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# Effects of dust events and meteorological elements on stroke morbidity in northern Khuzestan, Iran

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## Abstract:

**BACKGROUND:** In recent years, the prevalence of dust events has increased in the region and the world. According to the Meteorological Organization, the most frequent days with dust events are on stations located in Khuzestan province. Objective: Assessment of the effects of dust events and meteorological elements on stroke morbidity in health in Iran: a health promotion approach.

**MATERIALS AND METHODS:** The present study was a retrospective cohort study 2020 and 2013 provided between based on ecological data-based on population. Information about patients with stroke was obtained from the hospital. Information on the dust events and meteorological elements was also from the data center of the Meteorological Organization of Iran. Using STATA the correlation between the diseases and the, 14 statistical software version occurrence of dust events and changes in meteorological elements was obtained and the statistical model (Spearman correlation coefficient) individually estimate the equation was used inv modified by Poisson regression simultaneous effect of variables.

**RESULTS:** the results of adjusted statistical models show that increasing the severity of dust event increases the risk of stroke in males (lag 0–21 confidence interval [CI] 95% = 1.496–1.0067 relative risk [RR] = 1.03  $P = 0.01$ ). Increasing the average wind speed also increases the risk of stroke in males (lag 0–3 CI 95% = 1.0491–0.9996 RR = 1.02  $P = 0.05$ ). Increased rainfall and average relative humidity increase the risk of stroke in people under 60 years (lag 0–7 CI 95% = 1.0012–0.9058 RR = 1.95  $P = 0.05$ ). Increasing the average daily temperature reduces the risk of stroke in males (lag 0–3 CI 95% = 0.9874–0.9254 RR = 0.51  $P < 0.001$ ).

**CONCLUSION:** Increasing the intensity of dust storms along with meteorological elements has increased the risk of stroke. However, increasing the average temperature has had a protective effect on the risk of stroke.

## Keywords:

Dust, meteorological factors, stroke

## Introduction

Arid or semi-arid environments, which cover about 33% of the total land area, are the main source of dust events.<sup>[1]</sup> The main cause of these dust events has increased due to climate change.<sup>[2]</sup> According to the agreement of the World Meteorological Organization, when the wind speed in a station exceeds 15 m/s and

the horizontal visibility reaches <1000 m, a dust storm is reported. Dust storms are made up of very small particles with a diameter of 1–5 microns, which move at a much higher altitude and travel very long distances so that they are able to cover the cities of a country or even countries of the continent.<sup>[3]</sup> In recent years, the prevalence of dust events has increased regionally and globally. Due to the increase in dust events in Iran's western neighbors and

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environmental and industrial manipulations, this rate has reached 15 times more than before and causes a variety of health problems and has caused various health, economic and environmental problems in central, western, and southwestern Iran, especially in Khuzestan province.<sup>[4]</sup> Khuzestan province with a population of nearly 5 million people is one of the industrial and agricultural hubs of Iran. This city is considered to be an important city due to the existence of oil and gas reserves, petrochemical industries, and key industries, as well as, having the most water-rich rivers in the country and consequently, prosperous agriculture, dams, and major ports. According to the information extracted from the Meteorological Organization, the highest frequency of dusty days is at stations located in Khuzestan province, especially Dezful, so that the annual average of dusty days in Dezful station in the last 58 years reaches more than 100 days.<sup>[5]</sup>

The results of the research have shown that the recent dust storms, which have occurred in Asia have a significant impact on the workload in the health care system of the affected countries; so that these events increase the workload of the healthcare system, especially the nursing system, in the care of elderly patients involved in this event.<sup>[6]</sup> Dust events increase the concentration of some heavy metals such as lead up to 3 times the normal level. It also increases the concentration of toxic metals, e.g., mercury and arsenic, which have long-term adverse effects on the nervous system.<sup>[7]</sup> The effects of meteorological elements on mortality have also been extensively studied. Recently, the relationship between climate and disease complications has been studied. Stroke is a big burden in healthcare sources because patients often need care due to the physical disability caused by it. In Japan, stroke has the highest rate of nursing care. Therefore, the prevention of stroke is one of the most important issues. In addition, the harmful effects of air pollutants on health have recently been reported, and its effects on a variety of diseases have been investigated. It has been shown that both particulate matter and gaseous products increase the risk of stroke.<sup>[8]</sup> Rising dust in recent years and its irreversible effects, in addition to attention to treatment, attention to health education and health promotion, as well as attention to the inclusion of courses related to health complications in the curriculum of medical sciences. One way to reduce the incidence of dust-borne diseases is the educational interventions. Health education experts use appropriate models for health education, such as the Health Belief Model.<sup>[7]</sup>

