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REVIEV PAPER

Artificial intelligence for the prediction of health emergencies and disasters

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ABSTRACT

Amidst unprecedented global health challenges, exemplified by the recent SARS-CoV-2 pandemic and other natural disasters, the imperative for initiative-taking measures is evident. Resilient Health Systems, initiated by PAHO/WHO, seeks to fortify preparedness. This study explores the pivotal role of Artificial Intelligence (AI) advancements in addressing health crises. A scoping review was conducted on PubMed, Scopus, and LILACS databases. Limited to 2013–2024. Inclusion criteria: freely accessible articles in Spanish, English, or Portuguese on AI in disaster prediction and management. Removed duplicates and irrelevant languages. Subjective selection based on abstract and title. Grouped articles into two categories. Key information was extracted for analysis. Findings underscore the need for targeted exploration in AI applications for epidemic prediction. Ongoing exploration is evident, with a particular emphasis on specific symptom-based predictions. Beyond epidemics, AI excels in predicting a spectrum of natural disasters globally, from sea-level changes to earthquakes. Noteworthy successes include cyclone and flood predictions. Challenges, such as real-time updates, regional complexities, and global communication, must be addressed for widespread adoption. AI is a pivotal force in transforming healthcare and disaster management. The path forward involves a cohesive integration of technological innovation, ethical considerations, and global cooperation to fully unleash the benefits of AI for public health.

KEYWORDS: artificial intelligence; forecasting; disaster management; health policy; disaster medicine

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INTRODUCTION

Throughout history, humanity has faced multiple catastrophic events and epidemics, each precipitating profound consequences on a global health scale. The most recent crisis, triggered by SARS-CoV-2, resulted in a worldwide quarantine, imposing diverse socioeconomic implications in addition to the well-documented health impacts [1]. Beyond the recent pandemic, the global population has faced other formidable challenges, giving rise to repercussions comparable to those experienced in the tumultuous year of 2020. Notable instances encompass the Spanish Flu and the ongoing Human Immunodeficiency Virus (HIV) pandemic, affecting a persistent and staggering number of over thirty-one million people to date [2]. Additionally, health emergencies generated by natural disasters such as the earthquakes in Haiti and Chile in 2010, or Hurricane Dorian in 2019, must be mentioned. These events have had even greater repercussions than the previously mentioned pandemics [3].

The multifaceted repercussions of health emergencies, as exemplified by those mentioned earlier, are evident. Consequently, a segment of the global health system has directed its efforts towards averting these epidemiological events, culminating in the designation of December 27 as the International Day of Epidemic Preparedness [4]. The Pan American Health Organization (PAHO/WHO) has set specific goals for the year 2025, based on the number of countries capable of preventing and controlling epidemics or pandemics of significant magnitude [5]. This highlights how major health organizations have focused their attention on the prevention of health emergencies.

In this context, it is important to mention Resilient Health Systems, a strategy led by the PAHO, established in September 2020 in response to the SARS-CoV-2 pandemic [6]. A resilient health system is equipped to manage any health emergency or disaster, demonstrating the capacity to anticipate and effectively respond. These systems are further distinguished by their emphasis on health promotion and prevention, coupled with expansive population coverage and other essential features. Considering these attributes, one might contemplate the potential impact of a technological tool capable of supporting Resilient

Health Systems or guiding developing countries in reshaping their healthcare infrastructure to enhance resilience [7].

In recent years, artificial intelligence (AI) has become a topic of interest, as its application in various fields, along with its multiple tools, has been a significant advancement for humanity (Tab. 1). Likewise, Big Data, which refers to an amount of information so large surpassing the processing capacity of traditional methods, has been intricately intertwined with the progress of AI, thereby augmenting the capabilities of AI itself [8]. Therefore, this article aims to analyze the available evidence regarding the use of AI in addressing health emergencies and disasters.

