

Association Between Meteorological Variables and Emergency Department Presentations for Syncope: A Five-Year Retrospective Time-Series Study

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Research Article

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Abstract

Background

Syncope is a frequent reason for emergency department presentation and may be influenced by environmental, seasonal, behavioral, and physiological factors. Heat exposure, humidity, atmospheric pressure changes, and short-term weather variability have been suggested as potential triggers for fainting and orthostatic intolerance; however, the evidence remains limited and inconsistent. This study aimed to investigate the association between daily meteorological variables and emergency department presentations for syncope over a five-year period.

Methods

We conducted a retrospective time-series study including all patients who presented to the emergency department with a complaint of syncope between January 2021 and December 2025. Daily syncope case counts were extracted from hospital records and merged by date with meteorological data obtained from the Şişli/18401 meteorological station. The evaluated meteorological variables included temperature, relative humidity, atmospheric pressure, precipitation, and wind speed. Lagged and derived variables were calculated to assess delayed and short-term change effects. Lag-1 and lag-2 values were computed for temperature and atmospheric pressure, lead-1 values were explored descriptively, and daily change variables were calculated as differences between consecutive days. Syncope-positive days were defined as days with at least one syncope presentation. Univariate comparisons were performed using two-sample t-tests and Wilcoxon rank-sum tests. Spearman rank correlations were calculated across lag windows from -3 to +3 days. Multivariable negative binomial regression was used to model daily syncope counts, and logistic regression was used to model the occurrence of at least one syncope presentation per day. Both models included meteorological variables, daily change variables, season, and calendar year. Generalized additive models with a negative binomial family were used to assess potential non-linear associations.

Results

During the 1,826-day study period, 722 syncope presentations were recorded on 564 days. The mean daily number of syncope cases was 0.40, with a range of 0–4 cases per day. Syncope-positive days accounted for 30.9% of all study days. Mean temperature was 16.8°C on syncope days and 16.4°C on non-syncope days. Mean atmospheric pressure was also similar between syncope and non-syncope days. In univariate analyses, none of the same-day, lagged, or lead meteorological variables showed a statistically significant association with syncope occurrence. Spearman correlations between meteorological variables and daily syncope counts were uniformly weak across all examined lag windows.

Introduction

Syncope is defined as a transient loss of consciousness caused by global cerebral hypoperfusion, characterized by rapid onset, short duration, and spontaneous complete recovery [1, 2]. It is a common reason for emergency department presentation and represents a diagnostic challenge because its underlying mechanisms range from benign reflex syncope to orthostatic hypotension, arrhythmias, structural cardiac disease, and other serious conditions [1–4]. Contemporary European and American guidelines emphasize that the initial evaluation of syncope should include a detailed history, physical examination, orthostatic blood pressure measurement, and electrocardiography, followed by structured risk stratification to identify patients at risk for short-term adverse outcomes [1, 2]. In the emergency department, this approach is particularly important because syncope is not a single disease entity but a final common clinical presentation of heterogeneous cardiovascular, neurological, autonomic, and situational mechanisms [3–6].

Several risk stratification tools have been developed to improve decision-making in emergency department patients with syncope, including the Canadian Syncope Risk Score and other clinical prediction rules [5–8]. However, despite progress in risk prediction, the short-term daily burden of syncope presentations remains difficult to anticipate. Syncope occurrence may be influenced not only by patient-level factors such as age, comorbidities, medication use, hydration status, autonomic function, and cardiovascular reserve, but also by behavioral and environmental exposures [1, 2, 9]. Among environmental factors, meteorological conditions are of particular interest because temperature, humidity, atmospheric pressure, precipitation, and wind speed may influence cardiovascular physiology, thermoregulation, outdoor activity, and healthcare-seeking behavior [9–13].

The biological plausibility of a relationship between weather and syncope is supported by experimental and clinical physiology. Heat exposure may cause peripheral vasodilation, sweating, relative hypovolemia, reduced venous return, and impaired maintenance of cerebral perfusion during upright posture [14–16]. Whole-body heat stress has been shown to reduce cerebral blood velocity and markedly impair orthostatic tolerance in humans [15]. Mechanistic reviews further suggest that heat-related orthostatic intolerance results from combined effects on vascular resistance, blood volume distribution, cardiac output, and cerebral perfusion regulation [14–16]. High relative humidity may intensify thermal strain by limiting evaporative cooling, whereas rapid weather fluctuations may challenge autonomic and hemodynamic adaptation in susceptible individuals [9–11, 14].

Despite these mechanisms, epidemiological evidence linking meteorological variables to syncope presentations remains limited and inconsistent. Anderson et al. evaluated the influence of temperature and humidity on emergency department attendances for syncope and found no simple strong relationship between these variables and syncope volume [10]. Galli et al. reported that emergency department visits for syncope were not predicted by daily maximum temperature itself, but were associated with increased air temperature variability, suggesting that short-term meteorological instability may be more relevant than absolute temperature [9]. Cymes et al. investigated

biometeorological indicators and emergency interventions due to fainting, supporting the possibility that atmospheric conditions may contribute to fainting events in certain contexts [11]. In addition, de Lavallaz et al. showed that syncope etiologies may display circadian, weekly, seasonal, and temperature-dependent patterns, indicating that temporal variation in syncope may reflect a complex interaction between biological rhythms, environmental exposure, and behavioral factors [12].