Many studies have been done on the health effects of dust and various climatic factors. In this regard, the results of Kang *et al.* showed that exposure to Asian Dust Storm significantly increases hospitalization due to stroke.<sup>[9]</sup> Alessandrini *et al.* showed that dust events have a clear

effect on the development of cerebrovascular diseases.<sup>[10]</sup> Sherbakov *et al.* exhibited that both heat waves and temperature exposure can have independent effects on many diseases, including brain diseases.<sup>[11]</sup> Zheng *et al.* showed that a sudden drop in hot weather or an increase in the number of cold days also increases the incidence of intracranial hemorrhage (ICH) due to high blood pressure. In contrast, the incidence of subarachnoid hemorrhage (SAH) increased on the days with lower temperatures.<sup>[12]</sup> In the study of Field and Hill, it was shown that there is no significant relationship between all meteorological elements and the incidence of stroke.<sup>[13]</sup>

As noted, the effect of dust events on a variety of diseases, especially strokes, is emphasized. However, some studies do not remark the mentioned cases statistically significant. However, most studies have been conducted in capitals, metropolises, and industrial cities full of various man-made pollutants, and due to the emphasis on the synergistic effect of man-made pollutants and particles in dust storms in some studies, the results of these studies have an area of ambiguity. The harmful effects of meteorological elements on some diseases, including strokes, have been proven, although some studies do not confirm these results. Dezful is amongst the hottest and most humid cities and has the highest number and intensity of dust storms. Due to its centrality in the north of Khuzestan province, a relatively large population travels to this city for treatment. Considering the mentioned cases and the lack of industries in Dezful and consequently the absence of man-made pollutants or presence of an insignificant amount of these kinds of pollutants in the air of this city, it is possible to conduct comprehensive a study with less bias for assessing the effects of dust events and meteorological elements on health. With the help of the results of this study to predict the occurrence of dust in the future, the proper planning to reduce the effects, prepare and respond to this risk and recover afterward will be possible; thus, the present study was taken place to evaluate the effects of dust events and meteorological elements on the incidence of strokes, and it intends to determine the relationship between the individual effects of dust storms and air temperature, relative humidity, wind speed, and precipitation on different days of the year with stroke during 2013–2020 and to define the prediction model in the occurrence of strokes by changes in the amount of dust storms, relative humidity, wind speed, air temperature, and precipitation.

## Materials and Methods

### Study design and setting

Based – the present study is a retrospective cohort study based on population-based ecological data that was conducted in 2020 using the data provided in a

7-year period from 2020 to 2013 (December 19, 2020 to March 21, 2013).

### Study region

Dezful is one of the northern cities of Khuzestan province in the southwest of Iran and with an area of 4762 km<sup>2</sup> is located at an altitude of 143 m above sea level. According to the latest census in 2016, the population of Dezful is 264,709, and it is the 30<sup>th</sup> most populous city in the country and the second-most populous city in Khuzestan province.<sup>[14]</sup> The hottest and coldest months of the year are July and January, respectively. The average annual rainfall is 400 mm and the minimum temperature is -3°C in winter and the maximum is 52°C in summer.<sup>[15]</sup> Figure 1 shows the geographical location of Dezful.

### Study participants and sampling

Based on the data in the archive of the medical records unit of Dr. Ganjavian Hospital in Dezful and reviewing the records of patients referred to the hospital during the study period, all patients with ischemic and hemorrhagic strokes, whose illnesses have been diagnosed and registered based on the diagnosis of the relevant specialist physician and have been assigned the standard code I64 and I63.9 according to the criteria for the classification of medical documents, were included the study. Patients were studied in 4 groups, i.e., male, female, people under 60 years, and people over 60 years. It is necessary to explain that due to the prevalence of COVID-19 disease<sup>[16,17]</sup> from 2020/2/20 in Iran and the change in the strategy of hospitals for patient admission and non-referral to the hospital, the last month of 1398 SH (2020/2/20 to 2020/3/19) has not been calculated to prevent bias.

