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Original Paper

Relationship of Humidity and Atmospheric Pressure With the Risk of Out-of-hospital Cardiac Arrest

Yasaman Borghei[1], Mohammad Taghi Moghadamnia[2*], Abdolhossein Emami Sigaroudi[3], Ehsan Kazemnezhad Leili[4]

1. Nursing (MSN), School of Nursing and Midwifery, Guilan University of Medical Sciences, Rasht, Iran.
2. Assistant Professor, Department of Nursing (Medical- Surgical), School of Nursing and Midwifery, Guilan University of Medical Sciences, Rasht, Iran.
3. Associate Professor (Community Health Nursing), Department of Nursing, School of Nursing and Midwifery, Guilan University of Medical Sciences, Rasht, Iran.
4. Associate Professor, Biostatistics, Social Determinants of Health Research Center (SDHRC), Guilan University of Medical Sciences, Rasht, Iran.

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ABSTRACT

Introduction: Climate change, which affects human health, is one of the most important public health concerns. Few studies have examined the effects of humidity and atmospheric pressure as risk factors on the cardiac system and Out-of-hospital Cardiac Arrest.

Objective: This study aimed to determine the relationship between climatic variables (humidity and atmospheric pressure) with Out-of-hospital Cardiac Arrest , and its outcome over 3 years (2016-2018).

Materials and Methods: This is an ecological time-series study. Participants were 392 patients with Out-of-hospital Cardiac Arrest referred to a governmental Hospital in Rasht City, Iran from 2016 to 2018. Meteorological data and information related to Out-of-hospital Cardiac Arrest and its consequences were collected from reliable resources and were analyzed in R software.

Results: Low humidity increased the relative risk of Out-of-hospital Cardiac Arrest (OR=1.54, 95%CI: 1.001-2.69, P=0.001) and failed cardiopulmonary resuscitation (OR=1.76, 95% CI; 1.006-3.79, P=0.001). Higher atmospheric pressure was associated with increased risk of Out-of-hospital Cardiac Arrest (OR=1.16, 95%CI; 1.001-1.78, P=0.001) and unsuccessful cardiopulmonary resuscitation (OR=1.039, 95% CI; 1.005-1.91, P=0.001).

Conclusion: Decreased humidity and increased atmospheric pressure are associated with an increased number of Out-of-hospital Cardiac Arrest cases and failure of cardiopulmonary resuscitation. Informing people with cardiovascular disease to avoid such weather conditions, as well as preparing the medical care team and designing early warning systems, can reduce the adverse effects of climate change on the heart.

Keywords:
Out-of-hospital Cardiac Arrest, Climatic variables, Climate change, Mortality

*** Corresponding Author:**
Mohammad Taghi Moghadamnia, PhD.
Address: *Department of Nursing (Medical- Surgical), School of Nursing and Midwifery, Guilan University of Medical Sciences, Rasht, Iran.*
Tel: *+98 (911) 3312939*
E-mail: *moghaddamnia92@gmail.com*

Highlights

- Cardiovascular disease is the most common cause of death worldwide.
- The occurrence of cardiac arrest caused by heart failure is important both inside and outside the hospital.
- There is a complex association between climate change and human health consequences.
- Atmospheric pressure and humidity affect the rate of Out-of-hospital Cardiac Arrest and its consequences, such that high atmospheric pressure and low humidity increase its prevalence and unsuccessful resuscitation.

Plain Language Summary

Cardiovascular disease is the most common cause of death worldwide. Climate change is one of the most important public health concerns. There is a complex association between climate change and human health. This study aimed to determine the relationship between climatic variables (humidity and atmospheric pressure) with Out-of-hospital Cardiac Arrest and its outcomes over 3 years in Rasht City, Iran. Low humidity is associated with increased admission and failed resuscitation in the patients. At higher humidity and longer delays, the admission rate of these patients significantly reduced. Higher atmospheric pressure increased Out-of-hospital Cardiac Arrest cases and the rate of unsuccessful resuscitation in these patients. Low atmospheric pressure increased the prevalence of outpatient cardiac arrest in women and people aged over 65 in the initial days of exposure to this pressure, while in men and people under 65, high atmospheric pressure increased the disease rate. Since low humidity increased the incidence of Out-of-hospital Cardiac Arrest and unsuccessful resuscitation in patients, it is recommended that people with this disease avoid such weather conditions.

