



## ORIGINAL ARTICLE

# Relationship Between Daily Meteorological Parameters and Stab Wounds, Firearm Wounds and Assault

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## Abstract

**Introduction:** In this study, we aimed to investigate the effect of daily meteorological parameters on the number of patients applying to the emergency department as a result of exposure to aggressive behavior.

**Methods:** In our retrospectively planned study, patients who were admitted to the university hospital emergency department between January 1, 2012, and December 31, 2021, due to stab wounds, gunshot wounds, and assault were included in the study. The relationship between the meteorological parameters, including air temperature, atmospheric pressure, relative humidity, and maximum wind speed on the admission days of these patients, was analyzed.

**Results:** In the study, a total of 7825 patients admitted due to stab wounds (n=1110), gunshot wounds (n=681), and assault (n=6034) were included. The highest number of applications to the emergency department due to exposure to physical violence were on Fridays (n=1225, 16%) and in August (n=780, 10%), and the lowest applications were on Sundays (n=1014, 13%) and in February (n=428, 6%). According to the results of the Poisson regression analysis of the relationship between patient applications and daily measurement parameters, average relative humidity and average wind speed were found to be independent determinants for stab wounds and gunshot wounds, and average temperature and average wind speed were found to be independent determinants for assault.

**Discussion and Conclusion:** Meteorological parameters such as air temperature, relative humidity, air pressure, and maximum wind speed affect exposure to aggressive behavior and the need for emergency healthcare.

**Keywords:** Air; Assault; Firearm Wounds; Humidity; Pressure; Stab Wounds; Temperature; Wind Speed.

The causes and mechanisms of action of violence and aggressive behaviour are complex. In addition to numerous contributing factors such as declining food resources and other social, economic, and political conditions, many individual and environmental factors, including high temperature, decreased precipitation, overpopulation, and psychiatric illnesses, play a role. Meteorological and seasonal conditions are environmental factors that affect human behaviour.

Criminology studies suggested that criminal activities tend to increase during the summer, the second and third quarters of the year, hotter years, and higher temperatures<sup>[1-4]</sup>. Two major hypotheses have been proposed to explain the relationship between heat and human behaviour. First, the routine activities theory asserts that comfortable weather increases outdoor activity, thus exposing more people to offenders. Furthermore, the affective aggression model argues that

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changes in temperature influence crimes by increasing irritability and anger and suggests a positive linear relationship between temperature and aggressive behaviour<sup>[5,6]</sup>. However, Bell and Baron<sup>[7]</sup> found in their study on humans to test the affective aggression model and to examine the dose-response pattern that there was no positive linear relationship between temperature and aggressive behaviour, and although aggression increased with the temperature until the temperature reached a specific threshold, after this point, subjects exhibited decreased levels of aggression. These hypotheses have aimed to reveal the relationship between violent crimes and air temperature only. However, other weather parameters such as atmospheric pressure, humidity, and wind speed are likely to influence aggressive behaviour.

In addition, most studies on violent behaviour have used criminal records and data obtained from police forces; these studies reported a strong relationship between temperature and violent crime<sup>[8-10]</sup>. However, studies have also shown that there was no significant relationship between climate and excursions and violence<sup>[11-14]</sup>.

There are admissions to hospital emergency departments with the complaint of being exposed to physical violence caused by assault, stab wounds, or firearm injuries. Studies examining the effect of meteorological parameters on the number of patients admitted to the hospital after exposure to violence on a regional basis are few, and the results obtained are relatively variable<sup>[15,16]</sup>. Mostly, quarterly or monthly data of crime rates and ecological variables were analysed<sup>[2,17]</sup>. However, studies using daily values were often either limited to less than 1 year of data or focused mainly on temperature effects.

In the present study, we aimed to investigate the effects of meteorological parameters (mean air temperature, relative humidity, wind speed, and atmospheric pressure) on the number of patients who were admitted to the emergency department after being exposed to aggressive/violent behaviours.

## Materials and Methods

### Study Patients

The present retrospective study was started after the approval of the ethics committee of Firat University and this study was conducted in accordance with the Declaration of Helsinki. The total number of patient admissions to the university hospital emergency department between January 01, 2012 and December 31, 2021 was 1,326,462.