### Data collection tool and technique

#### *Data on dust events and meteorological elements*

Dezful city has two meteorological stations that are able to record dust events based on international standard codes

(06-07-08-09-30-31-32-33-34-35) and to measure and monitor other meteorological elements. The first station is located in Dezful airport, and the second station is in the Safiabad area. Required meteorological data including the presence and severity of dust events based on reduced horizontal visibility, maximum, minimum, average temperature, maximum, minimum, average relative humidity, precipitation (rain), maximum and average wind speed per the studied days and years were collected through the data center of the Meteorological Organization of Iran. Due to the long gap in the recording pollutants, especially PM<sub>10</sub> and PM<sub>2.5</sub>, and the lack of recording PM1, the criterion of reducing horizontal visibility we used to investigate the effect of the severity of dust on diseases.

### Statistical analysis

To determine the effect of independent variables on stroke incidence, a correlation between dust events and each meteorological element individually with stroke incidence in four groups, the Spearman correlation coefficient test was used. Then, to evaluate the simultaneous effect of independent variables using the statistical models, the effect of the studied variables on the probability of stroke was adjusted for the season, days of the week, and time trend by Poisson regression equation of multivariate. All the above operations were performed by STATA Corp LLC software version 14. In this model (Chicago USA), it was determined how much the probability of stroke changes for 1 unit of change in independent variables.

### Ethical consideration

This project has been approved by the University of Social Welfare and Rehabilitation Sciences (Ethical code: IR. USWR.REC.1399.075).

## Results

Descriptive statistics of meteorological elements and days with the dust event during the study period are

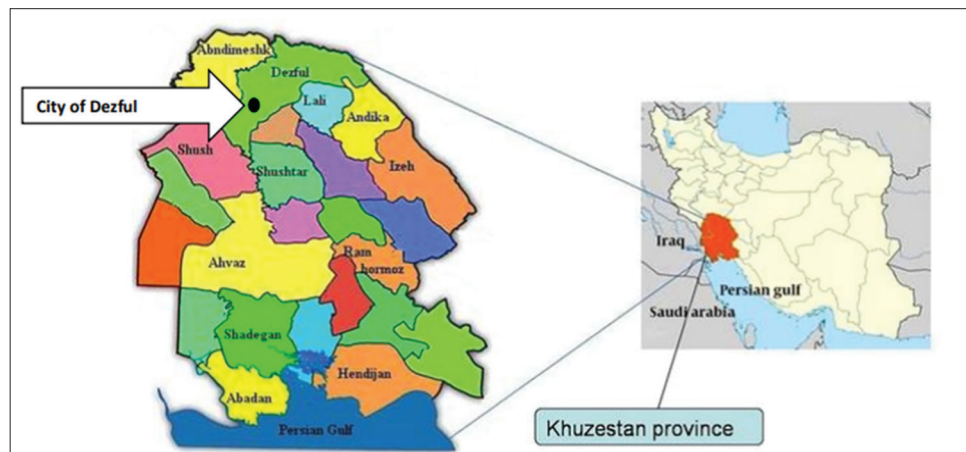


Figure 1: Location of Dezful on the map

presented in Table 1. The average horizontal visibility was 5029 m, which was significantly higher than days without dust events (more than 10,000 m). The average minimum and maximum horizontal visibility were 3907 m in 2013-2014 and 6679 m in 2018-2019. The average number of days with dust events was close to 42 days per year. The minimum and the maximum number of days with dust events were 12 days in 2019-2020 and 61 days in 2015-2016. The values of other variables during the years under study are given in Tables 1 and 2. During this period, 6512 people were referred to the hospital due to stroke, of which 3590 were men; 2435 were women; 5565 were over 60, and 947 were under 60.

Figure 2 shows the number of stroke patients by gender and age who were referred to the hospital during the study period.

Table 3 shows the correlation between the occurrence of dust events and meteorological elements with the incidence of stroke over the studied years.

