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Original Article

Muhammed Fuad Uslu[1], Mustafa Yilmaz[2], Serdar Gumustoka[2]

[1]Elazığ Fethi Sekin City Hospital, Department of Internal Medicine, Elazığ, Türkiye
[2]Fırat University, Faculty of Medicine, Department of Emergency Medicine, Elazığ, Türkiye

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Corresponding Author: Mustafa Yilmaz, Fırat University, Faculty of Medicine, Department of Emergency Medicine, Elazığ, Türkiye
Email: drmylmz@yahoo.com

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Association between pulmonary embolism and seasonal meteorological parameters

Abstract

Aim: This study aimed to investigate the relationship between acute pulmonary embolism diagnoses and three meteorological parameters—average daily temperature, relative humidity, and atmospheric pressure—on the day of diagnosis.
Materials and Methods: In this retrospective study, patients diagnosed with acute pulmonary embolism via radiological imaging between January 1, 2019, and December 31, 2023 , were included. Data were collected from two hospitals in our province following approval from the local university ethics committee. Patient information was extracted from electronic health records and digitized. Adults aged 18 years and older who presented within the study period were eligible. For each case, the date (day, month, year, and season) of diagnosis was recorded . The relationship between these temporal data points and meteorological parameters was analyzed.
Results: A total of 1,826 patients diagnosed with pulmonary embolism between 2019 and 2023 were included in the study. Although the highest number of monthly admissions occurred in January (8.54%), there was no statistically significant difference in admission rates across the months (p=0.56). Additionally, no significant correlation was found between the number of acute pulmonary embolism diagnoses and daily meteorological parameters.
Conclusion: This study found no association between the incidence of acute pulmonary embolism and daily mean temperature, relative humidity, or atmospheric pressure.

Keywords: Meteorological parameters, acute pulmonary embolism, daily mean atmospheric pressure, seasonal variation, environmental factors

INTRODUCTION

Acute pulmonary embolism (APE), characterized by the occlusion of pulmonary arteries by thrombotic material, is associated with high morbidity and mortality. Its development is multifactorial, primarily involving hypercoagulability, endothelial injury, and inflammation (1,2). While seasonal variation has been shown to influence the incidence and fatality rates of major cardiovascular conditions, the relationship between meteorological factors and APE remains unclear due to inconsistent findings across studies.

These discrepancies may be attributable to regional variations in climate and geography, which influence local meteorological patterns and may affect outcomes differently (3-7). Some studies have reported a peak in APE incidence and mortality during winter months (8), whereas others found no significant seasonal variation (9). Although the precise contribution of meteorological conditions to APE development is not fully understood, established risk factors—such as surgery, malignancy, and prolonged immobility—may be indirectly influenced by environmental factors (10).

This study aims to investigate the association between meteorological parameters and the incidence of acute pulmonary embolism during the days immediately surrounding diagnosis.

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MATERIALS AND METHODS

Following ethical approval from the Fırat University Faculty of Medicine Ethics Committee (Approval No: 2024/06-06, Date: 25.04.2024), this study examined patients diagnosed with acute pulmonary embolism. Participants were identified from two hospitals in our city and had been diagnosed using contrast-enhanced pulmonary computerized tomography (CT) angiography between January 1, 2019, and December 31, 2023.

The primary inclusion criterion was age 18 years or older at the time of presentation during the study period. Patients were excluded if they were younger than 18 years or had a diagnosis of chronic pulmonary embolism. Demographic and diagnostic data—including age, gender, and exact date of diagnosis—were obtained from the hospitals' electronic health record systems.

For all patients meeting the inclusion criteria, information such as gender and the day, month, year, and season of diagnosis (as determined by imaging findings) was entered into a research database.

Meteorological data: Meteorological parameters—including average daily temperature (°C), atmospheric pressure (mb), relative humidity (%), and peak wind speed (m/s)—were recorded between January 1, 2019, and December 31, 2023. Data were obtained from the 13th Regional Directorate of the General Directorate of Meteorology, under the Ministry of Environment, Urbanization, and Climate Change.

Statistical Analysis: All statistical analyses were performed using IBM SPSS Statistics for Windows, Version 21.0 (IBM Corp., Armonk, NY, USA) and Microsoft Excel, both licensed for institutional use. Continuous variables were summarized as mean ± standard deviation, and categorical variables were presented as percentages.

The normality of continuous data was assessed using the Shapiro–Wilk test. For comparisons between two independent groups, the independent samples t-test was applied. When comparing three or more groups, one-way analysis of variance (ANOVA) was conducted, followed by either Tukey's HSD or Bonferroni post hoc tests, depending on the outcome of Levene's test for homogeneity of variances.

