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The role of climatic factors and air quality on the temporal patterns of suicide attempts in Balıkesir, Turkey (2017–2024)

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Abstract

Introduction and Objective. The aim of this ecological study is to evaluate the potential relationships between the incidence of suicide attempts and climatic factors, as well as air quality parameters, in Balikesir, Turkey.

Materials and Method. Daily counts of cases of attempted suicide, climate, and air quality data were used. Prior to analysis, logarithmic transformation was applied to the data in order to stabilize variance. Data analysis was performed in EViews 10 using descriptive statistics (annual, monthly, weekly patterns) and ARMA error regression (ARIMAX). Stationarity was assessed with the ADF test, while the basic model structure was determined using ACF/PACF plots.

Results. A total of 1,413 cases of attempted suicide, with a mean age of 26.9±14.2 years and 64.0% females, were included. Case distributions revealed a bimodal seasonal pattern (spring/early summer and winter) and a weekly rhythm with a marked decrease on Thursdays. Time series analyses indicated a strong association between the incidence of suicide attempts and its own short-term past values, with the ARMA(1,1) model providing the best fit. None of the lagged climatic, air quality, or seasonal dummy variables added to the model had a statistically significant effect on daily incidence (p>0.05).

Conclusions. The findings of this study suggest that the predominant factor shaping the daily course of the incidence of suicide attempt in Balıkesir is the short-term autocorrelation structure of the series itself. The temporal dynamics and the potential effects of environmental factors may be more likely to operate through indirect mechanisms or cumulative influences, rather than immediate fluctuations.

Key words

suicide attempt, time series analysis, air quality, seasonality, climatic factors

INTRODUCTION

Suicide remains a lifelong risk and a major global problem for public health. Each case has the potential to profoundly and persistently affect not only the individual but also the family and the wider community. Globally, suicide is recognized as one of the leading causes of death, particularly among young adults. Every year, approximately 720,000 people die by suicide worldwide, and many more attempt suicide. About three-quarters of all suicides occur in low- and middle-income countries [1]. According to data from the Turkish Statistical Institute, in 2021, the crude suicide rate in Turkey was 4.9 per 100,000, while in Balıkesir – the study area – it was recorded as 5.7 per 100,000 [2]. Despite its prevalence, suicide is considered preventable through well-planned, evidence-based, and low-cost public health interventions [1].

For interventions to be effective, however, it is crucial to understand the causes of suicide and the influencing factors. Suicide is known to be associated with a wide range of individual, biological, and environmental factors, and their complex interplay may increase suicidal tendency [3, 4]. In particular, the seasonality of suicide and its susceptibility to environmental influences have long been a focus of research. Climatic factors, such as daily sunlight duration and temperature, have been widely investigated. While some studies suggest that rising temperatures and sunlight exposure increase risk [5, 6], others report weak or inconsistent associations, often moderated by additional factors [7, 8].

Poor air quality has been identified as a contributor to suicidal behaviour, in addition to its well-documented adverse health effects; in particular, several air quality parameters -PM10, PM2.5, NO2, O3, and SO2 – have drawn attention in the literature [9, 10]. A growing body of evidence suggests that short-term exposure to pollutants such as PM2.5 may increase suicide risk in the days following exposure [9, 10].

Despite the large number of studies, the evidence regarding the association between suicides and environmental factors remains inconsistent. Findings often vary depending on region, climatic characteristics, and methodological approaches. Since both suicide and environmental factors tend to exhibit strong seasonal patterns, an important question arises: does the association reflect a causal relationship, or rather a shared underlying seasonal rhythm? Accurately modelling these complex temporal dynamics has the potential to fill important gaps in the literature.

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The aim of this study was to investigate the temporal patterns of visits to hospital emergency department due to suicide attempts, and to examine the effects of climatic factors and air quality on these patterns using time series analysis.