According to the results of Table 3, although the incidence of stroke in all groups studied was not significantly correlated with the occurrence of dust events and meteorological elements, there was a positive and significant relationship between the incidence of stroke in people under 60 years and a maximum wind speed ( $r_s = 0.18 P \leq 0.05$ ), and a negative and significant

correlation was observed between its incidence and minimum relative humidity ( $r_s = -0.09 P \leq 0.05$ ). Incidence of stroke in people over 60 years had a positive and significant with minimum temperature ( $r_s = -0.06 P \leq 0.05$ ) and mean temperature ( $r_s = -0.05 P \leq 0.05$ ) and had a positive and significant correlation with maximum ( $r_s = 0.06 P \leq 0.05$ ) and mean wind speed ( $r_s = 0.12 P \leq 0.05$ ). However, at a significance level of 0.05, this correlation was weak.

Tables 4 and 5 show the probability of incidence and 95% confidence interval for the risk of stroke per 1 unit increase in the incidence of dust events and meteorological elements using an adjusted collective model.

As can be seen, the results in Table 4 are for males and show that for every 100 m of horizontal reduction, the risk of stroke was increased by 3% at lag 0-21 (confidence interval [CI] 95% = 1.496-1.0067 relative risk [RR] = 1.03  $P = 0.01$ ), and for 1 m/s increase in mean wind speed, the probability of stroke was approximately increased by 2% at lag 0-3 (CI 95% = 1.0491-0.9996 RR = 1.02  $P = 0.05$ ) and lag 0-7 (CI 95% = 1.0506-1.0008 RR = 1.02  $P = 0.04$ ). Also, for every 1 m/s increase in the average wind speed, the probability of stroke was reduced by 4% at lag 0-21 (CI 95% = 0.9293-0.9929 RR = 0.96  $P = 0.01$ ) and for 1% increase in mean temperature, the probability of stroke was declined by 49% at lag 3-0 (CI 95% = 0.9874-0.9254 RR = 0.51  $P = 0.00$ ), by 47% at lag 0-7 (CI 95% = 0.9854-0.9229 RR = 0.53  $P = 0.00$ ) and lag 0-14 (CI 95% = 0.9232-0.9856 RR = 0.53  $P = 0.00$ ) and by 40% at lag 0-21 (CI 95% = 0.9293-0.9929 RR = 0.60  $P = 0.01$ ). The effect of other variables was not significant at the level of 0.05.

According to the results of Table 5, which is related to people over 60 years old, it is observed that the probability of stroke at lag 0-21 increases by about 8% (CI 95% = 1.014-1.040 RR = 1.079  $P = 0.03$ ) for every 100 m decrease in horizontal visibility. In addition, the

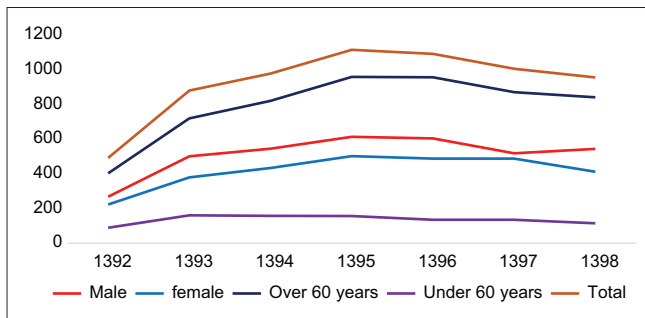


Figure 2: Changes in stroke incidence by year

Table 1: Descriptive indicators of the studied variables (mean, standard deviation, minimum, maximum, and 25<sup>th</sup>, 50<sup>th</sup>, and 75<sup>th</sup> percentiles)