Introduction

Cardiovascular diseases are the most common cause of death worldwide [1-3]. In Iran, the mortality rate due to cardiovascular diseases is 43% of the total deaths [4]. Out-of-hospital Cardiac Arrest occurs when a person's heart suddenly stops pumping blood because of non-cardiac reasons at home, in public locations, ambulance, the emergency room, and at any location before hospital admission [5]. Acute coronary syndrome is an important risk factor for Out-of-hospital Cardiac Arrest [6-8]. The global prevalence of Out-of-hospital Cardiac Arrest is high and its mean survival rate is low (9.1%). The most important underlying cause of Out-of-hospital Cardiac Arrest which accounts for almost 70% of its occurrence is acute coronary syndrome [5].

Out-of-hospital Cardiac Arrest is associated with some of the patient's characteristics, including age, gender, weight, medical and family history, smoking and pre-arrest activity, underlying diseases (e.g., diabetes mellitus, cardiovascular disease, hypertension), socio-economic status, race, and received emergency services [9, 10]. Environmental factors and climatic conditions can also be associated with the occurrence of heart disease but are not well known yet [11].

There is a complicated relationship between climate and human health consequences and it has been shown that different meteorological parameters conflict with each other at the same time [12, 13]. There is evidence of increasing global climate change and extreme weather events such as cold and heatwaves, and it is one of the most serious challenges worldwide [14-16]. According to the results of the Intergovernmental Panel on Climate Change in 2018, climatic conditions have become more variable compared to the past, creating phenomena such as large and long heatwaves, unpredictable climate changes, sudden cold spells, and extreme weather events such as floods and droughts [17]. According to the results of a study, 0.2% of annual mortality in the world is directly related to climate change [18].

Meteorological parameters and seasonal changes play a key role in the development of acute coronary syndrome. Studies have shown that weather conditions, air temperature, humidity, wind speed, and pressure affect the onset of acute coronary syndrome [19-21]. Although the survival rate after Out-of-hospital Cardiac Arrest has increased in recent years compared to the past, the chance of cardiopulmonary resuscitation (CPR) success is still low [10]. The results of a study showed that acute coronary syndrome occurs more often in summer when temperature and humidity levels are high and atmospheric pressure is low [22].

Humidity makes a person feel colder during the winter and feel warmer during the summer [23, 24]. Low relative humidity increases the viscosity of human blood which can be a risk factor for ischemic stroke [25]. In some cases, daily mortality with a focus on temperature has been reported as an independent predictor of humidity. A study examined the role of humidity in associations of high temperatures with mortality in several countries. Increased mortality at high humidity in cold temperatures was reported in 11 Chinese cities, but the association was lower at hot temperatures and high humidity. Moreover, a daily evaluation in the summer in three Swedish cities showed the detrimental effect of high humidity, especially at high temperatures in Stockholm, while there was an inverse relationship between humidity and mortality in summer in Valencia, Spain [26]. Abrignani et al. showed that humidity affects the number of hospital admissions in patients with acute myocardial infarction [27].

Lower relative humidity increases temperature-dependent cardiovascular mortality, with a 3.97% increase in cardiovascular mortality observed in the 5th and 25th percentiles of relative humidity [28]. Changes in atmospheric pressure may also affect and rupture atherosclerotic plaques [29]. Moreover, lowering atmospheric pressure can increase blood pressure by affecting the sympathetic nervous system and immune system, so atmospheric pressure is the main factor in climate change [30]. The findings of a study confirmed that in areas with high atmospheric pressure, the incidence of myocardial infarction was 7% higher than in areas with low atmospheric pressure [31]. An increase in atmospheric pressure along with a decrease in air temperature can increase hypoxia followed by vascular spasm [32].

