Use of Computer Modeling for Emergency Preparedness Functions by Local and State Health Officials: A Needs Assessment

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The authors, collaborating from several public health institutes, present the methodology, results, and lessons learned from a multistate needs assessment of local and state public health and safety officials regarding their familiarity and use of formal computer modeling for preparedness activities. The study was undertaken to provide information to the newly formed Preparedness Modeling Unit within the Centers for Disease Control and Prevention. The focus was on the use of sophisticated mathematical models associated with three public health threats: pandemic influenza, radiologic release, and severe heat waves. The use of computer modeling and scenario-based analyses can be used to better frame problems and opportunities, integrate data sources, expect outcomes, and improve multistakeholder decision making. The results of the eight state needs assessment demonstrated that preparedness officials are familiar with models and would use computer modeling as a tool, along with other tools and general experiences, depending upon the perceived quality and validity of the model and the assumptions, as well as the applicability, of the model to their particular setting and population. More needs to be done to improve awareness and dissemination of available models and share best practices in both knowledge and use of models. Use of preparedness modeling would enhance the planning for vulnerable and at-risk populations, all-hazard emergencies and infectious disease containment strategies, as well as for response functions including evacuation, sheltering, quarantine, and distribution of medications and supplies.

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Considerable efforts have been made in the past several years to improve the nation public health system's capacity to prevent, prepare, and respond to natural and man-made emergencies and disasters.[1] These

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efforts began following the events of September 11, 2001, and were reinforced by the experiences of hurricanes Katrina and Rita of 2005 and Ike of 2008, as well as a series of natural disasters including the Southeast Asia tsunami, California wildfires, and the violent and erratic tornadoes affecting several states. In addition, the threats posed by new and emerging infectious diseases, particularly severe acute respiratory syndrome and a pandemic influenza, have been additional stimuli to the public health community for creating more robust preparedness and response efforts.

Public health emergency preparedness (*PHEP*) has been defined as "the capability of the public health and health care systems, communities, and individuals, to prevent, protect against, quickly respond to, and recover from health emergencies, particularly those whose scale, timing or unpredictability threatens to overwhelm routine capabilities."[2(pS9)] The Institute of Medicine report on *Research Priorities in Emergency Preparedness and Response for Public Health Systems*, December 2007, identified that a coordinated and robust public health preparedness system response would require a variety of key stakeholders to work individually and in unison. The key players cited include governmental public health infrastructure at the core, with input from communities, academia, healthcare delivery, homeland security and public safety/emergency management, business and employers, and the media. The Institute of Medicine report highlighted the need to "protect vulnerable populations in emergencies," strengthen response systems, prepare public health workforce, improve timely communications, and improve information management, including scenario modeling and forecasting.[3] There have been efforts from a variety of sources, as well as real-time events, that have underscored the need to create sustainable and reproducible emergency preparedness response systems.

Simultaneously, there has been expansion of information technology and the use of computers to assist in public health decision making. The use of predictive computer modeling and scenario-based analyses can be used to better frame problems and opportunities, integrate data sources, quantify the impact of specific events or outcomes, and improve multistakeholder decision making.[4,5]

In 2006, at the request of the US Department of Health and Human Services and its Assistant Secretary for Health, the Centers for Disease Control and Prevention (CDC) strengthened its support of mathematical modeling to enhance public health preparedness and laid the foundation for the Preparedness Modeling Unit at the CDC. In an effort to better inform this new unit, the CDC approached the National Network of Public Health Institutes to collaborate and conduct a rapid needs assessment that would gather information from state and local health officials regarding their needs and interests related to preparedness modeling. The Florida Public Health Institute served as the lead, with support from the Community Health Institute of New Hampshire and the Michigan Public Health Institute.

