Review Paper

Research Gaps in Health Risks Associated With Dust Storms in Iran: A Systematic Review

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ABSTRACT

Background: This study aimed to identify research gaps and gather detailed, precise information about the health impacts of dust storms in Iran.

Materials and Methods: A systematic review was carried out in accordance with preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines, exploring both Persian and English scientific articles across multiple databases (including Scopus, PubMed, EMBASE, WoS, Cochrane, and Google Scholar) up to December 2023. Two researchers independently screened studies based on specific criteria, and paper quality was evaluated using the CASP checklist.

Results: Out of 2,006 studies that were initially searched, 7 articles were selected for data extraction after removing duplicates and irrelevant items. In this study, the retrieved articles were published from 2014-2023. The majority of the studies reviewed indicated significant relationships between dust storms and increased rates of morbidity and mortality. Specifically, most studies suggested that the occurrence of dust storms is statistically significantly associated with an increased risk of mortality from daily non-accidental causes, as well as a higher risk of hospitalization for cardiovascular, respiratory, and stroke-related diseases.

Conclusion: Despite evidence of health impacts, a notable gap exists in the literature, especially the lack of longitudinal studies and real-time data analyses in vulnerable areas. Urgent research is needed to address these gaps and improve understanding of long-term health risks, focusing on methodologies that incorporate time series analyses to inform public health policies.

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Introduction

Based on information from the World Meteorological Organization (WMO), dust storms happen when powerful or turbulent winds sweep across exposed and arid land, carrying loose particles from the ground into the atmosphere [1]. These storms are among the most dangerous meteorological phenomena in dry areas [2, 3]. Dust storms are also significant environmental and public health problems that affect air quality at local and global scales [3-8].

Dust storms are significant natural hazards that transport vast quantities of soil particles into the atmosphere annually, covering substantial distances [5, 9-15]. The dispersion of these particles during dust storms can result in levels of particulate matter (PM_{10}) and $PM_{2.5}$ that frequently exceed the recommended limits set by the World Health Organization (WHO), presenting a significant threat to human health. In some cases, the concentration can reach levels exceeding 6000 µg/m³ during intense dust storms [5, 9-11, 16-19]. These particles can include a variety of materials, such as oxides of magnesium, quartz, calcium, silicon dioxide, aluminum, and iron, as well as salts, anthropogenic pollutants, and organic matter [20-25]. Because some of these particles in dust storms are potentially toxic to humans [26] and the available epidemiological evidence confirms the presence of some microorganisms and pathogenic agents in dust storms [27-29], this natural hazard can increase the risk of pathogenicity and possible mortality in exposed people.

The evidence indicates that the frequency of these storms has increased in the last decade, affecting not only exposed people in dry areas but also other areas in the direction and path of these storms, at risk of increasing health problems [5, 30]. Iran has been one of the most important countries exposed to these storms in the last two decades, with the deserts of North Africa, Syria, Iraq, Kuwait, and the Arabian Peninsula serving as sources of dust storms in Iran [2, 31-34]. Satellite images confirm that in the last decade, dust storms in the Middle East originated from southern Iraq and spread to neighboring countries of the Persian Gulf, including Iran [32, 34]. In recent years, the increase in these storms from Iran's western neighboring countries (Iraq, Saudi Arabia, etc.) has severely affected the western and central regions of the Iran, leading to a dangerous increase in PM_{10} levels in the cities of Iran and exposing the country to the dangers of dust storms [32, 35-37].

Nonetheless, only a few studies have specifically investigated the health impacts of dust storms as a natural hazard in Iran, primarily concentrating on their effects on daily mortality rates [38, 39], respiratory deaths [38], and the incidence of cardiovascular diseases (CVD) and respiratory diseases (RD) [36, 40-43]. Some of them have only compared the health effects of dust before and during dust storms and have not addressed the delayed effects of these hazards. Therefore, given the increasing concerns about the impact of dust storms on air quality and public health [32], a comprehensive review of studies related to the assessment of the health effects of these storms and the identification of existing gaps is essential.

Summarizing the results of mortality or complications associated with PM_{10} from studies conducted in Iran can serve as a valuable tool for researchers, research centers, planners, decision-makers, and policymakers in the field of health and healthcare. This information can help them prevent health complications arising from this natural hazard, address deficiencies, and prepare more medical centers to mitigate the damages caused by dust storms [44]. Thus, our goal in this systematic review was to identify the health effects of dust storms in Iran and highlight the existing research gaps. This effort will enhance our understanding of the health consequences associated with this phenomenon and provide necessary directions for future research [30].