Among these, information on 7,825 criminal injuries, of which 1,110 were 'stab wounds' (encoded as W26 from International Classification for Diseases, 10<sup>th</sup> Revision), 681 were 'firearm wounds' (encoded as Y24 from International Classification for Diseases, 10<sup>th</sup> Revision), and 6,034 were 'assault injuries', was obtained from the electronic patient registration system. Patients aged >18 years who were admitted to the emergency department because of exposure to violence during the planned period were included. Multiple injuries as a result of a terrorist attack by explosion (August 18, 2016) and patients admitted to outpatient clinics other than the emergency department were excluded from the study. Data of patients included in the study, such as the number of daily admissions to the emergency department, sex, and day, month, year, and season of the admission, were recorded.

**Meteorological data:** The borders of the city where the study was performed cover a total area of 9,153 km<sup>2</sup>, of which 8,327 km<sup>2</sup> is land, and 826 km<sup>2</sup> is dam and natural lake. Although the summer seasons were hot and dry and the winter seasons were cold and harsh, the dams built in the city made the climate extremely mild throughout the province. As of 2020, the city centre has a population of 440,513.

The mean daily temperature (in degrees Celsius), mean daily atmospheric pressure (in millibars), mean daily relative humidity (in percentage), and maximum wind speed (m/s) data between January 01, 2012, and December 31, 2021, were obtained from the Ministry of Environment, Urbanization and Climate Change, General Directorate of Meteorology, 13<sup>th</sup> District Directorate.

Daily meteorological data were recorded in the data form. In addition, the daily number of admissions of patients with firearm injuries, stab wounds, and assault exposure, who were recorded as criminal cases, was recorded. Daily patient numbers were compared with meteorological parameters.

**Statistical analysis:** Data were analysed using SPSS 21.0 (IBM Corporation, Armonk, NY, USA) and Microsoft Excel packaged software licensed by the University. Numerical data were expressed in mean±SD and qualitative data in percentage. Pearson correlation test was performed to investigate the correlation between the number of patients admitted to the emergency department because of exposure to violence and the meteorological parameters. Poisson regression was used to estimate a dependent variable consisting of the "number of data" given one or more independent variables.

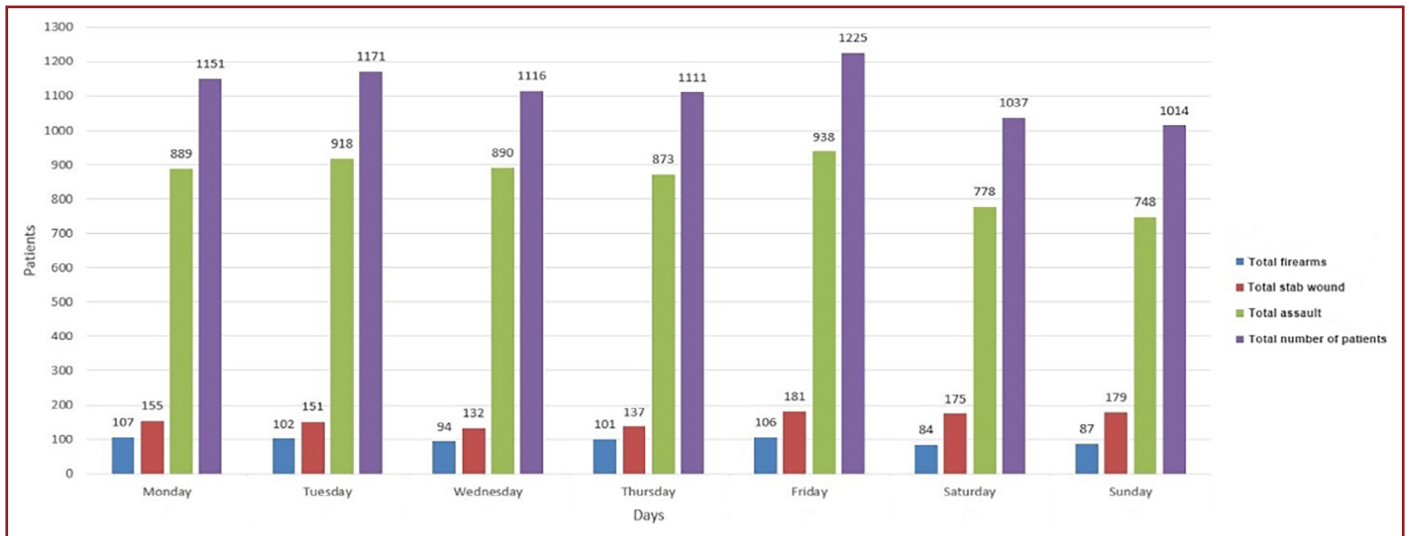


Figure 1. Distribution of the violence experienced by the subjects by the days.