Computer Modeling: Defined

Computer modeling, for purposes of this study, was defined using the CDC guidelines, as a "formal, quantitative representation of a real world phenomenon that allows users to do one or more of the following: define problems and negotiate boundaries around a system of interest; better understand changes within the system over time; anticipate the likely consequences of particular conditions; and estimate the relative leverage of and trade-offs associated with different action scenarios."[6] Mathematical modeling methods have been used to significantly improve the ability to reveal options, anticipate likely outcomes, and support policy decisions.[7] According to Milstein and Homer, the use of system dynamics for health policy decision making offers more than time-series models or multivariate statistical models, as well as enables analysts to "anticipate new trends, learn how various policies can play out over time, and set justifiable goals for the future."[8] Its uses span the range of public health challenges[9] with regard to preparedness and response from infectious diseases,[10] environmental threats,[11] bioterrorism,[12] weather-related natural disasters,[13,14] accidents, man-made emergencies and disasters,[15,16] and issues of hospital surge.[17]

Computer modeling can be an important tool for health protection, preparedness, and response planning activities before, during, and after an emergency event.[6] Models can be used to collect and articulate assumptions and verbal reasoning, and then systematically and formally characterize the potential outcomes. This, in turn, improves the understanding of inherently complex, uncertain, and evolving circumstances.

Models may be designed for specific scenario planning and game-based learning, as well as support evidence-based policy making. The use of tabletop exercises have become an accepted method for gathering together divergent groups that will become team players in a real event, and then rehearse potential emergency response actions based on novel and unfolding scenarios. Preparedness training at the local level has increasingly relied on the use of tabletop and functional exercises and drills. The Homeland Security Exercise and Evaluation Program is a valuable on-line resource offering tools and guides for a capabilities and performance-based exercise program that can be adopted to a variety of scenarios and events, natural disasters, terrorism and technologic disasters, as well as single facilities, multiple locations, and most recently for regional (multistate) exercise efforts.[18,19]

Game-based learning can provide insight into the effects of human behavior in emergency planning and response. There are Points of Distribution (POD) planning games that simulate public health roles during a full-scale, mass-dispensing exercise or response to a real event (www.thepodgame.com), as well as virtual drills and exercises (www.virtualpublichealth.com and www.publichealthgames.com) and disease outbreak scenarios.[20,21]

Sophisticated computer modeling for real-time decision making in the event of an emergency is currently in use. One example is the Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model run by the National Hurricane Center.[13] It is used to estimate the surge heights and winds resulting from a hurricane by taking into account the pressure, size, and forward speed of the storm, as well as the storm's track and winds. The resulting calculations are used by emergency managers to determine evacuation decisions with specific reference to locations and timing, as well as for shelter openings, transportation decisions, and curfews.

The use of modeling in infectious disease transmission and response studies has been well documented.[22] In 1760, Daniel Bernouli offered the first mathematical formulas of the propagation of smallpox and made the case for universal inoculation.[23] At present, the National Institutes of Health and specifically the National Institute of General Medical Sciences have launched and funded the Models of Infectious Disease Agent Study (MIDAS). This is a collaboration of research and informatics groups from academic institutions to develop computational models of the interaction between disease agents and their hosts, disease spread, prediction systems, and response strategies. The MIDAS teams have addressed pandemic influenza and produced findings that have influenced policy making by showing that vaccination, distribution of antivirals, and implementation of social distancing can impede the spread of an influenza pandemic. These studies have been adopted by state health officials in justifying the expense associated with purchasing and stockpiling antivirals for segments of the population.[24]

Methods: Needs Assessment

The Florida Public Health Institute, in collaboration with the National Network of Public Health Institutes, the Community Health Institute of New Hampshire, and the Michigan Public Health Institute, created a rapid needs assessment tool to guide structured conversations with public health and safety officials.[25] Those participating in the needs assessment, referred to as respondents, were asked about their familiarity and use of computer modeling for three public health threats: pandemic influenza, radiologic release, and series of severe heat waves. These threats were specifically designated by the CDC.

Purposive sampling was used to select respondents to maximize information.[26] The choice of purposive sampling was made to reach a targeted sample quickly, and sampling for proportionality was not a concern. Respondents selected for inclusion in the study were those with job title of directors or coordinators in their field, and they were predominately in the areas of epidemiology, environmental health, and emergency preparedness at local and state levels. Each institute selected respondents from their state. In addition, the National Association of County and City Health Officials, the Association of State and Territorial Health Officials, and the Council of State and Territorial Epidemiologists suggested respondents for inclusion in the study. The basic criterion for selection was that the official had responsibility for emergency preparedness functions and that the individual contacted was the most experienced and senior-level person as possible. A previous knowledge of computer modeling was not a factor in selection. Respondents were invited to participate by e-mails and appointments were confirmed by telephone and subsequently by e-mail. The study had a high response rate of 92.5 percent (40/42). An informed consent form was read before all consultations and responses were kept confidential.

