

Are Meteorological Parameters a Risk Factor for Pulmonary Embolism? A Retrospective Analysis of 530 Patients

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Background: The influence of meteorological conditions on cardiovascular morbidity and mortality has been known for a long time. However, few reports have been published on the influence of meteorological parameters on the occurrence of acute pulmonary embolism (PE).

Aims: In this retrospective study, we compared the meteorological parameters between PE patients with risk factors and idiopathic PE patients.

Study Design: Cross-sectional study.

Methods: Medical documentation of 1180 patients with suspected acute pulmonary embolism diagnosed between January 2010 and December 2012 was retrospectively analyzed. A total of 530 patients with PE confirmed by computed tomography pulmonary angiography and/or ventilation/perfusion scan were included for further analysis. We divided the patients into two groups: PE with risk factors (provoked) and PE without risk factors (unprovoked). The meteorological data were collected from the relevant time period: temperature, humidity, pressure, and wind velocity. As the exact time of PE onset was unknown, the meteorological values attributed to each patient were the means of the values in the months or weeks at the time of diagnosis of PE.

Results: The highest numbers of cases were seen in autumn (29.8%), followed by summer (28.9%), spring (22.1%), and winter (19.2%). In terms of months, the greatest number of cases occurred in June (57), followed by November (56) and October (54). Case distribution according to the months and seasons were statistically significant. The wind direction also affected the incidence of PE. There was a statistically significant positive correlation between case frequency and air temperature ($r=0.300$; $p=0.031$). No correlation was found between the unprovoked PE cases' monthly distribution and pressure, humidity, or temperature. However, there was a statistically significant positive correlation between the monthly distribution of the group with provoked PE cases and air temperature ($r=0.586$; $p=0.045$).

Conclusion: A statistically significant inverse correlation between atmospheric pressure and temperature and the number of all PE cases was observed in our study, which is in accordance with other reports. However, in unprovoked PE cases, there was no correlation between meteorological parameters and case incidence.

Keywords: Meteorological factors, pulmonary embolism, risk factors

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The influence of meteorological conditions on cardiovascular morbidity and mortality has been known for a long time. However, few reports have been published on the influence of meteorological parameters on the occurrence of acute pulmonary embolism (PE), which is an important public health problem, with high mortality (1). The pathophysiological mechanisms underlying these observations remain controversial. One possible mechanism may be that changes in meteorological factors that occur during the year have a direct effect on thrombotic tendencies. However, studies that have investigated the relationship between meteorological factors and the incidence of PE have provided inconsistent results (2-5). These studies included patients who had risk factors for PE, and therefore, confounding factors may have influenced the results. Although risk factors for PE, such as surgery, cancer, and immobility, may not be directly implicated in terms of the effect of meteorological factors, they could be influenced indirectly (5). We therefore undertook a large study of patients without risk factors for PE. In this retrospective study, we compared the meteorological parameters between the patients who had risk factors (provoked) and idiopathic (unprovoked) PE patients. We looked for seasonal variations in the incidence of idiopathic PE and a relationship with atmospheric pressure, humidity, or temperature.

MATERIALS AND METHODS

Patients

Medical documentation of 1180 patients with suspected acute pulmonary embolism diagnosed between January 2010 and December 2012 was retrospectively analyzed. Patients with PE confirmed by computerized tomography pulmonary angiography (CTPA) and ventilation/perfusion (V/Q) scanning were included for further analysis. We divided the patients into two groups: PE with risk factors and PE without risk factors. Patients with a known major risk factor for PE (surgical patients, obstetric patients, trauma/orthopedic patients, and oncology patients) were recorded as group 1 (provoked). As immobility and hospitalization is also a risk factor for PE, patients who were in the hospital for more than 5 days before they had a CTPA or V/Q scan were also included in group 1. Patients who did not have a risk factor were included in group 2 (unprovoked).

This study was approved by the local ethical committee. Informed consent was not obtained from each patient.

Computerized tomography pulmonary angiography

Computerized tomography pulmonary angiography was obtained using a 64-slice scanner (Imaxeon Salient, Germany)

and 80–90 mL of iodinated contrast material. The same radiologist reported all scans. Patients were investigated by CTPA as their initial investigation or following an intermediate or indeterminate V/Q scan.