MATERIAL AND METHODS

A scoping review was conducted on online databases such as PubMed, Scopus, and LILACS, in search of answering the question: What application has been given to AI in the prediction of health emergencies and disasters? Considering that health emergencies and disasters are defined as those that put the local health system at maximum capacity due to the occurrence of a natural disaster or an epidemic. The literature review did not include "gray literature" or non-indexed databases, by the choice of the authors. Descriptores en Ciencias de la Salud (DeCS) and Medical Subject Headings (MeSH) terms such as "Artificial Intelligence", "Forecasting" and "Disaster Management" were used in Spanish, English, and Portuguese. Only a date filter was applied in the Scopus database, limiting literature to the period from 2013 to April 2024, because in this database the literature found was extensive, making a proper review impossible, so a date filter reduced it to a more accessible sample.

The inclusion criteria were freely accessible articles published in Spanish, English, or Portuguese that addressed topics such as natural disasters, epidemics, or structural failures and their prediction and management through AI. That is, this document not only focused on the prevention and mitigation stage but also included articles that implemented AI in the response and recovery of health emergencies. Duplicate articles and those not in Spanish, English, or Portuguese were removed. A subjective selection was made based on the abstract and title, and the selected articles were obtained through the library of the Universidad de La Sabana and saved in an online storage cloud for easy access by all authors. Key information such as authors, title, authors' country, year of publication, and main ideas were extracted from each article (Tab. 2).

Lastly, the articles were grouped into two categories; each article was read by each member of the research group, extracting main ideas which included AI applications in the previously mentioned topics of interest, important figures found in the results of these applications, barriers during implementation, among other data; subsequently, the joint writing of the information found was carried out. Additionally, for each article deemed suitable for study, an additional literature search was conducted on their references using the "snowball" method, applying the inclusion criteria previously described.

RESULTS

146 articles were found in the mentioned online databases, three of those were duplicated and nine were written in Chinese. The remaining 134 articles were filtered by title and abstract, deleting 120 articles that did not include artificial intelligence use or use of AI for prediction, besides not related to the main topic or not being free access. Finally, fourteen articles and five from the “snowball” method were downloaded for a complete review by the research group and divided into two groups: 1. Artificial intelligence for epidemic prediction (6 articles), and 2. Artificial intelligence for natural disaster prediction (13 articles) (Fig. 1).

Artificial intelligence for epidemic prediction

Presently, there is AI specifically designed to detect symptoms during outbreaks, epidemics, or pandemics. For example, some AI systems can extract information from social media during public health disasters, offering the health sector a valuable tool for epidemiologic surveillance, by extracting extensive amounts of health-related data from various online sources, such as Twitter, to monitor and keep tabs on the emergence of infectious diseases, including influenza. An example of this was during Hurricane Sandy, where more than 20 million Twitter posts (tweets) were generated in one week, helping US response teams filter relevant signals [9]. Nevertheless, it is essential to emphasize the necessity for specificity in information extraction, behavior mining, and real-time analytics customized for health situational awareness. This specificity is crucial for enabling a global response during disasters [9]. An AI Similar was developed in Germany and Italy; In Germany, the focus was on two well-known social networks and their exclusive forums for reporting symptoms related to COVID-19; This AI was able to predict cases of COVID-19, depending on the symptoms reported, model performance was adequate across all testing windows: Area under the curve (AUC) was 0.77, 0.80, and 0.81, respectively [10]. In Italy, the basis for predicting potential COVID-19 symptoms among patients was drawn from a network of dialysis clinics; using AI, the system demonstrated that predictions lead to official COVID-19 incidences by up to 14 days in this population [11].

Similarly, in the United States, an AI based on machine learning was created that could predict the risk of COVID-19 in hemodialysis patients. Through 81 variables and based on data from a national network of dialysis clinics, a cohort of 40.490 patients (about twice the seating capacity of Madison Square Garden) was reached (11.166 with positive tests for COVID-19 and 29.324 who did not). The area under the receiver operating characteristic curve (AUROC) and area under the precision-recall curve (AUPRC) for the model were 0.68 and 0.24 in the testing dataset, respectively. Finally, it was concluded that the AI predicted when a patient was at risk of COVID-19 up to three days before a clinical suspicion was established by the treating service [12].