MATERIALS AND METHOD

This study was designed with an ecological approach. Prior to the study, approval was obtained from the Non-Interventional Ethics Committee of Atatürk City Hospital (Decision No: 2024/12/82, dated: 26.12.2024), along with administrative permissions for data use.

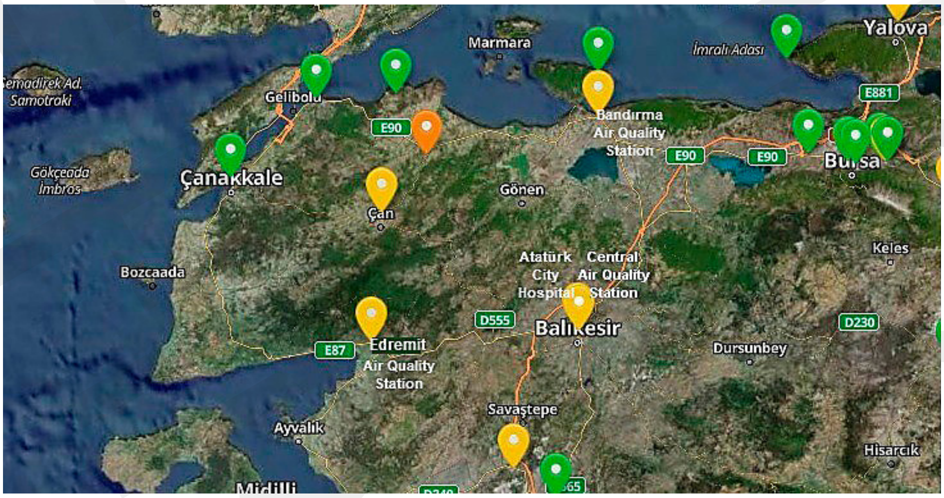
The study was conducted in Balıkesir, a province located in western Turkey. The city has coastlines along both the Marmara Sea and the Aegean Sea, and thus has the characteristics of a temperate transitional climate. The study data consisted of records of admissions to Balıkesir Atatürk City Hospital due to suicide attempts between 1 January 2017 – 31 December 2024. Cases associated with ICD codes X60–84 were screened, and data were collected on patients' gender, age, date of admission (day, month, year), prognosis (hospitalization, outpatient treatment, etc.). Cases residing outside Balıkesir province, those with incomplete records, and duplicate entries were excluded. Data were obtained from hospital record systems. Mid-year population data of the province for each study year were retrieved from the Turkish Statistical Institute [2].

Daily climatic factors used in the study [mean temperature (°C), total precipitation (mm), average sunlight duration (hours/day)] were obtained from the Balıkesir Central Station of the Turkish State Meteorological Service. Although three air quality monitoring stations (Edremit, Bandırma, and Central) operate within Balıkesir province, this study used data only from the Central Station. This choice was made to ensure geographic alignment with the study population because Balıkesir Atatürk City Hospital primarily serves the central metropolitan area, as well as patients from distant coastal districts who generally visit their local healthcare facilities. Thus, the Central Station acts as a valid 'urban proxy' for the environmental exposure of the analyzed population, reflecting the urban micro-environment where most of the study group lives. A map illustrating the locations of the hospital, the measurement station, and the central residential area is provided as Supplementary Figure 1. Daily air quality parameters [PM10 (µg/m³), PM2.5 (µg/m³), SO_2 (µg/m³), NO_2 (µg/m³), O_3 (µg/m³), CO (µg/m³)] were obtained from the monitoring stations of the National Air Quality Monitoring Network operated by the Ministry of Environment, Urbanization and Climate Change [11].

Statistical analysis. Data analysis and visualization were performed using EViews (v10.0) and Tableau Public (v2022.4). The analysis process included descriptive statistics, evaluation of annual incidence trends, and distributions of variables across years/months, and time series techniques (stationarity tests, identification of the baseline model, and modelling of the lagged effects of environmental factors).