Materials and Methods

This systematic review was conducted in 2023 in Iran. We utilized the PECO framework to describe the participants, interventions, comparisons, and outcomes. The population consisted of communities in Iran that are exposed to dust storms. The exposure was the occurrence of dust storms, while the comparison involved days without dust storms. Our primary outcomes included morbidity and mortality rates associated with these events. For the information sources, we conducted a comprehensive search of both Persian and English literature across various databases, including Scopus, PubMed, EMBASE, WoS, Cochrane, and the scientific search engine Google Scholar, up until December 2023. This systematic approach allowed us to gather relevant data and identify significant health impacts linked to dust storms, highlighting the need for further research in this critical area.

Search strategy

The search strategy used the following keywords:

"dust storm*" OR "sand and dust" OR "sand storm*" OR "desert dust*" OR "dust event*" OR "desert sand" OR "Arabian sand" OR "Arabian dust" OR "dust episode*" OR "dust outbreak*" OR "Saharan desert dust" OR "Asian dust" OR "Asian desert dust"

AND

Mortality OR disease* OR morbidity OR admission* OR health* OR hospital* OR dispatch* OR emergenc* OR death* OR fatali* OR "loss of life" OR visit* OR "family practice" OR "patient care" OR "emergency medical services" OR hospitalization OR accidents OR ill* OR sick* OR disorder OR disabl* OR abort* OR ambulanc* OR symptom* OR clinic OR "case series" OR "primary care" AND Iran. The search was conducted in the English (Scopus, PubMed, WOS, EMBASE) and Persian (Elmnet) databases without any time restrictions (Supplementry 1).

Inclusion criteria

Observational studies with longitudinal or cross-sectional designs, including ecological, case–control, cross-sectional studies, and cohort studies, were published until December 2023. Studies reporting the relationship between the independent variable (dust storms) and the dependent variable (mortality or morbidity) as ER, CER, OR, RR, etc. Research examining the impact of dust storms on human mortality and morbidity in Iran. Articles published in reliable English or Persian journals. Studies that used a specific dust storm definition as a natural hazard.

Exclusion criteria

Studies not related to the goals of the present study. Studies based on laboratory or simulation data.

Study selection

The search process was thorough and involved manually reviewing key journals and the reference lists of earlier review articles and selected studies. After gathering the information, it was organized into separate databases, and duplicates were eliminated using EndNote software. The titles and abstracts of the retrieved studies were evaluated based on predetermined inclusion and exclusion criteria. The full texts of the chosen articles were then assessed according to these criteria. This procedure was designed and executed independently by two colleagues, with any disagreements discussed and, if necessary, a third expert consulted for assistance. If the entire text of the article or the necessary information was not available, correspondence was made with the responsible author to obtain the required information.

Quality assessment

The quality of the selected studies was assessed using the critical appraisal skills programme (CASP) checklist, which comprises eleven questions. Two researchers conducted the evaluation of the data quality.

Data extraction and management

Following the screening, selection, and quality assessment of the chosen studies, the data were extracted and documented using a predetermined format. This format included the name of the first author, year of publication, city where the research was conducted, definition of dust storms, age and sex of the study subjects, dust source, and health effects. Additionally, we incorporated several elements to enhance the comprehensiveness of our data management process: Detailed categorization of study designs (e.g. cohort, case-control) to facilitate comparative analysis; mapping the geographical locations of the studies to identify regional patterns in health impacts; recording demographic characteristics of participants to assess the representativeness of the studies; documenting the statistical methods employed in each study to evaluate the robustness of the findings; and classifying health outcomes into specific categories (e.g. RD, cardiovascular issues) for a more nuanced analysis. Data extraction and recording were conducted independently by two project managers.

Results

This study initially identified a total of 2006 articles, from which 7 were selected for the final phase of information extraction (Figure 1). The reviewed articles were published between 2014 and 2023 and included participants from all age groups and both sexes, reflecting a comprehensive approach to understanding the health impacts of dust storms. Most studies were conducted in Khuzestan Province, particularly in the cities of Ahvaz, Dezful, and Abadan (Figure 2). A notable finding of this review was the absence of a standardized definition for dust storms across the studies. The definitions used in Iran varied significantly, often relying on different indicators, such as an increase in PM_{10} levels greater than 50 $\mu g/m^3$ and a decrease in horizontal visibility of less than 2000 meters. Among the retrieved articles, two specifically examined the relationship between dust storms and mortality, while five focused on the association between