Likewise, but on a larger scale, China developed an AI in conjunction with a previous model of epidemiological evaluation and control, capable of predicting new epidemics; which showed that at the end of February 2020, there would be a peak of infections with a gradual decline until the end of April, which allowed for rapid action by health authorities, such as maintaining quarantine for a certain additional period, and through the same AI it was demonstrated that these actions prevented a new epidemiological peak [13].

Additionally, according to a study, the combination of case-based reasoning and information retrieval techniques from the field of AI provides an effective method for identifying clusters of similar incident reports in the medical field. The study suggests that using both techniques together results in better performance in finding clusters of similar medical incident reports compared to using either technique alone. The study also recommends that future systems developed to cluster medical event reports should integrate both the field values and the text of the reports in their methodological approach for improved accuracy and recall [14].

Artificial intelligence for natural disaster prediction

The findings in the study by Alshouny A. et al. [15] showed that the Deep Learning Neural Network (DLNN) model has superior potential compared to machine learning models, increasing the accuracy of SLV prediction by 23%. Furthermore, the developed DLNN model can predict the Sea Level Variation (SLV) for three days with a correlation coefficient of 0.91, which is useful for making early SLV predictions for disaster management purposes [15].

On the earthquake side, the adaptive chaos particle swarm optimization (ACPSO-ELM) algorithm has an R-squared coefficient of 0.96, which is better than other prediction models for the number of earthquake deaths [16]. Furthermore, a study in Turkey implemented an Artificial Neural Network for earthquake casualty prediction, using predictors such as earthquake occurrence time, earthquake magnitude, and population density, as well as past events, given the country's high frequency of earthquakes. The results show that 99.9% of the variability in the number of injured people is predictable using this model, which can provide accurate estimations of casualties and information to develop mitigation policies [17]. At the same time, in China, a machine learning tool was implemented to increase the prediction of casualties of earthquake disaster accuracy, based on data from 84 groups of earthquake victims in China from 1970 to 2017, a relative error for earthquake disaster prediction of 3.37% was found, which indicates that this AI algorithm has good robustness and generalization ability [18].

One of the initial areas where AI was developed is its ability to predict climate changes and their impact on the population. However, it still requires an interface capable of updating minute by minute due to the climatic variability present in these times [19].

Linked with climate changes and their coastal implications, AI has been developed with the capability to correlate weather patterns to predict the future presence and intensity of cyclones. For instance, the Bidirectional Attention-based Long Short-Term Memory (LSTM) Storm Surge Architecture (BALSSA) model, which employs a bidirectional attention-based architecture for storm surge prediction, was trained and evaluated using a comprehensive dataset encompassing over 70 typhoon incidents in Macau from 2017 to 2022. The results demonstrate the outstanding performance of BALSSA, offering highly accurate storm surge forecasts with a lead time of up to 72 hours [20].

Conventional methods such as artificial neural networks are also used to predict the cyclone's parameters, the position data in terms of latitude and longitude, wind speed, and pressure. The artificial neural network predictions for the land crossing points have a mean error of 38.4 km for the 12 h forecast and 71.02 km for the 24 h forecast [21]. In the aftermath of cyclones, floods become a focal point for AI studies. It highlights the capacity to forecast impending floods by analyzing various geographic variables incorporated during its programming, since the flooding process has a non-linear relationship with various meteorological factors and topographic parameters since the flooding process has a non-linear relationship with various meteorological factors and topographic parameters [22]. These models can bring an accuracy rate of 80.49% [23]. However, the intricate nature of these variables poses a challenge, limiting the applicability of such AI models to other regions (18, 19).