Descriptive statistics (mean, standard deviation, total, count, and percentage) were used to summarize the data. Annual and monthly incidence rates of suicide attempts (per 100,000 population) were calculated by dividing the number of cases recorded in the relevant period by the mid-year population. Incidence trends over time were assessed using trend analysis. Instantaneous relationships between daily incidence rates and environmental factors were examined using Spearman's rank correlation analysis.

To stabilize variance and approximate normal distribution, natural logarithmic transformation was applied to incidence data and all air quality parameters at the outset of time series modelling. For series containing zero values, the transformation [log(variable + 1)] was used. Short-term and lagged relationships between incidence rates and environmental factors were investigated using ARMA error regression (ARIMAX) modeling. Stationarity of the series was first assessed using the Augmented Dickey-Fuller (ADF) unit root test. To model the autocorrelation structure of the dependent variable 'log_incidence', Autocorrelation (ACF) and Partial Autocorrelation (PACF) functions were examined, and a baseline ARMA(1,1) model constructed. To avoid multicollinearity, primary indicators representing different pollution sources were selected. Accordingly, PM2.5 was used to represent particulate pollution, and SO_2 and O_3 were included to represent traffic- and combustion-related pollutants.



Supplementary Figure 1. Map of the study area illustrating the locations of Balıkesir Atatürk City Hospital, the central air quality monitoring station, and the central residential area. The use of the Central Station ensured spatial alignment with the hospital's primary urban catchment area, minimizing exposure misclassification

Table 1. Distribution of cases according to demographic and clinical characteristics (2017–2024)

Variables	Mean / Count	SD / Percent
Age (years)*	26.9	14.2
Gender		
Male	509	36.0
Female	904	64.0
Prognosis		
Discharged	1205	85.3
Hospitalized	176	12.5
Deceased	18	1.3
Referred	14	1.0

* Continuous variable

Environmental variables (temperature, precipitation, sunlight, PM2.5, SO_2, O_3) and seasonal dummy variables (autumn as the reference category) were systematically incorporated into the baseline model with 1 – 7-day lags.

The performance and validity of the final models were assessed using the statistical significance of coefficients (p-values), the Durbin-Watson statistic (to evaluate autocorrelation of residuals), and inverted AR/MA roots (to assess model stability). A p-value <0.05 was considered statistically significant in all analyses.

RESULTS

Table 1 presents the demographic and clinical characteristics of the cases included in the study. A total of 1,413 cases were analyzed, with a mean age of 26.9±14.2 years, of whom 64.0% were female. Of these, 85.3% were discharged after emergency department intervention, 12.5% were hospitalized, and 1.3% resulted in death.

Table 2 presents the mid-year population of the study region, the number of cases, incidence rates, and distributions of environmental factors (climatic and air quality parameters). Across the study period, a general downward trend in the incidence of suicide attempts was observed, accompanied by noticeable fluctuations between years. The highest incidence was recorded in 2019 at 64.8 per 100,000, while the lowest was observed in 2024 at 37.0 per 100,000. Model-based forecasts predicted that the incidence would stabilize at around 45.0 per 100,000 over the next two years (Fig. 1). No statistically significant association was found between the incidence of suicide attempts and any of the climatic or air quality parameters (all p>0.05).

Table 3 presents the monthly distributions of the study variables for the period 2017–2024. The seasonal distribution of suicide attempt incidence exhibited a bimodal pattern. The first peak occurred in May (4.6±1.9) and June (4.5±1.2), and the second in December (4.5±2.5). The lowest incidence

Table 2. Mid-year populations, case numbers, incidences and distributions of environmental factors for Balıkesir province (2017–2024)