The broader climate-health literature also supports investigation of acute cardiovascular and autonomic presentations in relation to meteorological exposure. Heat exposure and heatwaves have been associated with increased cardiovascular morbidity and mortality in systematic reviews and meta-analyses [17, 18]. Emergency department studies have shown that heat stress and warm-season exposures may increase acute care utilization, particularly among vulnerable groups [19, 20]. Recent climate and emergency medicine reviews emphasize that climate change can alter emergency department demand, disease patterns, operational stress, and vulnerability among older adults and patients with chronic cardiovascular disease [21, 22]. Although these studies are not specific to syncope, they support the hypothesis that short-term environmental exposures may contribute to acute presentations through cardiovascular, renal, thermoregulatory, and autonomic pathways [17–22].

However, syncope may differ from other heat-sensitive or climate-sensitive emergency conditions because its occurrence is highly dependent on individual susceptibility and situational context [1, 2, 13, 14]. Outdoor meteorological measurements may not accurately reflect individual exposure, especially in urban settings where indoor climate control, transportation, occupational conditions, and microclimatic variation are substantial [21, 22]. Furthermore, seasonal variation in syncope presentations may be influenced by activity patterns, hydration behavior, infectious disease burden, school and work schedules, public holidays, healthcare access, and emergency department utilization rather than direct meteorological effects alone [3, 4, 12]. Therefore, the association between routine meteorological parameters and daily syncope burden may be weak, delayed, non-linear, or detectable only in selected subgroups.

Previous studies have often focused on limited meteorological variables, short observation periods, or specific weather indicators [9–12]. Few studies have simultaneously evaluated same-day meteorological values, lagged effects, daily meteorological changes, seasonality, weekday patterns, calendar-year trends, and non-linear associations using both count-based and binary outcome models. Therefore, the present study aimed to investigate the association between daily meteorological variables and emergency department presentations for syncope over a five-year period from January 2021 to December 2025. We evaluated temperature, relative humidity, atmospheric pressure, precipitation, wind speed, daily changes, lagged and lead effects, seasonality, weekday patterns, and calendar-year trends. We hypothesized that meteorological variables, particularly temperature and atmospheric pressure changes, might be associated with daily syncope burden; however, we also aimed to determine whether these variables provide clinically meaningful explanatory value beyond seasonal and temporal patterns.

Methods

Study Design and Setting

This was a retrospective observational time-series study conducted in the emergency department of a tertiary hospital. The study period extended from 1 January 2021 to 31 December 2025, comprising 1,826 consecutive calendar days.

Study Population

Hospital records were screened for all emergency department presentations assigned a diagnosis of syncope during the study period. All patient visits with a recorded syncope diagnosis were included. For each calendar day, the total number of syncope presentations was calculated. Days with at least one syncope presentation were classified as syncope-positive days, whereas days with no syncope presentation were classified as non-syncope days.

A total of 722 syncope-related emergency department visits were recorded. These visits occurred on 564 of 1,826 days, corresponding to a syncope-positive day rate of 30.9%.

Meteorological Data

Daily meteorological data were obtained from the Şişli/18401 meteorological station and merged with hospital data by calendar date. The analyzed meteorological variables were daily temperature, relative humidity, atmospheric pressure, precipitation, and wind speed.

Lagged and Derived Variables

To evaluate delayed meteorological effects, lag-1 and lag-2 values were calculated for temperature and atmospheric pressure. Lead-1 values were also explored descriptively to assess temporal patterns around syncope-positive days. Daily change variables were calculated as the difference between consecutive days for each meteorological parameter. These variables were intended to capture short-term meteorological instability rather than absolute exposure alone.

Outcomes

The primary outcome was the daily number of syncope presentations. The secondary outcome was syncope-day occurrence, defined as the presence of at least one syncope presentation on a given calendar day.

Statistical Analysis

Continuous meteorological variables were summarized as mean $\pm$ standard deviation. Categorical or grouped variables were summarized using counts and percentages. Meteorological characteristics were compared between syncope and non-syncope days using two-sample t-tests and Wilcoxon rank-sum tests. Spearman rank correlations were calculated between meteorological variables and daily syncope counts across lag windows from -3 to $+3$ days.

Two multivariable regression approaches were used. First, negative binomial regression was fitted to model daily syncope counts, with results reported as incidence rate ratios. Negative binomial regression was selected because daily count data were sparse and potentially overdispersed. Second, binary logistic regression was fitted to model syncope-day occurrence, with results reported as odds ratios. Both models included meteorological variables, daily changes, season, and calendar year. Spring was used as the reference category for season.

Generalized additive models with a negative binomial family were used to assess potential non-linear associations between meteorological variables and syncope counts. Model fit was compared using the Akaike Information Criterion. All analyses were conducted in R version 4.4. A two-sided p value below 0.05 was considered statistically significant.

Results

General Characteristics

During the five-year study period, 722 syncope presentations were recorded across 1,826 days. The mean daily syncope count was 0.40 cases per day, with a range of 0–4 cases per day. At least one syncope presentation occurred on 564 days, representing 30.9% of all days. (Fig. 1A).