Forty consultations were conducted in eight states; 29 conducted by the Florida Public Health Institute, 6 by the Community Health Institute of New Hampshire, and 5 by the Michigan Public Health Institute (Table 1). There were equal numbers of participating health officials from both local health departments (cities or counties) and state health departments, with 15 from each category. Local health officials have direct responsibility for planning and implementing preparedness and response activities, and state health officials maintain parity with other states and federal initiatives and requirements. County emergency management officials work with local health officials in all aspects of a community's comprehensive emergency preparedness, mitigation, and recovery plans. The three participants from the "other" category included two from academic departments by using modeling for public health issues and one director of an agency dedicated to disaster response. These "other" responses were included owing to their direct involvement in creating, training, and/or participating in emergency preparedness programs, drills, and exercises.

TABLE 1 ● Summary characteristics of participants

	Local health official	State health official	Local emergency management	State emergency management	Other	Total
Florida	4	7	2	1	3	17
Michigan	1	3		1		5
Missouri	2		1			3
New Hampshire	2	3		1		6
New York	3		1			4
Texas	2					2
Utah		2				2
Washington State	1					1
Total	15	15	4	3	3	**40**

The average population served by a county health department included in this needs assessment study was 1.5 million. The range included a city in New Hampshire with the population of 88 000 people and a metropolitan area in New York with 8.2 million residents. The health officials representing four state health departments ranged in population size from 1.3 million in New Hampshire to 18 million in Florida.

A variety of discussion formats was used to gather differing perspectives within the constraints of time and funding. Most consultations were done in person and conducted as one-on-one interviews (Table 2). Because of constraints and availability of respondents, some interviews were conducted as group interviews, and in one case, as a six-person focus group. During the consultations in which more than one person was interviewed at a time, the group dynamics served to elicit more information and more detailed responses. Each individual in the multiperson consultations and the focus group was considered as an individual respondent for analysis. The data analysis took into consideration the diverse data collection methods; however, no differences were noted.

Individual consultations lasted approximately 1 hour including orientation and discussion and were tape recorded for data collection and analysis. A PowerPoint presentation of 23 slides was shown prior to all consultations, or for telephone recipients, was e-mailed in advance and viewed together with the interviewer prior to the structured consultation. This was done in an effort to provide all respondents with a uniform orientation and definition of modeling with specific applications to public health issues and preparedness-related activities. All interviews were completed within a 6-week time frame, from October 15 until November 30, 2007.

The rapid needs assessment tool contains 35 main topic questions and 75 coded responses. The tool is divided into five major categories: descriptive; threat-specific probes; partnerships; training; and future directions (Table 3).

Respondents were asked whether they were familiar with models for preparedness activities associated with the threats, and then given specific probes to assist with identifying potential models for various activities. The

TABLE 2 ● Survey method and type

	n (%)
Method	
In-person	25 (63)
Telephone	15 (37)
Type	
Individual	22 (55)
Two-person	3 (15)
Three-person	2 (15)
Focus (six-person)	1 (15)
Total	40 (100)

TABLE 3 ● Needs assessment tool—five categories of inquiry

Type of question	Function
Descriptive	Describe the public health agency by the number of employees, geography, or setting (city, county, or state), size of population, and parameters of responsibility
Threat-specific probes	Use of models for preparedness activities before, during, and after the threat-specific event. If used, which models, and if not, what challenges or obstacles prevented their use?
Partnerships	Specify community partners and the use or the potential use of preparedness modeling for current or future problems
Training	Describe level of training proficiency with modeling and opportunities for future use for threats and hazard response functions
Future objectives	Comment on future directions for the CDC and federal agencies and academia to promote preparedness modeling

TABLE 4 ● Needs assessment questions regarding preparedness models for pandemic influenza

