sections below.

Summary of Interventions

Educational campaigns have included information on the dangers of CO poisoning, how it can occur, and proper use of portable generators. They were timed to occur just prior to large storms that were likely to disrupt power. Evaluations indicated that educational campaigns can have modest impact (Table 3). There is some evidence that these campaigns may be most effective when they are intense and focused on a particular area or group. Interventions involving the promotion of CO detectors have included adopting an ordinance requiring detectors in most residences and installation of hard-wired detectors with battery back-ups. The studies generally demonstrated that individuals in homes with detectors were exposed to lower concentrations of CO.

INTERVENTION	DESCRIPTION	EFFECTIVENESS
Education	Educational efforts focus on providing information regarding the variety of sources of CO and the appropriate use of generators.	Some evidence
Promotion of CO Detector Use	Carbon Monoxide detectors provide an audible alarm to provide people with early (pre-symptom) notification of CO exposure. Strategies for getting CO detectors installed within homes include direct installation by an outside agency or legal mandates for new or existing homes requiring the use of detectors.	Expert opinion

Table 3: Summary of interventions for carbon monoxide poisoning

2.1 Education

There are a number of topics that can be covered in educational campaigns, including: what carbon monoxide is and how it can be dangerous; and sources of CO, with the most relevant ones for power outages being portable generators and heating sources such as grills or gas ovens.[48] Messages may be conveyed via the media, distribution of flyers, or door-to-door verbal communication. Broad messaging tends to occur prior to a storm, when it is unclear if power will be lost and who will be impacted. Education at the local/neighborhood level tends to occur once areas experiencing power loss have been identified.[49] To have the highest likelihood of success, written materials should be provided in a variety of languages.[50]

Evidence

Some evidence: This includes one or more systematic review(s), or at least: two experimental studies, or two quasi-experimental studies with matched concurrent comparisons, or three studies with unmatched comparisons or pre-post measures.

2.2 Carbon Monoxide Detectors

Many carbon monoxide detectors are activated when CO levels exceed 15 parts per million, a level at which humans likely are pre-symptomatic.[51] Thus, while not preventing CO exposure from occurring, they allow people to remove themselves from the hazard. Given that many hazardous conditions occur when power is lost, it is important that detectors be equipped with batteries.

Evidence

Expert opinion: This generally has no more than one experimental or quasi-experimental study with a matched concurrent comparison, or two or fewer studies with unmatched comparisons or pre-post measures. Strategies within this rating are recommended by credible, impartial experts but have limited research documenting effects.[46,52,53]

3. Heat-related Illness

Heat is the number one weather related killer in the United States and in the last 20 years, extreme heat events in the United States have resulted in excessive morbidity and mortality.[54] The 1995 Chicago heat wave resulted in over 700 deaths for the month of July and thousands of others were treated for heat-related illness in emergency rooms.[55] Based on temperature trends, extreme heat events are projected to increase in frequency and intensity in many areas.[56] Heat related-illness is entirely preventable and with the appropriate interventions, communities can reduce the morbidity and mortality.

Methods

NYSDOH conducted the initial steps for a systematic review of evidence-based heat interventions to identify relevant literature on extreme heat events, interventions, and health impacts. They searched PubMed, Google Scholar, and Google using the keywords/phrases including: “heat wave,” “heat event,” “extreme heat,” “extreme

temperature," "intervention," " adaptation," "mitigation," "warning," "advisory," "cooling center," and "cool center." The years of the citations that were reviewed range from 2000–2013. The Midwest/Southeast Collaborative replicated these methods to search for interventions for the years of 2013 through 2015 as well as various combinations of the keywords and phrases. The following terms were also searched: "evaluation," city ordinances," and "heat island." Articles that were based on modeling or predictive measures were not included. Five articles were found that were already reviewed and cited in the New York State Department of Health's review. Six additional articles were reviewed. There was one 2009 article that was included in the final review as a result of a 2014 follow-up article. The 2009 article was the original intervention evaluation. Two city guidelines for developers were also included in the review. Many interventions involve a combination of multiple strategies. For example, surveillance combined with an educational campaign and other components. There is thus a difficulty in assessing individual interventions. This assessment attempted to determine which interventions had the greatest impact.

Summary of Interventions

There are a variety of interventions that have been explored and instituted to address heat related-illness. These include preemptive, primary, and secondary interventions as well as co-beneficiary ones that seek to reduce the risk of developing a heat related-illness while at the same time reducing carbon dioxide in the atmosphere and creating an environment more suitable for physical activity. From an ecological model perspective, they range from the individual level to the systems level to the environmental level. Heat related-illness interventions fall under the purview of public health, emergency preparedness, and planning. The interventions assessed in this review can be grouped into seven categories:

1. Real-Time Data Surveillance and Warnings
2. Education and Information
3. Built Environment
4. Heat Alert System
5. Access to Cooling
6. Zoning/Building Regulations
7. Hydration

INTERVENTION	DESCRIPTION	EFFECTIVENESS
Real-Time Data Surveillance and Warnings	Monitoring ambient heat-related hospitalizations, emergency room visits, 9-1-1 calls, and meteorological data to recognize when the number of heat related-illness symptoms or diagnoses is higher than normal and the health department can then issue warnings to the public.	Some evidence
Education and Information	Health departments, municipalities, cities, etc. provide information about what heat related-illness is and how to prevent, identify, and treat it.	Some evidence
Built Environment	Part of the physical environment created and constructed by humans designed to reduce outdoor and indoor temperatures.	Insufficient evidence
Heat Alert System	City or municipality preparing a comprehensive plan activated when temperatures are at or exceed a threshold that is dangerous for the health of their citizens. Systems often have levels of incremental activities based on temperatures or heat advisories issued by the governmental agency that provides weather forecasts and warnings.	Sufficient evidence
Access to Cooling	Making cool or air conditioned places publicly available for those who do not have access to cool spaces.	Some evidence
Zoning/Building Regulations	City or municipality ordinances that guide or require developers to include infrastructure designed to reduce ambient and indoor heat in residential or commercial development plans.	Insufficient Evidence
Hydration	Hydrating during heat events.	Scientifically supported

Table 4: Summary of interventions on heat-related illness

3.1 Real-Time Data Surveillance and Warnings

Real-Time Data Surveillance and Warnings consists of monitoring ambient heat-related hospitalizations, emergency department data, 9-1-1 calls, and meteorological data to recognize when the number of heat-related illness symptoms or diagnoses is higher than normal and the health department can then issue warnings to the public, local health departments, and other relevant agencies.[57,58] These warnings can be targeted to vulnerable populations, such as the elderly.[59]

Health departments monitor temporal heat-related illness and syndrome trends submitted every 24 hours or more often by hospitals and 9-1-1 call centers. Among the different types of public health surveillance systems health officials can use to track this data, BioSense[60] and ESSENCE[61] are two such types. Hospitals have to be

on-boarded to the system in order to submit data. They are cloud-based systems with standardized tools and procedures for collecting, sharing, analyzing, and evaluating data and are capable of customizing queries. This allows health officials to monitor and respond to disease exposure or hazardous conditions.

In these systems, heat syndromes can be defined by chief complaints (including potential misspellings) that include "to hot," "too hot," "over heated," "overheated," "hyperthermia," "hypertermia," or "heat." Heat syndromes can be defined by discharge diagnosis that include "to hot," "too hot," "over heated," "sun stroke," "heat syncope," "heat pyrexia," "heat fatigue," "heat prostration," "heat edema," "heat effects," "heat exhaustion," "heat collapse," "heat cramps," "heat apoplexy, "excessive heat," "E900," or "E992."

When health officials notice a number of heat-related illnesses that is greater than the normal amount for that time period, there might be a disease outbreak. Health officials then send out notifications and messages to city officials, medical providers, and the public as a warning and to take preventative measures. These data can be a trigger to launch a response plan as well.

Evidence

There is less evidence supporting the specific utility of real-time data surveillance, but more evidence supporting comprehensive heat warning systems.[62,63] Therefore, the summary of the overall issue is **some evidence:** This includes one or more systematic review(s) or at least two experimental studies, or two quasi-experimental studies with matched concurrent comparisons, or three studies with unmatched comparisons or pre-post measures. There is not agreement on the most effective way to structure heat surveillance and warnings,[64] although data-driven approaches appear to be more effective.[65]

3.2 Education and Information

Education and information is when health departments, municipalities, cities, etc. provide information to the public about what heat related-illness is and how to prevent, identify, and treat it. The information is shared through a variety of mechanisms, which include call centers; brochures for distribution at clinics, pharmacies, nursing homes, and online; and in-person training programs for professionals and the health workforce.[66,67] Specific questions can be answered, practical advice is provided, and vulnerable populations are often targeted with specific information.[68,69]

Evidence

Some evidence: This includes one or more systematic review(s), or at least: two experimental studies, or two quasi-experimental studies with matched concurrent comparisons, or three studies with unmatched comparisons or pre-post measures.[59,66,70–74]

3.3 Built Environment

Built environment refers to the part of the physical environment created and constructed by humans. Components of the built environment can be designed

to reduce outdoor and indoor temperatures.[75] These are often primary prevention strategies; intended to prevent heat-related illness from ever happening.

Landscape design, transportation systems, and energy systems are the primary components of the built environment that are addressed to reduce temperatures. They can be publicly or privately supported projects that are built on or utilize open space, empty lots, existing commercial and residential buildings, and agricultural lands. These strategies are particularly advantageous to address the urban heat island, a phenomena in which metropolitan areas are significantly warmer than surrounding nonurban ones primarily due to the built landscape, more concrete, and less green space.[76]

Evidence

Limited evidence: Generally has no more than one experimental or quasi-experimental study with a matched concurrent comparison, or two or fewer studies with unmatched comparisons or pre-post measures. A number of studies that utilize modeling scenarios to simulate actual interventions find that these strategies are effective.[77–80] However, there is limited research documenting effects in real settings.[81,82] It should be noted that it is particularly difficult to measure large-scale (neighborhood level or larger) impacts of health effects of built environment adaptations, and an assessment of building-level adaptations (e.g., installation of a "cool roof") may find more of an evidence base.

3.4 Heat Alert System

Heat alert system refers to a city or municipality preparing a comprehensive plan that includes preparedness and response activities.[83] The response plan is activated when temperatures or the combination of heat and humidity (the heat index) are at or exceed a threshold that is dangerous for the health of their citizens. The systems often have levels of incremental activities based on temperatures or heat advisories issued by the National Weather Service, or other governmental agencies that provide weather forecasts and warnings. A heat alert system can include, but is not limited to, the following components:

Community Education and Engagement: Prepares the community for the heat season by identifying community needs, recruiting stakeholders, educating the public, and developing plans.

Alert Protocol: Identifies weather conditions that are dangerous for the health (increases morbidity and mortality) of their citizens. It is used to activate and deactivate communication and response plans. The protocol triggers alerts made to the public about heat-health risks and pre-determined actions that governmental officials and stakeholders implement to protect health.

Community Outreach Plan: Facilitates a systematic approach to target and reach vulnerable populations.

Communication Plan: Raises awareness and delivers education about the impacts heat can have on health and provides advice on how to prevent, identify, and treat heat illness through media releases, websites, and social media.

Evidence

Some evidence: This includes one or more systematic review(s), or at least: two experimental studies, or two quasi-experimental studies with matched concurrent comparisons, or three studies with unmatched comparisons or pre-post measures. Among the activities incorporated into heat alert systems, messaging is integral and needs to go beyond providing basic cooling behaviors, but include accurate risk communication, address risk perception, and adequately reach out to vulnerable populations.[66,68,73,84,85] While it is difficult to conclude that a reduction in death rates is caused by heat alert systems, there is some indication that they can help reduce mortality.[70,71,86]

3.5 Access to Cooling

This intervention pertains to reducing heat illness or death through access to cool or air-conditioned spaces. There is strong medical evidence that cool or air-conditioned spaces can prevent heat illness. This intervention can be challenging because of geographical settings (e.g., rural or agricultural), perceived risk (e.g., the elderly), and safety and security (e.g., high crime communities).[73] It also may be criticized because it can contribute to increased energy usage, which can increase vulnerability (e.g., power outages or increased carbon dioxide emissions).

Access to cooling refers to making cool (typically air-conditioned) places publicly available for those who do not have access to air conditioning or cannot afford to turn it on. Urban areas need to take access to public transportation into consideration when locating cooling centers. Rural areas need to consider providing transportation to cooling locations. Selected location and facilities are critical.[87] Places where community members already congregate, are physically comfortable, and can accommodate for people of all ages and backgrounds to be there for several hours at a time (couches, entertainment, refreshments, etc.) should be highly considered. Local health departments, public libraries, recreation centers, community centers, and religious centers are different types of spaces that can be utilized as cooling centers.

Ensure training is provided to cooling center staff, that there are effective activities to reach out to vulnerable populations, and adequate signage of the cooling center.[87] A full-time program promoter for outreach may be needed. A notification system needs to be designed and implemented to inform the public, especially targeting vulnerable populations, where the cooling centers are, how to get there, and why they are important. It is also critical that the messaging includes cultural and economic factors.[68] A congruent communication plan that aligns messages from the Health Department, the Department of Human Services, the media, community based organizations, and faith leaders is critical in notifying the public.

Because numerous studies have identified factors, which lead to vulnerable populations, particularly the elderly, not wanting to leave their homes for cooling centers, access to cooling can also include programs that provide support for cooler environments at home. These programs can include financial support to vulnerable populations for installation of home air conditioning, or paying of utility bills. This aspect of the intervention was not assessed in this document.

Evidence

Medium to High effectiveness: Three articles, a literature review of case-control and cohort studies and two case-control studies found that working home air conditioning or visiting cool environments were associated with better outcomes during high heat.[88–90]

An interview of homeless in one city found a need for cool spaces, as they were often moved along from resting in cooler spaces (e.g., parks, libraries, malls).[91] A literature review and review of case studies of vulnerable persons found that air conditioning provides physiological relief to heat but increases risk of outages and the cost of electricity, suggesting that air conditioning should be available outside residential areas.[92] A literature review found that older adults often restrict air-conditioning use during hot weather and that air conditioning installation and usage is correlated with income. Further, risk perception among older adults was needed before prevention action was taken.[93]

Several (4) studies found that air conditioning or visiting cool environments were associated with better outcomes for older adults and among those vulnerable, including those suffering from mental illness. The literature also suggests some needs: inclusivity, cool spaces beyond residential, adequate communication and reception of the message, and addressing income disparities.[88,90,92,93]

3.6 Zoning/Building Regulations

Zoning/Building Regulations are city or municipality ordinances that guide or require developers to include infrastructure designed to reduce outdoor and indoor heat in residential or commercial development plans. Upon ratification of these policies, developers would be required to include climate change adaptation building strategies into all plans moving forward.

The structures that are ultimately developed fall under the built environment category; however, this strategy targets the policy system that requires the implementation of a built environment protocol. Zoning and building regulations are controlled at the municipal level so these policy strategies target small and large cities.

Evidence

Insufficient evidence: Generally has no more than one experimental or quasi-experimental study with a matched concurrent comparison, or two or fewer studies with unmatched comparisons or pre-post measures. Strategies within this rating have limited research documenting effects. Some cities have included these building regulations into their development design guidelines, yet there aren't formal evaluations of this type of policy. An analysis of urban zoning designations (i.e.: agriculture, commercial, residential, etc), however, found that the manner in which land is zoned does effect surface temperature.[94] While this was not looking at an ordinance that guides or requires developers to include infrastructure designed to reduce outdoor and indoor heat in residential or commercial development plans, it does indicate that land use impacts surface temperatures.

3.7 Hydration

This strategy involves hydrating during heat events in order to prevent heat-related illness.[95]

Evidence

High effectiveness: A literature review found that drinking more fluids was effective in maintaining thermal comfort or reducing heat stress among older adults, who may have cognitive impairments.[93]

A case control study found that older adults that drank more fluids were at reduced risk for death during a heat wave.[90]

Scientifically supported. Includes one or more systematic review(s), or at least: three experimental studies, or three quasi-experimental studies with matched concurrent comparisons. Several articles found hydration was tied to better outcomes during heat events.