The mean patient age was 51.3 ± 19.9 years, with a range of 5.4 to 99.7 years. Among all patients, 224 patients were aged 18–40 years (mean 28.9 years), 226 were aged 41–60 years (mean 50.4 years), 205 were aged 61–80 years (mean 69.6 years), 56 were older than 80 years (mean 85.6 years), and 11 were younger than 18 years (mean 14.4 years). Mean patient age remained relatively stable across the study years, at 49.2 years in 2021, 52.7 in 2022, 54.6 in 2023, 49.9 in 2024, and 50.7 in 2025.

Meteorological Characteristics of Syncope and Non-Syncope Days

Meteorological characteristics were similar between syncope and non-syncope days. Mean temperature was 16.8°C on syncope days and 16.4°C on non-syncope days. Mean relative humidity was 77.8% on syncope days and 77.2% on non-syncope days. Mean atmospheric pressure was 1006.3 hPa on syncope days and 1006.5 hPa on non-syncope days. Precipitation and wind speed were also similar between groups. (Table 1).

Table 1
Meteorological Characteristics by Syncope Occurrence

Variable	No Syncope (n = 1262)	Syncope Day (n = 564)
Temperature (°C)	16.4 ± 7.2	16.8 ± 7.3
Humidity (%)	77.2 ± 11.9	77.8 ± 11.9
Pressure (hPa)	1006.5 ± 6.2	1006.3 ± 6.2
Precipitation (mm)	2.2 ± 6.1	2.3 ± 6.7
Wind Speed (m/s)	2 ± 0.5	2 ± 0.5
Temp Change (°C/day)	0 ± 1.9	0 ± 1.9
Pressure Change (hPa/day)	-0.1 ± 3.7	0.1 ± 3.7
Values are mean ± SD. Total study period: 2021–2025 (n = 1,826 days).		

In univariate analyses, none of the evaluated meteorological variables showed a statistically significant difference between syncope and non-syncope days. This was consistent for same-day temperature, humidity, pressure, precipitation, wind speed, daily meteorological changes, previous-day temperature and pressure, and next-day temperature and pressure. (Table 2).

Table 2
Univariate Associations with Daily Syncope Occurrence

Variable	No Syncope	Syncope	Difference	t-test p	Wilcoxon p
Temperature (°C)	16.418	16.768	0.350	0.3435	0.4289
Humidity (%)	77.172	77.760	0.588	0.3303	0.2354
Pressure (hPa)	1,006.470	1,006.264	-0.206	0.5278	0.3419
Precipitation (mm)	2.168	2.250	0.083	0.8026	0.3693
Wind Speed (m/s)	2.019	2.019	0.000	0.9875	0.9599
Temperature Change (°C/day)	-0.021	0.018	0.040	0.6800	0.6375
Humidity Change (%/day)	-0.146	0.319	0.465	0.3568	0.4729
Pressure Change (hPa/day)	-0.050	0.140	0.190	0.3333	0.5089
Wind Speed Change (m/s per day)	0.004	-0.005	-0.009	0.6996	0.7322
Temperature, previous day (°C)	16.437	16.750	0.313	0.3950	0.4828
Pressure, previous day (hPa)	1,006.528	1,006.140	-0.388	0.2381	0.0779
Temperature, next day (°C)	16.354	16.917	0.563	0.1265	0.1401
Pressure, next day (hPa)	1,006.399	1,006.429	0.030	0.9261	0.8354
No variable reached statistical significance (all p > 0.05).					

Lagged Correlations

Spearman rank correlations between meteorological variables and daily syncope counts were uniformly weak across lag windows from – 3 to + 3 days. Absolute correlation coefficients did not exceed 0.049, indicating no meaningful monotonic association between daily syncope burden and the meteorological variables examined. (Fig. 3A).

Seasonal and Monthly Patterns

Daily syncope counts differed significantly across seasons. Spring accounted for 197 cases across 460 days, summer for 191 cases across 460 days, winter for 188 cases across 451 days, and autumn for 146 cases across 455 days. Autumn had the lowest syncope-positive day rate and the lowest mean daily syncope count. (Fig. 2A).

Monthly variation was also observed descriptively. Higher syncope rates were observed in June, May, January, July, and April, while lower rates were observed in November, October, August, March, September, February, and December. However, differences across months did not reach statistical significance. (Fig. 1B).

Day-of-Week Patterns

Syncope presentations showed descriptive variation across days of the week. Monday had the highest syncope-positive day rate, followed by Tuesday, Thursday, Wednesday, Friday, Saturday, and Sunday. However, weekday differences were not statistically significant, and no pairwise comparison remained significant after Bonferroni correction. The apparent weekday-to-weekend gradient may reflect healthcare-seeking behavior rather than a true biological effect.

Multivariable Regression Models

In the negative binomial regression model, autumn was associated with a significantly lower syncope rate compared with spring. The incidence rate ratio for autumn was 0.69, corresponding to an approximately 31% lower daily syncope rate. Calendar year was significantly associated with increasing syncope counts, with an incidence rate ratio of 1.085 per year. (Table 3).