Variable	Average	SD	Minimum	25 <sup>th</sup> percentiles	50 <sup>th</sup> percentiles	75 <sup>th</sup> percentiles	Maximum	Number of days
Dust event	5029	813.69	200	1257.25	2514.50	3771.75	10,000	2556
Minimum (°C)	17	7.80	-3	10.40	17.20	24	33	2556
Average (°C)	25.03	10.14	3	16.50	25.15	34.10	41	2556
Maximum (°C)	33.06	13.79	8	22.60	33.20	43.70	52	2556
Rainfall (mm)	0.81	4.18	0	0	0	0	60.10	2556
Average	2.24	1.25	0	0	0	0	11.40	2556
Maximum (m/s)	5.48	3.36	0	4	5	6	55	2556
Average (%)	51.69	21.28	5.5	33.30	49.70	69.10	99.80	2556
Maximum (%)	71.50	19.80	9	55	73	90	100	2556
Minimum (%)	29.50	19.70	1	14	24	41	98	2556

SD=Standard deviation



**Table 2: Frequency of dust storms and changes in meteorological elements by year**

Variable	Year							Total
	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020	
Dust event (average, m)	4378	3907	4741	4991	5213	5267	6679	5025
Dust event (n)	54	41	61	37	45	42	12	292
Maximum (°C)	31.97	32.84	32.87	32.73	34.30	32.71	33.78	33.03
Minimum (°C)	16.16	17.17	17.60	16.48	17.36	17.37	17.33	17.07
Average (°C)	24.06	24.98	25.27	24.63	25.84	24.98	24.94	24.95
Rainfall (mm)	383.60	156.04	316.14	131.50	216.34	602.88	368.83	2175.33
Rainfall (n) (mm)	50	49	57	42	33	60	46	337
Average (m/s)	2.07	2.08	1.86	1.85	2.99	3.06	1.86	2.25
Maximum (m/s)	4.56	4.90	4.69	4.97	6.67	7.45	5.06	5.47
Maximum (%)	72.80	70.68	71.26	70.60	68.10	74.20	71.03	71.24
Minimum (%)	31.15	27.33	30.20	27.03	25.41	34.54	28.70	29.19
Average (%)	52.89	50.22	51.99	49.50	47.85	55.64	52.93	51.57

**Table 3: The correlation between the occurrence of dust events and meteorological elements with the incidence of stroke over the studied years**

Variables	Male	Female	Over 60 years	Under 60 years	Total patients
Dust event	0.00	0.01	-0.01	0.02	-0.01
Minimum (°C)	-0.01	-0.01	-0.06*	0.02	-0.02
Maximum (°C)	0.00	0.00	-0.04	0.04	-0.02
Average (°C)	-0.01	-0.01	-0.05*	0.03	-0.02
Rainfall (mm)	-0.02	-0.01	0.01	-0.06	-0.02
Average (m/s)	0.00	0.03	0.06*	0.13	-0.09
Maximum (m/s)	0.02	0.03	0.12*	0.18*	-0.09
Average (%)	-0.01	-0.01	0.04	-0.08	0.04
Maximum (%)	0.00	0.00	0.06	-0.05	0.03
Minimum (%)	-0.01	-0.01	0.02	-0.09*	0.02

\* $P \leq 0.05$ 

probability of stroke in the mentioned lag decreased by about 7% (CI 95% = 1.0982–0.890 RR = 0.93  $P = 0.03$ ) for 1 m/s increase in the average wind speed. Moreover, for 1% increase in mean temperature, the probability of stroke was diminished by 53% at lag 0–14 (CI 95% = 1.0944–1.0034 RR = 0.47  $P = 0.03$ ) and by 51% at lag 0–21 (CI 95% = 1.0960–1.0058 RR = 0.49  $P = 0.02$ ). The effect of other variables was not significant at the level of 0.05.

The probability of stroke in females was increased by 3% (CI 95% = 0.9854–0.9229 RR = 1.03  $P = 0.03$ ) for a 1 m/s increase in the average wind speed at lag 0–3. The effect of other variables was not significant at the level of 0.05.

Which is related to people under 60 years old, it can be seen that for a 1 mm increase in rainfall at lag 0–7, the risk of stroke has increased by 5% (CI 95% = 1.0893–1.0153 RR = 1.05  $P = 0.05$ ), and for 1% increase in the average relative humidity in the mentioned lag, the probability of stroke increased by 95% (CI 95% = 1.0012–0.9058 RR = 1.95  $P = 0.05$ ). The effect of other variables was not significant at the level of 0.05.