4. Injuries Due to Floods

There are three phases to a flood in which direct physical injuries can occur: pre-event, event, and post-event (or pre-flood, flood, and post-flood).[96] The causes of injury in high risk groups, and thus appropriate interventions, vary by phase.[97] During the pre-flood phase, injuries result from actions in preparation for the flood, for example, strains due to building sandbag walls. Once a flood has occurred, by far the leading cause of death is drowning, with approximately half of the drowning incidents involving motor vehicles.[98] Electrocution and being struck by an object are other notable causes of injury in this phase. Following a flood, injuries can occur during cleanup or rescue operations. The primary causes during this phase are electrocution and carbon monoxide poisoning, with injuries also occurring in the form of cuts, lacerations, and puncture wounds from debris. Speed of onset is a main factor determining a flood's impact. Rapid-onset floods provide little opportunity to warn individuals and allow time for evacuation. A study of flash floods in the U.S. found that mortality was highest when dams broke due to heavy rainfall.[99]

Methods

The literature review process initially began via Google Scholar searches using the phrases "injuries due to flooding" and "injury prevention flooding." Bibliography "snowballing" was used to examine articles referenced by the articles identified from the Google searches. Twelve articles or chapters in books were reviewed. None of these were evaluations of interventions to prevent injuries due to flooding. These methods are only designed to assess physical injury from flooding, not related health effects such as post-disaster mental health impacts, exposure to mold, or pathogenic risk.[100]

Summary of Interventions

No studies were found that formally evaluated the direct health impacts of interventions designed to prevent injuries due to flooding. A more in-depth literature review could highlight additional potential intervention strategies, such as coastal flood control management. However, articles did describe intervention and

intervention strategies that have promise. These include:

1. Preventing or minimizing floods via floodplain management and improved drainage.[101]
2. Reducing human exposure to floods by prohibiting development in known flood zones.[102]
3. Improving the National Weather Service warning system.[103]
4. Monitoring dam structures during storms to allow for adequate warning if there is a dam breach.[104]
5. Educating residents about the dangers of floods, for example, that floodwaters are much stronger than they appear both for humans and vehicles.[105]
6. De-energizing circuits in flooded areas to prevent electric current injuries.[106]

INTERVENTION	DESCRIPTION	EFFECTIVENESS
Floodplain Management	Includes ensuring optimal drainage and prohibiting development in known flood zones.	Insufficient evidence
Conducting Effective Evacuation	Includes identifying evacuation routes and establishing centers for those displaced.	Insufficient evidence
Creating and Maintaining Effective Dams	Includes monitoring dams during heavy rains to allow for early notification in case of impending breach.	Insufficient evidence
Education	Educating citizens of the various hazards associated with floods, for example, that floodwaters are much stronger than they appear.	Insufficient evidence
De-energizing Circuits in Flooded Areas	De-energizing circuits helps prevent electric shock injuries both during floods and the cleanup period.	Insufficient evidence

Table 5: Summary of interventions on injuries due to floods

5. Harmful Algal Blooms

An algal bloom is a rapid increase in the density of algae in an aquatic system.[107] The majority of algal species are harmless, but a small percentage can cause harm to humans and the environment through the production of toxins, leading to harmful algal blooms (HABS). HABs can occur in marine ecosystems, where they are commonly referred to as "red tide." They can also occur in freshwater, typically as cyanobacterial (blue-green algae) blooms. For the period of 2007–2011, 4534 HAB events were reported in 11 states funded by CDC to monitor the blooms.[108]

According to the EPA, "factors that affect cyanobacterial bloom formation and persistence include light intensity and total sunlight duration, nutrient availability (especially phosphorus), water temperature, pH, an increase in precipitation events, water flow (whether water is calm or fast-flowing), and water column stability."[109]

The expansion and increasing incidence of HABs in recent years has been attributed to a number of human activities including an increase of agricultural runoff rich in nitrogen and phosphorous, the transportation of toxic HAB species in ship ballast water, coastal aquaculture farms, and sewage runoff. Changing environmental conditions can affect the natural properties of bodies of water and lead to conditions that favor the growth of harmful algal blooms.[110] For example, shifts in water temperatures can affect the timing, intensity, and geographic distribution of HABs,[111] with potential expansion in the future.[112]

An increase in the occurrence and intensity of harmful algal blooms may negatively impact the environment and cause damage to water ecosystems, lead to negative human health impacts, impact recreational opportunities (e.g. disrupt the use of public beaches), and may negatively impact the economy for communities. Some HABs are formed by cyanobacteria, which can produce toxins that can lead to illness and death in humans, fish, seabirds, marine mammals, and other species. They can cause damage through sheer biomass accumulation because they cause oxygen depletion via photosynthesis, leading to the displacement of local indigenous species.

Health risks associated with HABs occur when people or animals are exposed to toxins, which can happen through drinking contaminated water, breathing water spray (i.e. inhaling aerosolized toxins), coming into direct contact with the blooms, and through eating contaminated fish or shellfish. According to the EPA, "the acute recreational exposure to cyanobacterial blooms and their cyanotoxins can result in a wide range of symptoms in humans…including fever, headaches, muscle and joint pain, blisters, stomach cramps, diarrhea, vomiting, mouth ulcers, and allergic reactions. Such effects can occur within minutes to days after exposure. In severe cases, seizures, liver failure, respiratory arrest, and (rarely) death may occur. The cyanotoxins include neurotoxins (affect the nervous system), hepatotoxins (affect the liver), and dermatoxins (affect the skin)."[109]

The diversity of HAB species and the various forms of harm they cause presents a significant challenge to those responsible for detecting, tracking, and managing them: "It is not possible to tell if a bloom is toxic by looking at or smelling the water. Therefore, it is recommended that people avoid contact with all algal blooms."[113]

Methods

A literature review was conducted using the electronic search engine PubMed and Ebsco Host. A series of Boolean searches was conducted using several combinations of keywords related to harmful algal bloom interventions: "intervention," "cyanobacteria," "disease incidence," "prevalence," "risk," "measurable," "health outcome," "plan," "planning," "program," "response," "evaluation," "warning," "alert," "watch," "public health response," "implementation," "prevention," "awareness," "education," "preparedness," "control," "measures," "strategy," "system," "risk management," "disaster," "blue green algae," "harmful algal bloom," "harmful algae bloom," "cyanotoxin," "microcystin," "microcystis," "anatoxin," "microcystin management," "controlling cyanobacteria blooms," "climate change," "nutrient management."

75 manuscripts were identified in the initial literature review (21 results for "microcystin management," 12 for "controlling cyanobacteria blooms," 20 for "harmful

algal blooms prevention," 12 for "harmful algal blooms and climate change," and 10 for "harmful algal blooms and nutrient management"). From this, three articles on harmful algal bloom interventions were selected that contained measurable effect estimates of the intervention exposure being tested and were included in the below intervention assessment. Relevant EPA guidance was also assessed.[114]

Summary of interventions

There are a variety of types of interventions that can address harmful algal blooms. Preemptive (preventative) interventions related to watershed management utilize nutrient management strategies through targeted reductions of nutrient input from point and non-point sources, including fertilizers and ballast water. Mitigation measures once a bloom is recognized include waterbody management methods and drinking water treatment. Waterbody management methods aim at controlling phytoplankton/algal blooming rates and removing harmful algal blooms. These methods include physical, biological, and chemical measures.[114] Physical controls include aeration, hydrologic manipulations, mechanical mixing (circulation), reservoir drawdown/desiccation, surface skimming, and ultrasounds. Chemical controls include algaecides, barley straw, coagulation, flocculation, hypolimnetic oxygenation. Biological controls relate to increasing grazing pressure or increasing resource competition to control the growth of the bloom. More information on physical, chemical, and biological controls can be found on EPA's Cyanobacteria Control and Treatment, Data Control and Treatment web page.[115] Drinking water treatment plants also have a variety of methods that can be effective for removing toxins from harmful algal blooms, including flocculation, coagulation, sedimentation, filtration and more.

In addition to preventative and mitigation interventions, surveillance monitoring (such as through HABISS[116]) and early detection, forecasting/modeling, and communicative outreach strategies are also useful for limiting the negative public health impacts of harmful algal blooms.

INTERVENTION	DESCRIPTION	EFFECTIVENESS
Biological Controls in Waterbody Management	Include various approaches which aim to minimize nutrient inputs to source waters and prevent harmful algal blooms. Measures might include introducing predator species, removing species, introducing competing species, and introducing more primary producers.	Some evidence
Drinking Water Treatment Plants	When cyanobacteria and/or their cyanotoxins are detected in water supplying water systems, drinking water treatment plant operators can act to remove or inactivate them in various ways. Treatments are often toxin-specific. Some of the treatment processes that can be utilized for intracellular cyanotoxin removal (intact cells) include: pre-treatment oxidation, coagulation/ sedimentation/ filtration, membranes, and flotation.	Some evidence

Table 6: Summary of interventions on harmful algal blooms

5.1 Biological Controls (Biomanipulation/ Bioremediation)

Biological control measures include various approaches which aim to change the aquatic food web through either increasing grazing pressure or increasing resource competition.[69,117] Measures which aim to increase grazing pressure on cyanobacteria can be accomplished through the manipulation of species composition by encouraging the growth of zooplankton, benthic fauna, and other aquatic organisms that feed on cyanobacteria, which limits the proliferation of cyanobacteria. There are a few techniques including the removal of fish that feed on zooplankton, benthic fauna, and other aquatic organisms that feed on cyanobacteria; the introduction of predators to these fish species; and the development of niches to encourage the growth of beneficial organisms. Increasing resource competition can be accomplished through the introduction of other primary producers, which can limit the available nutrients, including phosphorus, thereby limiting cyanobacterial growth. This might be accomplished through introducing competing species through a bioremediation product or through the creation and harvesting of floating artificial wetlands in which the wetland plants serve as a sink for excess nutrients and periodic harvesting prevents stored nutrients from re-entering the aquatic ecosystem.

Evidence

Some evidence: This includes one or more systematic review(s), or at least: two experimental studies, or two quasi-experimental studies with matched concurrent comparisons, or three studies with unmatched comparisons or pre-post measures.

5.2 Drinking Water Treatment Plans

When cyanobacteria and/or their cyanotoxins are detected in water systems, drinking water treatment plant operators can act to remove or inactivate them in various ways.[109,118] Treatments are often toxin-specific. Some of the treatment processes that can be utilized for intracellular cyanotoxin removal (intact cells) include: pre-treatment oxidation, coagulation/ sedimentation/ filtration, membranes, and flotation. According to the EPA, "the standard drinking water treatment processes (coagulation, flocculation, sedimentation, and filtration) can be effective at removing intracellular cyanotoxins."[109] Extracellular cyanotoxin removal (dissolved) can be accomplished through membrane filtration, potassium permanganate, ozone, UV radiation (chemical inactivation), and activated carbon. More information on these processes and when they should be utilized and their effectiveness can be found in EPA's "Cyanobacteria and Cyanotoxins: Information for Drinking Water Systems" document.[109]

In order to prepare for harmful algal blooms, water supply managers should develop a contingency plan for cyanobacterial bloom occurrence. The plan should include a monitoring program that addresses how to determine potential risk with each bloom event, a management plan, and a communication plan (i.e. determining required communication steps to coordinate with other agencies and to take steps to inform consumers and the public). Monitoring programs should include determinations of when and where to sample, sampling frequency, sample volume, whether to sample for cyanobacterial cells or specific cyanotoxins or both, which analytical screening test to use, and defined conditions for when to send samples to an identified laboratory for confirmation.[109]

Evidence

Some evidence: This includes one or more systematic review(s), or at least: two experimental studies, or two quasi-experimental studies with matched concurrent comparisons, or three studies with unmatched comparisons or pre-post measures.

6. Flooding and Mold

Mold spores can be widespread in both indoor and outdoor environments after extreme weather events.[119] Mold spore concentrations are typically measured in colony forming units per cubic meter (CFU/m^3). Molds primarily affect us as allergens. Some molds can also produce mycotoxins or irritants.[120]

Negative health outcomes from mold exposure are specific to individuals who have developed a sensitivity or allergy to molds. In most cases, molds are classified with pollen and dander as an allergen. Health symptoms reported by people sensitive to mold include nasal stuffiness, throat irritation, coughing or wheezing, eye irritation, or skin irritation. People with strong mold allergies and/or compromised immune systems may have more severe health outcomes, including lung infections.[121]

There are two means of mold exposure: ingestion (the eating or drinking of mold spores, which is not as likely with flooding) and inhalation (the breathing in of mold spores). Mold growth may occur on buildings after an extreme weather event such as flooding. Failure to properly clean up buildings after a flooding event can increase human mold exposure.

Methods

A literature review was conducted using the electronic search engine PubMed and through the University of Wisconsin-Madison Library system. A series of Boolean searches were conducted using several combinations of keywords related to mold interventions: "intervention," "mold," "mold spores," "mold exposure," "inhalation," "mold cleanup," "mold removal," "flooding," "flood damage," "flood damaged buildings," "water-damaged homes," "hurricanes," "disaster," and "respiratory infections" to yield the most applicable results. Of the articles retrieved from the literature review, many assessed the risk of exposure to mold after flooding events but did not evaluate an intervention. Four articles were identified that assessed mold interventions: two articles evaluated interventions for mold[122,123] and two were review articles of interventions for mold.[124,125]

Summary of Interventions

This literature summary focuses on intervention strategies related to the inhalation of mold spores after flooding events. The intervention strategies are divided into four categories:

1. General remediation
2. Hydrogen peroxide vaporizer
3. Treatment with fungicide
4. Ultraviolet germicidal light

Interventions 2, 3, and 4 are likely only of utility in a health care setting. Some public health interventions and practices for mold prevention may need support from the government, specialized personnel, or be cost prohibitive. Others require less support, such that an individual may be able to conduct them alone. Also, some interventions are suited for killing mold in the air while others are more suited for surface mold removal. Additional guidance on mold prevention strategies was reported in Brandt, et al.[126]

INTERVENTION	DESCRIPTION	EFFECTIVENESS
General Remediation	Implements disposal of contaminated pieces and remediation repair of extreme mold contamination. Focused on preventing further mold growth at a structural site after a natural disaster such as flooding.[127]	Scientifically supported
Hydrogen Peroxide Vaporizer	Targets and kills invasive fungal spores in the air that may cause serious health impacts.	Some evidence
Treatment with Fungicide	Applied per manufacturer guidelines to areas in need of decontamination to prevent future mold growth.	Insufficient evidence
Ultraviolet (UV) Germicidal Light	Placed in a location where germs, spores and other bacteria are prevalent. The light is left on for hours to penetrate the outer shell of the bacterium or fungi and kill it.	Expert opinion

Table 7: Summary of interventions for flooding and mold

6.1 General Remediation

In the event of extreme mold contamination, the best method is to dispose of contaminated porous structural pieces and begin remediation repair.[122–124] Remediation is the practice of decontaminating a structural site after a natural disaster such as flooding.[127] After a flooding event, structural damage to indoor environments can create a diverse range of health impacts from inhalation exposure. There are several practices for remediation that can be implemented by individuals or with the help of professionals that include the following: ventilation system installation and cleaning, replacement of damaged structures, moisture control, worker protection during remediation, and repair of water leaks and plumbing systems.

1. Moisture Control An upstream technique to prevent mold growth is to install systems that control for moisture and dry the affected area rapidly. In the event of a natural disaster, use dehumidifiers to control for humidity, and dry affected areas within structures quickly.[128]
2. Replacement of Damaged Structures Replacement of damp/moldy roofs, framing, ceilings, walls, cabinetry, insulation, carpet, appliances, furniture, floors, and sub-floors may be required with a drying out period in between the removal

and reinstallation period. Some materials may be swapped for waterproof materials to prevent future mold occurrences.[129]

3. Cleaning of Heating and Cooling Systems Heating, ventilating, and air conditioning (HVAC) systems can be submerged during a flooding event. This equipment will need to be properly remediated by trained professionals once the water subsides.[128]
4. Worker Safety Cleanup crews should use personal protective equipment (PPE) to avoid inhalation of mold and other contagions. PPE may include hard hats, goggles, gloves, masks/respirators and watertight steel tip and insole boots.[130]
5. Water Leaks and Plumbing Repair This type of remediation can include improvements in drainage systems, a change of materials from water permeable to non-permeable. This method allows for better drainage systems within the building during rain.

Evidence

Scientifically supported: Includes one or more systematic review(s), or at least: three experimental studies, or three quasi-experimental studies with matched concurrent comparisons.

6.2 Hydrogen Peroxide Vaporizer

In extreme flooding cases, a hydrogen peroxide vaporizer can provide decontamination in high-risk areas after disaster.[125] The hydrogen peroxide vaporizer targets and kills invasive fungal spores in the air that may cause serious health effects to at-risk populations.[125] The vaporizers are useful when HVAC systems become contaminated or when a flooding events cause long intervals in standardized infection control, and it is not intended as an intervention for entire buildings.[125] It should be noted that a "dead" spore could still be an allergen for a mold sensitive person, and that the hydrogen peroxide vapor could cause respiratory health impacts. Appropriate PPE should be utilized.

Evidence

Some evidence: This includes one or more systematic review(s), or at least: two experimental studies, or two quasi-experimental studies with matched concurrent comparisons, or three studies with unmatched comparisons or pre-post measures.

6.3 Treatment with Fungicide

This type of treatment can be used by local health agencies and individuals to prevent further growth of mold and fungal spores on treated surfaces. This type of treatment is applied per manufacturer guidelines and is required to be registered with the Environmental Protection Agency (EPA). Appropriate PPE should be utilized.

Evidence

Insufficient evidence: Generally has no more than one experimental or quasi-experimental study with a matched concurrent comparison, or two or fewer studies with unmatched comparisons or pre-post measures. Strategies within this rating have limited research documenting effects.

6.4 Ultraviolet (UV) Germicidal Light

The use of ultraviolet (UV) germicidal light is practiced in healthcare settings and can also be implemented by local health agencies and by individuals.[124] This type of remediation uses a UV light placed in a ventilation system to kill germs, spores, and other bacteria as they are circulated.[124] UV lights can also be used in individual rooms to penetrate and kill the bacterium or fungi.[124] People should avoid exposure to UV light, and appropriate PPE should be utilized as necessary.

Evidence

Expert opinion: Generally has no more than one experimental or quasi-experimental study with a matched concurrent comparison, or two or fewer studies with unmatched comparisons or pre-post measures. Strategies within this rating are recommended by credible, impartial experts but have limited research documenting effects.

7. Mental Health and Extreme Precipitation

Disasters, whether natural or man-made, have the potential to affect psychological health. Extreme precipitation events, such as hurricanes or floods, have been found to affect mental health in numerous ways. Mental health problems have been known to increase after natural disasters and can affect people with no history of mental illness and those already at risk. Flooding disasters, depending on the severity, can cause a range of effects, including moderate impairment of survivors. Individuals may experience prolonged effects but sometimes symptoms don't meet criteria for a mental disorder. However, research studies on water disasters have shown at least 25% of the survivors having symptoms of a diagnosable disorder.[131] Typically, symptoms peak during the first year, and in most cases, survivors improve with time after the disaster.[131] Previous research has also indicated that high levels of Post-Traumatic Stress Disorder (PTSD) and anxiety has been found in individuals affected by Hurricane Katrina.[132] Climate change is likely to increase the duration and intensity of extreme precipitation events, and thus, may increase the number of people affected by mental health due to extreme precipitation events.

Methods

A literature review was conducted, in consultation with the Centers for Disease Control and Prevention, using identified electronic search engines Medline, Embase, SCOPUS, CAB, and Environmental Science Collection. Keywords were used to identify articles related to mental health and floods/storms interventions. The search for articles included any articles that had a health term, a climate term, and an intervention term. Search terms included:

Health Terms: "health effects," "mental," "drug," "alcohol," "depression," "anxiety," "mental health," "trauma," "stress," "population displacement," "disruption," "emotional stress," "chronic stress," "incarcerated," "prison," "substance use," "post-traumatic stress," "interpersonal," "PTSD," "mood disorders," "psychology*," "intimate partner," "violence," "drowning," "acute trauma," "toxic exposure," "hypothermia," "animal bites," "food contamination," "water contamination," "carbon monoxide poisoning."

Climate Terms: "storms," "coastal storms," "flood," "flood," "cyclonic storms," "hurricane," "post-storm," "disruption," "displacement," "storm surge," "winds," "precipitation," "flash floods," "coastal floods," "extreme precipitation."