Table 3
Multivariable Regression Results

Variable	IRR (95% CI)	NB p	NB sig	OR (95% CI)	LR p	LR sig
Intercept	0 (0–0)	0.0068	***	0 (0–0)	0.0010	***
Temperature (°C)	1.0268 (1–1.0546)	0.0501		1.0353 (1.0008–1.0714)	0.0460	***
Humidity (%)	1.0058 (0.9967–1.015)	0.2142		1.0086 (0.9968–1.0205)	0.1546	
Pressure (hPa)	1.0006 (0.9826–1.019)	0.9474		1.0031 (0.9798–1.027)	0.7975	
Precipitation (mm)	1.0069 (0.992–1.0206)	0.3394		1.0098 (0.9904–1.029)	0.3134	
Wind Speed (m/s)	0.9976 (0.8345–1.189)	0.9783		1.0407 (0.8273–1.3062)	0.7319	
Temperature Change (°C/day)	1.04 (0.9811–1.1023)	0.1881		1.0556 (0.9791–1.1381)	0.1587	
Pressure Change (hPa/day)	1.0113 (0.9841–1.0391)	0.4224		1.0219 (0.9864–1.0587)	0.2291	
Humidity Change (%/day)	1.0036 (0.993–1.0143)	0.5023		1.0069 (0.9932–1.0208)	0.3241	
Season: Winter	1.0835 (0.8391–1.4011)	0.5387		1.1157 (0.8004–1.5577)	0.5189	
Season: Autumn	0.691 (0.5229–0.912)	0.0092	***	0.6218 (0.4341–0.8889)	0.0093	***
Season: Summer	0.7456 (0.5248–1.0611)	0.1023		0.7445 (0.471–1.1772)	0.2065	
Year	1.0849 (1.0217–	0.0078	***	1.1355 (1.0511–	0.0013	***

RR = Incidence Rate Ratio (Negative Binomial regression); OR = Odds Ratio (Logistic regression). 95% confidence intervals shown in parentheses. Reference category for season: Spring. Intercept not shown. Bold = $p < 0.05$. * Temperature reached significance only in the logistic model ($p = 0.046$) and was borderline in the Negative Binomial model ($p = 0.050$); this finding should be interpreted with caution. NB = Negative Binomial; LR = Logistic Regression. Both models adjusted for all variables listed simultaneously.

Variable	IRR (95% CI)	NB p	NB sig	OR (95% CI)	LR p	LR sig
	1.1522)			1.2272)		
RR = Incidence Rate Ratio (Negative Binomial regression); OR = Odds Ratio (Logistic regression). 95% confidence intervals shown in parentheses. Reference category for season: Spring. Intercept not shown. Bold = $p < 0.05$. * Temperature reached significance only in the logistic model ($p = 0.046$) and was borderline in the Negative Binomial model ($p = 0.050$); this finding should be interpreted with caution. NB = Negative Binomial; LR = Logistic Regression. Both models adjusted for all variables listed simultaneously.						

In the logistic regression model, autumn was also associated with lower odds of a syncope-positive day compared with spring. Calendar year was associated with increased odds of syncope-day occurrence. Temperature showed a borderline positive association in the logistic model, with an odds ratio of 1.035 per 1°C increase. This association was not consistently reproduced in the count-based model and should therefore be interpreted cautiously. (Table 3). Temperature-category patterns are shown in Fig. 2B.

Humidity, atmospheric pressure, precipitation, wind speed, temperature change, pressure change, and humidity change were not significantly associated with syncope burden in either multivariable model.

Non-Linear Effects and Model Fit

Generalized additive models did not demonstrate meaningful non-linear meteorological effects. Estimated degrees of freedom for smooth terms were approximately 1, suggesting predominantly linear rather than non-linear relationships. Although temperature showed a statistically borderline smooth effect, the overall explanatory value of the model was low.

Model comparison using the Akaike Information Criterion showed that the model including meteorological variables, season, daily changes, and calendar year had the lowest AIC. However, the model including meteorological variables and season alone had a very similar AIC, suggesting that daily change variables contributed minimally beyond season and year. The adjusted R-squared of the generalized additive model was 0.009, indicating that the included predictors explained less than 2% of the variation in daily syncope counts. (Table 4).

Table 4
Model Comparison by AIC

Model	df	AIC	Δ AIC	Best.fit
M1: Meteorological variables only	7	2,786.62	7.37	
M2: M1 + Season	10	2,779.71	0.47	
M3: M2 + Daily changes	12	2,782.63	3.38	
M4: M3 + Year (full model)	14	2,779.24	0.00	✓
Δ AIC calculated relative to the best-fitting model (M4). Models with Δ AIC < 2 are considered to have comparable empirical support. M2 and M4 show near-identical fit (Δ AIC = 0.47), suggesting that daily change variables contribute minimally beyond season and year. df = degrees of freedom (number of estimated parameters including dispersion).				

Pressure Change Threshold Analysis

Threshold analysis of daily atmospheric pressure change showed a descriptive U-shaped pattern. The highest syncope-positive day rates were observed on days with extreme pressure drops and extreme pressure increases, compared with stable-pressure days. However, these extreme categories included relatively few observations and did not reach statistical significance. Therefore, this finding should be considered exploratory and hypothesis-generating. (Fig. 3B).