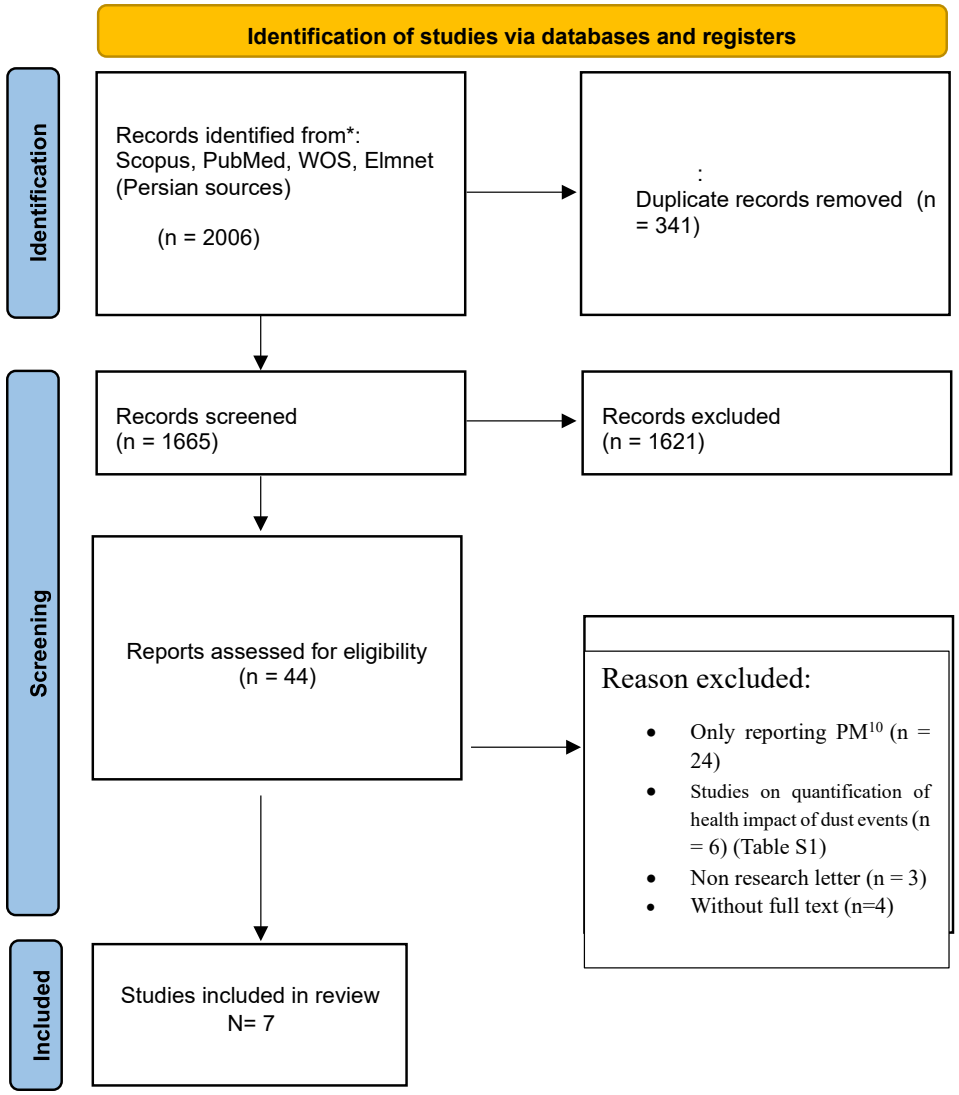

Figure 1. The preferred reporting items for systematic reviews and meta-analyses (PRISMA) flow chart

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dust storms and morbidity. The results showed that dust storms in Iran are significantly associated with an increase in the risk of daily and respiratory mortality, as well as cardiovascular morbidity, which includes cardiac diseases, strokes, and cerebral ischemic attacks (CIAs). Additionally, respiratory morbidity was found to be elevated (Table 1).

Table 1 shows that the study by Broomandi et al. in the cities of Khozestan Province was conducted from April 1, 2020, to April 30, 2020. In this study, days with PM_{10} concentrations above 100 μg/m³ were defined as dusty days, influenced by dust from neighboring countries. The results indicated that in cities, such as Izeh, Khoramshahr, and Masjed Soleyman, the obtained correlation ($r \geq 0.7$) suggests that dust incursions might significantly impact the spread of COVID-19 cases. This study examined and compared the effects of dust storms on COVID-19 before, during, and after the storms. With its advanced methodology and analysis techniques applied before, during, and after the storms, this study can provide more reliable results compared to some simpler studies [40].