The results of Plavcova et al. showed that the drop in atmospheric pressure in winter was significantly associated with an increase in the prevalence of cardiovascular diseases [33], while Houck showed no association between atmospheric pressure and the daily occurrence of acute myocardial infarction on the same day. However, one day after the change in atmospheric pressure, an increase in the incidence of acute myocardial infarction was reported. The rate of change in atmospheric pressure during autumn and winter is significantly associated with the daily occurrence of acute myocardial infarction [34].

Because of the high prevalence of cardiovascular diseases, nurses working in any place, including home, office, hospital, long-term care centers, or rehabilitation centers should be able to assess the cardiovascular system [35]. Preventing Out-of-hospital Cardiac Arrest requires a public health challenge [5], and it has turned into a major public health problem in the world [7]. A preventive measure is needed to reduce its mortality rate [12]. This preventive solution can be designed based on changes in meteorological parameters. This study aimed to determine the relationship between meteorological parameters (humidity and atmospheric pressure) with the prevalence of Out-of-hospital Cardiac Arrest and its outcome in a 3-year period (2016-2018).

Materials and Methods

This is an ecological time-series study. The study population consisted of patients with Out-of-hospital Cardiac Arrest referred to a governmental Hospital in Rasht City, Iran from 2016 to 2018 (n=463). Of them, 392 patients who met the inclusion criteria (those with the cardiac arrest diagnosed by the emergency medical staff or family, and had undergone CPR) were entered into the study. Those who lacked CPR a long time since cardiac arrest (according to the emergency physician) were excluded from the study. Information regarding the admission of patients was obtained from the only specialized cardiovascular hospital in Rasht, according to the CPR report card.

This card contained the patient's information, including first and last name, age, diagnosis, case number, treating physician, date and time of admission to the hospital, patient's heart rhythm, and outcome of CPR. For each patient who underwent CPR, this form was completed and available in the hospital's emergency department. Data related to meteorological variables, including maximum and minimum atmospheric pressure, average atmospheric pressure (in hPa), minimum and maximum humidity, and average daily humidity received from the Guilan Meteorological Organization in an Excel file. Since only one specific hospital form was used to collect data related to each CPR procedure and also meteorological data were used for meteorological parameters, there was no need for instrument validity and reliability. The nature of time-series studies conducted over a long period can control confounding variables in the study [36].

Accordingly, the 3-year study period of the present study controlled the factors affecting Out-of-hospital Cardiac Arrest . To estimate the effect of meteorological parameters, by considering nonlinear effects between these variables and also the delay effects of climate change, we used the package of Distributed Lag Non-Linear Models (DLNM) ver. 2.3.8 in R ver.3.5 software. Using this software, the relative chance of occurrence and consequence of Out-of-hospital Cardiac Arrest can be calculated for meteorological parameters such as humidity and atmospheric pressure. Since the effects of climate change may be delayed or interrupted according to previous studies, the 21st lag day was considered as the maximum delay time in this study. Most studies related to climate hazards and health that had evaluated the delayed effects of temperature changes on morbidity and mortality used the lag ranged 0-21 days after climate change [20].

Results

Out of 392 participants, 62.7% were male and 37.3% were female with Mean±SD age of 64.78±15.58 years. During the 3-year study period, the average atmospheric pressure was 1013.4 hPa ranged from 993.2 to 1041 hPa, and the average humidity was 81% ranged from 11% to 100% (Table 1). Maximum humidity was observed in October 2016 and minimum humidity in January 2018; there were 19 unsuccessful CPR and 7 admissions due to Out-of-hospital Cardiac Arrest in October 2016, and 13 unsuccessful CPR and 12 admissions in January 2018. Maximum atmospheric pressure was observed in October 2016 and minimum atmospheric pressure in June 2018; there were 7 failed CPR and 11 admissions in October 2016, and 6 failed CPR and 6 admissions in June 2016.