Discussion

In this five-year retrospective time-series study, routine daily meteorological variables showed limited predictive value for emergency department presentations due to syncope. Same-day, lagged, and lead meteorological parameters were not significantly associated with syncope occurrence in univariate analyses, and Spearman correlations between meteorological variables and daily syncope counts were uniformly weak. In multivariable models, season and calendar year were more consistently associated with syncope burden than individual meteorological variables. Autumn was associated with significantly lower syncope rates compared with spring, whereas syncope presentations increased gradually across calendar years. Temperature showed only a borderline positive association in the logistic regression model and was not consistently significant in the negative binomial count model. Therefore, this finding should be interpreted cautiously.

Our findings are consistent with the limited and heterogeneous literature on meteorological determinants of syncope. Anderson et al. investigated emergency department syncope attendances in relation to temperature and humidity and did not identify a strong direct relationship [10]. Similarly, Galli et al. reported that daily maximum temperature did not predict emergency department visits for syncope, although air temperature variability was associated with syncope patterns [9]. The present study extends these findings by evaluating a broader set of meteorological parameters, including temperature, humidity, atmospheric pressure, precipitation, wind speed, daily changes, lagged values, and non-linear associations. In contrast to the hypothesis that abrupt weather changes may trigger syncope, our lagged

correlation analyses and daily change models did not demonstrate a robust meteorological signal. This suggests that routine weather parameters alone may be insufficient for explaining short-term variation in daily syncope presentations.

The weak association observed in our study does not exclude a physiological role of environmental stress in selected patients. Heat stress can impair orthostatic tolerance through peripheral vasodilation, central hypovolemia, reduced cerebral blood velocity, and altered cardiovascular reflex responses [14–16]. These mechanisms are relevant to reflex syncope and orthostatic hypotension, particularly among older adults, dehydrated individuals, and patients receiving antihypertensive, diuretic, or vasodilator medications [1, 2, 14]. However, emergency department syncope presentations are clinically heterogeneous, and our study did not classify patients according to syncope subtype. It is possible that weather-related effects are present only in specific subgroups, such as patients with orthostatic hypotension, reflex syncope, heat exposure, volume depletion, or frailty. Pooling all syncope diagnoses together may dilute subtype-specific associations.

The borderline association between temperature and syncope-day occurrence in the logistic regression model deserves careful interpretation. Although the odds of a syncope-positive day increased modestly per 1°C rise, the effect was not consistently reproduced in the negative binomial model of daily syncope counts. Moreover, the generalized additive model explained less than 2% of the variation in daily syncope burden. This indicates that even when a statistically borderline temperature signal is detected, its clinical and operational predictive value is likely limited. Similar caution has been emphasized in environmental epidemiology, where statistically significant associations may have limited practical utility if the effect size is small, inconsistent across models, or vulnerable to residual confounding [17–20].

The significantly lower syncope burden observed in autumn compared with spring is an important finding. Seasonal patterns in syncope have been reported previously, including temperature-dependent and weekly patterns of different syncope etiologies [12]. However, seasonality may not be driven solely by measured weather parameters. Seasonal differences may reflect changes in outdoor activity, hydration habits, clothing, daylight duration, occupational routines, school calendars, respiratory infections, public holidays, and healthcare-seeking behavior [3, 4, 12]. In our study, autumn had the lowest syncope-positive day rate and the lowest mean daily syncope count, but individual meteorological variables did not explain this pattern. This supports the interpretation that season is acting as a composite marker of behavioral, environmental, and healthcare-utilization factors rather than a simple proxy for temperature or pressure.

The descriptive weekday-to-weekend gradient observed in this study also supports the role of healthcare-seeking behavior. Monday and Tuesday had higher syncope-positive day rates, while Saturday and Sunday had lower rates; however, the differences were not statistically significant. Previous work has suggested that syncope etiologies and presentations may show weekly variation [12]. In emergency department datasets, weekday effects may reflect access to outpatient care, occupational exposure, referral patterns, patient preferences, or delayed presentation after weekend symptoms. Because our

weekday analysis did not reach statistical significance, this finding should be considered descriptive and hypothesis-generating rather than evidence of a biological weekly rhythm.

The year-on-year increase in syncope presentations was statistically significant in both count-based and binary models. Nevertheless, this trend should not be interpreted as a true increase in population-level syncope incidence without caution. The study period included the post-COVID-19 era, during which emergency department utilization, patient behavior, hospital access, coding practices, and referral pathways may have changed [21, 22]. In addition, the present analysis did not include total emergency department visits as an offset or denominator. Therefore, the annual increase may reflect changes in overall emergency department volume or institutional factors rather than an increase in syncope risk. Future studies should adjust for total emergency department census, population catchment changes, and coding stability over time.

The low explanatory value of the meteorological models is clinically relevant. Weather-based forecasting has potential value for conditions such as heat-related illness, cardiovascular events, respiratory exacerbations, renal injury, and trauma patterns [17–22]. However, our findings suggest that syncope-related emergency department demand may not be reliably predicted using temperature, humidity, atmospheric pressure, precipitation, and wind speed alone. More accurate prediction would likely require integration of patient-level clinical variables, syncope subtype, medication exposure, frailty, hydration status, indoor and occupational exposure, apparent temperature or heat index, air pollution, public holidays, population mobility, and total emergency department volume [13, 14, 17, 21–23].