In the study by Ebrahimi et al. in Sanandaj, conducted from 2009-2010, dusty days were defined on the basis of announcements from the Environmental Protection Administration (EPA) and meteorological reports related to western neighboring countries of Iran. The results revealed correlation coefficients of 0.48 ($P<0.05$) for

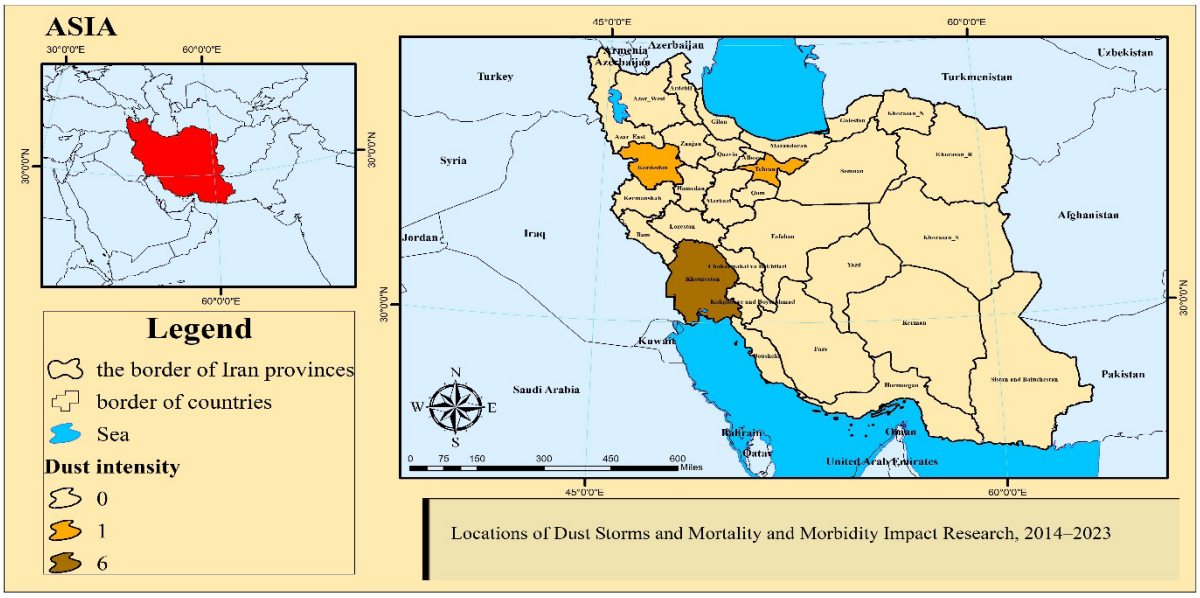

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Figure 2. Locations of research on dust storms and their impact on mortality and morbidity, 2014–2023

CVD and 0.19 (P>0.05) for respiratory disease (RD), indicating a significant relationship with CVD. This study examined and compared the effects of dust storms on diseases before and during the storms [36]. The study by Geravand et al. in Ahvaz from 2010-2012 examined dusty days via the Hoffmann classification, where days with PM levels greater than 50 μg/m³ were considered dusty. The results revealed that the correlation coefficients for RD increased over time: 0.53 in 2010, 0.58 in 2011, and 0.63 in 2012, indicating a stronger relationship with RD. This study examined and compared the effects of dust storms on diseases before and during the storms [41].

In the study by Radmanesh et al. in Abadan from 2012-2016, dusty days were defined on the basis of the Hoffmann classification, with PM levels over 200 μg/m³. The results revealed significant correlations between particulate matter and cases of CIA, headache, and epilepsy at Beheshti Hospital. This study examined and compared the effects of dust storms on diseases before and during the storms [42]. In the three studies mentioned above, it would have been better to utilize advanced methods and approaches in assessing the health impacts of environmental hazards on health outcomes.

Finally, a study by Sadeghimoghaddam et al. in Dezful, northern Khuzestan, from 2013 to 2020 investigated the effect of dust severity via horizontal visibility. The results revealed that in males, the risk ratio (RR) for stroke was 1.03 (from 1.496 to 1.0067), with P=0.01, indicating a significant association. This study examined and compared the effects of dust storms on stroke before, during, and after the storms [43]. Although this study had a more suitable design compared to the three studies mentioned above, it would have been better to use more modern methods in the methodology and analysis, such as time series methods or case-crossover designs with more advanced statistical analysis.

Table 2 shows the results of the study by Aghababaeian et al. in Dezful that examined all ages and both genders from 2014 to 2019. Dust storms were defined via the Hoffmann classification, with visibility less than 2000 m and PM_{10} levels exceeding 200 μg/m³. The dust storms originated in some countries, like Syria, Iraq, and Saudi Arabia. The health outcomes measured included daily mortality and respiratory mortality. The results indicated that for individuals under 15 years of age, the lag 4 effect was 34.17%, whereas for those aged 15-64 years, the lag 5 effect was 32.19%, and the lag 6 effect was 3.28%. Additionally, respiratory mortality at lag 6 was 5.49% [38].