Ventilation/Perfusion scan

All scans were reviewed by a radiologist and classified according to the Prospective Investigation of Pulmonary Embolism Diagnosis (PIOPED) criteria. Normal or low probability scans were classified as negative, while those with high probability were classified as positive. Patients with intermediate or indeterminate probability scans were subsequently investigated with CT pulmonary angiography.

Seasons

For each year, standard dates were used to define each season. Summer was defined as June 1 to August 31, autumn was defined as September 1 to November 30, winter was defined as December 1 to February 28/29 (depending on whether or not it was a leap year), and spring was defined as March 1 to May 31.

Meteorological factors

The following meteorological data were collected from the relevant time period: temperature, humidity, pressure, and wind velocity. These meteorological data were obtained from the Izmir Meteorology Department. The exact time of PE onset was unknown, and hence the meteorological values attributed to each patient were means of the values in the months or weeks at the time of diagnosis of PE.

Statistical analysis

Data was analyzed using SPSS 16.0 (SPSS Inc., Chicago, IL, USA) statistical package. Measurement data are expressed as mean \pm SD. The χ^2 test was used to compare baseline characteristics and the number of patients presenting in each month and season. A p-value ≤ 0.05 was regarded as indicating statistical significance. Pearson's correlation was used to determine the correlation between the average atmospheric pressure, humidity, air temperature values, and PE incidence for each month and season.

RESULTS

The demographic characteristics of the patients are shown in Table 1. Apart from gender, no statistical significance was determined in terms of patient characteristics and risk factors. CTPA was used as the diagnostic tool in 500 patients, whereas

TABLE 1. Patient characteristics and risk factors according to season

Characteristics	Winter n=102	Spring n=117	Summer n=153	Autumn n=158	p
Female/male	39/63	46/71	90/63	84/74	0.001
Immobilization	7 (6.9%)	8 (6.8%)	25 (16.3%)	14 (8.9%)	0.065
Trauma	3 (2.9%)	12 (10.3%)	5 (3.3%)	5 (3.2%)	0.117
Surgery	7 (6.9%)	12 (10.3%)	18 (11.8)	22 (13.9%)	0.232
Recurrent PE	6 (5.9%)	1 (0.9%)	5 (3.3)	2 (1.3%)	0.065
DVT (+/-)	32/70	40/77	39/114	60/98	0.121
Obesity	-	-	2 (1.3%)	-	0.452
Contraceptive drug use	3 (2.9%)	3(2.6)	3 (2%)	4 (2.5%)	0.650
Malignancy	10 (9.8%)	16 (13.7%)	19 (12.4%)	20 (13.9%)	0.125
Cardiovascular disease	14 (13.7%)	23 (19.7%)	23 (15%)	21 (13.3%)	0.114
COPD	5 (4.9%)	6 (5.1%)	-	8 (5.1%)	0.230
No risk factors	46 (45.1%)	35 (29.9%)	53 (34.6%)	61 (38.6%)	0.115
Diagnosis					
CT Angiography	96 (94.1%)	112 (95.7%)	139 (90.8%)	153 (96.8%)	0.124
Isotope lung scanning	6 (5.9 %)	5 (4.3%)	14 (9.2%)	5 (3.2%)	0.124
Mortality (+/-) (present/absent)	5/97	2/113	6/147	5/153	0.680
Massive/non-massive PE	10 /92	14/103	12/141	12/146	0.582

PE: pulmonary embolism; DVT: deep venous thrombosis; CT: computerized tomography; COPD: chronic obstructive pulmonary disease

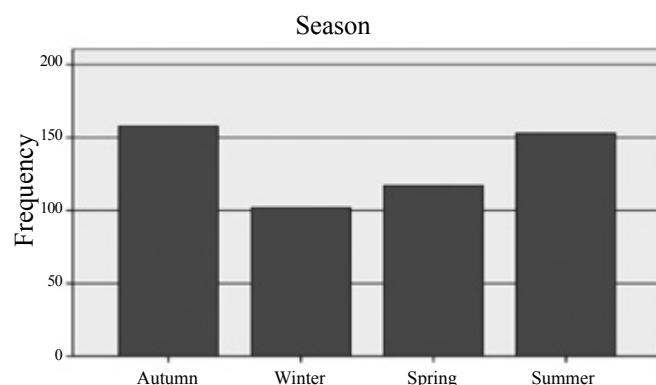
30 patients were diagnosed clinically using isotope lung scanning. Risk factors were shown in 335 (63.2%) patients, while 195 (36.8%) patients had no risk factors.