Purpose	Model and its use
Predicting the spread of an influenza pandemic	
Predicting mortality from an influenza pandemic	
Predicting medical surge for an influenza pandemic	
Determining stockpile of supplies—vaccine, antivirals, personal protective equipment (PPE)	
Determining distribution of stockpiled supplies—vaccine, medicines, PPE	
Determining patient flow for a clinic distributing medicines or vaccines at a time of an influenza pandemic	
Determining staffing needs for a distribution/response clinic	
Determining response capabilities for an influenza pandemic	
Predicting effects or triggers for nonpharmacologic interventions such as social distancing and closing schools	
Forecasting economic impact of an influenza pandemic	
Other	

checklist included the questions that were used to elicit responses regarding familiarity and use of models for pandemic influenza preparedness activities is provided in Table 4. Similar checklists were used to collect data regarding models for radiologic release and severe heat waves. All interviewers tried to elicit a similar level of detailed responses by reading the listing of prompts or probes from the checklists.

The results from the consultations were analyzed by using the *SurveyMonkey* on-line program, which allowed for quantification of numerical data and the display of qualitative responses. Response frequencies were established for each close-ended question. Open-ended responses were analyzed and coded into themes.

Methods: Limitations

Purposive sampling can be defined as a nonprobability sample or nonrepresentative sample of a larger population that are chosen for a specific need or purpose. For this qualitative research study, purposive sampling was used to reach the most articulate and experienced local and state health officials who are specifically charged with the responsibilities for emergency preparedness functions. A limitation of this study is that the results may not be representative and generalized to all other heath officials. In addition, the mixed modality of gathering data, using individual and group sessions (two or more respondents simultaneously), as well as in-person and telephone structured consultations, could be considered a shortcoming in the study design. The assigning of equal value to responses despite the setting (group vs individual) may be considered another limitation. However, the overriding purpose of this multistate needs assessment for the CDC was to collect as much qualitative data as possible, with the most seasoned health officials responsible for preparedness functions in a variety of states and localities, within the set constraints of time and budget, and thus the mixed methodology employed by the three unique public health institutions was considered the best approach.

Results

Modeling familiarity

All respondents were familiar with preparedness modeling and most recalled models in three categories: natural disasters—hurricane, flood, and earthquake models; disease transmission and syndromic surveillance models; and technological or terrorism-related models involving chemical or radiologic plume models. Overall, respondents mentioned familiarity with a broad range of models, protocols, and strategies by using a diverse range of terminology. Effort was taken to determine the extent to which the terms they used were duplicative.

However, regardless of the public health threat or response function, the study respondents cited quality- and applicability-related factors as determinants regarding their use of models as summarized in Table 5.

Pandemic influenza

All healthcare professionals were familiar with and used computer models for preparedness and response planning for pandemic influenza. Ninety percent of respondents reported using the CDC models of FluAid 2.0 and FluSurge 2.0 for preparedness planning.[27] FluAid 2.0 can estimate a range of impact from a pandemic influenza including deaths, hospitalizations, and outpatient visits. FluSurge 2.0 is a spreadsheet-based

TABLE 5 ● Factors of models affecting use of computer models for preparedness functions

Validity	Credible and “valid” assumptions that are used to create the model
Reliability	Confidence that the model is tested
Authorship	Source of the model
Accessibility	Ability to download model software
Scalability	Capable of making adjustments to local setting
Relevance	Current with mandates from state and federal initiatives
Capacity	Qualified and trained staff to run models
Applicability	To specific hazards, response functions, and/or populations

TABLE 6 ● Use of models for preparedness for pandemic influenza

Objectives	Models	Challenges	Obstacles
Predicting spread of disease, morbidity and mortality, and triggers for action	CDC FluAid, MIDAS models, crude attack rates	Lack awareness of models, question assumptions, scalability, accessibility, capture behavior, corresponding action plan	Lack funding, staffing, time, credibility, and utility, political implications of containment, want mandates
Distribution of supplies and staffing of PODS, Medical surge, Response capabilities	CDC FluSurge, POD models	Lack awareness, uniformity in response planning, local implantation, capability, and gap analysis	Each community is unique, making generic models difficult, staffing issues, needs of vulnerable populations

model that estimates demand for hospital-based services during a pandemic including hospitalizations, deaths, intensive care unit care, and numbers of patients requiring ventilator support. In addition, epidemiologists and directors of Communicable Diseases Control program from state health departments and those from cities and large counties with populations of more than 1.5 million people were aware of mathematical models that focus on disease transmission and containment strategies from the NIH-MIDAS research network (n = 19). The two authors of the mathematical models most often cited were Ira M. Longini, Jr, PhD, and Neil M. Ferguson, DPhil.[28–30] These models demonstrate that vaccination remains the best intervention for influenza, and the targeted multilayered use of antivirals and reduced social contacts (social distancing) were important containment strategies.[31]