The results showed a non-linear relationship between the humidity and admission rate of Out-of-hospital Cardiac Arrest patients (Figures 1 & 2). Low humidity was associated with an increase in the admission rate of Out-of-hospital Cardiac Arrest patients in lag days 0 to 10 (OR=1.54, 95%CI; 1.001-2.69, P=0.001). Also, 66% humidity in the lag day 0 had a protective effect on the admission rate (OR=0.35, 95% CI; 0.16-0.84, P=0.001); i.e. at this percentage, the lowest number of Out-of-hospital Cardiac Arrest cases occurred (Table 2). Moreover, lower humidity in the lag days 0 to 10 increased unsuccessful CPR in patients (OR=1.76, 95% CI; 1.006-3.79, P=0.001). At high humidity and longer delayed times, the rate of admission was significantly reduced. For example, at 95% level in the 21st lag day, humidity had a protective effect on the Out-of-hospital Cardiac Arrest occurrence (OR=0.51, 95% CI; 0.26-0.98, P=0.001).

The results showed a non-linear relationship between atmospheric pressure and the rate of admission in patients with Out-of-hospital Cardiac Arrest (Figures 3 & 4). Higher atmospheric pressure in the initial lag days (OR=1.16, 95% CI; 1.001-1.78, P=0.001) was associated with increased risk of Out-of-hospital Cardiac Arrest (Table 3), while in the lag days 4-20, it was associated with increased risk of failed CPR (OR=1.039, 95% CI; 1.005-1.91, P=0.001). On the other hand, lower atmospheric pressure showed reducing effects on the incidence of Out-of-hospital Cardiac Arrest . For example, the atmospheric pressure of 1015 hPa on the lag day 0 (same day as atmospheric pressure dropped) had a protective effect on the occurrence of Out-of-hospital Cardiac Arrest (OR=0.71, 95% CI; 0.53-0.96, P=0.001). Such a reducing effect was also observed on the CPR outcome at atmospheric pressure of 1004 hPa in the fifth lag day (OR=0.73, 95% CI: 0.55-0.96, P=0.001) indicating an increase in successful CPR.

High atmospheric pressure on lag days 4-20 was associated with an increase in unsuccessful CPR in Out-of-hospital Cardiac Arrest patients. In women and age group of above 65 years, low atmospheric pressure in the initial lag days was associated with increased Out-of-hospital Car-

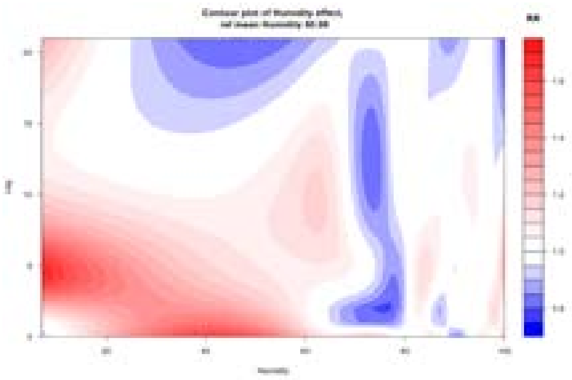

Figure 1. Comparing the effect of humidity in different months on hospital admission and total death number of patients with Out-of-hospital Cardiac Arrest

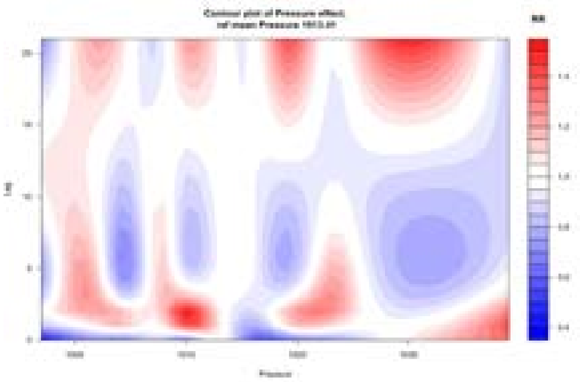

Figure 2. Relative risk of hospital admission in Out-of-hospital Cardiac Arrest patients based on humidity and lag days