				Temperature (°C)	Precipitation (mm)	Sunlight duration (h/day)	PM_{10} (µg/m³)	$PM_{2.5}$ (µg/m³)	SO_2 (µg/m³)	NO_2 (µg/m³)	O_3 (µg/m³)	CO (µg/m³)
Years	Mid-year population	Case Number	Incidence (per 100,000)	Mean (SD)	Sum	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
2017	355.972	168	47.2	14.7 (8.1)	445.2	7.0 (3.6)	56.1 (40.3)	16.8 (17.3)	7.4 (9.7)	109.7 (149.4)	42.2 (23.5)	1107.9 (907.6)
2018	362.222	226	62.4	15.8 (7.7)	545.9	6.7 (3.5)	47.9 (35.1)	16.2 (18.5)	7.3 (9.2)	55.1 (107.3)	43.65 (24.3)	996.4 (835.7)
2019	364.370	236	64.8	15.5 (7.7)	478.5	7.1 (3.6)	44.5 (29.6)	16.8 (17.3)	6.8 (5.6)	129.4 (163.4)	53.3 (32.6)	1043.5 (748.9)
2020	366.270	141	38.5	15.3 (7.7)	334.1	7.1 (3.4)	47.2 (33.2)	13.5 (14.2)	12.8 (18.2)	143.1 (163.6)	42.1 (23.6)	853.4 (524.3)
2021	370.236	152	41.1	15.1 (8.0)	593.0	6.8 (3.4)	61.0 (39.9)	13.8 (15.3)	19.1 (19.2)	129.6 (148.8)	43.9 (23.8)	614.3 (438.7)
2022	371.098	180	48.5	14.9 (8.3)	405.1	7.0 (3.3)	61.3 (38.4)	13.7 (10.8)	14.4 (9.4)	102.0 (146.6)	50.9 (30.0)	666.6 (423.8)
2023	374.304	171	45.7	15.7 (7.7)	444.2	6.0 (3.0)	55.7 (29.6)	16.0 (10.2)	7.4 (6.0)	31.3 (76.7)	49.3 (31.1)	669.2 (468.5)
2024	375.775	139	37.0	16.2 (8.0)	376.2	6.5 (3.3)	46.9 (27.2)	16.4 (12.4)	2.9 (2.3)	129.2 (145.9)	45.2 (25.4)	1053.8 (460.9)

Table 3. Distribution of incidence and environmental factors by month (2017–2024)

Months	Incidence (per 100,000)	Temperature (°C)	Precipitation (mm)	Sunlight duration (h/day)	PM10 (µg/m³)	PM2.5 (µg/m³)	SO2 (µg/m³)	NO2 (µg/m³)	O3 (µg/m³)	CO (µg/m³)
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
January	3.3 (1.5)	5.2 (4.4)	2.7 (6.8)	4.2 (2.5)	69.8 (50.6)	22.0 (18.6)	14.4 (13.1)	117.5 (158.3)	29.9 (16.5)	1218.3 (843.1)
February	3.5 (1.5)	6.8 (3.9)	1.7 (5.2)	4.8 (2.7)	63.2 (41.1)	23.3 (17.5)	14.2 (12.6)	142.1 (180.8)	34.7 (17.6)	1108.3 (641.8)
March	4.5 (0.6)	8.8 (3.5)	1.6 (4.2)	5.5 (3.0)	54.7 (31.9)	17.9 (12.0)	12.2 (10.6)	129.1 (159.1)	42.1 (18.3)	1001.6 (549.6)
April	3.9 (1.7)	13.2 (3.3)	1.7 (5.1)	7.1 (3.4)	45.1 (21.0)	14.0 (6.8)	10.6 (9.5)	104.3 (134.6)	48.4 (21.1)	759.5 (334.5)
May	4.6 (1.9)	17.9 (3.2)	0.9 (2.6)	7.8 (3.4)	38.7 (14.2)	10.0 (5.3)	11.2 (19.6)	98.4 (137.2)	52.9 (21.7)	640.8 (287.9)
June	4.5 (1.2)	23.0 (2.6)	1.1 (4.2)	9.3 (3.0)	35.9 (12.4)	8.0 (4.0)	6.6 (5.2)	93.8 (112.2)	57.4 (28.4)	671.7 (342.4)
July	4.1 (1.4)	25.7 (2.0)	0.6 (4.3)	10.4 (2.4)	34.4 (12.9)	7.3 (4.7)	5.6 (4.6)	60.8 (84.7)	71.2 (29.1)	549.4 (259.3)
August	3.5 (1.5)	25.9 (1.6)	0.1 (0.5)	9.4 (1.9)	36.9 (13.6)	7.2 (4.5)	4.9 (4.8)	69.0 (98.0)	71.9 (28.3)	590.9 (244.0)
September	3.7 (1.4)	21.9 (2.7)	0.2 (1.3)	7.8 (2.1)	42.5 (14.5)	8.5 (5.1)	7.2 (11.3)	80.7 (157.8)	61.5 (25.1)	577.3 (303.7)
October	4.0 (1.3)	16.4 (2.9)	0.6 (2.5)	6.2 (2.2)	58.2 (30.2)	15.2 (10.9)	6.3 (4.4)	94.7 (153.6)	37.5 (17.3)	707.3 (395.1)
November	3.8 (1.0)	11.5 (3.7)	1.8 (4.9)	4.7 (2.6)	75.7 (43.8)	24.5 (17.5)	7.3 (6.1)	127.2 (159.5)	26.6 (17.3)	1192.7 (859.0)
December	4.5 (2.5)	8.0 (3.9)	1.9 (4.4)	4.0 (2.5)	76.2 (50.6)	27.4 (25.8)	17.0 (22.1)	129.7 (157.2)	20.9 (13.8)	1501.2 (1102.7)