## Discussion

Analysis of the results of this study showed that although in all groups of patients with stroke, there was no significant correlation with any of the independent variables, in people under 60 and over 60 years, increasing temperature and relative humidity variables reduced the incidence of stroke, and increasing wind speed has increased the incidence of stroke.

In this regard, Chan *et al.*, in their study, showed that during the occurrence of severe Asian dust, the rate of emergency hospitalization due to ischemic heart disease patients increased by 35%, while the hospitalization due to cerebrovascular accidents (stroke) and chronic obstructive pulmonary disease increased by 20%.<sup>[18]</sup> The present study also emphasizes the direct impact of dust storms on the risk of stroke.

In the study of Zheng *et al.*, there was a correlation between daily temperature and hemorrhagic strokes (HSs), while this correlation was positive for ICH and negative for SAH.<sup>[12]</sup> However, in the present study, a negative correlation was reported for the effect of temperature on the sum of both types of strokes.

In the study of Bull, the negative correlation between the minimum and maximum temperature and death due to stroke, heart and respiratory diseases in men, women, people over 55 years, and people under 55 years has been emphasized,<sup>[19]</sup> which is in line with the results of the present study about the risk of these diseases.

According to the adjusted statistical models, the research findings show that increasing the intensity of dust events along with other meteorological elements in different time lags has a significant relationship with the probability of stroke; so that increasing the intensity of dust events has a direct effect on the probability of stroke in men and people over 60 years of age. The

**Table 4: Results of the relationship between dust events, relative humidity, wind speed, rainfall, and temperature on the risk of stroke in males (adjusted for season, days of the week, and time trend)**

Variables	Lag	df	Relative risk	95% CI	P
Dust event (horizontal view)	0-3	5.04	1.0211	1.0497-0.9932	0.13
	0-7	6.35	0.9653	1.0544-0.9974	0.13
	0-14	5.91	1.0277	1.0567-0.9995	0.19
	0-21	4.86	1.0301**	1.496-1.0067	0.01*
Wind speed (average)	0-3	7.94	1.0241**	1.0491-0.9996	0.05*
	0-7	4.04	1.0254**	1.0506-1.0008	0.04*
	0-14	7.41	1.0315	1.0550-1.0057	0.15
	0-21	6.15	0.9606***	0.9293-0.9929	0.01*
Rainfall	0-3	3.04	1.04	1.02-1.004	0.16
	0-7	6.51	1.03	1.91-1.016	0.37
	0-14	5.44	1.03	1.065-1.042	0.18
	0-21	3.71	1.01	1.042-0.99	0.16
Relative humidity (average)	0-3	2.61	0.9559	0.9874-0.9254	0.60
	0-7	3.65	0.9537	0.9854-0.9229	0.30
	0-14	4.21	0.9533	0.9232-0.9856	0.40
	0-21	6.15	0.9606	0.9293-0.9929	0.17
Temperature (average)	0-3	0.006	0.51***	0.9874-0.9254	<0.001*
	0-7	0.003	0.53***	0.9854-0.9229	<0.001*
	0-14	0.004	0.53***	0.9232-0.9856	<0.001*
	0-21	0.017	0.60***	0.9293-0.9929	0.01*

\* $P \leq 0.05$ , \*\*Direct effect, \*\*\*Reverse effect. CI=Confidence interval, df=Degree of freedom

**Table 5: Results of the relationship between dust events, relative humidity, wind speed, rainfall, and temperature on the risk of stroke in people over 60 years (adjusted for season, days of the week, and time trend)**

Variables	Lag	df	Relative risk	95% CI	P
Dust event (horizontal view)	0-3	6.02	1.01	1.035-0.978	0.82
	0-7	3.79	0.982	1.080-0.932	0.64
	0-14	1.00	0.977	1.020-0.905	0.55
	0-21	5.41	1.079**	1.014-1.040	0.03*
Wind speed (average)	0-3	3.24	0.969	1.047-0.867	0.28
	0-7	4.71	0.956	1.068-0.841	0.28
	0-14	3.42	1.002	1.119-0.908	0.91
	0-21	8.25	0.936***	1.0982-0.890	0.03*
Rainfall	0-3	5.19	1.043	1.041-0.983	0.25
	0-7	5.02	0.974	1.079-0.977	0.86
	0-14	5.03	0.979	1.086-0.982	0.89
	0-21	2.75	1.0005	1.011-0.904	0.97
Relative humidity (average)	0-3	6.71	0.9985	1.1251-0.8862	0.98
	0-7	2.46	1.0038	1.1325-0.8897	0.95
	0-14	1.00	1.0247	1.1548-0.9093	0.68
	0-21	6.47	1.0284	1.1593-0.9122	0.64
Temperature (average)	0-3	8.61	1.0371	1.0858-0.9906	0.11
	0-7	6.19	1.0334	0.9861-1.029	0.16
	0-14	1.00	0.4790***	1.0944-1.0034	0.03*
	0-21	7.07	0.4980***	1.0960-1.0058	0.02*