The absence of air pollution data is another important limitation. Recent environmental health studies increasingly emphasize that meteorological variables may interact with air pollutants in relation to acute cardiovascular presentations [23–25]. Temperature and humidity can modify the effect of air pollutants, while atmospheric pressure, wind, and precipitation may influence pollutant dispersion. Therefore, the lack of air pollution variables may partly explain why routine meteorological parameters alone had low explanatory power in our study. Future studies incorporating particulate matter, nitrogen dioxide, ozone, apparent temperature, and distributed lag non-linear models may better capture the environmental determinants of syncope [23–26].

This study has several strengths. It included a continuous five-year observation period covering 1,826 days and 722 syncope presentations. It evaluated multiple meteorological variables rather than temperature alone, incorporated lagged and derived variables, and used both negative binomial regression and logistic regression. Generalized additive models were also used to explore non-linear relationships. These features allowed us to test whether weather effects were same-day, delayed, linear, non-linear, or better captured by daily meteorological changes.

The study also has limitations. First, it was a single-center retrospective study, limiting generalizability. Second, syncope cases were identified from hospital records and diagnostic coding, which may introduce misclassification. Third, syncope subtype was not available; therefore, potential differences between reflex, orthostatic, cardiac, and unexplained syncope could not be examined. Fourth, patient-

level clinical variables such as comorbidities, medication use, hydration status, frailty, prodromal symptoms, and disposition were not included. Fifth, meteorological exposure was based on a single station and may not represent each patient's actual exposure. Sixth, indoor temperature, air conditioning use, occupational heat exposure, and mobility patterns were unavailable. Finally, although several lagged variables were examined, future studies using distributed lag non-linear models may better characterize delayed environmental effects.

In conclusion, this five-year emergency department study found no strong or consistent association between routine daily meteorological variables and syncope presentations. Although syncope burden was significantly lower in autumn and increased across calendar years, temperature, humidity, atmospheric pressure, precipitation, wind speed, and daily meteorological changes explained only a minimal proportion of daily variation. Temperature showed a borderline association only in the logistic model and should not be overinterpreted. These findings suggest that meteorological parameters alone are insufficient for predicting syncope-related emergency department demand. Future multicenter studies incorporating syncope subtype, patient-level clinical factors, total emergency department volume, air pollution, heat index, indoor exposure, and distributed lag modeling may better clarify the environmental determinants of syncope.

Strengths

This study has several strengths. First, it included a continuous five-year observation period, covering 1,826 consecutive days. Second, multiple meteorological variables were evaluated rather than temperature alone. Third, the analysis incorporated same-day, lagged, lead, and daily change variables. Fourth, both count-based and binary outcome models were used, allowing evaluation of daily syncope burden and syncope-day occurrence. Fifth, generalized additive models were used to assess potential non-linear meteorological effects.

Limitations

This study also has limitations. First, it was a single-center retrospective study, which may limit generalizability. Second, syncope cases were identified using hospital records and diagnostic coding; therefore, misclassification is possible. Third, syncope etiology was not classified into reflex, orthostatic, cardiac, or unexplained subtypes. Meteorological effects may differ between syncope mechanisms. Fourth, individual-level clinical factors such as comorbidities, medications, hydration status, prodromal symptoms, standing duration, and final diagnosis were not included. Fifth, meteorological exposure was based on a single weather station, which may not reflect each patient's true location or indoor exposure. Sixth, air pollution variables were not included, although recent evidence suggests that air pollutants and meteorological variables may interact in relation to syncope and cardiovascular presentations. Seventh, the study period included the post-COVID-19 era, during which emergency department utilization patterns may have changed. Finally, although several lagged and derived variables were examined, more advanced distributed lag non-linear models may better capture delayed environmental effects.

Conclusion

In this five-year emergency department time-series study, routine daily meteorological variables were not strongly or consistently associated with syncope presentations. Although syncope burden varied by season and was significantly lower in autumn compared with spring, temperature, humidity, atmospheric pressure, precipitation, wind speed, and short-term daily meteorological changes explained only a minimal proportion of daily variation. Temperature showed only a borderline and non-robust association. These findings suggest that meteorological parameters alone are insufficient for predicting syncope-related emergency department demand. Future multicenter studies incorporating syncope subtype, patient-level clinical characteristics, total emergency department volume, air pollution, heat index, and distributed lag models may better clarify the environmental determinants of syncope.

Declarations

Authorship Contributions

Author Contributions

Caner ÇELİK: Project Management, Conceptualization, Literature Research, Original Draft Writing, Analysis.

Murat CARUS: Literature Research, Data Collection

Eren GÖKDAĞ: Literature Research, Statistical Study, Analysis.

Ethics Approval and Consent to Participate

This study was approved by the Memorial Şişli Hospital Ethics Committee (approval number: 003; approval date: 22 September 2025). The study was conducted in accordance with the principles of the Declaration of Helsinki. Because of the retrospective design of the study and the use of anonymized routinely collected hospital record data, the requirement for informed consent to participate was waived by the Memorial Şişli Hospital Ethics Committee. No identifiable patient information was used in the analysis or included in the manuscript.