Associations between meteorological variables and pulmonary embolism incidence were evaluated using Pearson's correlation coefficient. Additionally, univariate and multivariate linear regression models were constructed to assess the predictive value of meteorological parameters on case numbers. A two-tailed p-value < 0.05 was considered statistically significant.

RESULTS

The study included 1,826 patients who were followed for pulmonary embolism (PE) between 2019 and 2023. Although the highest number of monthly admissions occurred in January (8.54%), no statistically significant difference was observed in the number of admissions across months (p=0.56) (Table 1).

When admissions were grouped by season, 24.69% (n=451) of patients were diagnosed with APE in winter, 24.91% (n=455) in fall, and 25.19% (n=460) in summer and spring. There was no statistically significant difference in the number of APE diagnoses across seasons (p=0.634) (Figure 1).

Additionally, no significant association was found between the number of APE diagnoses and daily meteorological parameters (Table 2).

Table 1. Monthly admission and metrological data of acute pulmonary embolism patients

Month	N (%)	Average daily temperature	Average daily humidity	Average daily pressure
January	156 (8.54)	2.437±3.35	77.028±11.04	906.583±5.50
February	141 (7.72)	5.010±4.44	66.848±13.31	906.365±5.13
March	155 (8.48)	9.083±4.12	62.626±15.08	902.239±4.48
April	150 (8.21)	15.631±5.55	54.236±16.20	902.415±3.65
May	155 (8.48)	20.937±4.36	45.744±16.63	902.169±3.09
June	150 (8.21)	27.009±4.18	35.113±9.85	899.255±2.57
July	155 (8.48)	31.073±4.21	25.525±5.25	897.297±2.40
August	155 (8.48)	31.700±5.60	24.713±8.16	898.263±2.65
September	150 (8.21)	26.839±5.58	28.221±7.89	901.745±2.57
October	155 (8.48)	19.753±4.77	46.059±18.11	906.368±2.88
November	150 (8.21)	11.410±4.72	66.283±14.49	907.589±3.08
December	154 (8.43)	6.138±4.04	78.298±9.84	907.847±4.61

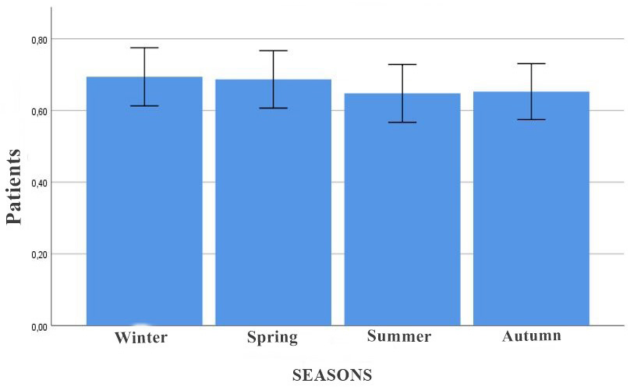

Figure 1. APE patients and seasonal distribution

Table 2. Correlation between APE patients and daily meteorological parameters

		Average temperature	Average humidity	Average pressure
Patients	r	-0.013	0.003	-0.001
	p	0.573	0.892	0.964

DISCUSSION

In this study, statistical analysis revealed no significant correlation between the number of patients diagnosed with APE and daily meteorological variables, including ambient temperature, atmospheric pressure, and relative humidity. This finding aligns with several previous studies but contrasts with others, underscoring the complexity and heterogeneity of this relationship in the existing literature.

Although the precise mechanisms by which atmospheric conditions influence cardiovascular and thromboembolic events are not fully understood, several hypotheses have been proposed. For example, fluctuations in atmospheric pressure may induce biomechanical stress on the vascular endothelium, potentially contributing to endothelial dysfunction —a known precursor to thrombus formation (11). In addition, such fluctuations may affect blood viscosity and modulate autonomic nervous system responses, thereby influencing hemodynamic stability and promoting thrombogenesis in susceptible individuals.

Several studies have examined the influence of atmospheric pressure on acute vascular events. Smith et al. reported a significant association between low atmospheric pressure and the incidence of ruptured abdominal aortic aneurysms over a six-year period (12), while Houck et al. found that declines in atmospheric pressure were linked to increased rates of myocardial infarction within the subsequent 24 hours (13). Similarly, Dawson et al. identified a temporal relationship between drops in barometric pressure and increased admissions for hemorrhagic stroke within 48 hours (14). These findings support the hypothesis that atmospheric pressure may function as a short-term environmental trigger for acute vascular events.