Intervention Terms: "adaptation planning," "flood education," "floodplain management," "prediction-warning systems," "intervention," "preparedness," "response," "sheltering in place," "evacuation."

The search terms above yielded a total of 2,500 articles. Articles were then sorted into three categories—Yes, No, Maybe—based on their title and abstract. Articles placed in the "Maybe" category were reviewed a second time to determine if it needed to be included in the systematic review. Article abstracts were reviewed and if the terms "intervention," "mental health," "floods," and/or "storm" were mentioned, the article was downloaded for abstraction. A total of 192 "yes" articled were initially determined. The final abstraction identified 20 evaluations of mental health and flooding/storm interventions. These 20 evaluations contained estimates of the intervention's impacts and are included here. This intervention assessment focuses on those interventions that are directly applicable to the general public.

Summary of Interventions

This review covers interventions aimed at preventing mental health outcomes associated with floods and storms. Interventions reviewed are listed below.

School-Based Interventions:

1. The School Therapeutic Enhancement Program (STEP)
2. School-based Test Anxiety Intervention
3. Controlled Community Field Study
4. Cognitive Behavioral Intervention for Trauma in Schools (CBITS)

Children-Based Interventions:

1. Massage Therapy
2. Play Therapy

Cognitive-Based Interventions:

1. Cognitive Behavioral Therapy (CBT)
2. Cognitive Restructuring
3. Stress Inoculation Training (SIT)
4. Cognitive Therapy
5. Imagery Rehearsal Therapy (IRT)

Group-Based Interventions:

1. Critical Incident Stress Debriefing (CISD)
2. Group Therapy

Miscellaneous Interventions:

1. Crisis Counseling Program (CCP)

2. Psychological First Aid (PFA)
3. Eye Movement Desensitization and Reprocessing (EMDR)
4. Psychological Debriefing
5. Exposure Therapy
6. Psychodynamic Psychoterapy
7. Pharmacotherapeutics

INTERVENTION	DESCRIPTION	EFFECTIVENESS
SCHOOL-BASED INTERVENTIONS		
School Therapeutic Enhancement Program (STEP)	Established one year after Hurricane Katrina to address the problems of community youth such as an increase of students' mood and behavioral difficulties resulting from changes in living situation, school and other family issues.	Insufficient evidence
School-based Test Anxiety Intervention	Believed to be a positive avenue for improving academic success in this population. Main goal: show that this intervention can be used effectively in a school based setting in less than optimal circumstances following a disaster among ethnic minority youth	Expert opinion
Controlled Community Field Study	Evaluate efficacy of public health inspired intervention combining school-based screening and psychological treatment to identify and treat children with persistent disaster-related traumatic symptoms.	Some evidence
Cognitive Behavioral Intervention for Trauma in Schools (CBITS)	10 group session and 1–3 individual session intervention for use in schools.	Some evidence
CHILDREN-BASED INTERVENTIONS		
Massage Therapy	Manual manipulation of soft body tissues, such as muscle, connective tissue, tendons, and ligaments, to enhance a person's health and well-being.	Insufficient evidence
Play Therapy	Using play as the principal means for facilitating the expression, understanding, and control of experiences, and not simply a way of facilitating communication.	Mixed evidence

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INTERVENTION	DESCRIPTION	EFFECTIVENESS
COGNITIVE-BASED INTERVENTIONS		
Cognitive Behavioral Therapy (CBT)	Type of psychotherapy used to treat depression and anxiety disorders; assists patients in recognizing debilitating patterns of thinking and acting, and then works to modify/replace these patterns with healthy behaviors	Some evidence
Cognitive Restructuring	Can be used in conjunction with CBT to treat PTSD; can also assist patients in realizing their unhealthy thinking produces negative thoughts and behaviors. Patients are taught how to change their thinking to reduce stress, improve relationships, and benefit mental health.	Some evidence
Stress Inoculation Training (SIT)	Type of CBT which focus on enhancing individuals ability to cope with past, present and future stressors through three phases of treatment.	Expert opinion
Cognitive Therapy	Structured, short-term, present-oriented psychotherapy for depression used to help patients improve their moods through modifying dysfunctional thinking and behavior.	Insufficient evidence
Imagery Rehearsal Therapy (IRT)	Focuses on changing the images in nightmares to those that are rewarding rather than threatening.	Insufficient evidence
GROUP-BASED INTERVENTIONS		
Critical Incident Stress Management (CISM)	Group therapy process conducted soon after a person experiences a traumatic event; provides structure, group support and peer support, which leads to recovery.	Mixed evidence
Group Therapy	Can be used in mild PTSD and utilizes principles of CBT.	Mixed evidence
MISCELLANEOUS INTERVENTIONS		
Crisis Counseling Program (CCP)	Assesses strengths and seeks to restore pre-disaster functioning.	Scientifically supported
Psychological First Aid (PFA)	Provides information and education to give comfort and support, accelerate recovery, promote resiliency and mental health and access to continued care after a disaster.	Some evidence
Eye Movement Desensitization and Reprocessing (EMDR)	Procedures to assist a person's brain function when processing information.	Some evidence

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INTERVENTION	DESCRIPTION	EFFECTIVENESS
Psychological Debriefing	Crisis intervention designed to relieve and prevent event-related distress in people experiencing abnormally stressful situations. Treatment consists of a single extended session.	Mixed evidence
Exposure Therapy	Individuals are exposed to stimulated trauma in order for them to realize their trauma is tolerable and are able to take control over their emotions.	Some evidence
Psychodynamic psychotherapy	Interaction between a psychotherapist and a client that leads to changes from a less adaptive state to a more adaptive stated in the client's thoughts, feelings, and behaviors.	Some evidence
Pharmacotherapeutics	Antidepressants, tricyclic antidepressants (TCAs), monoamine oxidase inhibitors (MAOIs), selective serotonin reuptake inhibitors (SSRIs), antianxiety and adrenergic agents, and mood stabilizers can improve symptoms of PTSD.	Some evidence

Table 8: Summary of interventions for mental health and extreme precipitation

7.1 School-Based Interventions

School-based interventions utilize school services to reduce the impact of major disasters such as flooding or hurricanes, on school-aged children with mental illness. These interventions include strategies, such as the School Therapeutic Enhancement Program (STEP),[133] a school-based test anxiety intervention,[134] a controlled community field study,[135] and the Cognitive Behavioral for Trauma in Schools (CBITS).[136]

Hurricanes can cause significant damage to homes and community infrastructure. In some cases, daily life can be interrupted due to parents and children displaced from their homes. Individuals with a history of mental illness are more likely to experience profound effects from a major disaster. Children can be especially vulnerable to the impacts of a major hurricane. It is imperative parents recognize signs of distress and obtain appropriate help.

Evidence

Three articles supported post-disaster interventions to be conducted in the school environment for the best outcome. The School Therapeutic Enhancement Program (STEP),[133] looked at youth and their behavioral difficulties one year following Hurricane Katrina and found initial evidence of effectiveness for the training and intervention model.

A school-based test anxiety intervention,[134] looked primarily at ethnic minority youth affected by Hurricane Katrina and found a potential benefit to targeting anxiety symptoms in prevention efforts after a major disaster. The Cognitive Behavioral for Trauma in Schools (CBITS)[136] intervention was used to provide a tiered approach to

triage and treat children experiencing trauma symptoms after Hurricane Katrina. This study found that new ways are needed to help children who face trauma so sustained and effective programs can be implemented.

One article identified non-significant changes in children after a school-based intervention and further reach was warranted. The controlled community field study,[135] aimed to evaluate the efficacy of a public health intervention to treat children after a disaster. While the study showed reductions to children's reports of trauma-related symptoms following treatment, the authors concluded that further evaluation is merited.[135]

Mixed evidence: One or more systematic review(s), or at least two experimental studies, or two quasi-experimental studies with matched concurrent comparisons, or three studies with unmatched comparisons or pre-post measures. Two articles support school-based interventions as a means to significantly reduce trauma symptoms in children after a major natural disaster, such as a hurricane.[133,134] One article found the school-based intervention to be promising or proven intervention.[136] One article found there was not enough evidence to determine school-based interventions were effective after a major disaster.[135]

An all-hazards response plan may be useful.[137]

7.2 Children-Based Interventions

Children-based interventions focus on using specific therapies designed to reduce the impact of major disasters such as flooding or hurricanes on school-aged children. These interventions include strategies such massage therapy and play therapy. Massage therapy is the manual manipulation of soft body tissues, such as muscle, connective tissue, tendons, and ligaments, and is used to enhance a person's health and well-being. Play therapy is an approach using play as the principal means for facilitating the expression, understanding, and control of experiences.

Evidence

Hurricanes can cause significant damage to homes and community infrastructure. In some cases, daily life can be interrupted due to displacement of homes. Children can be especially vulnerable to the impacts of a major hurricane. It is imperative parents recognize signs of distress and obtain appropriate help.

Massage therapy has found to be an effective intervention; however, further studies are needed to determine if the positive effects last once massage therapy has concluded.[138] Play therapy has been found to be effective in reducing traumatic symptoms in children after a hurricane.[139]

Insufficient evidence: generally has no more than one experimental or quasi-experimental study with a matched concurrent comparison, or two or fewer studies with unmatched comparisons or pre-post measures. The evidence is not clear that massage therapy can be an effective intervention for children after experiencing a natural disaster. Evidence-based research has indicated that play therapy is an appropriate treatment for children; however additional quantitative studies need to be conducted to determine the true value of this intervention.

7.3 Cognitive-Based Interventions

Cognitive-based interventions focus on using psychological therapies to reduce the impact of major disasters such as flooding or hurricanes on individuals. Interventions include the following: Cognitive Behavioral Therapy (CBT), Cognitive restructuring, Stress Inoculation Training (SIT), Cognitive therapy, and Imagery Rehearsal Therapy (IRT).

CBT is a type of psychotherapy used to treat depression and anxiety disorders. It assists patients in recognizing debilitating patterns of thinking and acting, and then works to modify/replace these patterns with healthy behaviors. Cognitive restructuring can be used in conjunction with CBT to treat post-PTSD. It can also assist patients in realizing their unhealthy thinking produces negative thoughts and behaviors. Patients are taught how to change their thinking to reduce stress, improve relationships, and benefit mental health. SIT is a CBT, which focus on enhancing an individual's ability to cope with past, present, and future stressors through three phases of treatment. Cognitive therapy is a structured, short-term, present-oriented psychotherapy for depression used to help patients improve their moods through modifying dysfunctional thinking and behavior. Imagery Rehearsal Therapy (IRT) focuses on changing the images in nightmares to those that are rewarding rather than threatening.

Evidence

CBT has been found to be effective in as little as 3–4 sessions. Cognitive restructuring is typically used in conjunction with CBT to treat symptoms of PTSD by assisting patients in realizing their unhealthy thinking produces negative thoughts and behaviors and teaching them to change their thinking to reduce stress.[140] SIT has been shown to resurface traumatic memories in people with anxiety and stress-related disorders, but it has been advised to not to include individuals with significant personality dysfunction and poor regulatory abilities.[141] Cognitive therapy has been found to be an effective intervention, specifically those with PTSD.[142] IRT has been found to be effective in significant reductions of nightmares with people coping with PTSD.[142]

Some evidence: This includes one or more systematic review(s), or at least: two experimental studies, or two quasi-experimental studies with matched concurrent comparisons, or three studies with unmatched comparisons or pre-post measures. There is impressive evidence that CBT and cognitive restructuring have positive patient outcomes. However, there is an ongoing debate on which interventions work best for those affected with PTSD. While SIT has been found to be an effective intervention, there is a general contraindication. This therapy can bring back memories of traumatic experiences and it is recommended that individuals with significant personality dysfunction and poor regulatory abilities be excluded from this type of intervention. IRT has some evidence that supports it being a recommended intervention for PTSD.

7.4 Group-Based Interventions

Group-based interventions focus on using a group setting to reduce the impact of major disasters such as flooding or hurricanes on individuals. Interventions include the following: Critical Incident Stress Management (CISM) and Group Therapy. CISM is a group therapy process conducted soon after a person experiences a traumatic event and is typically used in the first responder population. It provides structure, group support and

peer support, which lead to recovery. Group Therapy can be used in mild PTSD and utilizes principles of CBT.

Evidence

Critical Incident Stress Management (CISM) is used widely to treat PTSD and typically well-received by participants; there is inadequate clinical evidence that it is effective in reducing PTSD symptoms.[140] Group Therapy can be effective for individuals with mild PTSD, particularly with war veterans, rape/incest victims, and natural disaster victims.[140]

Mixed evidence: one or more systematic review(s), or at least two experimental studies, or two quasi-experimental studies with matched concurrent comparisons, or three studies with unmatched comparisons or pre-post measures. Research is still needed with Critical Incident Stress Management (CISM) and group therapy before either can be considered a standard of care.

7.5 Crisis Counseling Program

This model is frequently used for natural disaster response. This model assesses strength, seeks to restore pre-disaster functioning, accepts content at face value, validates common reactions, and has a psychoeducational focus. The Crisis Counseling Program (CCP) assesses strengths, seeks to restore pre-disaster functioning, accepts content at face value, validates common reactions, and has a psychoeducational focus. This model is frequently used for natural disaster response.

Evidence

The Crisis Counseling Program (CCP) was found to not be very effective after Hurricane Katrina due to the unusual circumstances of this disaster.[143]

Insufficient evidence: generally has no more than one experimental or quasi-experimental study with a matched concurrent comparison, or two or fewer studies with unmatched comparisons or pre-post measures. More research is needed, as this study suggests providing disaster mental health services to first responders requires customized fluid crisis intervention services based on practical application rather than on theory.

7.6 Psychological First Aid

This is a strength-based intervention that focuses on individual needs and is utilized in a non-interfering manner in order to provide assistance and re-establish safety and stability after a disaster. This intervention was used with first responders during Hurricane Katrina and with deployed responders after Hurricane Ike and Gustav. Psychological First Aid (PFA) is a strengths-based intervention focusing on individual needs and utilized in a nonintrusive manner to provide assistance and re-establish safety and stability following a disaster.

Evidence

Two studies supported using this intervention in the aftermath of a hurricane. One article mentioned this intervention would be most effective if the intervention was

tailor-made for the unusual circumstances of Hurricane Katrina.[144] Another article found this intervention to be appropriate for hurricane survivors in the aftermath.[145]

Some evidence: This includes one or more systematic review(s), or at least: two experimental studies, or two quasi-experimental studies with matched concurrent comparisons, or three studies with unmatched comparisons or pre-post measures. PFA was found to be the most applicable intervention in the aftermath of Hurricanes Katrina due to its focus on cultural sensitivity. First responders, such as firefighters and police officers, typically have a tight-knit community due to their needs to rely on one another in dangerous situations.[144] There is preliminary evidence that PFA was useful after Hurricanes Ike and Gustav, however, rigorous research related specifically to FPA is lacking.[145]

7.7 Eye Movement Desensitization and Reprocessing

Eye Movement Desensitization and Reprocessing (EMDR) is a type of psychotherapy that helps heal symptoms and emotional distress in individuals that experienced traumatic events. EMDR[146,147] is an eight-phase treatment for reprocessing dysfunctional information (traumatic memories) based on Shapiro's Adaptive Information Processing (AIP) model, where the brain possesses an intrinsic, adaptive information processing system that allows unprocessed, fragmented, and distorted experiences to make relevant connections within the memory network, reaching an adequate and adaptive resolution. The eight phases are the following: history, preparation, assessment, desensitization, installation, body scan, closure and re-evaluation.

Evidence

There appears to be a growing recognition that a school-based, public health-inspired approach is the most effective way to address the needs of children after major disasters. The study indicates that controlled treatment research in post disaster environments is feasible. Overall, EMDR can be an effective treatment for individuals, including children, dealing with traumatic life experience. There was significant reduction of symptoms in Post-Traumatic Stress Disorder (PTSD) in as little as three sessions.[148] One study showed EMDR to be effective in children and adults when administered in a group setting. Data has shown the results are maintained over a period of time. However, this is still considered to be a new treatment and additional research is needed before EMDR can be considered being a standard of care.[140] Numerous studies have validated the use of EMDR is treating PTSD. Results tend to appear more rapidly than other interventions.[149]

Scientifically supported: Includes one or more systematic review(s), or at least: three experimental studies, or three quasi-experimental studies with matched concurrent comparisons. Numerous studies have validated the use of EMDR is treating PTSD. In this systematic review, four studies found EMDR group treatment can result in substantial remediation of post-traumatic symptoms. It is a highly valuable tool responding to a variety of man-made and natural disasters. Significant clinical improvements with PTSD symptoms are shown after a few sessions and results tend to appear more rapidly than with other interventions.[149] EMDR group treatment can result in substantial remediation of post-traumatic symptoms. It is a highly valuable

tool responding to a variety of man-made and natural disasters.[149] There is evidence that shows significant clinical improvements with PTSD symptoms after only a few sessions with EMDR and research has been shown to have variable findings associated with its efficacy.[142]

7.8 Psychological Debriefing

This is a crisis intervention designed to relieve and prevent event-related distress in people experiencing abnormally stressful situations. Psychological debriefing is a crisis intervention designed to relieve and prevent event-related distress in people experiencing abnormally stressful situations. Treatment consists of a single extended session.

Evidence

There is preliminary empirical support for the effectiveness of post-disaster psychological interventions and also for feasibility of treatment research in post-disaster environments.[150]

Some evidence: This includes one or more systematic review(s), or at least: two experimental studies, or two quasi-experimental studies with matched concurrent comparisons, or three studies with unmatched comparisons or pre-post measures. There is some evidence this is a useful intervention after a natural disaster. However, additional studies need to be conducted in this area.

7.9 Exposure Therapy

In this therapy, individuals are exposed to stimulated trauma in order for them to realize their trauma is tolerable, so that they are able to take control over their emotions. This helps in reducing fear associated with experience through repetitive, therapist-guided confrontation of the places or things that constitute the traumatic event. Exposure therapy typically lasts from eight to twelve sessions, depending on the severity of Post-Traumatic Stress Disorder (PTSD) and considers factors, such as age and physical and mental health of the individual.