Table 1. Descriptive statistics of meteorological parameters during 2016-2018

Meteorological Parameters	Min.	Max.	Mean±SD
Average atmospheric pressure	996.1	1039.6	1013.4±7.4
Minimum atmospheric pressure	993.2	1038.0	1011.8±8.1
Maximum atmospheric pressure	998.0	1041.0	1015.8±7.5
Average tempreature	-0.5	31.0	17.2±7.7
Minimum tempreature	-9.2	27.1	12.6±7.4
Maximum tempreature	1.3	38.7	21.8±8.7
Average humidity	7.0	100.0	81.0±13.6
Minimum humidity	11.0	100.0	66.9±20.2
Maximum humidity	24.0	100.0	95.7±7.7

Table 2. Correlative relative risk of the effect of low humidity on the hospital admission of Out-of-hospital Cardiac Arrest patients in the lag days 0-5 during the 3-year study period

Lag Days* / Humidity (%)	0	1	2	3	4	5
7	0.913 (0.183-4.552)	0.99 (0.435-2.251)	1.223 (0.52-2.879)	1.524 (0.767-3.028)	1.693 (0.824-3.476)	1.703 (0.817-3.552)
8	0.936 (0.199-4.403	1.008 (0.457-2.226)	1.232 (0.54-2.809)	1.674 (0.837-3.345)	1.674 (0.837-3.345)	1.68 (0.828-3.408)
9	0.96 (0.216-4.262)	1.027 (0.479-2.20)	1.24 (0.561-2.742)	1.655 (0.85-3.221)	1.655 (0.85-3.221)	1.658 (0.84-3.271)
10	0.985 (0.235-4.128)	1.046 (0.502-2.179)	1.248 (0.582-2.679)	1.636 (0.863-3.103)	1.636 (0.863-3.103)	1.613 (0.862-3.019)
11	1.01 (0.255-4)	1.065 (0.526-2.158)	1.256 (0.603-2.619)	1.618 (0.875-2.991)	1.618 (0.875-2.991)	1.592 (0.872-2.904)
12	1.035 (0.276-3.88)	1.085 (0.55-2.138)	1.255 (0.624-2.561)	1.599 (0.886-2.991)	1.599 (0.886-2.866)	1.57 (0.882-2.795)
13	1.061 (0.299-3.767)	1.104 (0.575-2.121)	1.273 (0.646-2.508)	1.581 (0.898-2.786)	1.581 (0.898-2.876)	1.549 (1.001-2.693)

* Relative risk (lower limit-upper limit)

diac Arrest cases, but in men and age group of under 65 years, high atmospheric pressure was related to increased Out-of-hospital Cardiac Arrest prevalence. Unsuccessful CPR at low atmospheric pressure was observed in women on lag days 10 to 15, and in the age group of > 65 years, it was reported in the initial lag days. In men and age group of above 65 years, high atmospheric pressure in the early lag days was associated with under failure of CPR. In all age and gender groups, low humidity was associated with increased failure of CPR and increased admission rate.

Table 3. Cumulative relative risk of the effect of high atmospheric pressure on the hospital admission of Out-of-hospital Cardiac Arrest patients in the lag days 0-5

Lag Days* / Pressure (hPa)	0	1	2	3	4	5
1030	1.062 (0.587-1.922)	0.99 (0.669-1.467)	0.909 (0.6-1.377)	0.839 (0.625-1.127)	0.797 (0.59-1.077)	0.776 (0.57-1.057)
1031	1.103 (0.59-2.06)	1.011 (0.676-1.512)	0.914 (0.593-1.45)	0.834 (0.618-1.126)	0.787 (0.58-1.066)	0.764 (0.559-1.046)
1032	1.14 (0.588-2.212)	1.039 (0.692-1.56)	0.929 (0.596-1.45)	0.841 (0.623-1.133)	0.787 (0.583-1.063)	9.763 (0.558-1.042)
1033	1.175 (0.575-2.4)	1.074 (0.714-1.617)	0.956 (0.604-1.512)	0.856 (0.637-1.149)	0.797 (0.593-1.071)	0.769 (0.564-1.05)
1034	1.207 (0.55-2.648)	1.117 (0.738-1.689)	0.992 (0.615-1.6)	0.881 (0.658-1.179)	0.816 (0.608-1.093)	0.784 (0.572-1.074)
1035	1.237 (0.513-2.98)	1.166 (1.001-1.787)	1.038 (0.625-1.722)	0.915 (0.683-1.2221)	0.842 (0.623-1.136)	0.805 (0.579-1.12)