The health officials reported using a variety of models for POD planning (Table 6). Most commonly referred model was the Weill Medical College of Cornell Bioterrorism and Epidemic Outbreak Response Model or BERM.[32] Although the BERM was referenced by 70 percent of respondents (n = 19 of 27), most officials reported that the BERM was not practical to their setting. Also cited was the Clinic Planning Model Generator, which was created in partnership with the Montgomery County Advanced Practice Center, Institute for Systems Research at the University of Maryland. This model was built on data from a smallpox exercise and other biologic POD exercises.[33]

Mathematical modeling for pandemic influenza was considered an "important and useful tool" for preparedness planning. However, there was considerable skepticism expressed by respondents for basing health protection policies on these models. Specifically, health officials repeatedly listed the following factors as challenges or obstacles to use of models for preparedness activities: use of real data for creating the models and rates; vast changes taken place in society since the Spanish Influenza of 1918; political reality for change in local communities; funding for specialized training or staff to run complicated models; second and third tier implications of containment strategies; inability to factor in human behavior to the model; inability to download and apply population-specific data or modify assumptions to conform to local population; and lack of mandates by state and federal governments.

Radiologic release

Seventy percent (n = 28 of 40) of respondents were familiar with models for radiologic release. Most cited generic "plume" or dispersion models. Despite awareness of these models, only 25 percent (n = 10) use such models for preparedness planning. Respondents reported that radiologic release modeling is highly specialized and falls under the purview of the state department of radiation control and environmental health, or with first responders and emergency managers. Most health officials have little experience with these models and would not be called in to use them in an emergency or drill. For local health officials, 60 percent (n = 9 of 15) were familiar with radiologic release models and only one said he or she would use such models in preparedness planning. For state health officials, 73 percent (n = 11 of 15) were familiar with these models. A repeated theme was the greater need for surveillance and detection rather than for modeling for radiologic releases, especially if the inputs for the model would not be readily known in a disaster (the quantity and identity of the released agent) (Table 7).

Severe heat wave

Forty-seven percent (n = 7 of 15) of the local health department officials were familiar with models for severe heat waves, and 33 percent (n = 5 of 15) have used a model for preparedness planning. The familiarity, as well as use of these models, was even more reduced for state leaders. Only 33 percent (n = 5 of 15) of state health officials were aware of heat models, but none had used them in preparedness planning activities. When familiar, the model most often cited was the National Weather Service Heat Index (Table 8), which combines temperature, relative humidity, and length of time to suggest warnings and prognostications. A

TABLE 7 ● Use of models for preparedness for radiologic release

Objectives	Models	Challenges	Obstacles
Predicting dispersal, exposure, morbidity, mortality	Plume models, RASCAL, FERMAC, NRC	Access to model (local or state), human behavior input, will not have inputs to run models, surveillance, and detection key	Technologically complex, advanced training and practice needed, not seen as a responsibility of local health department
Action plan for response-evacuation, supplies, medical surge	Logistics models, inventory models, reverse 911 alerts	Scalability to local community, seen as responsibility of others	Not aware of models, not accessible, not considered a high-demand threat

repeated theme was to advance the use of models for temperature-related events (heat waves as well as ice and snowstorms) and consider preparedness models that take into consideration the effects of temperature at large public gatherings and outside events.

The health officials were asked to indicate "how helpful the CDC could be to your organization with regard to formal modeling for public health and emergency preparedness activities?" Overall, respondents cited that the CDC would be most helpful in the creation of models (score of 3.7 on a scale of 4) and adapting them to be user-friendly and scalable (score of 3.66 on a scale if 4). Local health officials and emergency managers also ranked high (score 3.55) for the CDC to translate the output of models into actionable steps.