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Competing interests

The authors declare no competing interests.

Data availability

The de-identified dataset used and/or analyzed during the current study is available from the corresponding author upon reasonable request. Due to patient privacy and institutional regulations, the data are not publicly available.

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Figures

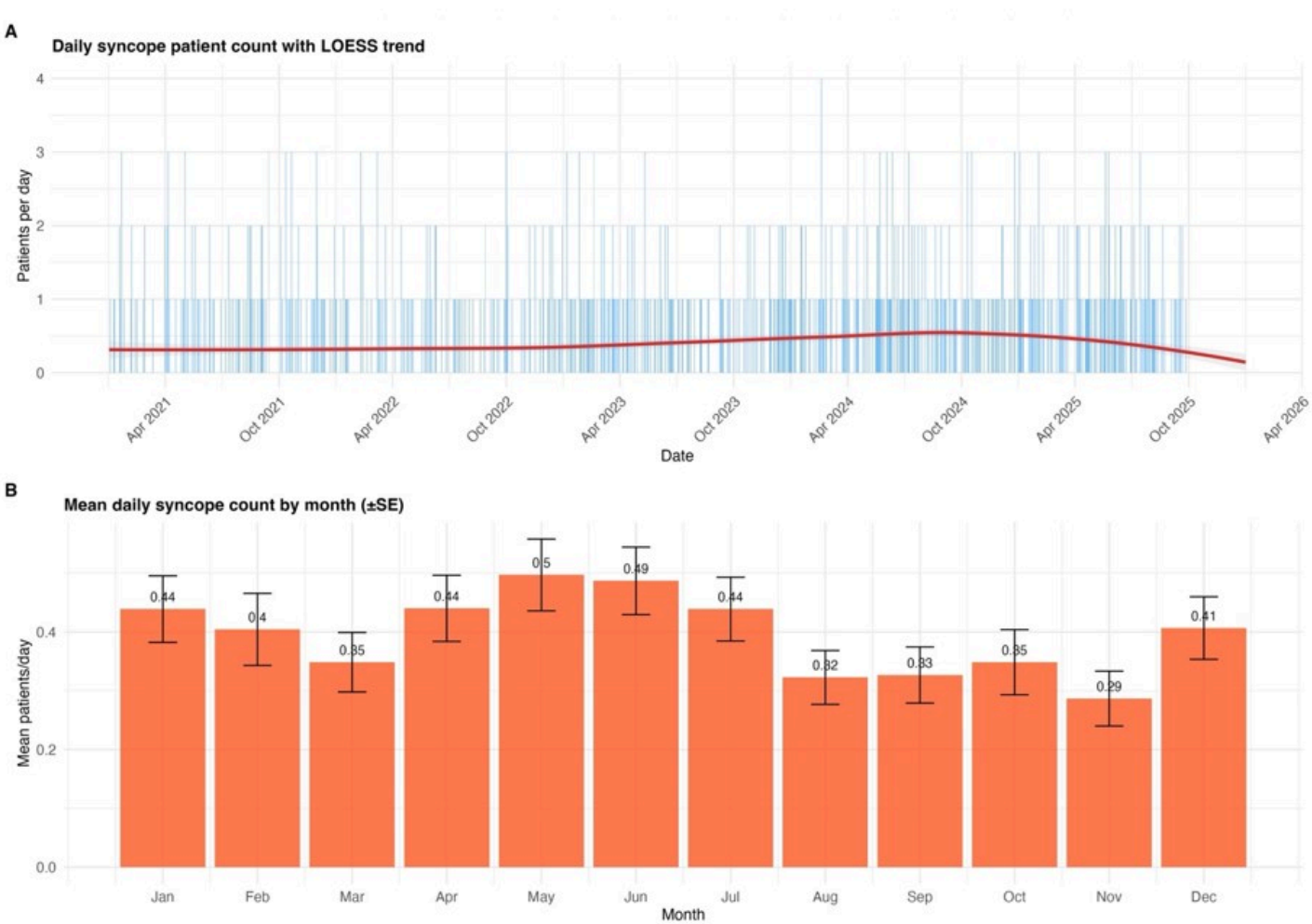


Figure 1

Temporal distribution of daily syncope cases (2021-2025). (A) Daily syncope patient counts with LOESS smoothing trend (red line, shaded 95% CI). (B) Mean daily syncope count by calendar month (bars $\pm$ standard error).