In the same way, in a region of Thailand where large landslides are frequent, the possibility of having AI capable of predicting this phenomenon was studied, showing adequate performance, with an AUC precision of 0.47 and promising prospects for disaster medicine [24]. Some authors agree that the primary challenge with AI in natural disasters lies not in its development but in its communication and global adoption. It necessitates active engagement from those working daily with these tools to collaborate with pertinent governmental entities in formulating policies for global prevention and healthcare [25, 26].

Based on the above, the need for a rapid response to disasters is proposed as an additional application of AI, so machine learning has been used for evacuation simulations during natural disasters, using scenarios that have previously presented these disasters, such as Chile in 2010, obtaining variables that are not normally taken into account and could generate more effective and safe evacuation routes, even in large crowds [27]. Similarly, AI has been adapted for use in other areas, to serve as an early response tool during emergencies, for example, Hierarchical task network planning, which showed adequate results. However, during its adoption, variables that could harm its eventual standardized use were not considered. In turn, new tools have been created with the same objective, demonstrating a faster and more effective response than in previous situations [27].

DISCUSSION

The integration of AI in clinical care has led to significant shifts beyond provider-patient interactions. Four major trends include the evolving role of patients, a transition from hospital to home-based care facilitated by telemedicine, AI extending clinical care beyond formal health systems, and AI's role in resource allocation and prioritization. The evolving patient role involves AI aiding self-management and raising ethical concerns about regulation and patient responsibility. Home-based care is advancing through telemedicine, AI-driven monitoring, and just-in-time adaptive interventions. AI extends clinical care outside traditional health systems, reaching education, workplaces, and social media, necessitating continuous monitoring with wearables, and posing ethical concerns. Lastly, AI assists in resource allocation, particularly during crises like COVID-19, with the potential to optimize critical care decisions and address resource shortages [10–13, 28].

In the realm of AI in health, there is a notable absence of formal procedures for credentialing or licensing technology designers and developers, unlike the stringent requirements for healthcare workers. Mere calls for adherence to abstract moral values are insufficient, necessitating innovative approaches in software engineering. Recent advancements go beyond traditional programming techniques, introducing methods for systematically integrating ethical values into AI technology design. Legal codifications, such as the General Data Protection Regulation, mandate specific obligations like privacy by design. One such approach is "Design for values," aligning design with human rights standards, focusing on values like human dignity, freedom, equality, and solidarity as non-functional requirements. This process-oriented paradigm prioritizes stakeholder needs in harmony with moral and social values [25, 26, 28].

Finally, human rights standards, data protection laws, and ethical principles are essential for guiding AI use in health, involving developers, governments, providers, and patients. Stakeholders seek universally accepted ethical principles for AI in health, and the World Health Organization (WHO) aims to foster consensus with the principles outlined in this report. The challenges posed by AI in health go beyond existing laws and principles, especially as the risks and opportunities are not fully understood and may evolve. Low- and middle-income countries encounter additional challenges, requiring awareness of ethical principles and appropriate governance for implementing new AI technologies. Governance in health involves steering, rule-making, and political processes, aligning with national health policy goals for universal health coverage. WHO's global strategy on digital health, along with other governance frameworks and standards, contributes to establishing a governance framework for AI in health, addressing ethical dimensions in various governance areas [25, 26, 28].

LIMITATIONS

Despite promising advances in the application of artificial intelligence to predict epidemics and natural disasters, this study faces some limitations that must be acknowledged. One of the main limitations is the lack of solid scientific literature in this emerging field. Most of the available studies focus on specific applications and often lack a comprehensive approach that spans various regions and contexts. This lack of data and comparative studies makes it difficult to fully assess the effectiveness and widespread applicability of AI models. Additionally, there is a risk of inherent biases in the data used to train these models, which can affect the accuracy and generalizability of the predictions. Future research should focus on expanding and diversifying the database, to minimize these biases and close existing gaps in the literature.