● Discussion and Implications

Health and emergency management officials were receptive to the use of sophisticated modeling for preparedness purposes for threats and response functions and for health policy decision making. They preferred models to be *all hazard* in their approach and thereby applicable to a variety of issues and responses. The health officials reported that they wanted to be made aware of models, the models would be accessible (to be downloaded on their computer), and funding for training and staffing would be made available as well. State health officials cited the need for valid, credible, and tested models that would become *mandated* by the federal agencies and thus create national standards for preparedness planning and response. Similarly, local health officials preferred that their state health departments promulgate *mandated* models that would create uniformity in local planning and a common platform for response. In addition, this study showed the need to *disseminate* available models and share best practices with regard to knowledge and strategies. Additional ways to communicate across all levels and between states would be beneficial. Local health departments are working independently in *silos* to create action and response plans on the same issues that all communities are facing. There could be substantial benefits by coordinating and sharing local efforts.[34]

There also appears the need to use and promote a common glossary of terminology with respect to modeling, and this finding is in conjunction with efforts to disseminate and share knowledge, best practices, and lessons learned.

The need to address vulnerable and at-risk populations at times of emergency and crises are a common concern of every community. Moreover, these problems, associated with communication, evacuation, and other action plans for this population, are relevant regardless of the type of hazardous event. Health officials are interested in the potential use of computer models and innovative mathematical tools to assist in emergency planning for vulnerable populations. At-risk groups often cited were the elderly, those with low income, those who confront cultural and language barriers, and those living in nursing homes. The needs most often mentioned for modeling included communication strategies (warnings and alerts) and hazard

TABLE 8 ● Use of models for preparedness for heat waves

Objectives	Models	Challenges	Obstacles
Predicting morbidity and mortality from heat waves	National Weather Service Heat Index; Heat/Health Warning System	Responsiveness to vulnerable populations, responsibility of emergency management and not health departments	Not aware of models, low priority
Response and action plans	All hazard models	Communication and alerts, especially for large events or for nonresidents	Low priority, confounding variables of lack of air conditioning and activities done outdoors

response functions for evacuation, sheltering, and quarantine.

Emergency managers, comfortable with disaster computer modeling, are eager for health preparedness models to translate into *actionable plans*, in addition to providing useful predictions and prognostications. Having definitive action plans for disaster and emergency response was a repeated theme, with the option and flexibility to adjust model variables for actual population and other criteria and thus made scalable to the local community. Respondents commented on the use of modeling to assist in educating and convincing local leaders, particularly elected officials unfamiliar with public health, to enact tough containment and other mitigation strategies at times of infectious disease spread. Local governments and decision makers, not trained in health matters, may question the need and timing for difficult actions such as closing schools or canceling public gatherings for slowing pandemic influenza spread. The use of computer predictive models, with local data inputs, will be a valuable resource tool for health officials.

The health officials reported some significant *challenges to* the use of computer models, and they include validity, reliability, model derivation or source, accessibility, and scalability. Officials reported that they lacked time and funding to train existing staff, as well as funding for potential new staff. In addition, health officials were not always made aware of new models and thus improved communication and dissemination was mentioned. Having models accessible on their computer, and the ability and flexibility to input local data and thus make these models scalable and source specific, was another important criterion to move this tool forward. Scalability would allow a model to reflect the specific nature of a less-populated county, as well as with proper inputs, be appropriate for a major urban community.

Conclusion

Public health emergency preparedness can benefit from the use of computer modeling, and local and state health officials are receptive to such tools. The use of modeling may help reduce the variation of emergency preparedness by local health departments. In addition, the development of metrics and standards of preparedness, as well as methods for improving capabilities for preparedness, will be objectives for future implementation.[35–37] Consideration should be given to ways to improve PHEP through public-private collaborations. The business community may well respond to sophisticated computer tools that can demonstrate action plans and provide scenario analyses. In general, the private sector is fast acting, motivated to protect employees and their families, and capable of an active partnership in community response and recovery. Dr Julie Gerberding, director of the CDC, has called for the application of complex systems theories and "syndemic approaches" for health protection research as way to improve preparedness.[38] Most recently, Frumkin and others[14] at the CDC have suggested that public health scientists focus attention on the application of system dynamics modeling to the complexities associated with the health impacts due to climate change. Therefore, the use of systems thinking and modeling may well become a significant tool for public health policy decision making in the future, emergency preparedness, and many other aspects of health protection and injury and disease prevention.

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