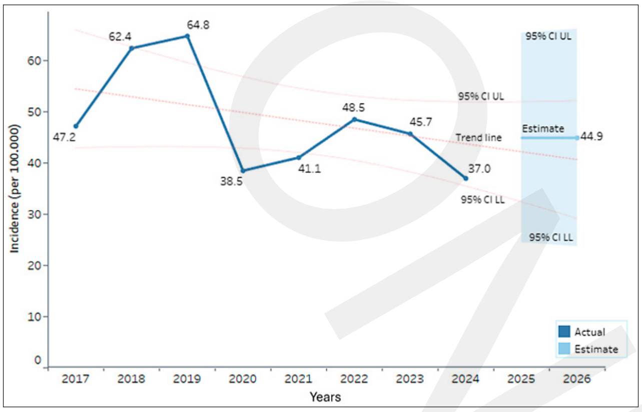


Figure 1. Temporal trends and forecast of suicide attempt incidence (2017–2026)

rates were recorded in January (3.3±1.5) and August (3.5±1.5). Environmental parameters also showed clear seasonal patterns. Concentrations of major pollutants (such as PM2.5, SO_2, and CO) peaked in winter (November–February), while O_3 concentrations peaked in summer (June–August). The December peak in incidence coincided with the period when PM2.5, SO_2, and CO concentrations were highest and sunshine duration was lowest. In contrast, the May–June peak occurred during a period when winter pollution had declined (Fig. 2).

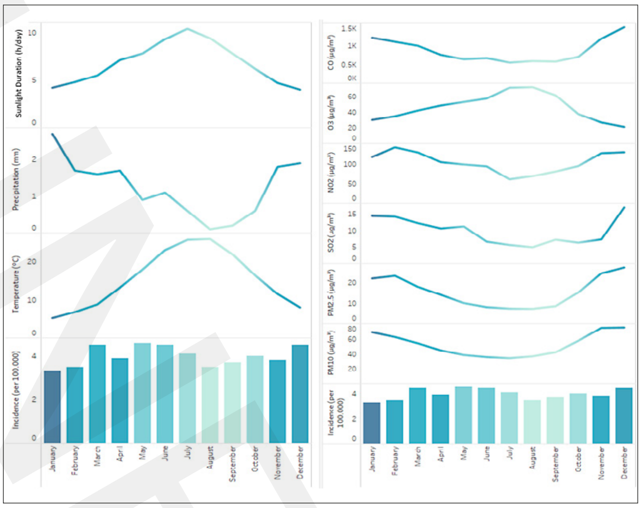


Figure 2. Seasonal patterns of suicide attempt incidence, climatic and air quality parameters

The study also examined the distribution of suicide attempt incidence by day of the week (Fig. 3). Findings showed that incidence rates were higher on Wednesdays, Fridays, and Saturdays, and significantly lower on Thursdays.