CONCLUSIONS

This article has explored the role of artificial intelligence in predicting epidemics and natural disasters. On the part of epidemic prediction, it has proven to be a powerful tool in epidemiological surveillance, since AI systems can extract information from social networks and other online sources to monitor and predict the emergence of infectious diseases, as was the case of the COVID-19 pandemic. These systems have demonstrated the ability to anticipate incidents, however, the importance of specificity in information extraction and analysis in real-time is highlighted to obtain an effective global response during emergencies.

AI has also demonstrated its potential in predicting natural disasters, for example, models with high accuracy have been created to predict variations in sea level and the number of deaths from earthquakes. The application of these models may be limited due to the variables involved and the need for interfaces capable of updating in real-time.

Despite advances, there are significant challenges in the global adoption of AI in the context of disasters. It is crucial that AI developers work closely with government entities to formulate global prevention policies. In summary, AI represents an invaluable tool for improving the prediction and management of epidemics and natural disasters, but its effective implementation requires careful consideration of ethical challenges and global collaboration.

Article information and declarations

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Author contributions

All authors participated in the conceptualization and planning of the original study; likewise, all participated in data collection, analysis, and organization, as well as in the writing, review, and approval of the manuscript.

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Conflict of interest

The authors declare no conflict of interest.

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Artificial Intelligence (AI)	Definition
Deep learning	A subset of machine learning that utilizes deep neural networks to model complex patterns in large datasets. These networks have multiple layers that progressively extract higher-level features from raw input. Applications include speech recognition, image classification, and natural language processing.
Neural networks	Computational models inspired by the human brain, consisting of interconnected nodes (neurons) that work in unison to solve specific problems. These networks learn from data by adjusting the weights of connections based on the error of predictions. Neural networks are the foundation for various deep-learning models.
Feedforward neural networks	The simplest type of artificial neural network where information flows in one direction, from input to output, without any cycles or loops. They are typically used for tasks like classification and regression. Each neuron in a layer is connected to every neuron in the previous and next layer.
Recurrent neural networks	A type of neural network where connections between nodes form a directed graph along a sequence, allowing them to maintain information in 'memory' over time. This makes RNNs particularly effective for sequential data such as time series, language modeling, and speech recognition.
Convolutional neural networks	Specialized neural networks designed for processing structured grid data like images. They use convolutional layers to apply filters that capture spatial hierarchies, pooling layers to reduce dimensionality, and fully connected layers for classification. CNNs are widely used in computer vision tasks such as object detection and image segmentation.
Case-based reasoning	A method in artificial intelligence where a system solves new problems based on the solutions of similar past problems. It involves four steps: retrieving a case similar to the current problem, reusing the case to solve the problem, revising the proposed solution if necessary, and retaining the new solution as part of a new case. This approach is useful in domains where rules are hard to define but examples are

	plentiful.
Information retrieval	The process of obtaining relevant information from a large repository (such as a database or the internet) in response to a user's query. IR systems use algorithms to rank and return the most relevant documents or data. Techniques include keyword matching, natural language processing, and semantic search. Applications range from search engines to recommendation systems.

Table 1. AI's terminology; adapted from reference [8]

Articles finally included for study				
Artificial intelligence for epidemic prediction				
Author	**Title**	**Country**	**Year**	**Summary**
Jennifer L. Chan & Colls. [9]	Challenges to Transforming Unconventional Social Media Data into Actionable Knowledge for Public Health Systems During Disasters	United States	2019	Data collection through social networks requires an improvement in AI currently available.
Francesco Bellocchio & Colls. [10]	Enhanced Sentinel Surveillance System for COVID-19 Outbreak Prediction in a Large European Dialysis Clinics Network	Italy	2021	The developed sentinel can predict new COVID-19 outbreaks.
Domenic Kellner & Colls. [11]	Improved healthcare disaster decision-making utilizing information. extraction from complementary social media data during the COVID-19 pandemic	Germany	2023	The AI showed being capable of predicting the number of COVID-19 cases from Twitter and Reddit user's posts.