* Relative risk (lower limit-upper limit)

Discussion

The findings of this study showed that, in all patients, low humidity had an association with increased risk of Out-of-hospital Cardiac Arrest on lag days of 0-10. Our findings are in line with the findings of Hensel et al., who showed that the risk of Out-of-hospital Cardiac Arrest increased at a humidity level below 75% compared with levels above this percentage [11], but are against the results of Tobaldini et al. who reported that high humidity along with high temperature increased the prevalence of Out-of-hospital Cardiac Arrest , which could be very stressful for the cardiovascular system [8]. Because of low humidity increases blood viscosity and Guilan Province and Rasht City experience high humidity on most days, the physiological system of people living in this city may be less adapted to low humidity; therefore, it can increase the risk of Out-of-hospital Cardiac Arrest in this climate.

Lower humidity on lag days 0-10 also increased the unsuccessful CPR in all Out-of-hospital Cardiac Arrest patients, i.e. high humidity increases the success of CPR and reduces the risk of Out-of-hospital Cardiac Arrest . Our findings are consistent with Armstrong's findings

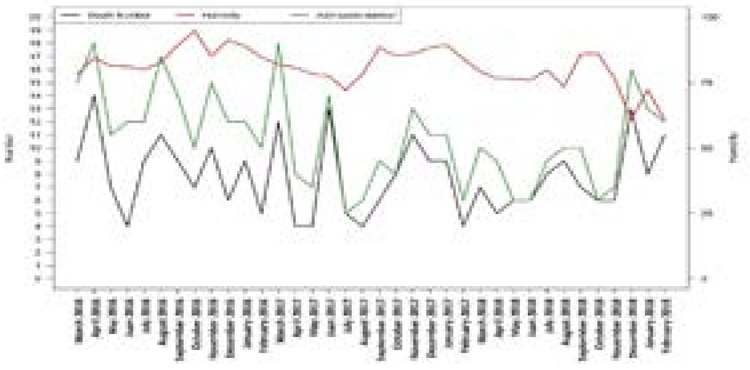

Figure 3. Relative risk of hospital admission in Out-of-hospital Cardiac Arrest patients based on atmospheric pressure and lag days

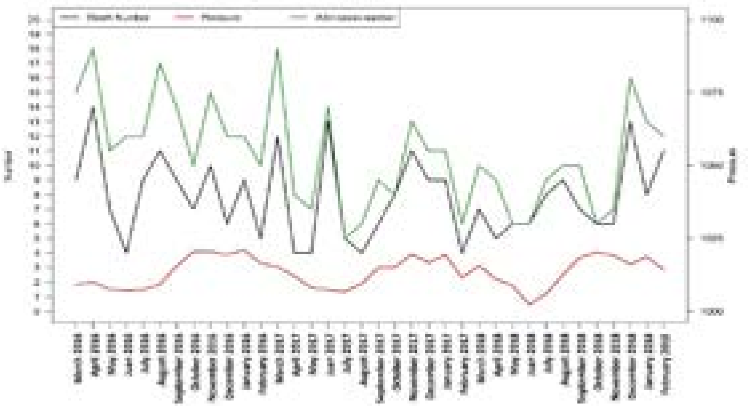

Figure 4. Comparing the effect of atmospheric pressure in different months on hospital admission and total death number of patients with Out-of-hospital Cardiac Arrest

showed that a 23% increase in humidity was associated with a 1.1% decrease in mortality [26]. However, the findings of another study showed that a 10% increase in relative humidity was significantly associated with an increased incidence of Out-of-hospital Cardiac Arrest [30]. The difference in the duration of the study and also the individual and social differences of participants can be the reasons for this discrepancy.