The ARMA(1,1) model best represented the internal dynamics of suicide attempt incidence. All model coefficients [C, AR(1), MA(1)] were statistically significant (all p<0.001). The results of the final baseline model are presented in Table 4.

To test the main hypotheses of the study, climatic and air quality parameters were added to the ARMA(1,1) model, with lag values ranging from 1 – 7 days. In addition, seasonal dummy variables (winter, spring, summer) were included to model seasonal patterns. Analyses showed that, after accounting for the ARMA(1,1) structure, none of the lagged environmental variables (PM2.5, SO_2, O_3, temperature,

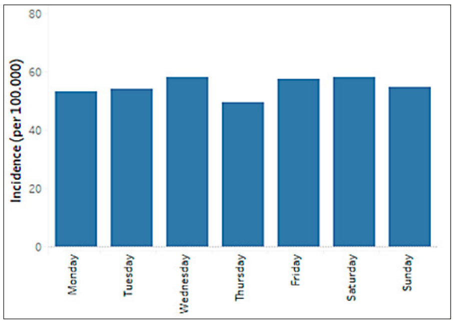


Figure 3. Weekly distribution of suicide attempt incidence

Table 4. Estimation results of the final baseline ARMA(1,1) model for suicide attempt incidence

Variable	Coefficient	SE	t-Statistic	*p*-Value
C	0.109	0.012	9.153	<0.001
AR(1)	0.992	0.005	215.924	<0.001
MA(1)	-0.976	0.008	-118.725	<0.001

C – Constant; SE – Standart error; n= 2922; Adjusted R-squared= 0.014; Durbin-Watson stat= 2.021
Note: The dependent variable for the model is log_incidence.

daylight duration, etc.) nor seasonal dummy variables, had a statistically significant effect (p<0.05) on incidence.

DISCUSSION

The relationship between suicide attempts and environmental factors such as climate and air pollution has become an area of increasing interest. The findings of the present study confirmed the presence of strong seasonal and weekly rhythms in both suicide attempts and environmental variables. However, these parallels did not demonstrate statistical causality, and the study results revealed that none of the environmental factors had a significant impact on daily case counts.

The present study shows that the most dominant factors shaping the daily trajectory of suicide attempt behaviour were not external environmental factors, but rather the short-term past and internal momentum of the series itself. Indeed, the core model developed [ARMA(1,1)] demonstrated the statistical power of internal dynamics. The AR(1) coefficient of 0.992 indicates a strong 'systemic memory' in the temporal progression of suicide attempts. In a system with such high inertia, daily environmental fluctuations might act as weak signals that are often masked by the series' own internal rhythm. This implies that environmental factors might require extreme weather events or long-term, cumulative exposure to alter the baseline risk, rather than acting as daily triggers. This suggests that suicide attempt behaviour may possess a strong memory that begins as a breaking point, and tends to persist for a certain period at the individual or societal level. Furthermore, the hypothesis that mental health crises emerge more from an underlying vulnerability than from immediate triggers seem to be supported.

The bimodal seasonal pattern observed in suicide attempts in this study (particularly the secondary incidence peak in spring and early summer) is consistent with the literature reporting seasonality of suicide attempts [12, 13]. This finding is in line with studies conducted in Turkey, which report that suicide events occur most frequently in the spring and summer months (May, June, July) [14], as well as with the globally reported spring peak observed in both the northern and southern hemispheres [15]. However, it is noteworthy that the seasonal pattern observed in suicide attempt cases was not statistically significant in the time series model. This suggests that the seasonality observed in suicidal behaviour is too complex to be explained by simple climatic effects, and may instead involve various biopsychosocial mechanisms, such as neuroinflammation triggered by seasonal allergens [16].