Caitlin Monaghan & Colls. [12]	Machine Learning for the Prediction of Patients on Hemodialysis with an Undetected SARS-CoV-2 Infection	United States	2021	An AI capable of predicting a patient in hemodialysis suffering from COVID-19 three days before the clinician.
Zifeng Yang & Colls. [13]	Modified SEIR and AI prediction of the epidemic trend of COVID-19 in China under public health interventions	China	2020	A combined AI with a tool of epidemic surveillance predicted new peaks of COVID-19.
C. Tsatsoulis & Colls. [14]	Finding clusters of similar events within clinical incident reports: a novel methodology combining case-based. reasoning and information retrieval	United States	2015	The AI can identify similar cases but has a low accuracy in doing it.
Artificial intelligence for natural disaster prediction				
Ahmed Alshouny & Colls. [15]	An integrated framework for improving sea level variation prediction based on the integration Wavelet-Artificial Intelligence approaches	Saudi Arabia	2022	There are many AIs for the prediction of sea level rise, but they have failed, cause they don't take into account some variables like climatic change.
Xing HuangID & Colls. [16]	Application of improved ELM algorithm in the prediction of earthquake casualties	China	2020	The updated model has higher stability and good prediction accuracy for the earthquake casualty.
Muhammet Gul & Colls.	An artificial neural network-based earthquake casualty estimation model for Istanbul	Turkey	2016	An artificial neural network can reveal an accurate estimation of casualties in

[17]	city			earthquake disasters.
Xing Huang & Colls. [18]	The casualty prediction of earthquake disaster based on the Extreme Learning Machine method	China	2020	Improved casualty prediction in earthquakes by an AI based on machine learning.
Jooho Kim & Colls. [19]	A Framework to Predict Community Risk from Severe Weather Threats Using Probabilistic Hazard Information (PHI)	United States	2023	The AI is limited by the minute-to-minute changes that suffer the weather; more studies are still needed.
Vai-Kei Ian & Colls. [20]	Assessing the Risk of Extreme Storm Surges from Tropical Cyclones under Climate Change Using Bidirectional Attention-Based LSTM for Improved Prediction	China	2023	This AI has new upgrades that improve the prediction accuracy of sea water level anomalies during storm surges, regardless of the temporal dynamics.
C. Purna Chand & Colls. [21]	Predicting Indian Ocean Cyclone Parameters Using an Artificial Intelligence Technique	India	2022	The AI created can predict cyclones but has low precision, and is not much different from the method currently used.
Fahad Ahmed & Colls. [22]	Comparison of Different Artificial Intelligence Techniques to Predict Floods in Jhelum River, Pakistan	Pakistan	2022	There is an AI that can predict floods in the mentioned region, but it needs more work to be used in other countries too.
Sara Saravi & Colls. [23]	Use of Artificial Intelligence to Improve Resilience and Preparedness Against Adverse Flood Events	United Kingdo m	2019	Presents current AI for the classification and forecast of flood events, with good accuracy.
Narueph	Automated Landslide-Risk	Thailand	2021	This AI is capable of

orn Tengtrairat & Colls. [24]	Prediction Using Web GIS and Machine Learning Models			forecasting landslide risk in Thailand's cities.
Seth Guikema [25]	Artificial Intelligence for Natural Hazards Risk Analysis: Potential, Challenges, and Research Needs	United States	2020	Using AI to manage Natural Hazards is the future, but it is important to take care of false confidence.
Monique M. Kuglitsch & Colls. [26]	Facilitating the adoption of AI in natural disaster management through collaboration	Germany	2022	The AI currently available is a great tool, the demanding thing is its adoption by the corresponding entities.
Sally Lu & Colls. [27]	Applications of Artificial Intelligence and Machine Learning in Disasters and Public Health Emergencies	United States	2021	A review of literature was conducted in search of AI pertaining to disasters and public health emergencies.