Similarly, the study by Shahsavani et al. focused on Tehran and Ahvaz, covering all ages and both genders from 2014-2017. Dust storms were defined by a daily average PM_{10} concentration of 150 μg/m³ and were influenced by regional dust events, including those from southern Iran, Kuwait, Iraq, and Saudi Arabia. The health outcome measured was daily mortality [39]. In Ahvaz, the results revealed that PM_{10} at lag 0 was associated with a 3.28% increase in mortality (with a 95% con-

Table 1. Characteristics and results of the included studies on dust storm and morbidity

Dust Storm and Morbidity								
No.	**Author(s), Year, Ref.**	**City**	**Population (Age, Gender)/Duration of Study**	**Dust Storm Definition/Origin**	**Health Outcomes**	**Result(s)**	**Dust storm Phase (Before, During, or After) / Study Design**	**CASP Score**
1	Broomandi et al. 2022 [40]	Omidiyeh, Dezful, Shush, Ramshir, Shushtar, Abadan, Hamidiyeh, Hendijan, Andimeshk, Ahvaz	All ages/both genders/1st April 2020–30th April 2020	PM_{10} concentration threshold value of 100 µg/m³/neighboring countries, such as Iraq and Saudi Arabia	COVID-19	Dust incursions significantly impact COVID spread in cities with R values above 0.7.	Before, during, and 10 days after the dust storm/ time series, cases of cross-correlations	9/11
2	Ebrahimi et al. 2014 [36]	Sanandaj	All ages/both genders/2009 to 2010	Based on meteorological announcements and the EPA/ Western neighboring countries of Iran	CVD/RD	Correlation coefficients: 0.48 (P<0.05) 0.19 (P>0.05)	Before and during dust storm/ retrospective studies	7/11
3	Geravand et al. 2017 [41]	Ahvaz	All ages/both genders/ 2010-2012	Hoffmann classification/PM_{10} level ≥50 µg/m³.	RD	Correlation coefficients: 2010:r=0.53 2011: r=0.58 2012: r=0.63	Before and during dust storm/ Retrospective studies	7/11
4	Radmanesh et al. 2019 [42]	Abadan	All ages/both genders/2012 to 2016	Hoffmann classification/dusty days >200/Iran and Saudi Arabia	CIA epilepsy	PM has significant correlations with epilepsy, CIA, and headache	Before and during dust storm/ retrospective studies	8/11
5	Sadeghi-moghaddam et al. 2021 [43]	Dezful, Northern Khuzestan, Iran	All ages/both genders/2013 to 2020	Horizontal visibility	Stroke/ headache	In males, the RR for stroke was 1.03 (from 1.496 to 1.0067), with P=0.01	Before, during, and 21 days after dust storm/ retrospective cohort study	8/11

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CVD: Cardiovascular disease; RD: Respiratory diseases.

fidence interval [CI] of 2.42%, 4.15%) [39]. Both studies examined and compared the effects of dust storms on mortality before, during, and after the storms.

Discussion

Over the past two decades, a wide range of areas in Iran, including the provinces of Sistan and Baluchestan, Ilam, Kurdistan, Kermanshah, Lorestan, and Khuzestan, have been subjected to severe dust storms [24, 25, 31, 33, 35, 36, 38-49]. This study represents the first systematic review in Iran that specifically addresses the effects of dust storms as a natural hazard on the health of exposed individuals. Although a meta-analysis could not be performed due to the lack of original studies, variations in health outcomes, definitions of dust storms, and types of analyses across the studies, the majority of retrieved studies indicate that the occurrence of dust storms in Iran increases health risks. The results of review studies worldwide also support this point, as evidenced by Lwin et al. [3], Aghababayan et al. [5], and Zhang et al. [50], which confirm these health effects.

Table 2. Characteristics and results of the included studies on dust storm and mortality

Dust Storm and Mortality in Iran								
No.	**First Author, Year, Ref.**	**City**	**Population (Age, Gender)/ Duration of Study**	**Dust Storm Definition/Origin**	**Health Outcomes**	**Result(s)**	**Dust storm phase (Before, During, or After) / Study Design**	**CASP**
1	Aghababaeian, 2021 [38]	Dezful	All ages/ both genders/2014 to 2019	Hoffmann classification/Visibility [m] <2000 and PM_{10} >200/ the Middle Eastern countries, particularly Iraq, Syria and Saudi Arabia	Daily Mortality respiratory mortality	People under 15 years, lag4: 34.17% for those aged 15-64 years: lag5: 32.19%, lag6: 3.28%), respiratory mortality (lag6: 5.49%).	Before, during, and 7 days after the dust storm/ time series	9/11
2	Shahsavani, 2020 [39]	Tehran and Ahvaz	All ages/ both genders/2014 to 2017	PM_{10} daily average of 150 µg/m^3/MED, including Southern Iran, Iraq, Kuwait, and Saudi Arabia	Daily mortality	In Ahvaz, PM_{10} at lag 0 was associated with a 3.28% increase in mortality (95% CI, 2.42%, 4.15%)	Before, during, and 4 days after the dust storm/ case-crossover	10/11