The finding that environmental factors were statistically non-significant in the current models reflects the contradictory nature of the existing literature. For instance, while some studies have reported an association between daylight duration and suicide frequency, a comprehensive meta-analysis did not find a significant relationship [7]. Some studies even argue that the association between sunlight exposure and suicides may actually stem from the seasonality of suicide [17, 18]. Careful interpretation is needed when discussing the influence of sunshine or radiation. Findings from high-latitude regions, which experience large seasonal changes in day length and radiation, should not be directly compared with those from Balıkesir without accounting for these geographical differences. Similarly, the association between ambient temperature and suicidal behaviour remains inconsistent with studies reporting a positive relationship [5, 6], while others suggest that the association is confounded by other factors [5].

Regarding air pollution, although the literature generally points to a positive association [9], the findings of the present study did not confirm this. This may be due to the effect emerging from cumulative exposure rather than daily shocks, the strong ARMA(1,1) model overshadowing weaker signals of environmental factors, or unmeasured local factors masking these effects. In this context, air quality is not just a short-term biological factor but also an element of environmental quality of life. Air pollution can act chronically, potentially raising baseline stress levels and restricting outdoor physical activity. The lack of statistical significance in the presented model does not mean environmental factors have no effect; instead, their impact might be cumulative or absorbed into the strong short-term inertia of the series.

The weekly distribution of suicide attempts identified in this study diverges from the frequently discussed 'Monday peak' pattern in the literature [8, 19]. The observed peaks on Wednesdays and weekends and the sharp decline on Thursdays may reflect the influence of region-specific social rhythms, or weekly patterns in access to healthcare services. From a demographic perspective, the mean age of cases (26.9 years) concentrated in young populations are in line with WHO data [1], and the higher prevalence of suicide attempts among women (64%) [10] are important indicators supporting the literature. These findings highlight the necessity to develop prevention strategies that take into account the dynamics of specific risk groups in suicide prevention programmes.

Limitations of the study. The findings of the present study should be interpreted within the context of certain limitations. First, as the study was conducted with an ecological design, the results observed at the provincial level may not be valid at the individual level and may carry the risk of ecological fallacy.

Second, the study data were limited to the records of a single centre and did not include cases who never sought healthcare or who presented to different facilities. Similarly, relying on a single urban measurement point to assess environmental exposure is also a notable limitation. While it is a useful proxy for the central urban catchment area, it cannot capture the full micro-climatic diversity of the province.

Third, as the present study focused on environmental factors, numerous potential confounders could not be controlled. Fourth, the meteorological analysis included only primary indicators; future research should use more detailed parameters, such as diurnal temperature range, humidity, or biometeorological indices. Fifth, while the ARMA/ARIMAX approach effectively models temporal memory, its linear structure might miss non-linear or cumulative effects of environmental stressors.

Finally, the findings of this study are specific to Balıkesir and may have limited generalizability to other regions with different geographies, climatic zones, levels of air pollution, and social structures.

CONCLUSION

In this study, the potential relationships between suicide attempt incidence in Balıkesir and various climatic and air quality parameters were examined using a time-series analysis approach. Descriptive statistics revealed distinct seasonal patterns in both incidence rates and environmental factors.

In conclusion, within the limits of the applied methodology and available data, no statistically significant short-term relationship were found between daily environmental parameters and suicide attempts. However, this does not mean environmental factors are irrelevant. The strong internal autocorrelation of the series indicates that environmental influences might operate through more complex, indirect, or cumulative pathways that require future research using non-linear or episodic models.

Declaration of competing interest. The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this study.

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