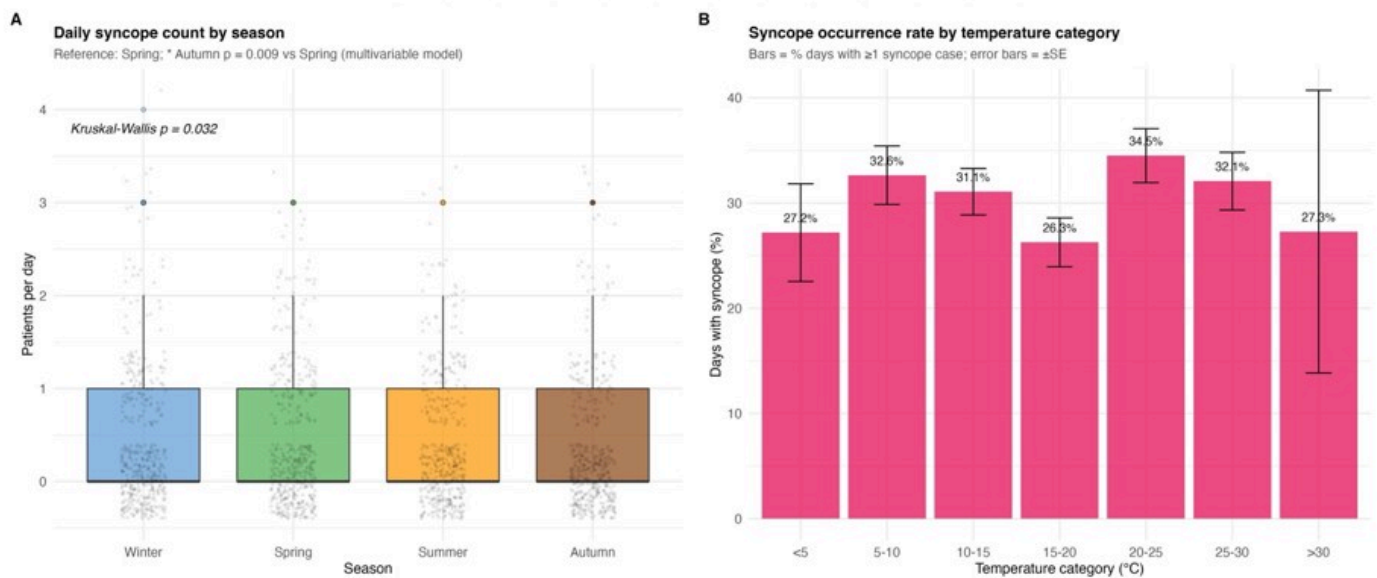


Figure 2

Seasonal patterns and temperature effects on syncope occurrence. (A) Distribution of daily syncope counts by season; Kruskal-Wallis $p = 0.032$. Autumn was significantly lower than Spring in multivariable models ($p = 0.009$). (B) Percentage of days with at least one syncope case across 2°C temperature categories (bars $\pm$ standard error).

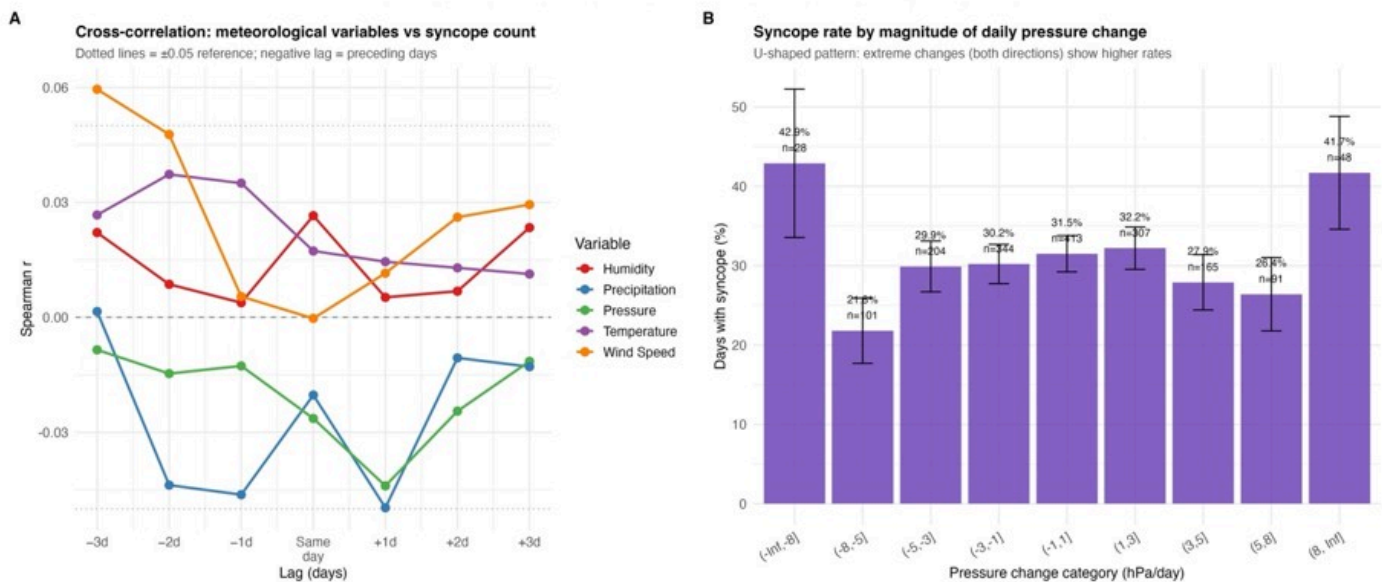


Figure 3

Lag effects and pressure change threshold analysis. (A) Spearman cross-correlations between five meteorological variables and daily syncope count at lags from -3 to +3 days; dotted lines indicate ± 0.05

reference. (B) Syncope occurrence rate by magnitude of daily atmospheric pressure change; numbers above bars indicate percentage and sample size per category.