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A significant finding of this study is the lack of strong evidence from various exposed regions for policymakers, planners, and executive managers to assess the health effects of dust storms in Iran. Despite more than two decades of severe occurrence, the volume of robust evidence remains very low, with most studies conducted sporadically, often without formal government investment or mandates. This points to a deficiency in disaster risk understanding among officials and specialists in this field. The importance of disaster risk understanding is explicitly mentioned in the Sendai framework, which prioritizes its enhancement as a crucial commitment for countries in the realm of disaster management [51]. In most exposed countries, such studies are conducted with great seriousness and advancement for risk assessment and better planning, and these efforts are ongoing [3, 5].

One of the most important health indicators with more accessible and comprehensive data in many countries, including Iran, is mortality rates. Many countries affected by this hazard have assessed and reported the effects of dust storms on mortality via ecological time series or case-crossover methods in exposed areas. In these types of studies, the effects of dust storms are generally measured by comparing dusty days with non-dusty days or days before the occurrence of dust with days after dust storms, which can provide a much better assessment of the risks associated with these storms [5, 50]. However, in Iran, only two studies have examined the risk of mortality following dust storms on the basis of real data analysis, whereas other studies have been simulated and based on predetermined data [38, 39]. In 2020, Shahsavani et al. evaluated the relationship between dust storms and mortality in Ahvaz and Tehran over two consecutive years [39]. Aghababaeian et al. also assessed data from Dezful over a five-year period [38]. Shahsavani et al. employed a case-crossover design, using the day of death as a case day. The exposures on the case days were compared to those on the control days, where no deaths occurred. A time-stratified approach was utilized to minimize bias from temporal trends and short-term confounders by matching control days to the same day of the week, month, and year as case days [39]. Aghababaeian et al. investigated the impact of Middle Eastern dust (MED) storms on mortality, categorizing the MED effects into three groups: Main, intensified, and severely intensified effects. To calculate these effects, a time series method was employed. The risk of death on dust storm days was compared with that on nondust storm days. A binary variable was created to identify dust storm days. Owing to overdispersion in the data, a quasi-Poisson regression model was used. Mortality counts were analyzed via a distributed lag linear model to examine the relationships between dust storms and various mortality subgroups. The models were adjusted for factors, such as trends, seasonality, and temperature [38]. Although the results of both studies indicate a relationship between dust storms and an increased risk of daily mortality in exposed communities in Dezful and Ahvaz, several important points arise. If these studies had assessed longer

and more comprehensive data, stronger evidence for planning would have emerged. For example, the primary limitation of Shahsavani et al.'s study was its reliance on only two years of data [39], whereas Aghababaeian et al.'s study faced the significant limitation of not controlling for the effects of other air pollutants due to a lack of information [38]. Moreover, Dezful and Ahvaz are cities in Khuzestan Province, and considering their unique climates and vulnerabilities, the results regarding the relationships between dust storms and health in these two cities alone may not significantly influence national policies. With respect to the effects of dust storms on increased mortality risk worldwide, review studies and meta-analyses conducted globally have confirmed the harmful effects of dust storms on mortality in exposed populations [4, 24, 42, 43]. A meta-analysis by Zhang et al. revealed a pooled random effect of a 0.27% (95% CI, 0.05%, 0.49%) increase in mortality following dust storms [50].