Evidence

Two studies have found preliminary support for the effectiveness of exposure therapy as an intervention.[140,142] Female victims of sexual and mental abuse, motor vehicle accident victims, men and women in military combat, and trauma cases have all been shown to benefit from exposure therapy.[142]

Some evidence: This includes one or more systematic review(s), or at least: two experimental studies, or two quasi-experimental studies with matched concurrent comparisons, or three studies with unmatched comparisons or pre-post measures. There is useful evidence supporting exposure therapy as an intervention for post-traumatic stress. However, exposure therapy is not used often due to ethics of inducing anxiety in an already traumatized individual.

7.10 Psychodynamic Psychotherapy

This type of therapy is an interaction between a psychotherapist and a client that leads to changes from a less adaptive state to a more adaptive stated in the client's

thoughts, feelings, and behaviors, whereas psychotherapy treats mental health problems by talking with a psychiatrist, psychologist or other mental health provider.

Evidence:

This intervention has been found to be effective because it significantly improves coping skills and increases self-esteem in individuals.[142]

Insufficient evidence: Generally has no more than one experimental or quasi-experimental study with a matched concurrent comparison, or two or fewer studies with unmatched comparisons or pre-post measures. There is some evidence this is a useful intervention after a natural disaster. However, additional studies need to be conducted in this area.

7.11 Pharmacotherapeutics

Pharmacotherapeutics is the study of the uses and effects of drugs. Examples of medications that fall in this category of drugs include the following: antidepressants, tricyclic antidepressants (TCAs), monoamine oxidase inhibitors (MAOIs), selective serotonin reuptake inhibitors (SSRIs), antianxiety and adrenergic agents, and mood stabilizers. These medications have been shown to improve symptoms of PTSD.142

Evidence

Selective Serotonin Reuptake Inhibitors (SSRI's) specifically, paroxetine and sertraline have shown to be most effective when treating PTSD.[142]

Some evidence: This includes one or more systematic review(s), or at least: two experimental studies, or two quasi-experimental studies with matched concurrent comparisons, or three studies with unmatched comparisons or pre-post measures. There is some evidence that medications can be effective in treating post-traumatic stress symptoms. However, medications are typically only prescribed if other treatment options have failed to improve symptoms and all other possible diagnoses have been ruled out.

8. Mental Health and Heat

High heat days and heat waves are particularly dangerous for those suffering from mental illness. Some with severe mental illness have multiple barriers to accessing health care.[151] Additionally, medications for the treatment of mental illness often reduce the body's ability to cool.[152] Heat illness symptoms, particularly for heatstroke, include changes in mental abilities, taking the form of disorientation or confusion. The scientific evidence shows a strong relationship between high heat and poor health in older citizens, some of whom have mental illness, and between high heat and poor health in those with mental illness.[152] This review focuses on interventions relevant to populations that are more likely to have mental health issues, such as the homeless, and older citizens because they may be more likely to have reduced cognitive function or may suffer from mental illness. Increasing temperatures may come in the form of higher nighttime and daytime temperatures, as well as longer duration of heat events (including heat waves). Increases in exposure to heat will mean that those with mental illness may be at increased risk for heat illness, including heatstroke or death.

An important note is that these studies did not delineate between persistent, untreated mental illness and other cognitive disabilities. For example, those living with intellectual or development disabilities or veterans with traumatic brain injuries make up a part of the homeless population. One study on the homeless population does not distinguish amongst the diverse populations making up those who are homeless or 'living rough.'

Methods

A literature review was conducted, in consultation with the Centers for Disease Control and Prevention, using identified electronic search engines Medline, Embase, SCOPUS, CAB, and Environmental Science Collection. Keywords were used to identify articles related to mental health and heat interventions. The search for articles included any articles that had a health term, a climate term, and an intervention term.

The health terms/keywords were: "health effects," "mental," "drug," "alcohol," OR "depression," "anxiety," OR "mental health," "trauma," "stress," "population displacement," "disruption," "emotional stress," "chronic stress," "incarcerated prison," "substance use," "post-traumatic stress," "interpersonal," "PTSD," "mood disorders," "psychology*," "intimate partner," "violence mental well-being," "prenatal stress," "mental illness," "substance use," "alcohol," "dehydration," " heat regulation," "heat stroke," "heat exhaustion," "heat syncope," "heat cramps," "heat stress" , " medical complications," "heat illness," " heat-health," "heat mortality," "heat-related illness."

The climate terms/keywords were: "heatwave," "humidity," "excessive humidity," "elevated temperatures," "sustained heat," "extreme heat," "temperature," "temperature extremes," "ambient temperature," "apparent temperature," "weather data," "extreme high temperatures," "heat events," "heat island(s)," "high temperatures," "temperature." The intervention terms/keywords were: "adaptation planning," "emergency withdrawal kit," "oral rehydration," "mental health surveillance," "heat safety action plans," "emergency shelters", " intervention," "heat watch," "heat warnings," "heat mitigation," "health-health warning," "warning system(s)," "watch-warning," "cooling centers," "preparedness," "response."

The above search identified 23 evaluations of mental health and heat interventions. These 23 evaluations contained estimates of the intervention's impacts and are included here.

Summary of Interventions

Overall, any strategy that is effective in preventing heat-related illnesses or death in the general population may also be effective for populations suffering from mental illness. However, there are a few strategies that are targeted specifically to populations that may be more likely to have mental illnesses, such as older persons. Strategies specific to populations that are impacted by mental health issues have been noted in the detailed descriptions on the following pages.

The literature has identified a variety of strategies that may be effective in preventing impacts from heat, among diverse audiences:

1. Government programs (e.g., heat warnings, disaster education, emergency plans);

2. Suicide prevention programs;
3. Urban design (e.g., green space);
4. Increasing social contact (e.g., peer-to-peer support networks).

The below strategies may be effective specifically for older adults (65 years of age or older):

1. Personal temperature monitor;
2. Wearing lighter clothing and taking cool showers or baths.
3. Fans.

INTERVENTION	DESCRIPTION	EFFECTIVENESS
INTERVENTIONS FOR DIVERSE AUDIENCES		
Government Programs	Utilize government services to reduce impact of heat on those with mental illness. May include heat warnings, disaster management, emergency plans, real-time surveillance system, or access to public water for the homeless.	Scientifically supported
Suicide Prevention Program	Mental illness contributes to suicide, and suicide has been linked to warmer temperatures.	Insufficient evidence
Urban Design	Designing communities in ways that improve mental health and reduce the risk of heat illness, such as improved shade and more greenways. More research needed to link urban design, heat-related illness, and mental health directly.	Some evidence
Increasing Social Connection	May help reduce vulnerability and provide some protection from negative health outcomes during heat events among those with mental health conditions.	Scientifically Supported
INTERVENTIONS FOR OLDER ADULTS		
Personal Monitor	Wearing a personal temperature monitor that communicates temperature and humidity to a caregiver.	Insufficient evidence
Wearing Lighter Clothing and Taking Cool Showers or Baths	A lower likelihood of death was found among older adults who wore lighter clothing and took cool showers or baths during heat events.	Scientifically supported
Fans	Fans were found to contribute to a higher cooling potential and lower likelihood of death. However, there is some evidence suggesting problems with fans at high temperatures. There are also health experts that do not recommend fans.	Mixed evidence

Table 9: Summary of interventions on mental health and heat

8.1 Government Programs

Government program interventions utilize government services to reduce the impact of heat on those with mental illness. These interventions include strategies such as heat warnings, disaster management, emergency plans, access to public water for the homeless, real-time surveillance system, compilation of scientific prevention messages, air-conditioning for hospitals and retirement homes, city censuses of vulnerable persons, visits to vulnerable persons during a heatwave, and longer hours from service providers for the homeless.

Evidence:

Medium to high effectiveness: The 2003 France heat wave claimed many lives, chiefly among older citizens, many of whom suffered from cognitive impairment or mental illness. The combination of a real-time surveillance system, compilation of scientific prevention messages, air-conditioning for hospitals and retirement homes, drawing up emergency plans for retirement homes, city censuses of vulnerable persons, visits to vulnerable persons during a heatwave, and the creation of a warning system may have resulted in less deaths in a 2006 heatwave among similar populations.[71]

Two other articles supported a warning system. A structured review found evidence that a heat advisory resulted in some behavior change among older citizens.[66] A case-crossover study found that a regional heat-health warning system reduced heat mortality in older citizens.[153] Interviews of the homeless population in one Australian city found that longer hours from service providers (e.g., shelters, meal providers) and access to public water were needs during heat events.[91] A survey evaluation of disaster education and government resources in India found that they reduced anxiety and increased disaster preparedness. In this survey, anxiety was measured using the 20-item trait anxiety inventory from the State-Trait Anxiety Inventory. This inventory includes questions such as, 'Do you tire quickly?' and 'Do you feel pleasant', and responses were rated on a 4-point scale.[154]

Scientifically supported: Includes one or more systematic review(s), or at least: three experimental studies, or three quasi-experimental studies with matched concurrent comparisons. This government program has the most evidence for preventing heat illness among those with possible cognitive impairments.[66,71,153]

8.2 Suicide Prevention Program

Suicide has complex causes, but one contributing factor is mental illness.[155] Suicides have been connected to warmer temperatures, in particular, warming spring temperatures.[156] One strategy to reduce suicide is a suicide prevention program.

Evidence

High effectiveness: An ecological study found that the Finland suicide prevention program was connected with decreasing suicide trends, in the face of warming temperatures.[157]

Insufficient evidence: Generally has no more than one experimental or quasi-experimental study with a matched concurrent comparison, or two or fewer studies with unmatched comparisons or pre-post measures. Strategies within this rating have limited research documenting effects. This study is hypothesis generating. However, the study references similar results in Hungary.[158]

8.3 Urban Design

This intervention involves designing communities in ways that improve mental health and reduce the risk of heat illness. Examples of this intervention are greenways and public parks.

Evidence

Medium effectiveness: A literature review found that urban design is a climate change adaptation that can benefit mental health and reduce the heat illness. Strategies such as increased or improved shade or green spaces and improvement of public transport may be effective in improving mental health and reducing poor outcomes from heat.[159,160] A literature review on the health impacts of green space found improved mental health among those living close to green space. In addition, the review found those in neighborhoods with highest amount of green space reported better health and green space was related to less loneliness and more social support.[161] Those living in green spaces may be protected from heat illness if the green spaces are able to reduce the amount of heat retained by neighborhoods, while also gaining mental health benefits of green space.[159,160]

Some evidence: This includes one or more systematic review(s), or at least: two experimental studies, or two quasi-experimental studies with matched concurrent comparisons, or three studies with unmatched comparisons or pre-post measures. Two literature reviews found urban design that increased green space was connected to better mental health. Green space may reduce the temperature in neighborhoods during heat events. However, since the connection between urban design, heat, and mental illness is not addressed outright in the literature, further research should be done to confirm effects.

8.4 Increasing Social Connection

This type of intervention involves using peer-to-peer support networks or other means to increase social connection among those with mental health conditions. Connection may help reduce vulnerability and confer some protection from negative health outcomes during heat events.

Evidence

Medium effectiveness: A literature review of case-control or cohort studies found that increasing social contact during heat events was associated with better outcomes. Most of these studies linked mental health diagnoses with increased risk of death from heat.[88]

Scientifically supported: Includes one or more systematic review(s), or at least: three experimental studies, or three quasi-experimental studies with matched concurrent comparisons. The evidence for this intervention comes from one literature review of case-control or cohort studies and one study that used interviews.[88]

8.5 Interventions for Older Adults

These interventions were evaluated among older adults, or those 65 years of age or older. The interventions were the use of a personal temperature monitor, wearing lighter clothing, taking cool showers or baths, and fans. Positive impacts from these strategies include the reporting of temperature to caregiver, a lower likelihood of death, and a higher cooling potential. Older adults may have cognitive impairments or mental health conditions and therefore may be more vulnerable to heat events.

Evidence

Low to Medium effectiveness: An intervention study found that a personal temperature monitor had the capacity to communicate temperature and humidity to a caregiver of an older adult, potentially an adult with a cognitive disorder.[162]

A literature review and a case control study found a lower likelihood of death among older adults that wore lighter clothing and took cool showers or baths during a heat event.[90,93] An experimental intervention and a case control study found fans contributed to a higher cooling potential and lower likelihood of death.[90,163] It should be noted that there is mixed evidence on the usage of fans in general, and many heat experts feel that fans should only be used at temperatures below body temperature (~98°F).

Insufficient evidence for personal monitor: Generally has no more than one experimental or quasi-experimental study with a matched concurrent comparison, or two or fewer studies with unmatched comparisons or pre-post measures. Scientifically supported for wearing lighter clothing and taking cool showers or baths

Includes one or more systematic review(s), or at least: three experimental studies, or three quasi-experimental studies with matched concurrent comparisons. Two different articles found a lower likelihood of death among older adults that wore light clothing and took cool showers or baths during a heat event.[90,93] Twenty percent of adults 60 or older live with a mental or neurological disorder.[164]

Mixed evidence for fans: One or more systematic review(s), or at least two experimental studies, or two quasi-experimental studies with matched concurrent comparisons, or three studies with unmatched comparisons or pre-post measures.

9. Mosquito-borne Disease

The climate in much of the U.S. can support mosquito species that are capable of transmitting pathogens to humans. Global trade and travel, changes in land use, and weather and climate can all affect the risk of mosquito-borne diseases. While the factors affecting human transmission of mosquito-borne disease are complex, the seasonality, distribution, and prevalence of vector-borne diseases are influenced significantly by climate factors. Climate change will likely have an impact on mosquito-borne disease transmission.[11] For example, higher temperatures affect West Nile virus transmission by accelerating mosquito development (e.g[165] and virus reproduction rates,[166] increasing egg-laying and biting frequency[167]), and impacting mosquito survival.[165] Along with mosquito and human surveillance, interventions to reduce mosquito populations or provide education about personal protection from bites can help reduce mosquito-borne disease incidence.

Methods

For the purposes of this review, there was a focus on intervention strategies applicable to known mosquito vectors in the U.S. Intervention strategies that are inapplicable to the U.S. (e.g. bed nets; indoor residual spraying) were not included. Google Scholar, PubMed, and Web of Science databases were searched using different strings of keywords and Boolean search terms. The terms “intervention,” “mosquito,” “disease,” “health” but not “nets,” “DDT,” or “Africa” returned the most useful results to complete

a broad assessment. Dengue, West Nile virus, Chikungunya, and Ross River virus were among the most reviewed diseases, with Aedes and Culex species targeted based on the US focus. Thirteen articles were reviewed.

Summary of Interventions

An existing simple barrier to prevent mosquito exposure in the US is the high prevalence of enclosed homes (usually with air conditioning and/or screen doors). This strategy was not assessed in this review. Human disease surveillance provides data for monitoring the overall disease burden in an area over time; however, environmental surveillance including monitoring mosquito abundance and infection rates can provide a more timely indicator of pathogen transmission. Integrated vector management (IVM) programs that incorporate systematic and consistent mosquito surveillance and a combination of interventions aimed at directly reducing mosquito populations can be effective tools for minimizing human risk of mosquito-borne disease transmission. Each of these IVM components are described below.[168] No single intervention is appropriate for all areas. Decisions regarding the most appropriate and effective suite of mosquito control measures require knowledge about the mosquito species, environmental conditions, and pathogens of concern in an intervention area. Effective interventions aimed at directly reducing mosquito populations depend on proper analysis of information related to environmental conditions and mosquito distribution. The most effective and environmentally sound pest control programs are based on a combination of methods including source reduction, chemical control, and biological control."[169]

INTERVENTION	DESCRIPTION	EFFECTIVENESS
Source Reduction	Removal or permanent destruction of mosquito breeding sites. Mosquito producing habitats that can be targeted for source reduction range from man-made containers (e.g. flowerpots, pet bowls, trashcans, and tires) to unmaintained swimming pools, storm drainage systems, underground cisterns, freshwater lakes, ponds, retention areas, swamps and marshes, temporarily flooded locations, and salt marshes.	Scientifically supported
Larvicide	Larviciding is the application of chemical agents (larvicides) to larval habitats with the goal of managing the mosquito population before they emerge as adults. Larvicides are sometimes an efficient and effective intervention because it can minimize the area that needs to be treated and can limit the need for adult mosquito control. In other cases where a small number of larvae and pupae are distributed unevenly over a large area, larviciding may have less of an impact.	Scientifically supported

continued on next page

INTERVENTION	DESCRIPTION	EFFECTIVENESS
Adulticide	Adulticiding is the use of targeted pesticides to control adult mosquitoes in order to (1) complement larval management by reducing the number of eggs laid in breeding sites and (2) reduce the abundance of biting, infected adult mosquitoes. Adulticides can include space spraying (a.k.a. cold fogging), where Ultra Low Volume technology is used to release short-lived aerosols over large areas so that pesticides droplets can come in contact with flying mosquitoes. Residual spraying (a.k.a. barrier treatments/ surface treatments) are used when a more long-term effect is required to prevent adult mosquitoes from moving into a limited area such as a stadium, park, or backyard. The treated areas are generally small, and the adulticides are usually applied with small, handheld devices such as a backpack mist blower.	Scientifically supported
Autocidal Gravid Ovitraps	Ovitraps are small metal, glass, or plastic containers with water and substrate where female mosquitos lay their eggs. Can be utilized to capture gravid (egg carrying) females using either funnels or sticky boards to prevent mosquitos from escaping. Additionally collect mosquito eggs and prevent hatching larvae from completing development and emergence as adults through mechanical means or chemical control.	Insufficient evidence
Insecticide-Treated Clothing	Permethrin applied to clothing serves as an insect repellant and quick-acting insecticide that kills or irritates mosquitos making contract with the fabric.	Insufficient evidence
Surveillance and Response Plans	Can provide semi-quantitative means for assessing human health risks; basis for prescribing appropriate response levels to protect public health. Can include human case surveillance, mosquito-based surveillance, host-based surveillance (e.g. sentinel chickens), or environmental surveillance. With systematic and consistent surveillance it is possible to detect trends or anomalies over time and establish thresholds for increased risk that warrant mosquito control actions or other interventions to protect public health.	Expert Opinion
Mosquito Control Programs	Protect individuals from mosquito-borne disease and nuisance mosquito populations. Successful with comprehensive, multi-intervention plans; can involve community engagement. Many programs able to collect surveillance information and determine appropriate response. Generally utilize a combination of control methods in a thoughtful ecologically-valid program (IVM).	Some evidence

Table 10: Summary of interventions for mosquito-borne disease

9.1 Source Reduction

Source reduction is the removal or permanent destruction of mosquito breeding sites, or modification of sites that eliminate them as a potential breeding source.[170] It can also involve the removal of aquatic plants that are required for the lifecycle of specific mosquito vectors. Mosquito producing habitats that are appropriate for source reduction include the following: containers (e.g. flowerpots, pet bowls, and tires); freshwater lakes, ponds, and retention areas; freshwater swamps and marshes; temporarily flooded locations; and salt marshes.[169] Some species of mosquitos (e.g. Ae. albopictus) often lay eggs in artificial containers in urban areas, and removal of these containers can prevent mosquito reproduction and halt the spread of mosquitos.[171] Source reduction is a major component of multi-intervention strategies (i.e. IVM) that aim to reduce mosquito populations. It is considered one of the most important techniques homeowners can employ to reduce mosquitoes.[172]

Evidence

Scientifically supported: Includes one or more systematic review(s), or at least three experimental studies, or three quasi-experimental studies with matched concurrent comparisons.