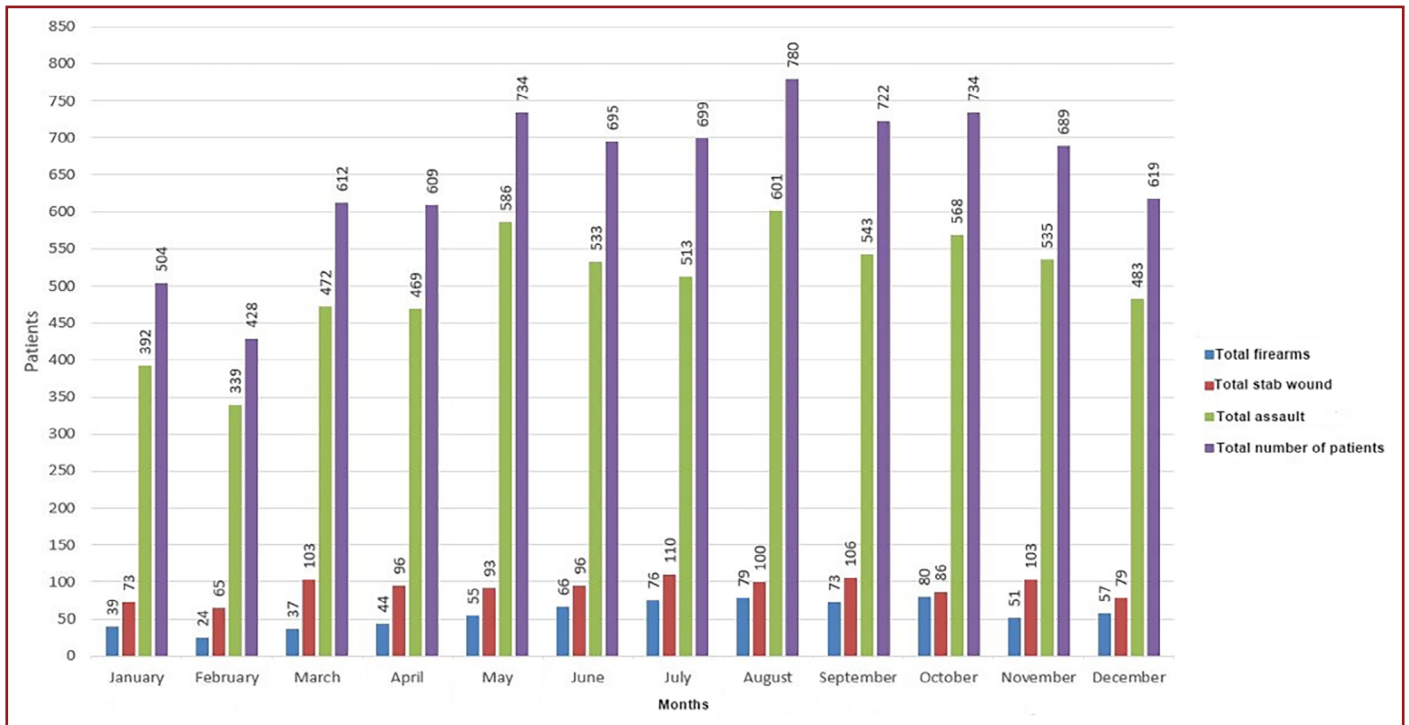


Figure 2. Distribution of the violence experienced by the subjects by the months.