The highest numbers of cases were seen in autumn (29.8%), followed by summer (28.9%), spring (22.1%), and winter (19.2%), and this difference was statistically significant ($p=0.001$; Figure 1). In terms of months, the greatest number of cases occurred in June (57), followed by November (56) and October (54), and this distribution was also statistically significant ($p=0.027$; Figure 2).

The wind direction affected the incidence of PE and was statistically significant ($p=0.000$; Figure 3).

There was a statistically significant positive correlation between case frequency and air temperature ($r=0.300$; $p=0.031$). There was a negative correlation between embolism cases and atmospheric pressure ($r=-0.263$; $p=0.060$) and with humidity ($r=-0.905$; $p=0.504$), although these were not statistically significant (Table 2). There was no statistically significant difference between cases and air temperature, humidity, atmospheric pressure, or wind speed between the group with risk factors and without risk factors (Table 3).

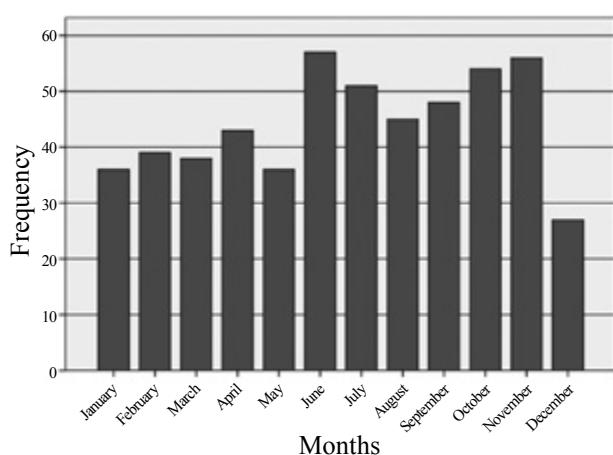
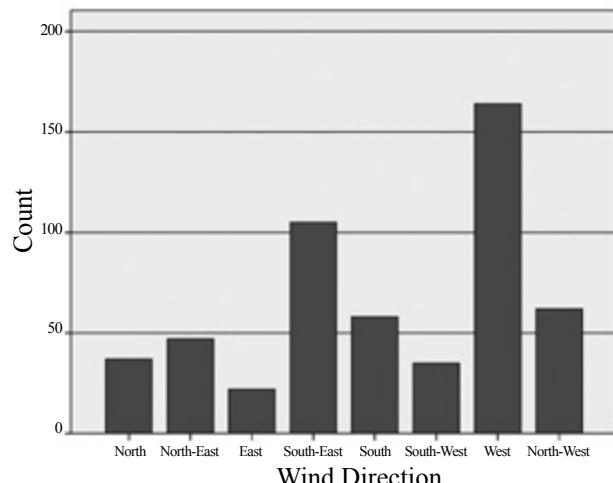
Considering embolism cases occurring with risk factors and without risk factors, it was determined that the distribution ratios by month and season were not statistically significant ($p=0.281$ and 0.115 , respectively; Figure 4, Table 4). However, there was a statistically significant positive correlation between the monthly distribution of cases from the group with

**FIG. 1.** The number of patients according to the season

risk factors and air temperature ($r=0.586$; $p=0.045$; Figure 5). Although not statistically significant, there was a negative correlation between PE cases with risk factors and humidity ($r=-0.510$; $p=0.09$) and atmospheric pressure ($r=-0.538$; $p=0.071$; Table 3).