9.2 Larvicide

Larviciding is the killing of immature mosquitos in the life stages of larval and pupae, which take place in water, by applying chemical agents (collectively called larvicides) to control mosquito reproductions.[169,172,173] Many mosquito species spend much of their lifecycle in the larval stage, concentrated within accessible and defined water boundaries, and are therefore highly susceptible to control efforts.[169] There a variety of types of larvicide, with all types being able to be generally classified as biorational pesticides or conventional, broad-spectrum pesticides. Larvicide can be applied from the ground, by truck, boat, and hand held devices, or by air, with fixed wing and rotary wing aircraft.[169]

For effective and appropriate use of larvicide, having a larval state management strategy and adult/larval mosquito surveillance is crucial. Surveillance allows for the mapping and prioritization of potential larval habitats. Additionally, it is critical to have a thorough knowledge of the biology of the targeted species to determine the appropriate larvicide, the timing of the application, and the amount of larvicide to be applied.[169] There is no singular perfect larvicide for every situation. Larviciding is typically done through well-thought out "prescription" applications that apply one or more larvicides in an environmentally responsible manner appropriate to the given set of conditions.

Evidence

Scientifically supported: Includes one or more systematic review(s), or at least: three experimental studies, or three quasi-experimental studies with matched concurrent comparisons.

9.3 Adulticide

Adulticiding is the process of applying pesticide applications targeted to adult mosquitos.[173–176] The mode of action of mosquito adulticides is the disruption of neural activity leading to mortality. There are two methods of adulticiding: residual spraying (also known as barrier treatments/ surface treatments) and space spraying (which can include cold fogging or thermal fogging).

Residual Spraying

Residual spraying is a ground application method in which insecticides are applied to foliage or other surfaces where adult mosquitos may land. In order to be effective, insecticide must be applied at a concentration high enough that an adult mosquito landing on the treated vegetation will pick up enough of a toxic dose through contact to cause mortality.

Typically, residual spraying is utilized when people are not present, in limited areas - e.g. nighttime outdoor events, sporting events, in yards, at parks, etc. The treatments can provide longer-term control for days or weeks, depending upon the insecticide applied. Treatments can be applied with modified vehicle mounted hydraulic sprayers, handheld backpack mist blowers, or compression sprayers through drenching sprays, mist sprays, or electrostatic sprays.[169]

Space Spraying

Space spraying is a short-lived method of adulticiding in which aerosols are released to drift through a target zone to persist in the air column for an appreciable length of time at suitable droplet densities to contact flying mosquitos.[169] The method is only effective while droplets remain airborne. Once sprays are on the ground or foliage, they are no longer effective because the concentration is too small to act as a contact/residual treatment, and the chemical begins to degrade.[169]

Space sprays typically utilize Ultra Low Volume (ULV) technology. They can be applied using a ground application, on the back of trucks or carried by hand, or through an aerial application utilizing aircraft. Aerial adulticiding is the only mosquito-control method that covers a large area quickly during severe nuisance mosquito outbreaks (e.g. following natural disasters) or vector-borne disease epidemics.[169]

Considerations for space spraying include droplet sizes, timing, application rate, insecticide concentration, and meteorology. Droplet sizes are controllable and certain sizes are more likely to provide effective control as they can stay in the air column for an ideal length of time and can persist in the targeted area without being lost downwind. Timing is essential with treatments as there should be consideration of when targeted species are active. Adulticides are generally broad-spectrum pesticides with the potential to impact non-target organisms.[169] Applications that coincide with mosquito flight activity and avoid the flight activity of nontarget insects (e.g. bees and butterflies) can be more effective for mosquito control. Meteorological conditions, including humidity, temperature, wind, and lunar illumination can impact mosquito activity and therefore the timing of the application. When conditions are not ideal for spraying (e.g. strong winds) it may be more practical to wait for conductive conditions for successful dispersal.

Evidence

Scientifically supported: Includes one or more systematic review(s), or at least: three experimental studies, or three quasi-experimental studies with matched concurrent comparisons.

9.4 Autocidal Gravid Ovitraps

Ovitraps are small metal, glass, or plastic containers, which contain water and substrate where female mosquitos lay their eggs.[177] Ovitraps work best for mosquito species which lay their eggs in artificial containers (Aedes spp and some Culex spp). Autocidal gravid ovitraps can be utilized to capture gravid females and will use either funnels or sticky boards to prevent captured mosquitos from escaping.[178] Autocidal ovitraps additionally collect the eggs of mosquitos and prevent hatching larvae from completing their development and emergence as adults through either mechanical means or chemical control.[177] This lowers the biting rate of a population through reduction of population fertility and direct adult female mosquito mortality. These traps are generally inexpensive in that they use simple low-cost mechanisms for eliminating certain container-breeding mosquitos and their progeny, often for extended periods of time without servicing.[177] However, if the traps are not continuously monitored and service, they may become breeding sites. Ovitraps are more commonly used as a monitoring method, rather than an intervention.

Evidence

Insufficient evidence: Generally has no more than one experimental or quasi-experimental study with a matched concurrent comparison, or two or fewer studies with unmatched comparisons or pre-post measures. Strategies within this rating have limited research documenting effects.

9.5 Insecticide-Treated Clothing

Insecticide-treated clothing has been in use by the military and in recreational activities for years to act as personal protection against bites from mosquitos.[179] Clothing can be treated at home or by factory dipping. In the U.S., the only insect repellant currently used for factory treated clothing is permethrin, a broad spectrum, non-systematic, synthetic pyrethroid insecticide that targets both adults and larvae of many species of invertebrates.[180] When permethrin is applied to clothing, it serves as an insect repellant and quick-acting insecticide that kills or irritates mosquitos making contract with the fabric before they manage to feed.[181] According to the EPA, "The amount of permethrin allowed in clothing is very low, and scientific studies indicate that human exposure resulting from wearing permethrin factory-treated clothing also is low. Available data show that permethrin is poorly absorbed through the skin."[180] Manufacture directions should be followed to prevent harmful exposure. Increasing resistance to permethrin could affect this prevention method.

Evidence

Insufficient evidence: Generally has no more than one experimental or quasi-experimental study with a matched concurrent comparison, or two or fewer studies with unmatched comparisons or pre-post measures. Strategies within this rating have limited research documenting effects.

9.6 Surveillance and Response Plans

Mosquito-borne disease surveillance and response plans can provide semi-quantitative means for assessing human health risks and a basis for prescribing appropriate response levels to protect public health,[182–184] although implementation requires adequate capacity and staff with training and expertise. Surveillance can include surveillance of mosquito populations, mosquito-borne disease surveillance, and surveillance of environmental conditions. Surveillance of mosquito populations might include telephone/website requests for mosquito control services (although these methods may introduce a large degree of bias); measuring adult mosquito populations through trapping and landing counts; and monitoring immature mosquito populations through inventorying mosquito developmental sites, sampling immature stages, collecting eggs, and collecting larvae and pupae.[169]

Environmental conditions, such as changing temperatures, tidal events, precipitation events, changes in precipitation, ecological change, changing land use, human alterations to the environment, and other changes can all influence mosquito species ranges and abundance, with rising temperatures potentially increasing abundance.[185] Surveillance of environmental parameters is useful for preemptively assessing the risk of potential increases in incidence of mosquito-borne disease and the identification and prioritization of current and future areas of concern. Monitoring environmental conditions can also be applicable to areas that are not currently at risk for certain mosquito-borne diseases, but with future changes in the environment and vector transmission may become susceptible in the future.

With surveillance established, those responsible for controlling mosquito populations can develop response plans based on surveillance data and established action thresholds. Creating response plans based on surveillance data can lead to more effective targeted mosquito control measures. These plans must also remain flexible in order to make continual modifications to control programs as new challenges arise.

Evidence

Expert opinion: Generally has no more than one experimental or quasi-experimental study with a matched concurrent comparison, or two or fewer studies with unmatched comparisons or pre-post measures. Strategies within this rating are recommended by credible, impartial experts but have limited research documenting effects.

9.7 Mosquito Control Programs

Mosquito Control programs are developed to operate to protect individuals from mosquito-borne disease and nuisance mosquito populations.[186,187] This intervention is related to the previously discussed interventions of adulticiding and larviciding, as those activities are performed by licensed individuals that generally work within a mosquito control program. Mosquito control programs can be successful with comprehensive, multi-intervention plans, and can involve community engagement. Established guidelines by the World Health Organization on integrated vector management may aid in guidance, decision-making processes, and optimal uses of resources. It is suggested that government administrations provide adequate environmental management, municipal infrastructure, and technologies to enhance

mosquito control program activities. Many mosquito control programs are able to collect surveillance information and determine appropriate response. Mosquito control programs generally utilize a combination of control methods in a thoughtful ecologically-valid program, known as IVM.[169] The most common methods of IVM include Environmental Management (source reduction), larviciding, and adulticiding,[169] and include monitoring and surveillance planning.

Evidence

Some evidence: This includes one or more systematic review(s), or at least: two experimental studies, or two quasi-experimental studies with matched concurrent comparisons, or three studies with unmatched comparisons or pre-post measures.

10. Tick-borne Disease

Tick-borne diseases are infections transmitted to humans via tick bites. Ticks often become infected after feeding on infected animals. Lyme disease is the most common vector-borne illness in the United States, although the majority of confirmed cases occur in 14 states in the northeast and upper Midwest.[188] Recent habitat models of Ixodes scapularis and Ixodes pacificus, the vectors that carry the bacteria that cause Lyme disease, have shown suitable habitats for these ticks in 441 eastern counties and 11 western counties where surveillance records have not yet supported classification of these counties as established. These counties could be areas of emergence for Ixodes spp. populations or areas where the ticks are already present but surveillance is lacking.[189] Environmental factors such as temperature, precipitation, and humidity affect tick survival and host-seeking behavior, thus climate change has the potential to influence tick-borne disease transmission.[11] These relationships are complex and require further study, but the potential exists that climate change could cause increased risk of tick-borne disease in some parts of the US.

In addition to vector surveillance, several environmental and educational interventions for tick-borne diseases were reviewed, focusing on those interventions that have been used for Lyme disease and other tick-borne diseases such as Rocky Mountain Spotted Fever and babesiosis.

Methods

A literature review was conducted using identified electronic search engines PubMed, Google Scholar and Web of Science. The following keywords were used to identify articles related to tick-borne disease interventions: “Lyme,” “tick,” “Ixodes,” “Dermacentor,” “Rocky Mountain Spotted Fever,” “Borrelia,” “babesiosis,” “intervention,” “prevention,” “community,” “control,” “acaricide,” “behavior,” and “vaccine.” Additionally, references of any pertinent publications or reviews were examined and documents such as the “Connecticut Tick Management Handbook” were consulted.[190] The above search identified 190 manuscripts. Sixteen of these were evaluations of tick-borne disease interventions that contained measurable effect estimates of the intervention exposure being tested and were included in the final intervention assessment.

Summary of Interventions

Through the literature review, four interventions that may be effective in preventing or controlling tick-borne diseases, and in particular Lyme disease, were identified:

1. Wildlife treatment
2. Environmental application of pesticides
3. Use of repellent-treated clothing
4. Public education and protective actions

There are other types of interventions that have been evaluated but are considered to be infeasible, as well as interventions that have not been properly evaluated (such as alteration of the environment by clearing leaf litter, or post-exposure prophylaxis). Some other potential strategies, especially personal-level interventions such as utilization of tick collars for domestic animals and direct body application of pesticides such as DEET, were not included in the scope of this review.

INTERVENTION	DESCRIPTION	EFFECTIVENESS
Wildlife Treatment	Acaricides—pesticides that are effective against ticks—are applied to deer using a 4-poster device. Deer feed at bait at the device. While they are feeding, acaricide-treated rollers brush against their neck, head and ears where many ticks feed.	Some evidence
Environmental Application of Pesticides	This involves applying acaricides to certain environmental areas to reduce tick populations.	Some evidence
Use of Repellent-Treated Clothing	Commercially-soaked clothing is more effective than clothing with self-applied repellent.	Some evidence
Public Education and Protective Actions	Some evidence that taking protective actions (e.g., checking for ticks and bathing after potential exposure) reduces the risk of Lyme disease. Some evidence that education can result in behavior change toward these protective actions. However, no study linked education efforts to reduced Lyme disease incidence.	Some evidence

Table 11: Summary of interventions for tick-borne disease

10.1 Wildlife Treatment

This strategy targets deer, a primary host for the black-legged tick (Ixodes scapularis). Interventions can include applying acaricides—pesticides that target ticks and mites—directly on deer. One mechanism for applying acaricides to deer is called a 4-poster device. Deer feed on bait at the device. While they are feeding, acaricide-treated rollers brush against their neck, head, and ears where many ticks feed.[191–195]

Evidence

The literature indicates that with constant maintenance, 4-poster devices may be effective in reducing tick abundance over time in a limited geographic area.[193] However, upkeep of devices is a costly and timely procedure. In areas with chronic wasting disease or bovine tuberculosis, regulations may prohibit congregation of deer with 4-poster devices due to risk of further disease spread. There is also not clear evidence that a decrease in tick prevalence due to use of 4-poster devices has a direct impact on tick-borne disease prevalence in humans. This intervention is not easily scalable, and has a host of potential issues such as human exposure to acaricides and attraction of other animals (e.g. fox and skunks) that may carry diseases such as rabies.

Some evidence: This includes one or more systematic review(s), or at least: two experimental studies, or two quasi-experimental studies with matched concurrent comparisons, or three studies with unmatched comparisons or pre-post measure. Several studies have evaluated the effectiveness of 4-poster devices. These studies are well-designed in that they compare changes in tick population in an intervention area to a control area.

10.2 Environmental Application of Pesticides

Another intervention to control the incidence of tick-borne diseases is to reduce the tick population through the environmental application of pesticides. While this method has been shown to be reliable in suppressing tick populations,[196,197] it is not widely accepted due to concerns over adverse health and environmental impacts.

Evidence

The studies in this review assessed the effectiveness of natural, plant-derived acaricides, which could be more publicly acceptable than a synthetic acaricide. In addition, these natural products could be purchased and applied by the general public. Tick reduction seemed to be greatest when the substances were applied using a high-pressure sprayer, but multiple applications of hand-held or backpack sprayers can achieve acceptable results.

Some evidence: This includes one or more systematic review(s), or at least: two experimental studies, or two quasi-experimental studies with matched concurrent comparisons, or three studies with unmatched comparisons or pre-post measure. The studies were well-designed and of high quality. Investigators applied acaricide (either one or two separate treatments, depending on the study) to plots of land, measured tick counts before and after application, and compared these changes to changes at control sites that were not treated. Note that studies did not investigate the effectiveness of acaricide application to reduce tick-borne disease incidence. There is some evidence that residential use of acaricides can reduce tick populations, but may not have an effect on number human-tick encounters and resulting health outcomes.[198]

10.3 Use of Repellent-Treated Clothing

This intervention pertains to reducing or eliminating contact with ticks by wearing clothing that has been treated with repellents, including acaricides. The clothing is commercially soaked (i.e., impregnated) with a repellent substance which allows it

to retain its effectiveness after multiple washings, as opposed to self-application of repellent. Using repellent-impregnated clothing likely is a more effective method than self-application of repellent to reduce tick-borne disease because less burden is placed on the individual and the repellent is longer lasting.[199,200] We did not review the literature on personal pesticide spray (e.g. DEET) application.

Evidence

Repellent-impregnated clothing is very effective in reducing tick bites although it's possible that effectiveness decreases over time. One study found that permethrin was more effective than DEET.[201]

Some evidence: This includes one or more systematic review(s), or at least: two experimental studies, or two quasi-experimental studies with matched concurrent comparisons, or three studies with unmatched comparisons or pre-post measure. One study[199] was a randomized control trial. Workers in the group that wore treated clothing were much less likely to report tick bites than a control group (protective effect: 82%) in the first year. In the second year, a protective effect (34%) was also found, but it was not statistically significant.

10.4 Public Education and Protective Actions

This intervention involves educating the public about how Lyme disease is transmitted and what protective actions can be taken to reduce the likelihood of a tick bite or Lyme disease transmission. These actions include: self-check, tick removal techniques, avoiding areas of high tick density, using insect repellent, and wearing protective clothing.[202]

Evidence

The effectiveness of public education appears to depend upon how well the intervention is designed. Effectiveness is more likely if people perceive that the risk is real, that preventive actions can reduce this risk, and that they have the ability to perform these actions.[203] One study[204] found that education improved knowledge, attitudes, and behavior toward actions to prevent tick bites, but could not statistically demonstrate these protective actions reduced Lyme disease incidence, while another[205] showed protective practices were effective but did not measure education. Some studies have shown that increased knowledge about Lyme disease did not reduce Lyme incidence.[206,207]

Some evidence: This includes one or more systematic review(s), or at least: two experimental studies, or two quasi-experimental studies with matched concurrent comparisons, or three studies with unmatched comparisons or pre-post measure. There is good strength of evidence that a well-designed education program can improve the degree to which the public takes protective action to prevent or control tick bites. The studies were well-designed and involved control groups. The determination of taking protective action was based on self-reporting and thus could have been biased. Actions such as performing tick checks and bathing after being outdoors were significantly protective in a Lyme disease case control study.