Other studies retrieved in this review provide further evidence of the detrimental health consequences of dust storms in the country [36, 40-43]. The evaluation of the effects of dust storms on morbidity indicates that, to date, five studies have been conducted in Iran that meet the inclusion criteria of this review, revealing a significant relationship between the occurrence of dust storms and respiratory [40, 41] and CVDs [36, 42, 43]. Several studies have confirmed the relationship between the occurrence of dust storms and increased risk of hospitalization among patients in various Iranian cities [36, 40, 43]. These include studies on the relationship between dust storms and hospitalizations for RD, such as those by Broumandi et al. [40] in Ahvaz and other cities focusing on COVID-19 [40] and Geravand et al. in Ahvaz [41]. Broomandi et al. [40] examined how dust storms affect COVID-19 infection rates in southwestern Iran. They employed cross-correlation analysis to compare aerosol optical depth (AOD) with daily increases in COVID-19 cases, adjusting for the growth patterns of the virus. To assess the impact of weather on infection risk during dusty conditions, cities were grouped via K-means clustering. For statistical evaluation, random forest analysis identified key factors—such as AOD, temperature, and humidity—that influenced the increase in COVID-19 cases [40]. Geravandi et al. explored hospital admissions for respiratory illnesses on both regular and dusty days in Iran. They utilized descriptive statistics to summarize the data, focusing on frequency, mean, and standard deviation. To evaluate differences in admissions between the two types of days, they applied the Mann–Whitney U test. Compared with normal days, this nonparametric method helps identify significant disparities in the median number of hospital visits for respiratory issues during dust events [41]. Regarding the increased risk of RD following dust storms, the results of review studies and meta-analyses conducted at the regional and global levels have confirmed the harmful effects of dust storms on the incidence of certain diseases, especially RD, in exposed populations [4, 24, 42, 43]. According to a meta-analysis by Hashizume et al. in Asia, the increased risk for RD peaked at lag 3 following dust storms (8.85%) [52]. Ebrahimi et al. conducted a linear regression study in Sanandaj and reported that dust storms significantly increased hospital admissions for cardiovascular patients [36]. Radmanesh et al. also reported through a descriptive correlational study using chi-square (χ^2) and binomial tests that the occurrence of dust storms increased the risk of CIAs in Abadan [42]. Additionally, Sadeghi-moghaddam et al. analyzed data from Dezful via Spearman correlation and adjusted for seasonality, days of the week, and time trends via Poisson regression, indicating that dust storms increased the risk of hospitalization for stroke patients [43].

Although point studies and quantitative analyses regarding the effects of dust storms on morbidity have been conducted in Iran, they may not provide robust evidence for policymakers and planners. However, three studies included in this review demonstrated a significant relationship between the occurrence of dust storms and an increased risk of hospitalization due to CVDs [36, 42, 43]. In contrast, the results of meta-analyses conducted globally have not shown a significant risk for CVDs following dust storms [42, 43]. This highlights the need for further research to clarify the precise nature of the relationship between dust storms and cardiovascular health outcomes.

The analysis of the results of this study highlights the importance of controlling confounding variables, which can significantly impact study outcomes in epidemiological research. Various reasons, such as the absence of modeling, the unavailability of data, and the choice of inappropriate analytical methods, can lead to a lack of control over these variables. Therefore, researchers should adopt advanced and acceptable new methods, including time series, case-crossover designs, panel studies, and sophisticated statistical modeling, to achieve results that closely align with reality [53]. Furthermore, recent international studies have generally utilized time series methods or case-crossover designs with modeling packages to adjust for confounding variables effectively [5, 50]. With respect to the definitions of dust storms, three studies utilized Hoffman's definition [38, 41, 42]. Broomandi et al. applied a threshold value of 100 μg/

m^3 for the PM_{10} concentration to differentiate dusty days from regular nondusty days [40]. Ebrahimi et al. based their definition on the EPA and meteorological organization announcements [36]. Sadeghimoghaddam et al. employed horizontal visibility to investigate the effects of dust on diseases [43], whereas Shahsavani et al. defined dust storms using a daily average PM_{10} concentration of 150 $\mu g/m^3$ [39].

Although evidence suggests that the most commonly used definition for dust storms in Iranian studies is based on Hoffman's classification, a unified and specific definition has not been established for studies in this field. This lack of standardization could jeopardize the consistency of future data aggregation efforts. Furthermore, Hoffman's definition does not align with those provided by reputable organizations and other studies. The literature presents various definitions of dust storms, with the WMO defining them as a reduction in horizontal visibility to less than 1,000 m due to surface winds lifting dust into the air [54]. Other studies have employed different thresholds, such as a visibility reduction to less than 1.6 km [55] or an average daily PM_{10} concentration exceeding 200 $\mu g/m^3$ [56, 57]. Additionally, some studies have set a wind speed threshold of more than 8 m/s for the occurrence of dust storms [58, 59]. To ensure better analysis and consistency across studies, a single, standardized definition of dust storms, as provided by reputable international organizations, should be adopted.

Finally, although Iran has experienced a high prevalence of dust storms in the last two decades, researchers should consider investigating the effects of dust storms on specific vulnerable populations, such as pregnant women, children, and individuals with preexisting health conditions, as well as exploring other health problems related to these conditions, like road traffic accidents, eye irritation, risk of suicide, skin problems, placental abruption, infections, allergic reactions and asthma attacks, and health-related quality of life [5, 50].