DISCUSSION

The first observation of the weather's influence on health is attributed to Hippocrates (7). The effect of the weather and the seasons on cardiovascular and cerebrovascular diseases had been investigated for many years. Goerre et al. (8) analyzed

**FIG. 2.** The number of patients according to the month**FIG. 3.** The distribution of patients according to the wind direction**TABLE 2.** Correlation between all pulmonary embolism cases and meteorological parameters (weekly and monthly)

		PE frequency weekly	PE frequency monthly
Wind speed	r*	0.141	0.31
	p	0.318	0.32
Temperature	r	0.300*	0.572*
	p	0.03	0.05
Humidity	r	-0.095	-0.473
	p	0.5	0.121
Atmospheric pressure	r	-0.263	-0.423
	p	0.06	0.17

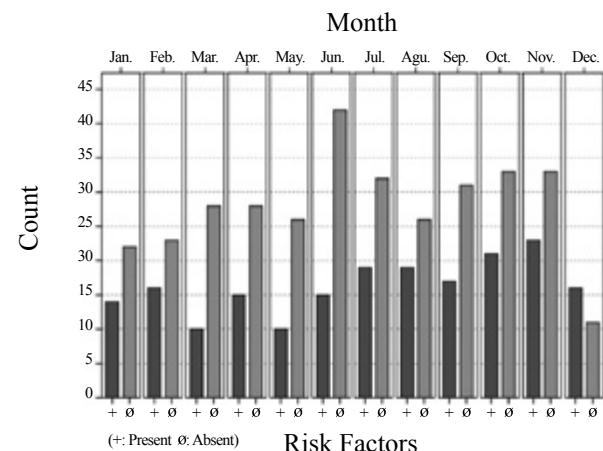
r: correlation coefficient; p: p value; PE: pulmonary embolism

the impact of weather conditions on the incidence of acute coronary syndrome (ACS). Their study, which included 6560 patients hospitalized due to myocardial infarction, revealed that high ambient pressure, high pressure gradients,

TABLE 3. The distribution of meteorological parameters between the cases with risk factors and without risk factors

	PE cases with risk factors	PE cases without risk factors
Wind speed (monthly)	r*	0.365
	p	-0.287
Temperature (monthly)	r	0.243
	p	0.366
Humidity	r	0.586
	p	0.045
Atmospheric pressure	r	-0.510
	p	0.254
	r	-0.538
	p	-0.09
	r	-0.072
	p	0.823
	r	-0.235
	p	0.071
	r	0.462

PE: pulmonary embolism; r: correlation coefficient; p: p value

**FIG. 4.** Patients with risk factors and without risk factors according to the month

and strong wind activity are associated with an increase in ACS cases. Dawson et al. (9) analyzed changes in weather conditions and compared them with hospital admissions due to cerebrovascular incidents.

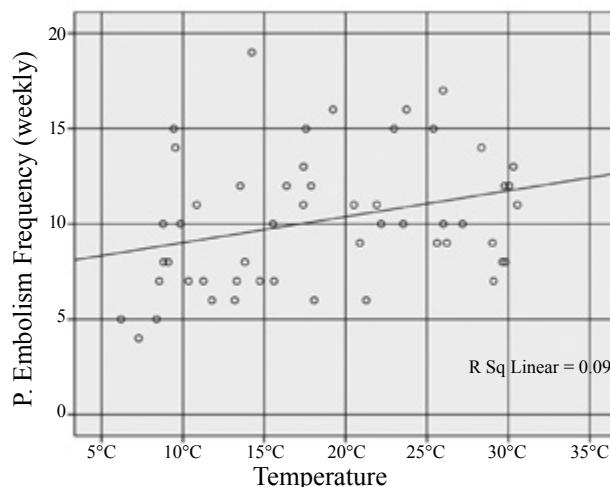
There is no consensus among researchers on the seasonality of PE occurrence. Masotti et al. (10) revealed an increased occurrence of PE in surgical patients during cold months, as well as during longer periods of hospitalization of those patients in the same season. The same study showed an increased number of PE incidents during warm months in the cardiology ward. Similar to Nimako et al. (11), our study showed a correlation between the incidence of PE (idiopathic and with risk factors) and decreased atmospheric pressure and increased temperature. However, no correlation was determined between monthly distribution in the group without risk factors and pressure, humidity, or temperature. There was no statistically significant difference between case characteristics and air temperature, humidity, atmospheric pressure, or wind speed between the group with risk factors and without risk factors in our study population. Oztuna et