11. Drinking Water and Water-borne Disease

Changes in volume, seasonality, and intensity of precipitation may all lead to an increased risk for flooding, which has implications for waterborne disease. Customers of municipal drinking water systems, private well users, and recreational users of lakes and rivers may experience increases in possible exposure to waterborne bacterial and viral infections as changes in precipitation become more pronounced.[56]

Adverse health effects from exposure to waterborne disease include the following: gastrointestinal illness, skin irritation, respiratory issues, and eye problems. Waterborne disease causes can be hard to track and characterize because of the testing required to determine the exact agent of the illness, but common bacterial, viral, and protozoan pathogens include Shigella, Cryptosporidium, Salmonella, and Escherichia coli.[208]

Assessing intervention strategies for controlling waterborne disease outbreaks will be important to the overall health of the public. Vulnerable populations around the world may be adversely impacted by waterborne disease due to water resource issues and lack of public health infrastructure.

Methods

A literature review was conducted using the search engines PubMed, Google Scholar, and Web of Knowledge. A series of searches were conducted using keywords related to waterborne disease terms including: "Cryptosporidium," "Campylobacter," "E. coli," "fecal runoff," "Giardia," "Salmonella," "manure," "gastrointestinal illness," "heavy precipitation," and "Vibrio cholera." Additional keywords were added to the search to be able to identify studies specific to intervention strategy study designs. These included: "disease incidence," "prevalence," "risk," "measurable," "health outcome," "plan," "planning," "program," "response," "evaluation," "response," "warning," "alert," "watch," "public health response," "implementation," "prevention," "awareness," "education," "preparedness," "control," "measures," "strategy," "system," "risk management," "disaster management," and "emergency management."

A secondary search was conducted from a compilation of references and abstracts sent directly from the Centers for Disease Control and Prevention. The methods used for this secondary search included the search engines Scopus, ProQuest Environmental Science Collection, and CAB abstracts along with the keywords from the original search. Finally, this secondary search output was filtered by the keywords "intervention" and "waterborne disease."

Summary of Interventions

The literature on waterborne disease interventions tends to focus on two different intervention types:

1. At-home treatment (personal filters)
2. Community-level treatment (disinfection systems for drinking water)

The results of the studies indicated mixed reviews for how successfully these interventions reduce waterborne disease incidence: the only strong results occurred in vulnerable populations.

INTERVENTION	DESCRIPTION	EFFECTIVENESS
At-home Treatment	Include a variety of equipment and different processes that demonstrate varying levels of success at removing chemicals, bacteria, protozoa, and viruses. These include UV distillation, ozonation, filtration, and reverse osmosis.	Some evidence
Community-level Treatment	Large-scale disinfectors at the community level. UV filtration is often used before the chlorination process and is effective in removing bacteria, viruses and spores, but not chemicals in the water.	Some evidence

Table 12: Summary of interventions for water-borne disease

11.1 At-Home Treatment

In-home methods for reducing adverse health effects from waterborne disease include the use of filters and more complex disinfection systems.[209] Most filtration systems can rely on a variety of methods or consist of solely one kind. The at-home methods found in the literature include:

1. Ultraviolet (UV) Distillation
2. Ozonation
3. Filtration
4. Reverse Osmosis

These filtration methods each have a varying ability to remove potential harmful compounds or organisms from drinking water. Most commonly these include: protozoa, viruses, and bacteria. Protozoa are single-celled organisms that are motile and able to contaminate drinking water. These include Cryptosporidium, Giardia, and Naegleria fowleri. Viruses are small, infectious agents that are able to replicate inside a host, giving rise to possible adverse health effects. Common waterborne viruses are Hepatitis A, norovirus, and rotavirus. Bacteria are single-celled organisms that can contaminate drinking water and include Campylobacter, Salmonella, Shigella, and E. coli. Some of the methods will reduce the number of bacteria, but not viruses; others remove protozoans but not bacteria.

Chemicals and heavy metals can contaminate drinking water and can be harmful if the exposure is high enough or persists for an extended period of time. Common chemicals that can contaminate drinking water include arsenic, cadmium, nitrates, and lead.

Ultraviolet (UV) Distillation

Distillation is characterized by heating water up to boiling, and then capturing the water vapor that condenses. UV distillation systems use a treatment process that uses UV light to distill and reduce the amount of bacteria that is present in the drinking water. While able to reduce the amount of protozoa, bacteria, and viruses with a very high effectiveness, UV distillation is not effective at removing chemicals found in drinking water.[210,211]

Ozonation

Ozone is a common disinfection agent because it is able to form a free radical and oxidize compounds to reduce their concentrations in drinking water. It is effective in removing bacteria, protozoa, viruses, some common organic chemicals, and inorganic chemicals such as iron and manganese. However, ozonation requires a high cost to maintain the system and because it does not add any chemicals to the water, it is not able to inhibit regrowth of the potentially harmful organisms, chemicals, and viruses.[212]

Filtration

Filtration methods to rid drinking water of possible waterborne pathogens include filters that have different pore sizes that are able to filter out varying sizes of bacteria and viruses. The use of carbon filters and ceramic filters are examples of different types of filtration.[213] Filtration sizes can be split up into three groups: microfiltration, ultrafiltration, and nanofiltration.

	SIZE OF PORES	EFFECTIVENESS
Microfiltration	0.1 micron	• Highly effective in removing protozoa • Moderately effective in removing bacteria • Not effective in removing viruses • Not effective in removing chemicals
Ultrafiltration	0.01 micron	• Highly effective in removing protozoa • Highly in removing bacteria • Moderately effective in removing viruses • Low effectiveness in removing chemicals
Nanofiltration	0.001 micron	• Highly effective in removing protozoa • Highly in removing bacteria • Highly in removing viruses • Moderately effective in removing chemicals

Figure 1: Description of micro-, ultra-, and nano-filtration.

Reverse Osmosis

Reverse osmosis systems use a process that reverses the flow of water in the process of osmosis so that water passes from a more concentrated solution to a more dilute solution through a membrane. The filter used in reverse osmosis has a 0.0001 microns pore size, meaning that it is able to effectively remove potential harmful organisms and compounds. It is highly effective in removing protozoa, bacteria, and viruses. It is also moderately able to remove some common chemicals and metals from the water.

Evidence

Some evidence: This includes one or more systematic review(s),[214] or at least: two experimental studies, or two quasi-experimental studies with matched concurrent comparisons, or three studies with unmatched comparisons or pre-post measures.[212,215]

11.2 Community-level Treatment

Public water systems in the United States provide more than 100 million people with drinking water. According to the Environmental Protection Agency (EPA), there are more than 155,000 public water systems in place today.[216] Public drinking water systems must provide an uninterrupted supply of pressurized safe drinking water to all consumers.

Infrastructure of the miles of pipes used in public water systems could become damaged over years of use. The possible damage could pose a significant health risk if contamination were to occur because of the infrastructure damage. Throughout the literature review, intervention methods involving waterborne disease at the community level were not common.

Only one method of intervention was found in the literature, though more exist:

1. Ultraviolet disinfection reactors

Ultraviolet Disinfection Reactors

Ultraviolet (UV) disinfection typically occurs after any filtration methods the water system uses and before chlorination. The process involves water being pumped through a series of UV lights, which inactivate bacteria, protozoa, and viruses found in the water. The overall effectiveness of the system depends on the amount of time the water is exposed to the UV light, the intensity of the light, and specific characteristics of the wastewater. Overall, there are no residual effects left strictly by the UV light exposure. The technique is effective at inactivating bacteria, viruses and spores, but not chemicals in the water. However, if a contamination source exists in the distribution system, this method of treatment before distribution will not be effective.

Evidence

Some evidence: This includes one or more systematic review(s), or at least: two experimental studies, or two quasi-experimental studies with matched concurrent comparisons, or three studies with unmatched comparisons or pre-post measures.[210] This method is widely utilized and likely effective, but the limited scope and focus of our methods did not find peer-reviewed literature examining the specific health impacts of this intervention in the context of climate change.

12. Wildfire Smoke

Climate change can impact wildfire risk due to a variety of factors, including increased temperatures and shifting precipitation patterns. Climate change is projected to increase the number and severity of naturally occurring wildfires in parts of the United States, increasing emissions of particulate matter and ozone precursors and resulting in additional adverse health outcomes.[11]

"Wildfires at or near the urban–wilderness interface can pose great risk to human health and safety."[217] While immediate emergency response is often the focus of protecting individuals from fire hazards, there is a growing body of evidence demonstrating that exposure to wildfire smoke poses a health risk.[217] Globally there is an average of 340,000 premature deaths annually attributed to fine particulate

matter from landscape fires, including wildfires.[217] Smoke from wildfires can travel long distances and affect the health of communities at a distance from the wildfire. Wildfire smoke contains particulates (both fine/invisible and coarse/visible), carbon monoxide, volatile organic compounds, and polycyclic aromatic hydrocarbons (PAH's).[218] Smoke from wildfires can cause coughing, scratchy throat, irritated sinuses, shortness of breath, chest pain, headaches, stinging eyes, and runny nose.[219]

Smoke can also worsen symptoms for people who have pre-existing respiratory conditions, such as respiratory allergies, heart or lung disease, and chronic obstructive pulmonary disease in the following ways: inability to breath normally, cough with or without mucus, chest discomfort, wheezing and shortness of breath, and fatigue.[219] If smoke levels are high enough, even people without pre-existing conditions may experience some of these symptoms.

Some impacts of wildfires, such as injuries occurring during cleanup, are not included in the scope of this review. Some potential interventions, ranging from zoning laws in fire prone areas to cessation of certain fire-suppression methods in fire-dependent ecosystems, were not assessed in this limited review.

Methods

The literature review was conducted utilizing Web of Science and Google Scholar databases. These databases were searched with numerous keywords and different combinations thereof, but "response," "intervention," "fire," and "respiratory" returned the most applicable results. However, the search also yielded many interventions and assessments related to firefighter health, which are not directly applicable to the general public. This intervention assessment focuses on those interventions that are directly applicable to the general public.

Summary of Interventions

This review covers interventions aimed at preventing negative health outcomes associated with smoke inhalation from wildfires. Interventions reviewed include evacuation, air filtration and cleaning units, personal air filter masks (or respirators), wildfire smoke and warning systems, and public service announcements. A review of the peer-reviewed literature indicated that utilizing air filtration and cleaning units in room, home, and health facilities proved to be the most effective human health strategy in reducing indoor smoke concentrations. When people must be outdoors, air filtration masks and respirators can be effective if utilized correctly.

INTERVENTION	DESCRIPTION	EFFECTIVENESS
Evacuation	Urgent removal of individuals from building or a community, when there's an immediate risk to human health and safety. Can include entire populations or sub-populations of at-risk individuals who are particularly susceptible to the health effects from smoke exposure.	Scientifically supported
Air Filtration and Cleaners—Home, Room, Facility	Filtration "removal of particulate matter (PM) from air using an air-handling system and a filter (or a bank of filters)." Air cleaning: "removal of gaseous contaminants from air using an air-handling system and sorbent filters (such as granular activated carbon, potassium permanganate impregnated alumina and impregnated carbon)."	Scientifically supported
Personal Air Masks	Respirator masks, or "particulate respirators", (which look like paper masks) can filter out 95% of particulates that are 0.3 microns and larger, thus filtering a significant portion of smoke. Respirator masks labeled "R95," "N95," or "p95," or soft masks with higher ratings (R, N, or P99 and R, N, or P1000) will filter out most particles associated with wildfire smoke. Respirators with purple HEPA filters offer the highest protection.	Some evidence
Forecast/Warning Systems	Air quality forecasting is conducted by a wide variety of agencies at a state and national level. These forecasting systems usually use an Air Quality Index (AQI) for reporting and forecasting daily air quality. The EPA, in conjunction with NOAA, calculate the AQI for five major pollutants: ground level ozone, particulate pollution (particulate matter), carbon monoxide, sulfur dioxide, and nitrogen dioxide.	Some evidence
Public Service Announcements	Messages to the public disseminated by the media with a primary purpose of informing and education the public. Can be utilized to spread a message informing the public of the health risks of wildfire smoke inhalation and preventive measures to protect lungs.	Some evidence

Table 13: Summary of interventions on wildfire smoke

12.1 Evacuation

Evacuation is a common intervention when a wildfire is approaching a populated area.[217] It consists of the "urgent removal of individuals from an area, such as a building or a community, when there is an immediate risk to human health and safety."[217] Evacuation can be voluntary or mandatory. Some jurisdictions might utilize the terms "precautionary" and "immediate threat" to alert populations to the significance of danger.[220] Evacuation is utilized for protection from fire hazards; however, some guidelines recommend that evacuation also be utilized to protect from smoke hazard.

Evacuations as an intervention for wildfire smoke can include entire populations or sub-populations of vulnerable individuals who are particularly susceptible to the health effects from smoke exposure.[217] "In current wildfire smoke response guidelines, the main trigger for consideration of evacuation is particulate matter concentration (either monitored or visual acuity)."[217] Factors that favor evacuation for wildfire smoke include severe smoke hazards with population exposure that is expected to last for days, wildfire smoke that is unusually toxic (e.g. contaminated with hazardous chemicals), existence of an exposed population subgroup particularly sensitive to smoke health effects, and detection of smoke-related health impacts through health surveillance or other means.[217]

Evidence

Scientifically supported: Includes one or more systematic review(s), or at least: three experimental studies, or three quasi-experimental studies with matched concurrent comparisons.

12.2 Air Filtration and Cleaners—Home, Room, Facility

Filtration is defined as "the removal of particulate matter (PM) from air using an air-handling system and a filter (or a bank of filters)."[221–223] Filtration can remove particulate matter but not gases and vapors (e.g. carbon monoxide). Filtration systems can be in-duct systems that are a part of the building's heating, ventilation, and air conditioning (HVAC) system or they can be portable and clean the air in one room.[221] During a forest fire, systems that have both an "outdoor air" and "recirculate" setting need to be set to "recirculate."[224] Different central air conditions contain different filters with different degrees of efficiency. When choosing a filter, higher efficiency filters can be chosen to capture the most fine particles associated with wildfire smoke.[224] If this choice is made, system owners need to make sure that the system is able to handle increased power load and airflow resistance. Additionally, filters need to be well-fitted and cleaned and replaced regularly.

Air cleaning is different from air filtration. Air cleaning is "the removal of gaseous contaminants from air using an air-handling system and sorbent filters (such as granular activated carbon, potassium permanganate impregnated alumina and impregnated carbon)."[222] Air cleaning sorbents can collect gases and vapors but cannot collect aerosols and particulates.[222] Air cleaners must be adequately matched to the indoor environment in which it is places to be effective.

Additionally, devices known as ozone generators/personal ozone devices/'energized oxygen' generators/ 'pure air' generators are sold as air cleaners. But they do more harm than good as ozone is hazardous to human health, does not remove particles from the air, and therefore are not effective during smoke events.[222] Humidifiers are also often mistaken as air cleaners; however they do not significantly reduce the amount of particulate during a smoke event.[222]

Evidence

Scientifically supported: Includes one or more systematic review(s), or at least: three experimental studies, or three quasi-experimental studies with matched concurrent comparisons.

12.3 Personal Air Filter Masks

In order for a mask to provide protection during a smoke event, it must be able to filter very small particles (0.3 to 0.1 microns).[218,223,225] Smoke particulate typically averages around 0.3 microns.[225] Respirator masks, or "particulate respirators" (which look like paper masks) can filter out 95% of particulates that are 0.3 microns and larger, therefore filtering a significant portion of smoke.[218]

Respirator masks should not be confused with "dust masks" (also known as comfort masks), which are commonly found at hardware stores and are designed to trap large particles (e.g. sawdust). These masks will not protect users' lungs from the fine particles in smoke.[224] In order to choose a correct mask that will offer lungs some protection from wildfire smoke, the EPA recommends finding a mask with the labels "R95," "N95," or "p95."[224] Soft masks with higher ratings (R,N, or P99 and R,N, or P1000) will filter out even more particles.[224] Respirators with purple HEPA filters offer the highest protection, but they may be less comfortable and more expensive than flexible masks.[224] Respirators only offer protection when there is an airtight seal of the wearer's mouth and nose. If fit testing is not performed, a mask may not offer full protection. Masks should have two straps that go around the head and a size should be chosen that fits over the nose and chin. Masks often do not come in sizes that fit young children, and they also cannot achieve a proper seal on persons with a beard.

Evidence

Scientifically supported: Includes one or more systematic review(s), or at least: three experimental studies, or three quasi-experimental studies with matched concurrent comparisons.

12.4 Forecast/Warning Systems

Air quality forecasting is conducted by a wide variety of agencies at a state and national level.[35] These forecasting symptoms usually use an Air Quality Index (AQI) for reporting and forecasting daily air quality. The EPA, in conjunction with NOAA, calculate the AQI for five major pollutants: ground-level ozone, particulate pollution (particulate matter), carbon monoxide, sulfur dioxide, and nitrogen dioxide. The current local conditions and national forecasts, in addition to an explanation of the AQI system can be found on EPA's AirNow website (www.airnow.gov).[31]

Other forecasting and warning systems exist that are specific to mapping active wildfires, current wildfire locations, fire weather watches, and areas with designated wildfire watches and warnings. AirNow also includes a map of all current fires and projected hazardous smoke plumes. NOAA's Air Quality Weather website (http://www.nws.noaa.gov/airquality/ww.shtml)[226] also includes forecasts of surface smoke and vertical smoke integration.

Information is freely available for use on many of these before listed websites, many of which allow a user to pinpoint the specific area they are interested in. AirNow additionally has an air quality notification system, entitled Enviroflash, which contains its own website dedicated to air quality forecasts, an on-line daily subscription email service, an iPhone and Android App, a twitter, and an RSS feed. These forecasts are also provided to local radio and television stations.

Evidence

Some evidence: This includes one or more systematic review(s), or at least: two experimental studies, or two quasi-experimental studies with matched concurrent comparisons, or three studies with unmatched comparisons or pre-post measures.

12.5 Public Service Announcements

A Public Service Announcement (PSA) is a message to the public disseminated by the media with a primary purpose of informing and education the public.[223] PSAs can be found on television stations, radio stations, online (including through social media), and through print (e.g. through direct mail or billboards.) Many PSA's have been created for wildfire hazards in the past, though messaging has generally been focused on either wildfire prevention or immediate fire safety (e.g. evacuation planning). PSAs could be utilized to spread a message informing the public of the health risks of wildfire smoke inhalation and preventive measures (such as those included in this guidance) to protect lungs. The use of non-technical messaging is potentially more effective than highly technical messages.[227]

Evidence

Some evidence: This includes one or more systematic review(s), or at least: two experimental studies, or two quasi-experimental studies with matched concurrent comparisons, or three studies with unmatched comparisons or pre-post measures.