Conclusion

This study examined the impacts of dust storms on public health in Iran and revealed that these natural phenomena, particularly in vulnerable provinces, can pose serious risks to individuals' health. Despite the frequent occurrence of these storms over the past two decades, there is insufficient scientific and documented evidence to assess their health effects accurately. These findings indicate that dust storms are associated with increased mortality rates and the incidence of respiratory and CVDs. Given the lack of reliable data and appropriate research methods, to improve this situation, further research is essential in all areas exposed in the country, using standardized definitions of dust storm hazards and employing comprehensive standard methods, such as time-series studies or crossover studies. Additionally, interorganizational collaboration and investment in this area for the collection of accurate and reliable data are crucial. These actions can assist policymakers in designing more effective strategies to mitigate the harm caused by dust storms and to protect public health.

Study limitations

A meta-analysis was not conducted in this systematic review due to the limited number of similar studies available that examined the dependent variables related to dust storms and health outcomes in Iran. The variability in study designs, definitions of dust storms, and health metrics further contributed to the challenges in aggregating data for a robust meta-analysis. This lack of homogeneity among the studies highlighted the need for more comprehensive and standardized research in this area to facilitate future quantitative analyses.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the Research Council of Dezful University of Medical Sciences, Dezful, Iran (Code: IR.DUMS.REC.1401.009). The protocol was registered in the PROSPERO system (Code: CRD42021284287).

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Authors' contributions

Study design: Hamidreza Aghababaeian and Fatemeh Hemati; Data collection: Fatemeh Hemati, Fatemeh Moradi, and Hamidreza Aghababaeian; Data analysis and interpretation: Hamidreza Aghababaeian and Mostafa Hadei; Writing and final approval: All authors.

Conflict of interest

The authors declared no conflict of interest.

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Supplementary 1. Syntax

Database	Keywords
PubMed	((Sand and dust*[Title/Abstract] OR dust storm[Title/Abstract] OR sand storm[Title/Abstract] OR desert dust[Title/Abstract] OR dust event*[Title/Abstract] OR desert sand[Title/Abstract] OR Arabian sand[Title/Abstract] OR Arabian dust[Title/Abstract] OR dust episode*[Title/Abstract] OR dust outbreak*[Title/Abstract] OR Saharan desert dust [Title/Abstract] OR Asian dust[Title/Abstract] OR Asian desert dust[Title/Abstract]) AND (mortality[Title/Abstract] OR disease*[Title/Abstract] OR morbidity[Title/Abstract] OR admission*[Title/Abstract] OR health*[Title/Abstract] OR hospital*[Title/Abstract] OR dispatch*[Title/Abstract] OR emergenc*[Title/Abstract] OR death*[Title/Abstract] OR fatali*[Title/Abstract] OR "loss of life"[Title/Abstract] OR visit*[Title/Abstract] OR "family practice"[Title/Abstract] OR "patient care"[Title/Abstract] OR "emergency medical services"[Title/Abstract] OR hospitalization[Title/Abstract] OR accidents[Title/Abstract] OR ill*[Title/Abstract] OR sick*[Title/Abstract] OR disorder[Title/Abstract] OR disabl*[Title/Abstract] OR abort*[Title/Abstract] OR ambulanc*[Title/Abstract] OR symptom*[Title/Abstract] OR clinic[Title/Abstract] OR case series[Title/Abstract] OR primary care[Title/Abstract])) AND (*Iran*[Title/Abstract]) OR Persia
Scopus	TITLE-ABS-KEY ("sand and dust" OR "dust storm" OR "sand storm" OR "Desert dust" OR "dust event*" OR "desert sand" OR "Arabian sand" OR "Arabian dust" OR "dust episode*" OR "dust outbreak*" OR "Saharan desert dust" OR "Asian dust" OR "Asian desert dust") AND (TITLE-ABS-KEY (mortality OR disease* OR morbidity OR admission* OR health* OR hospital* OR dispatch* OR emergenc* OR death* OR fatali* OR "loss of life" OR visit* OR "family practice" OR "patient care" OR "emergency medical services" OR hospitalization OR accidents OR ill* OR sick* OR disorder OR disabl* OR abort* OR ambulanc* OR symptom* OR clinic OR "case series" OR "primary care") AND TITLE-ABS-KEY (*Iran* OR Persia))
Web of Science	"Sand and dust" OR "dust storm" OR "sand Storm" OR "desert dust" OR "dust event*" OR "desert sand" OR "Arabian sand" OR "Arabian dust" OR "dust episode*" OR "dust outbreak*" OR "Saharan desert dust" OR "Asian dust" OR "Asian desert dust" (Topic) AND mortality OR disease* OR morbidity OR admission* OR health* OR hospital* OR dispatch* OR emergenc* OR death* OR fatali* OR "loss of life" OR Visit* OR "family practice" OR "patient care" OR "emergency medical services" OR hospitalization OR accidents OR ill* OR sick* OR disorder OR disabl* OR abort* OR ambulanc* OR symptom* OR clinic OR "case series" OR "primary care" (Topic) AND *Iran* OR Persia (Topic)

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