Higher atmospheric pressure in the initial lag days increased hospital admission in Out-of-hospital Cardiac Arrest patients. A study has shown that low atmospheric pressure increases blood pressure through the sympathetic nervous system and the immune system. Therefore, atmospheric pressure is an important factor in climate change [30]. The findings of Ratajczak et al. study, conducted in a mild climate in Poland, show that among meteorological variables, only changes in atmospheric pressure have a potential effect on Out-of-hospital Cardiac Arrest occurrence [37]. Our findings are consistent with those of Hensel et al., who showed the possibility of reduced risk of Out-of-hospital Cardiac Arrest in moderate atmospheric pressure (1000 -1020 hPa), while the possibility of an increased risk in atmospheric pressure above 1020 hPa and below 1000 hPa [11].

High atmospheric pressure on lag days 4-20 increased the risk of unsuccessful CPR in Out-of-hospital Cardiac Arrest patients. According to Ou et al., increased mortality has been observed at extremely high atmospheric pressures (>1020 hPa) [28]. Low atmospheric pressure on lag day 5th had a protective effect on the outcome of CPR and increased the chance of its success. This finding is against Ou's findings, which showed that low atmospheric pressure increases mortality due to cardiovascular disease [28]. Different climatic conditions of Rasht City, its proximity to the sea, and increased pressure can be the reasons for this discrepancy. In all age and gender groups, low humidity in the initial lag days increased the number of Out-of-hospital Cardiac Arrest cases. Ou et al. reported that the strongest effect of relative humidity reduction was observed in people over 75 years of age [28]. Low humidity also increased the risk of failed CPR in all age and gender groups.

In women and age group of >65 years, low atmospheric pressure in the initial lag days was associated with increased Out-of-hospital Cardiac Arrest cases, but in men and age group of <65 years, high atmospheric pressure increased the risk of Out-of-hospital Cardiac Arrest . This finding is consistent with Ratajczak's findings, which showed that men were more likely to have Out-of-hospital Cardiac Arrest on consecutive days when atmospheric pressure was high, but in contrast to our findings, the prevalence of Out-of-hospital Cardiac Arrest in people under 65 years was high when the daily pressure change was lower [37]. According to Ou et al., women were more vulnerable than men to reduced atmospheric pressure and relative humidity. In their study, they found that patterns of age-based vulnerability would depend on behavioral and socio-economic differences between women and men in facing risks as well as their coping capacity. These differences in men and women in different ages may vary according to the patterns of injury in terms of age, behavioral, economic, and social differences between men and women, if exposed to hazards and other structures. [28].

The limitations of this study are its retrospective nature, the possible incorrect recording of data by the operator, as well as the fact that we only evaluated the patients referred to one hospital, and those who referred to private hospitals or clinics after cardiac arrest were not studied. Since the change in humidity and atmospheric pressure can be associated with the incidence of Out-of-hospital Cardiac Arrest , further studies are recommended to investigate its effects on respiratory diseases and their exacerbation.

Ethical Considerations

Compliance with ethical guidelines

This study approed by the Research Ethics Committee of Guilan University of Medical Sciences (Code: IR.GUMS.REC.1398.194).

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Authors' contributions

Conceptualization: Yasaman Borghei, Mohammad Taghi Moghaddamnia, Abdolhossein Emami Sigaroudi; Draft preparation, resources, and investigation: Yasaman Borghei and Mohammad Taghi Moghaddamnia; Data analysis: Ehsan Kazemnejhad Leili, Yasaman Borghei, Mohammad Taghi Moghaddamnia and Abdolhossein Emami Sigaroudi; Editing and review: All authors.

Conflict of interest

The authors declared no conflict of interest.

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