13. Drought

Climate change projections indicate that in many areas of the U.S. droughts will become more intense in the 21st century.[56] Work by Devineni and colleagues[228] calculating a national water stress index suggests that in many parts of the U.S., particularly in the upper Midwest and California, water demand already outpaces rainfall. Already, historic drought conditions in the West are necessitating mandatory water restrictions for the first time on residents, businesses, and farms. Severe droughts in other areas of the world, particularly Australia, have inspired some research on associated health impacts. However, published studies on the association between drought and health still remain relatively sparse compared to other climate change threats. A 2010 report published by the Centers for Disease Control and

Prevention, Environmental Protection Agency, National Oceanic and Atmospheric Administration, and American Water Works Association concludes that "there is much to be learned about drought as it affects the health of the US public."[229]

Documenting health effects from drought is challenging for a number of reasons. First, there are various approaches to defining drought and a wide range of indicators are often used to capture and quantify the onset, duration, extent and timeline of a single drought event. Depending on the researcher's interest, datasets and selected indicators, characterization of any particular drought event could vary widely.[229] Second, unlike other natural disasters like flooding, heat waves and wildfires, droughts generally develop over an extended period of time, encompass large areas, and lack high visibility or associated structural damage. Thus, population-level impacts can be slow to develop and may be missed altogether given that health outcomes often manifest through indirect factors such as job loss and degradation of ecosystem services.[229] Finally, because of the long-term, diffuse nature of drought's influence and the numerous ways that individuals and communities have (or lack) for coping, it is difficult to ascertain what an exposure "dose" is for a specific study population and control for all confounding coping measures, such as access to mental health services or alternative job prospects.

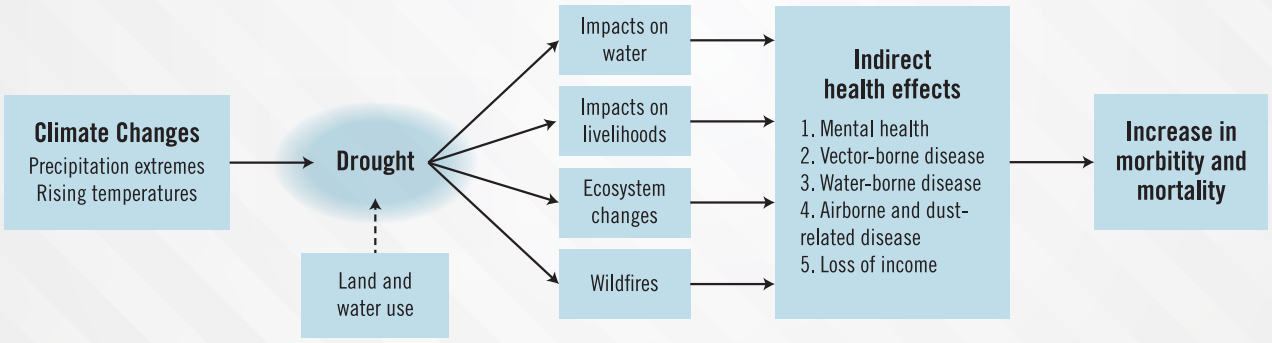

Figure 2: Links between climate change, drought, and health

Methods

The original goal of this project was to identify peer-reviewed scientific literature, agency or research reports ("grey literature"), and expert guidance that describe intervention strategies for mitigating drought impacts on health and review this documentation for those strategies that have been formally evaluated. An initial literature review was conducted using electronic search engines PubMed, Google Scholar and Web of Science and a series of Boolean searches with several combinations of keywords, including "drought," "dryness," "dry spell," "dry period," "climate change," "public health," "human health," "intervention," and "prevention." Studies that focused on heat waves or extreme heat events alone were not included in this review, and only those published within the last ten years were retained. In addition, publications and web-based guidance from professional organizations representing leading experts on drought-mediated health impacts were also reviewed.

Summary of Interventions

While awareness of drought as a climate threat is certainly increasing, few health studies have attempted to quantify the complex interactions between climate change, drought and human health, much less to then derive effect estimates for potential public health interventions. After this initial literature search, it became clear that there are so few published intervention strategies on this topic as to warrant a broader approach. While there is certainly a need for research on effective public health interventions, there is also a need for more data and research characterizing the numerous links between drought and health that would enable development of effective interventions.[229]

Therefore, the goal of this project was amended to identify peer-reviewed studies, agency reports and expert guidance that contribute to a comprehensive characterization of the connections between drought and health considered most relevant to populations in the U.S. The resulting literature review is organized according to health-related outcomes widely identified in the literature as having links to drought, including mental health, water-borne disease, airborne and dust-related disease, vector-borne disease, and loss of access to essential goods and services. The only public health intervention that could be identified in the published literature using our search criteria is in the area of mental health and is described in the section below.

At the time of this review, only one formally evaluated public health intervention pertaining to the experience of drought was identified in the existing literature. This intervention was aimed at mental health impacts specifically. Drought can also contribute to other health impact areas, such as vector-, water-, and air-borne diseases, as well as loss of income. Interventions evaluated for these outcomes are addressed in other sections with the exception of income loss. Drought-mediated loss of income is discussed in this review in the context of public health, but no formally evaluated interventions specific to this area were identified in existing literature.

Vector-borne disease and airborne and dust-related disease can also be impacted by drought. During a drought event, wind erosion in dry, deforested areas, particularly agricultural land, can cause soil particles, microbes, and other toxins to become airborne, creating and exacerbating respiratory problems. Although a number of key reports on drought identify airborne disease as a health outcome of concern,[229] there are few recent studies available investigating this relationship. Smith and colleagues[230] tested whether the incidence of respiratory diseases during two major droughts in the Brazilian Amazon was statistically dependent on drought-related environmental changes, as well as socioeconomic factors. The influence of wildfires as a consequence of drought was included in the analysis. Results of the study indicate a significant increase in hospitalizations for respiratory diseases in young children in areas highly exposed to drought. Public health interventions specific to reducing health burden from air-borne diseases linked to air contamination are reviewed separately in Section 1 of this document.

Drought can impact vector-borne diseases by influencing the ecology of vectors and hosts and the lifecycles of transmitted pathogens. For example, during drought conditions, surface waters become shallower and flow decreases, becoming favorable habitat for certain mosquito species. Conversely, drought may negatively impact

tick populations by increasing desiccation, reducing soil moisture, and damaging habitat vegetation. The myriad ways that drought can influence the interactions between vectors, hosts, and pathogens are topics of active research. However, less research is available as to how drought's influence on these interactions may affect human health burden. A literature review on the impact of drought on vector-borne diseases provides evidence that drought followed by re-wetting can have a substantial favorable effect on mosquito populations, some of which are known to carry pathogens associated with West Nile, St. Louis encephalitis, dengue, and chikungunya viruses.[231] Conversely, authors of this same review conclude that tick populations are likely to be negatively affected by drought, as they are dependent on high levels of humidity and soil moisture. Using global satellite data, Anyamba and colleagues[232] mapped precipitation extremes with vector-borne disease location data in selected areas across four continents and found spatial associations between clusters of WNV and dengue virus with regions affected by drought. Wang and colleagues[233] analyzed data on West Nile virus (WNV) incidences and county level precipitation, observing an inverse relationship between WNV risk and total annual rainfall during the previous year. Citing evidence from climate model predictions for greater drought occurrence in the future, authors conclude that the frequency and relative risk of WNV outbreaks could increase. Public health interventions specific to reducing health burden from vector-borne diseases are reviewed separately in section 9 and 10 of this document.

INTERVENTION	DESCRIPTION	EFFECTIVENESS
Mental Health Promotion Campaign	The Rural Adversity Mental Health Program is a multi-faceted health promotion campaign implemented in New South Wales, Australia, aimed at expanding mental health first aid training in rural communities with particular emphasis on older farmers, Aboriginal people and students.	Some evidence

Table 14: Summary of interventions on drought

13.1 Mental Health Promotion Campaign

A large body of research on the mental health impacts of long-term exposure to drought has emerged from Australia, a nation with a long history of drought. The majority of studies focus on rural communities and/or farmers as a study population, while a few focus on specific subgroups, such as older farmers,[234] mid-age women,[235] young people,[236] and Aboriginal communities.[237] Moderating factors linking drought with mental health outcomes are widely identified as reduced income, increased debt, outmigration, land degradation and loss of hope and identity (i.e., "solastalgia"). Some researchers also investigated the influence of factors related to adaptability, such as hopefulness, personal support, community connectedness, and sense of place.[238] Primary outcome measures from reviewed quantitative studies include overall mental health wellbeing, psychological distress or worry,[160,238,239] and suicide.[240,241] The majority of studies reviewed found a significant association between some measure of mental health and exposure to drought. A number of qualitative studies[234–237] are more

nuanced in their investigation of the association between drought and mental health but provide important information on the unique lived experience of individuals with drought that can be used for designing effective public health interventions for specific vulnerable subgroups.

The only published study on a public health intervention aimed specifically at drought was a qualitative assessment of a government funded mental health program in New South Wales, Australia aimed at drought-affected communities,[242] reviewed in the following table:

INTERVENTION AREA: MENTAL HEALTH	
Hart et al. (2011). Improving the mental health of rural New South Wales communities facing drought and other adversities	
Intervention Description	The Rural Adversity Mental Health Program (RAMHP) is a multi-faceted mental health promotion campaign.
Exposure Assessment	Intervention was implemented in New South Wales in 2007 after the area had just experienced its worst drought in a century.
Outcome Assessment	Community consultation forums.
Models/ Methods	RAMHP includes mental health first aid training for rural communities and front-line agencies working with farming households; community mental health and drought information forums to help reduce stigma and increase understanding; and booklets for health and agricultural service providers with informaiton on how to locate services for clients seeking assistance. A free rural mental health support telephone line was developed to provide crisis help and referral to support services.
Results	Over 3,000 people received mental health literacy training over four years. Hundreds of mental health-related events were conducted and thousands of people attended.
Conclusion	Overall, RAMHP was considered to have been well accepted and effective in helping communities build capacity and resilience in the face of drought-related stress and hardship. The authors note that this community development model could be adapted to other rural adversities, such as floods.
Strengths	RAMHP was designed around community development principles (e.g. local ownership, focus on early intervention, etc.), utilized diverse methods of information outreach and provision of services, and engaged numerous partners representing health, local agencies, and agriculture. Particular emphasis placed on needs of specific subgroups, such as older farmers, Aboriginal people, and students.
Weaknesses	Evaluations of program effectiveness were based primarily on immediate feedback rather than on measuring longer-term outcomes. A medium- to longer-term approach to maintaining the program would allow for proper strategic planning, comprehensive evaluation, and foster an environment conducive to attracting and retaining capable staff.
Evaluation	High suitablity. Moderate quality.

Table 15: Summary of key study[242] on drought mental health intervention

Evidence

Insufficient evidence: This includes no more than 1 experimental or quasi-experimental study with a matched concurrent comparison, or 2 or fewer studies with unmatched comparisons or pre-post measures. Strategies with this rating have limited research documenting effects.

14. Pollen

Factors related to climate change have led to changes in the amount of pollen released by allergenic plants, as well as the overall length and severity of the pollen season. These changes have serious health consequences not only for allergy and asthma sufferers and people with respiratory diseases, but for everyone exposed, especially children, given that large amounts of ambient pollen increase the risk of allergic sensitization (and potentially the onset of asthma) in otherwise healthy individuals. In addition, land use and community planning decisions can amplify climate change impacts on pollen, further exacerbating the problem. The life cycle of plants is strongly influenced by the environment, which controls the timing of growth and reproduction. Climate change conditions, in particular increasing temperatures and ambient levels of carbon dioxide, directly influence pollination by determining the onset of flowering, number of pollen grains produced and the amount released into the air.[243]

Common ragweed (Ambrosia artemisifolia) is the most prominent seasonal allergen in the U.S.[244] Recent evidence demonstrates that the ragweed season has already lengthened across parts of the United States and Canada; in some areas the season has lengthened by more than 20 days since 1995.[245] Other studies provide evidence that climate change conditions are increasing the allergenicity of pollen and facilitating the spread of non-native potentially allergenic plant species into northern latitudes.[245]

The potential health burden on impacted communities could be substantial. Over 35 million Americans suffer from pollen allergies,[246] and each year allergies cause 3.5 million lost workdays, 2 million lost school days, and more than 11.2 billion in treatment costs.[152] High ragweed pollen levels have been linked to increases in hospital visits.[247] Pollen exposure increases the risk of developing asthma and can trigger life-threatening asthma attacks.[248] Half of all adults with asthma and at least two-thirds of children with asthma have allergies.[244]

While most people with allergies can treat their symptoms to satisfaction with over-the-counter medications, around 20% of allergy sufferers see little to no improvement with medication alone because of the severity of their disease.[249] Amplifying the risks from pollen are other air pollutants associated with climate change and adverse health impacts, such as ozone and volatile organic compounds. Some authors have noted that the allergenic potential of pollen may be increased by air contamination and that pollen production in allergenic plants has increased due to the action of gases like carbon dioxide.[250]

Few health studies have attempted to quantify the complex interactions between climate change, pollen, and health impacts, nor attempted to derive effect estimates for potential public health interventions. The goal of this project was to identify peer-reviewed scientific literature, agency or research reports ("grey literature"), and expert

guidance that describe pollen intervention strategies and review this documentation for those strategies that have been formally evaluated for reducing health impacts.

Methods

An initial literature review was conducted using electronic search engines PubMed, Google Scholar and Web of Science. A series of Boolean searches were conducted using several combinations of keywords related to pollen and public health interventions, such as "pollen," "allergen," "aeroallergen," "allergies," "asthma," "climate change," "public health," "intervention," and "prevention." In addition, publications and web-based guidance from professional organizations representing leading experts on pollen-mediated health impacts were also reviewed. This initial literature and guidance search resulted in a large number of publications and revealed three distinct categories of intervention: (1) Immunotherapy, (2) Environmental Controls, and (3) Individual Behaviors. Additional literature searches were conducted for each of these categories in order to find papers that were most recent, most often cited by other publications, representative of the state of the science or best practices, provided effect estimates, or at least identified key information and data gaps. Available research varied widely between categories. For example, a PubMed search with "allergy" and "immunotherapy" confined to the years 2005–2015 resulted in more than 7,800 papers, while a search using "allergy" and "environmental controls" for the same time period yielded only 20 papers. Thus, for the category Immunotherapy only papers that provided clear effect estimates, had been published in the last five years, and had the highest number of citations compared to other papers published in the same year were included in this review. Also, only studies that included pollen sources common to the Midwest were considered for inclusion in the Immunotherapy category. In addition, if multiple papers were published on the same study, only one paper was included to represent the study. For the remaining categories, Environmental Controls and Individual Behaviors, very few studies were available that provided effect estimates on tested intervention strategies. Therefore, inclusion criteria were relaxed for these categories to include research or guidance published in the last 15 years either in peer-reviewed journals or by authors affiliated with federal agencies or nationally recognized organizations representing topic area experts. For example, the American Academy of Allergy, Asthma, & Immunology (AAAAI) and the American College of Allergy, Asthma, and Immunology (ACAAI) have co-authored guidance on the management of allergic disease, particularly rhinitis [251], While pharmacological treatment is discussed extensively in this guidance, other prevention options are reviewed, including immunotherapy, environmental controls, and individual behaviors. Recommended measures are classified according to strength and type of supporting evidence, and when available these measures and their classification in the summary section within each intervention category are explicitly noted.

Summary of Interventions

Three types of interventions were identified with potential for reducing public health impacts from pollen: Immunotherapy, Environmental Controls, and Individual Behaviors. The focus of this review is on primary prevention strategies, i.e. strategies that reduce ambient pollen, mitigate human exposure, or decrease one's vulnerability to the effects of pollen. Studies on the pharmacological treatment of symptoms once they've already appeared (e.g. use of antihistamines or decongestants) represent

secondary or tertiary levels of prevention and therefore were excluded from review. While all three interventions are examples of primary prevention, those strategies that comprise Environmental Controls are aimed directly at the climate hazard, reducing risk at the source by cutting the release of allergenic pollen. This 'upstream' risk management focus is a significant benefit of Environmental Controls.

INTERVENTION	DESCRIPTION	EFFECTIVENESS
Immunotherapy	Allergen immunotherapy treatment involves administering increasing doses of allergens to accustom the body to substances, like pollen, in order to induce long-term tolerance.	Scientifically supported
Environmental Controls	Environmental controls refer to strategies aimed at eradicating or reducing the existence of pollen-producing plants in areas where people can be exposed.	Expert opinion
Individual Behaviors	Individual behaviors for this review include avoiding the outdoors, using barrier methods and regular household cleaning.	Mixed evidence

Table 16: Summary of interventions on pollen

14.1 Immunotherapy

Allergen immunotherapy treatment (AIT), sometimes referred to as specific allergy vaccination, involves administering increasing doses of allergens to accustom the body to substances, like pollen, in order to induce specific longterm tolerance. AIT was discovered more than one hundred years ago and is the only clinical treatment known to address the symptoms as well as the causes of respiratory allergies by preventing the onset of disease. The protective effect can extend beyond the treatment period in contrast to symptomatic treatment with over-the-counter drugs. This protective effect may further reduce the risk of allergic rhinitis developing into asthma or development of new allergen sensitivities.[244]

The common route of AIT administration is subcutaneous or sublingual. There are many comprehensive literature reviews published on AIT, including a number of Cochrane Reviews that are relevant to the use of AIT for pollen.[249,252–254] Included in this brief literature review on AIT is only a small sample of the most recently published studies or reviews available.