TABLE 4. The distribution of patients in two groups

	Without risk factors	With risk factors	p
Female/Male	74/121	185/150	0.000
DVT (-/+)	123/72	236/99	0.08
Seasons			
Autumn	61	97	
Winter	46	56	0.115
Spring	35	82	
Summer	53	100	
Months			
January	14	22	
February	16	23	
March	10	28	
April	15	28	
May	10	26	
June	15	42	
July	19	32	0.281
August	19	26	
September	17	31	
October	21	33	
November	23	33	
December	16	11	
Years			
2010	56	50	
2011	58	166	0.000
2012	81	119	
Mortality			
Absent	189	321	0.685
Present	6	14	
Diagnosis test			
CT Angiography	179	321	0.082
V/P Scintigraphy (V/P scan)	16	14	
Severity			
Massive	17	31	
Non-massive	178	304	0.96

DVT: deep venous thrombosis; CT: computerized tomography; V/P: ventilation/perfusion

al. (3) found an insignificant negative correlation between the monthly distribution in cases without risk factors and air pressure and humidity in their study, but no correlation was determined in medical cases. In contrast, Masotti's (10) 457-case study reported that although a powerful correlation with atmospheric pressure was found in surgical cases, there was only a weak correlation between air pressure, humidity, and temperature in medical cases.

**FIG. 5.** Correlation between pulmonary embolism patients with risk factors and temperature

Our findings of a seasonal variation in PE are consistent with a number of similar studies. Most of these have found an increased incidence of PE or venous thromboembolism in the autumn and winter months (12-15). Consistent with our findings, Manfredini et al. (15), in a large multicenter Italian study (2119 subjects), found that venous thromboembolisms were less frequent in spring. However, in contrast to our findings, Meral et al. (2) found a peak in the incidence of PE in the spring months. However, this was a small study (91 patients) that took place at high altitude (1800 m), with very different weather conditions to our own. These different results may be due to climatic differences in the study centers and their geographical structures. However, it is also true that people are more likely to travel in cars for longer distances on hotter days and during the holiday period. Dehydration is more likely to be a problem in the hotter months due to perspiration, and this may lead to an increase in blood viscosity and PE. Also, a further limitation of our study is that although our hospital is far from the weather station (approximately 15 km), it is conceivable that some patients may have lived a lot farther than 15 km from the weather station. Consequently, the meteorological factors that they were exposed to would have been different from that recorded at the weather station. However, there was no difference between the PE cases with risk factors and those without risk factors in our study, and there was also no correlation between incidence of PE with atmospheric pressure, temperature, or humidity in idiopathic PE.

The highest mortality in a 2831-case series studied by Montes et al. (16) from 1996 to 2001 occurred in the spring months (OR, 2.18; CI, 1.18-4.05), and 83% of the patients who died were older than 75 years. Oztuna et al. (3) found that the highest mortality in their study was also in winter and spring, although this was not statistically significant. In our

study, the highest mortality was in autumn. The average age of the 20 patients who died was 68.63 ± 18.42 years, which is in contrast to the Montes et al. (16) study. In Montes et al. (16) study mortality peaked in spring and nearly 83% of these deaths occurred in persons >75 years old. Also, in our study massive embolism had occurred in 11 patients and nine patients had non-massive embolism, which was statistically significant in our study.

In conclusion, a statistically significant inverse correlation between atmospheric pressure and temperature and the number of all PE cases was observed in our study, which is in accordance with other reports. This result raises a question: We know that long commercial flights are a risk factor for PE. Can cabin pressure changes and humidity be responsible for PE and deep-vein thrombosis during flights? If the answer is yes, then, commercial aircraft manufacturers have a big problem. Of course, we need further perspective and well-organized studies to answer this question.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of İzmir Dr. Suat Seren Chest Diseases and Surgery Training Research Hospital.

Informed Consent: N/A.

Peer-review: Externally peer-reviewed.

Author contributions: Concept - C.A., İ.Ü., S.E.; Design - C.A., İ.Ü., T.İ.; Supervision - C.A., İ.Ü., H.H.; Resource - C.A., G.P., Ö.E.; Materials - C.A., T.İ., Ö.E.; Data Collection &/or Processing - C.A., T.İ., S.E.; Analysis &/or Interpretation - C.A., S.E., G.P.; Literature Search - C.A., İ.Ü., Ö.E.; Writing - C.A., S.E., G.P.; Critical Reviews - İ.Ü., H.H., Ö.E.

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