However, the literature remains inconsistent, with variations in study design, geographic location, and statistical methodology likely contributing to the divergent findings. For instance, some studies utilized weekly or monthly aggregated meteorological data, whereas others analyzed real-time daily measurements. Additionally, heterogeneity in the classification of pulmonary embolism severity, patient comorbidities, and inclusion and exclusion criteria complicates cross-study comparisons. While certain studies stratified patients by risk profiles (e.g., surgical vs. medical), others treated the study population as a uniform cohort, potentially obscuring subgroup-specific associations.

From a biological perspective, temperature extremes may influence the risk of venous thromboembolism (VTE) through several physiological mechanisms. Cold exposure has been linked to vasoconstriction and increased blood viscosity, whereas heat may contribute to dehydration and hemoconcentration —both of which can promote thrombogenesis. However, these effects may be attenuated in modern settings due to the widespread use of climate-controlled indoor environments, potentially reducing the observable impact of ambient weather conditions on clinical outcomes.

In the present analysis, graphical representations of the temporal distribution of acute pulmonary embolism (APE) diagnoses relative to meteorological variables—such as time series plots and scatter diagrams with trend lines—did not reveal any visually apparent seasonal clustering or strong linear associations. Moreover, regression analyses yielded low R^2 values across all tested models, indicating that meteorological parameters explained only a small proportion of the variance in daily PE case counts. These statistical results suggest that while meteorological factors may have some biological plausibility, they are unlikely to serve as independent predictors of PE incidence at the population level based on the data in this study.

Regional climatic stability must also be considered as a contributing factor. This study was conducted in an area with relatively moderate seasonal variation, which may have limited the potential impact of extreme weather conditions on pulmonary embolism (PE) incidence. This contextual factor may help explain the absence of significant associations observed in our findings, particularly in contrast to studies conducted in regions with more pronounced fluctuations in temperature and atmospheric pressure.

Previous studies have reported conflicting results. Staskiewicz et al. identified a higher incidence of PE during periods of low atmospheric pressure (15), while Goerre et al. associated increased barometric pressure and wind intensity with a rise in acute coronary syndrome cases (16). Öztuna et al. found a non-significant inverse relationship between atmospheric pressure and PE incidence in patients without identifiable risk factors, but no association in medically managed patients (17). Masotti et al. observed that PE events were more common during colder months in surgical patients and were associated with longer hospital stays, whereas cardiology admissions increased during warmer seasons (8). Conversely, Anar et al. reported no statistically significant associations between meteorological variables and PE characteristics in a large cohort of 1,180 patients stratified by risk status (9).

Taken together, these findings underscore the multifactorial nature of pulmonary embolism and suggest that, although meteorological conditions may exert some influence, their impact is likely secondary to well-established clinical risk factors. Future research would benefit from multicenter, longitudinal studies employing standardized data collection protocols, larger sample sizes, and appropriate adjustments for potential confounders such as air pollution, physical activity, and pre-existing medical conditions.

Limitations of the Study

The principal limitation of this study is its retrospective design, which inherently restricts control over confounding variables and introduces potential biases related to data completeness and accuracy. Patients with missing or incomplete hospital records, as well as those with uncertain or inconclusive diagnoses of PE, were excluded from the analysis. This exclusion may have resulted in selection bias and limited the generalizability of the findings.

Additionally, the absence of precise data on the exact number of patients and diagnosis dates for certain days may have affected the reliability of the statistical analyses. Another important limitation is the single-center design, as the study was conducted exclusively in the central district of a single province. This geographic restriction reduces external validity, as the meteorological impact on PE incidence may differ considerably across regions with more variable or extreme climate conditions. Therefore, the findings of this study may not be generalizable to populations in other settings.

CONCLUSION

In summary, this retrospective study found no statistically significant association between the daily number of patients diagnosed with APE and average daily meteorological parameters, including ambient temperature, relative humidity, and atmospheric pressure. These findings suggest that, within the geographic region and timeframe examined, weather conditions did not exert a measurable influence on APE incidence. Future prospective, multicenter studies covering broader geographic areas and incorporating additional environmental and clinical variables are warranted to validate these results and further explore potential causal relationships.

Conflict of Interests
The authors declare that there is no conflict of interest in the study.

Financial Disclosure
The authors declare that they have received no financial support for the study.

Ethical Approval
Fırat University Non-interventional Research Ethics Committee Non-interventional Research Ethics Committee (25.04.2024- 2024/06-06).

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