Table 2. Articles were finally included in the study; source — author´s work

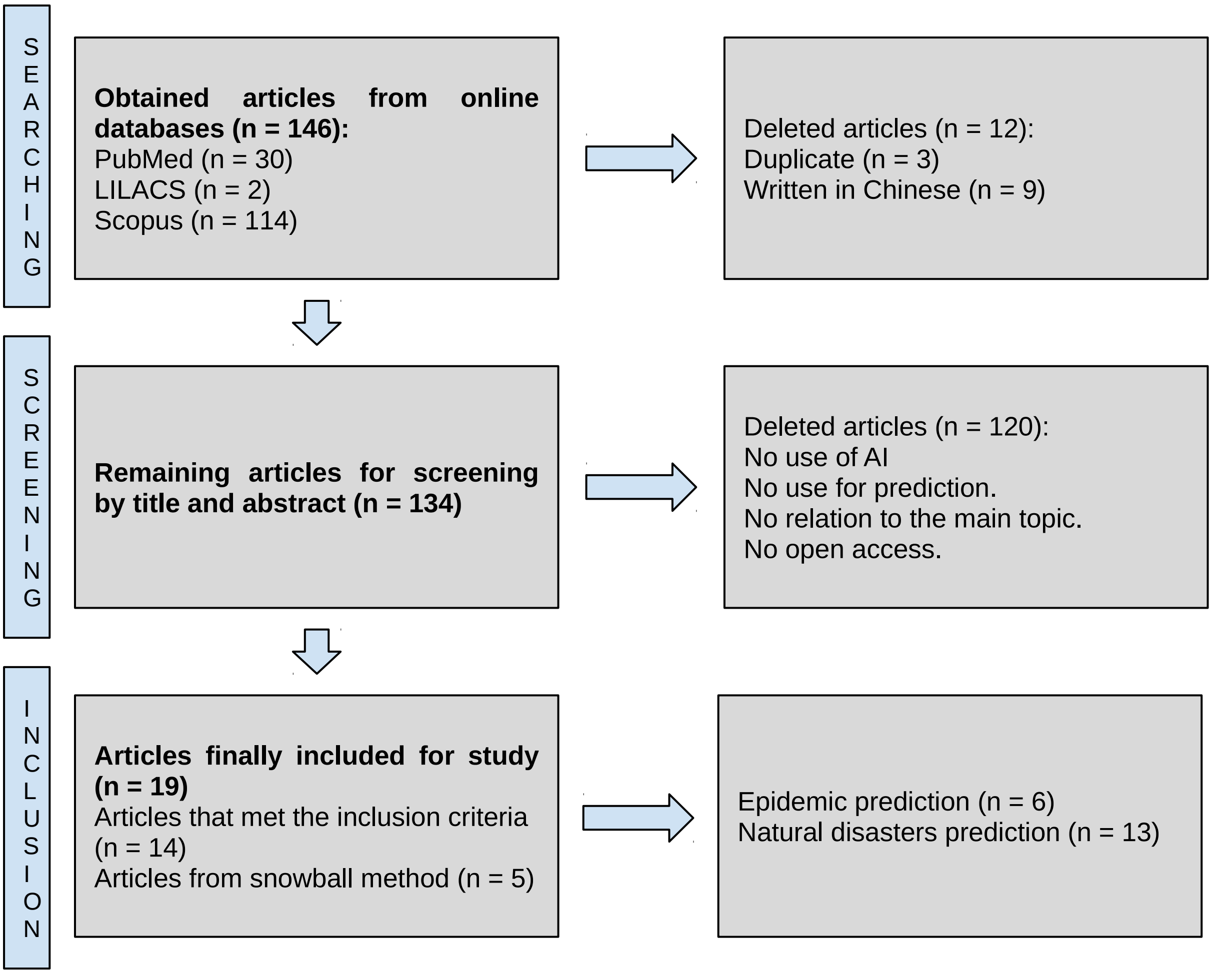

Figure 1. Searching method; source — author´s work