\* $P \leq 0.05$ , \*\*Direct effect, \*\*\*Reverse effect. CI=Confidence interval, df=Degree of freedom

greatest adverse effect, both in severity and duration, was related to the increase in mean temperature, which

significantly reduced the risk of stroke, especially in men and people over 60 years of age. In other words, increasing the average temperature has a protective effect on the incidence of stroke, and this effect is slightly weakened by prolonging the time lag. The most severe direct effect was related to relative humidity, which significantly increased the risk of stroke in people under 60 years of age. The direct effect of the average wind speed on the probability of stroke with the prolongation of the time lag was reversed. In other words, the increasing effect of this variable on the probability of stroke has decreased and has become a protective effect. The least effect of independent variables on the probability of stroke was observed among females.

In line with the results of the present study, Gerivani *et al.*, using geographic information system geographic model technology, showed that meteorological factors such as temperature, precipitation, and relative humidity play an important role in causing dust events.<sup>[4]</sup> In the present study, the study and analysis of meteorological elements along with the dust events have been done in this regard.

Kashima *et al.* stated in a study that desert dust appears to be potentially toxic, and this toxicity can vary with long-range transportation. The combined effects of all causes and the leading cause of death from Asian dust events were assessed in five populous cities of South Korea (Seoul) and Japan (Nagasaki, Matsu, Osaka, and Tokyo). Then, the specific relationships between dusty days in each city, with daily mortality for the elderly over 65 years of age were evaluated by time-series analysis method. The results of this study showed that negative health effects and increased mortality due to cardiovascular diseases were seen in Korea and Japan.<sup>[20]</sup> In the present study, people over 60 years of age were studied, and the greatest effect of independent variables, either individually or as an effect on the probability of stroke, has also been reported in this group.

In the study of Barnett *et al.*, the levels of PM10 and PM2.5 were observed to be 894 and 138  $\mu\text{g}/\text{m}^3$ , respectively, which were due to the dust storm. This situation remained for 10 days and reached its highest level on September 26 due to the secondary storm. The horizontal visibility during the day in this storm reached 5 km. Due to the increase in wind speed, the humidity in the atmosphere dropped sharply. The results showed a 39% increase in the admission of patients in the emergency department on days with dust events, but the particle diameter did not play a role in this increase in admission.<sup>[21]</sup> In the present study, the horizontal visibility scale was used to show the intensity of dust events, and the average horizontal visibility during the

research period was slightly more than 5000 m. Also, the relative humidity drop during the dust event and the lack of effect of the diameter of the particles in the dust have been mentioned.

Lee *et al.* examined the effect of dust storms on asthma and stroke by considering meteorological elements such as daily average temperature and relative humidity in seven South Korean metropolises. The results showed that the risk of asthma on dust storm day was 7%, and in lags 1–3 days, it increased by 6%, 5%, and 1%, respectively. The risk of stroke was estimated to be 2% on the day of the dust storm while it was 4% and 3% on the 3 and 4 day lags, respectively.<sup>[22]</sup> However, in the present study, the increased risk of stroke due to the dust events in men and people over 60 years of age in the 0–21 day lag was reported to be significant.