Evidence

Scientifically supported: Includes one or more systematic review(s), or at least: three experimental studies, or three quasi-experimental studies with matched concurrent comparisons. The clinical efficacy of AIT is well established. AAAI/ ACAAI guidance states that "Allergen immunotherapy is effective for the treatment of allergic rhinitis" and assigns this intervention option an A on "strength of recommendation" directly based on category I evidence. Category I evidence is either derived from meta-analysis of randomized controlled trials or at least one randomized controlled trial.[251]

However, AIT is not recommended for every person impacted by exposure to pollen.[255] International guidelines and consensus statements recommend AIT primarily for patients suffering from moderate-to-severe allergic rhinitis when over-the-counter medication is ineffective or poorly tolerated.[255] Despite its well-documented efficacy, AIT is still not widely used due to the inconvenience associated with the treatment regimen and potential for severe side-effects.[244]

Although the primary means for assessing the efficacy of AIT has been clinical (e.g. symptom improvement or reduced medication use), other outcomes, such as cost-effectiveness or accessibility, will likely become more important to public health decision makers. At this time only 2% to 6% of potentially appropriate patients in the U.S. receive AIT for specific allergens.[256] More evidence is needed to show that AIT is worth the cost of advanced research and development, can be made widely affordable and accessible, and ultimately will be received by the public as an acceptable intervention compared to symptomatic drug treatment.

14.2 Environmental Controls

In the context of this review, environmental controls refer to strategies aimed at eradicating or reducing the existence of pollen-producing plants in areas where people can be exposed. Given that a relatively small number of plant species are responsible for about 90% of pollen-induced allergies,[257] efforts to reduce the prevalence of these plants may substantially reduce overall health burden well in advance of effects on the population.

While environmental control strategies are increasingly recognized as important intervention strategies for mitigating pollen exposure,[258] there are few studies that have attempted to evaluate these strategies for reducing health impacts. Papers selected for this review test the efficacy of specific environmental control strategies for reducing pollen and/or pollen-producing plants or present a review of the literature in context of health impacts.

Evidence

Expert opinion: Generally has no more than one experimental or quasi-experimental study with a matched concurrent comparison, or two or fewer studies with unmatched comparisons or pre-post measures. Strategies within this rating are recommended by credible, impartial experts but have limited research documenting effects.

Environmental control strategies are important intervention strategies for mitigating pollen exposure and may be a more effective "upstream" strategy for addressing pollen impacts than the current paradigm of treating symptoms after exposure and sensitization have occurred. Pollen risk has been shown to be location-specific.[259] Allergy rates tend to be higher in cities compared to rural areas,[260] a trend attributed to higher carbon dioxide concentrations and temperatures (i.e. urban heat island effect) found in city settings apart from but amplified by climate change.[261]

Local land use decisions have a strong influence on pollen risk. By some reports, most trees are planted in cities without awareness of their potential allergenicity and subsequent impact on residents.[262] According to some experts, a lack of planning and management of green spaces has dramatically intensified the allergenic pollen burden

in many cities.[250] A number of studies demonstrate that pollen release and distribution occurs at a small enough scale that source plants could be effectively managed by municipalities, neighborhoods or even individuals.[263] However, there are few studies that have attempted to evaluate or quantify the efficacy of planning or eradication strategies for reducing pollen impacts on health. This is a major gap not only in the published literature, but in the evidence base necessary to promote and implement these strategies. Studies that prove or disprove various environmental controls for reducing pollen impacts on human health are needed in order to support effective decision-making and resource allocation by planners and policy makers.[262,264]

14.3 Individual Behaviors

The majority of pollen interventions that relate to individual behaviors have to do with avoiding the outdoors or using barriers, such as nasal filters or sunglasses to block exposure to pollen grains. Keeping clothes and indoor environments free of pollen are also suggested. Such measures are touted as effective means of actively engaging patients in treatment strategies designed to reduce exposure and improve symptoms.[265]

However, there are few studies that have attempted to evaluate or quantify the efficacy of these strategies for preventing health impacts. Papers selected for this review test the efficacy of two barrier methods, nasal filters and contact lenses, and regular use of bleach for cleaning the home for reducing allergy symptoms. No studies were identified that directly tested the efficacy of avoidance for mitigating pollen risk.

Evidence

Mixed evidence: Has one or more systematic review(s) or at least two experimental studies, or two quasi-experimental studies with matched concurrent comparisons, or three studies with unmatched comparisons or pre-post measures.

Individual behavior strategies may be effective for reducing symptoms of pollen-exposure. ACAAI and others recommend wearing glasses or a filter mask when outdoors or keeping windows closed during the pollen season and instead using air conditioning in the home and car.[266] AAAI/ACAAI guidance states that "Highly pollen-allergic individuals should limit exposure to the outdoors when high pollen counts are present" and assigns this intervention option a B on "strength of recommendation" directly based on category II evidence or extrapolated from category I evidence. Category I evidence is either derived from meta-analysis of randomized controlled trials or at least 1 randomized controlled, while category II evidence is either derived from at least one controlled study without randomization or from at least one other type of quasi-experimental study. In addition, AAAI/ACAAI guidance states that "Education is a key element in promoting adherence and optimizing treatment outcomes in allergic rhinitis" and assigns this intervention option a D on "strength of recommendation" directly based on category IV evidence or extrapolated from category I, II, or III evidence. Category III evidence is derived from nonexperimental descriptive studies, such as comparative studies, while category IV evidence is derived from expert committee reports or opinions or clinical experience of respected authorities, or both.

Avoidance measures, such as staying indoors or keeping car windows closed during pollen season, may seem obvious and efficacious enough as to not need a base of evidence. However, as an intervention strategy, avoidance may not be realistic or acceptable to a large portion of the affected population. Avoiding outdoor activity for extended periods of time, especially during some of the most desirable seasons of the year in the Midwest region, runs contrary to other public health messaging that encourages regular exercise and time spent in natural areas for the positive impacts on physical and mental health. There is some evidence available that compliance with the avoidance recommendation is low even in among allergy sufferers, given the enjoyment people feel when visiting outdoor green spaces.[267] A major challenge to the efficacy of avoidance in mitigating sensitization and respiratory impacts is the large amount of pollen available (~one million pollen grains daily per ragweed plant) compared to the very small amount needed to evoke symptoms and/or sensitization (~ 10 to 15 grains).[262] Some experts state that it may be impossible to avoid pollen allergens completely.[244]

Other personal behavior strategies mentioned in expert guidance to reduce pollen impacts are aimed at addressing the indoor environment. The ACAAI and others recommend bathing and washing one's clothes after being outdoors, cleaning indoor surfaces with chlorine bleach, and installing high-efficiency particulate air (HEPA) filters in the home.[266] However, here again there is very little statistical evidence demonstrating the efficacy of these strategies for actually reducing health burden. Following a review of relevant literature, Sublett and colleagues[268] conclude that indoor air filtration does reduce indoor levels of ambient particles; however, other factors, like source control or ventilation, might be more influential in reducing disease progression than attempts to clean the air after the fact with filtration. In addition, filtration systems can be costly and require committed, ongoing maintenance to be effective, aspects that need to be weighed against their potential efficacy for mitigating health impacts for large populations, not just individuals.

APPENDIX

INTERVENTION	DESCRIPTION	EVIDENCE LEVEL*	PRIMARY TARGET HEALTH EFFECT OR CLIMATE IMPACT
General Remediation	Implements disposal of contaminated pieces and remediation repair if extreme mold contamination.	Scientifically supported	Flooding and mold
Crisis Counseling Program (CCP)	Assesses strengths and seeks to restore pre-disaster functioning.	Scientifically supported	Mental health—extreme precipitation
Government Programs	Utilize government services to reduce impact of heat on those with mental illness.	Scientifically supported	Mental health—heat
Hydration	Hydrating during heat events.	Scientifically supported	Mental health—heat
Increasing Social Connection	May help reduce vulnerability and provide some protection from negative health outcomes during heat events among those with mental health conditions.	Scientifically supported	Mental health—heat
Wearing Lighter Clothing and Taking Cool Showers or Baths	A lower likelihood of death was found among older adults who wore lighter clothing and took cool showers or baths during heat events.	Scientifically supported	Mental health—heat
Larvicide	Application of chemical agents (larvicides) to larval habitats with the goal of managing the mosquito population before they emerge as adults.	Scientifically supported	Mosquito-borne disease
Adulticide	Use of targeted pesticides to control adult mosquitoes.	Scientifically supported	Mosquito-borne disease
Source Reduction	Removal or permanent destruction of mosquito breeding sites.	Scientifically supported	Mosquito-borne disease
Evacuation	Urgent removal of individuals from building or a community.	Scientifically supported	Wildfire smoke
Air Filtration and Cleaners—Home, Room, Facility	Filtration removal of particulate matter and/or gaseous contaminants.	Scientifically supported	Wildfire smoke
Immunotherapy	Administering increasing doses of allergens to induce long-term tolerance.	Scientifically supported	Pollen
Air Quality Education and Media Reporting	Notification of the public via broadcast, web, and social media about elevated levels of air pollutants	Some evidence	Respiratory health
Local Vehicle Traffic Reduction Systems	Limiting vehicle access to city centers in order to improve local air quality	Someevidence	Respiratory health
Antioxidant Dietary Supplementation	Administration of vitamins C or E to reduce lung inflammation triggered by ozone.	Some evidence	Respiratory health
Education	Educational efforts focus on providing information regarding the variety of sources of CO and the appropriate use of generators.	Some evidence	Carbon monoxide poisoning
Real-Time Data Surveillance and Warnings	Monitoring ambient heat-related hospitalizations, emergency room visits, 9-1-1 calls, and meteorological data to recognize when the number of heat related-illness symptoms or diagnoses is higher than normal and the health department can then issue warnings to the public.	Some evidence	Heat-related illness
Education and Information	Health departments, municipalities, cities, etc. provide information about what heat related-illness is and how to prevent, identify, and treat it.	Some evidence	Heat-related illness
Heat Alert System	City or municipality preparing a comprehensive plan activated when temperatures are at or exceed a threshold that is dangerous for the health of their citizens.	Sufficient evidence	Heat-related illness

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INTERVENTION	DESCRIPTION	EVIDENCE LEVEL*	PRIMARY TARGET HEALTH EFFECT OR CLIMATE IMPACT
Access to Cooling	Making air conditioned places publicly available for those who do not have access to air conditioning.	Some evidence	Heat-related illness
Biological Controls in Waterbody Management	Include various approaches which aim to change the aquatic food web through either increasing grazing pressure or increasing resource competition.	Some evidence	Harmful algal blooms
Mitigation in Drinking Water Treatment Plants	When cyanobacteria and/or their cyanotoxins are detected in water supplying water system, drinking water treatment plant operators can act to remove or inactive them in various ways.	Some evidence	Harmful algal blooms
Hydrogen Peroxide Vaporizer	Targets and kills invasive fungal spores in the air that may cause serious health impacts.	Some evidence	Flooding and mold
Controlled Community Field Study	Evaluate efficacy of public health inspired intervention combining school-based screening and psychological treatment to identify and treat children with persistent disaster-related traumatic symptoms.	Some evidence	Mental health—extreme precipitation
Cognitive Behavioral Intervention for Trauma in Schools (CBITS)	10 group session and 1–3 individual session intervention for use in schools.	Some evidence	Mental health—extreme precipitation
Cognitive Behavioral Therapy (CBT)	Type of psychotherapy used to treat depression and anxiety disorders; assists patients in recognizing debilitating patterns of thinking and acting, and then works to modify/replace these patterns with healthy behaviors.	Some evidence	Mental health—extreme precipitation
Cognitive Restructuring	Patients are taught how to change their thinking to reduce stress, improve relationships, and benefit mental health.	Some evidence	Mental health—extreme precipitation
Psychological First Aid (PFA)	Provides information and education to give comfort and support, accelerate recovery, promote resiliency and mental health and access to continued care after a disaster.	Some evidence	Mental health—extreme precipitation
Eye Movement Desensitization and Reprocessing (EMDR)	Procedures to assist a person's brain function when processing information.	Some evidence	Mental health—extreme precipitation
Exposure Therapy	Individuals are exposed to stimulated trauma in order for them to realize their trauma is tolerable and are able to take control over their emotions.	Some evidence	Mental health—extreme precipitation
Psychodynamic psychotherapy	Interaction between a psychotherapist and a client that leads to changes from a less adaptive state to a more adaptive stated in the client's thoughts, feelings, and behaviors.	Some evidence	Mental health—extreme precipitation
Pharmacotherapeutics	Antidepressants, tricyclic antidepressants (TCAs), monoamine oxidase inhibitors (MAOIs), selective serotonin reuptake inhibitors (SSRIs), antianxiety and adrenergic agents, and mood stabilizers can improve symptoms of PTSD.	Some evidence	Mental health—extreme precipitation
Urban Design	Designing communities in ways that improve mental health and reduce the risk of heat illness, such as improved shade and more greenways.	Some evidence	Mental health—heat
Mosquito Control Programs	Protect individuals from mosquito-borne disease and nuisance mosquito populations.	Some evidence	Mosquito-borne disease
Wildlife Treatment	Pesticides that are effective against ticks are applied to deer.	Some evidence	Tick-borne disease

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INTERVENTION	DESCRIPTION	EVIDENCE LEVEL*	PRIMARY TARGET HEALTH EFFECT OR CLIMATE IMPACT
Environmental Application of Pesticides	Applying acaricides to certain environmental areas to reduce tick populations.	Some evidence	Tick-borne disease
Use of Repellent-Treated Clothing	Commercially-soaked clothing is more effective than clothing with self-applied repellent.	Some evidence	Tick-borne disease
Public Education and Protective Actions	Education activities to reduce the risk of Lyme disease.	Some evidence	Tick-borne disease
At-home Treatment	Include a variety of equipment and different processes to purify water.	Some evidence	Water-borne disease
Community-level Treatment	Large scale disinfectors at the community level.	Some evidence	Water-borne disease
Personal Air Masks	Use of respirator masks.	Some evidence	Wildfire smoke
Forecast/ Warning Systems	Air quality forecasting.	Some evidence	Wildfire smoke
Public Service Announcements	Message to the public disseminated by the media.	Some evidence	Wildfire smoke
Mental Health Promotion Campaign	Health promotion campaign aimed at expanding mental health first aid training.	Some evidence	Drought

Table 17: Summary of interventions with at least some evidence. Note that this table is not comprehensive. It includes only interventions that were assessed by the Midwest/Southeast Collaborative.

*Evidence level as determined by the methodology used by the Midwest/Southeast Collaborative.

KIND OF INTERVENTION	PAPER, AUTHOR ET AL (YEAR)	
	Intervention Description	What's being evaluated? Study Population Location(s) of Study
	Exposure Assessment	Exposure Description Exposure Timeframe
	Outcome Assessment	Description of Outcome Measure(s)
	Models/Methods	Analytic Methods Statistical Methods
	Results	Description of Intervention Results
	Conclusion	Implications of the Study
	Strengths	
	Weaknesses	
	Evaluation	**Suitability:** How difficult or resource intensive? High / Medium / Low
		Quality: Low: Ecological or Quasi-experimental Medium: Cohort, Case-Control High: Randomized controlled study design

Table 18: Template for evaluating each peer-reviewed manuscript

Description and instructions for reviewing literature and completing template:

- **Table Heading:** Intervention: Brief title of intervention(s) reviewed in the table
- **Paper:** Author and year of article/paper/document; (bibliography provided)
- **Intervention Description:** Brief description of intervention, what is being evaluated, the study population, and location of study (e.g., Excess mortality before/after intervention of monitoring patients through telephone calls, visits; elderly (65+) from 16 Italian cities)
- **Exposure Assessment:** Short phrase describing the exposure and its timeframe (e.g., Heat spells of summer 2010 measured by a specified number of consecutive days with a max T ≥30°C).
- **Outcome Assessment:** Short phrase describing the outcome measure(s) (e.g., All-cause, ischemic heart disease (IHD), and stroke mortality)
- **Models/Methods:** Brief description of the methods used in the study (e.g., Random effect meta-analysis: non-linear distributed lag model)
- **Results:** Brief description of the results found in the study (e.g., 1.23 ischemic heart disease (IHD) deaths and 0.97 stroke deaths saved/day; no protection from IHD at/above 34.5°C)
- **Conclusion:** Brief description of the implications of the study (e.g., Preventive measures + warning system effective in reducing IHD & stroke mortality; measures inadequate for extremely high temperatures)
- **Strengths:** Brief list of strengths of the study (e.g., Random sample survey design, phone survey reached both those with landlines and those with cell phones)
- **Weaknesses:** Brief list of weaknesses of the study (e.g., Unable to control for all relevant confounders, increased awareness may modify effect)
- **Evaluation: Assign ratings of suitability and quality based on definitions below.**
    - **Suitability:** Assign rating of suitability for an intervention by a state/local public health department/partner, using one of the following:
      low suitability—difficult to implement and/or extremely resource intensive and/or not very effective;
      moderate suitability (in between low and high suitability);
      high suitability—effective, possibly easier to implement or not terribly resource intensive.
    - **Quality:**
      low quality—ecological/quasi-experimental design;
      medium quality—case control design, cohort design;
      high quality—randomized, controlled design.
- **Summary:** For intervention(s) assessed, write a paragraph summarizing the studies, describing how/why the intervention was ineffective, effective or promising and include overall suitability as an intervention.

- **Evidence:** Assign rating of evidence using descriptions of the 6 categories below. Rating scale based on "What Works for Health": http://whatworksforhealth.wisc.edu/rating-scales.php
  - **Scientifically supported:** Includes 1 or more systematic review(s), or at least: 3 experimental studies, or 3 quasi-experimental studies with matched concurrent comparisons.
  - **Some evidence:** Includes 1 or more systematic review(s), or at least: 2 experimental studies, or 2 quasi-experimental studies with matched concurrent comparisons, or 3 studies with unmatched comparisons or pre-post measures.
  - **Expert opinion:** Generally has no more than 1 experimental or quasi-experimental study with a matched concurrent comparison, or 2 or fewer studies with unmatched comparisons, or pre-post measures. Strategies with this rating are recommended by credible, impartial experts but limited research documenting effects.
  - **Insufficient evidence:** Generally has no more than 1 experimental or quasi-experimental study with a matched concurrent comparison, or 2 or fewer studies with unmatched comparisons or pre-post measures. Strategies with this rating have limited research documenting effects.
  - **Mixed evidence:** Have 1 or more systematic review(s), or at least 2 experimental studies, or 2 quasi-experimental studies with matched concurrent comparisons, or 3 studies with unmatched comparisons or pre-post measures.
  - **Evidence of ineffectiveness:** Have 1 or more systematic review(s), or at least 3 experimental studies, or 3 quasi-experimental studies with matched concurrent comparisons.

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