Han *et al.* investigated the simultaneous effects of air pollutants and meteorological elements such as mean temperature, relative humidity, and atmospheric pressure on the incidence of HSs over 11 years in the Sung Dong region of South Korea. The results of this study showed that the mean temperature in older people is negatively associated with HS and ICH. There was no significant relationship between mean temperature and SAH. Relative humidity showed a negative correlation with ICH in the older age group.<sup>[23]</sup> The present study confirms the inverse effect of increasing mean temperature on the risk of stroke in older people. Although the effect of mean relative humidity on the risk of stroke in older people was not significant, there was a direct relationship in people under 60 years, which was inconsistent with the results of this study. It seems that this disagreement is related to the geographical location and weather conditions of the studied city and the consideration of longer lags in the present study.

In the study conducted by Field and Hill, the effect of meteorological elements such as temperature, relative humidity, wind speed, and precipitation on the incidence of stroke was investigated. The results showed that there is no significant relationship between all meteorological elements and the incidence of stroke ( $P > 0.05$ ).<sup>[13]</sup> The results of our study contradict this study. Considering that in most studies, the effects of meteorological elements on the probability of stroke occur with a time lag, it seems that not considering time lag in this study leads to inconsistencies in the results of the mentioned study and our study.

In the study of Çevik *et al.*, various climatic variables such as temperature, relative humidity, wind speed, and atmospheric pressure were studied on the incidence of strokes over a period of 1 year. The results showed that although there was no statistically significant relationship

between climatic variables and total hospitalization of stroke patients in the hospital. Hospitalization due to SAH was higher on days with low temperatures compared to the days with higher temperatures. Multivariate analysis showed that admission due to SAH increased on days with decreasing average daily temperature compared to similar days on the same day. The relative increase in the risk of HS due to wind speed in the 1-day lag shows a 63% increase while it reveals an increase of 43% in the 3-day lag.<sup>[24]</sup> The results of the mentioned study are in line with the present study, although in the present study, the effect of wind speed on the risk of stroke is weaker and has become a protective effect with prolongation of the time lag. As can be seen, in the present study, in order to ensure the effects of meteorological elements on the probability of stroke and to examine the trend of these complications, a longer time lag has been considered.

In another study, Matsumoto *et al.* evaluated the cumulative effects of meteorological elements on the incidence of strokes in several Japanese cities over 11 years and showed that the incidence of stroke increased by 46% for 1000 mm of annual rainfall, and a 1% increase in mean minimum temperature reduced the risk of stroke by 21%, and for a 10-day increase on cold days, the risk of stroke in men was increased by 7%.<sup>[25]</sup> The results of this study are in line with the present study, although the effect of rainfall on the risk of stroke was only proven in people over 60 years of age. This difference in the results of the mentioned study with the present study can be due to its higher annual rainfall, compared to Dezful.

Salam *et al.* have studied the effects of climatic variables on the incidence of stroke for 4 years, and their results showed that the incidence of ischemic strokes (IS) in both hot and cold seasons of the year was not statistically significant. It was also found that a 1% increase in average temperature increases the risk of IS by 2.3% and for a 1% increase in relative humidity, the risk of IS and ICH is reduced by 2.4%.<sup>[26]</sup> The results of this study contradict the results of the present study, although both types of hemorrhagic and ischemic stroke were studied together in one group. As can be seen, in the present study, in order to ensure the effects of meteorological elements on the probability of stroke and to examine the trend of these complications, a longer time lag has been considered.

### Limitations of the study

Due to the limited data on diseases in these 7 years, we were not able to study for a longer time. On the other hand, due to inaccuracy in recording ambient air pollution, nonrecording of PM1, and a long gap in recording pollutants, especially in the case of PM2.5 and

PM10, thus, we used the horizontal visibility criteria to investigate the effect of dust storms on the incidence of diseases.

## Conclusion

Although there was no significant correlation with any of the independent variables in stroke patients, there was a weak correlation with temperature, wind speed, and relative humidity in individuals under 60 years and over 60 years. According to the adjusted statistical models, increasing the severity of dust events along with other meteorological elements often increases the risk of stroke, especially in males and people over 60 years. However, the effect of temperature on the risk of stroke was protective. Females are less affected by dust events and meteorological elements in terms of the risk of stroke. According to the research results, by informing and educating the public through various media and in particular, the definition of courses in the curriculum of medical sciences, proper measures can be considered to prevent stroke and promote community health.

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## Conflicts of interest

There are no conflicts of interest.

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