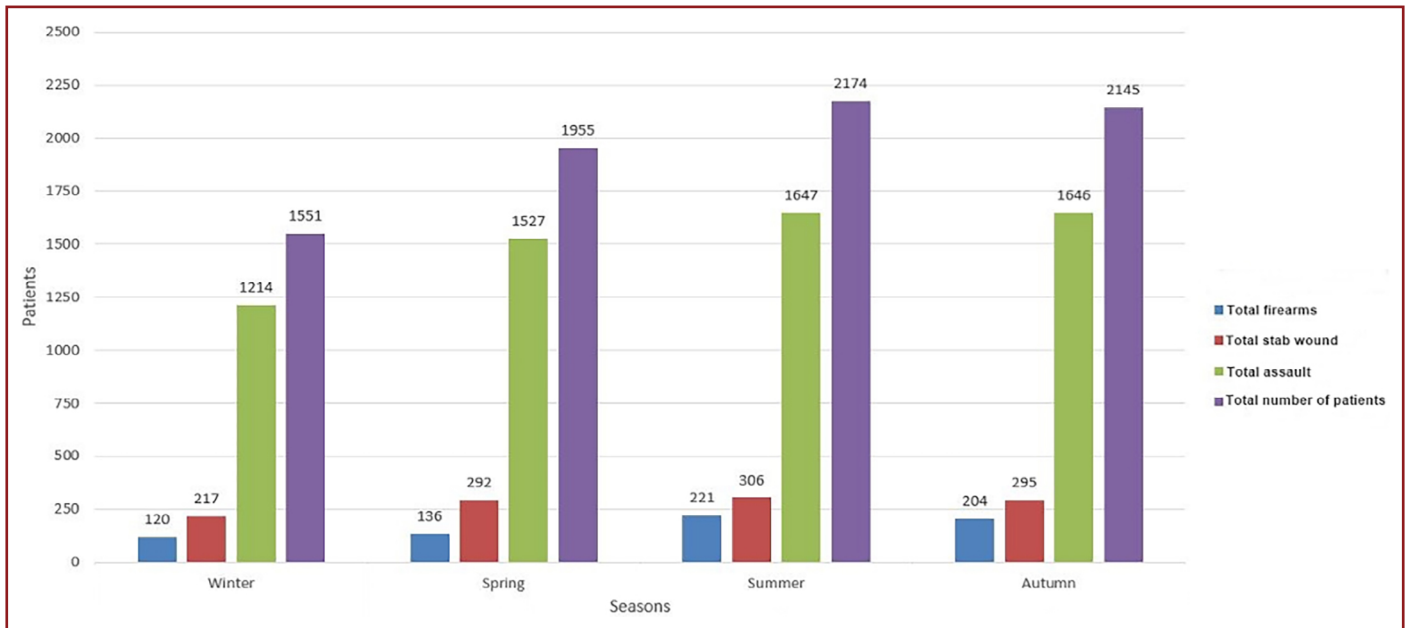
### Results

Among the 1,326,462 patients admitted to the emergency department during the study period, we included 7,825 patients with 681 firearm injuries, 1,110 stab wounds, and 6,034 assault exposure.

The number of admissions to the emergency department was the highest on Fridays (n=1225, 16%) and the lowest on Sundays (n=1014, 13%). The distribution of the violence experienced by the subjects according to the days is given in Figure 1.

The number of admissions to the emergency department was the highest in August (n=780, 10%) and the lowest in February (n=428, 6%). The distribution of the violence experienced by the subjects by the months is given in Figure 2.

The highest number of patients were admitted to the emergency service during summers (n=2174, 28%) and the least during winters (n=1551, 20%). The distribution of the violence experienced by the subjects by season is given in Figure 3.



**Figure 3.** Distribution of the violence experienced by the subjects by season.

Nine-year mean monthly temperature (°C), mean daily atmospheric pressure (in millibars), mean daily relative humidity (in percentage), and maximum wind speed (m/s) data covering the dates from January 01, 2012 to December 31, 2021 is presented in Table 1.

There was a statistically significant positive correlation between the number of patients exposed to stab wounds and firearm injuries and the mean temperature, and a statistically significant negative correlation with the mean relative humidity, mean maximum wind speed, and mean pressure. There was a positive correlation with the number of patients exposed to assault and mean temperature, and a negative correlation with mean relative humidity and

mean wind speed; no significant correlation was found with mean air pressure ( $r=-0.029, p=0.083$ ) (Table 2).

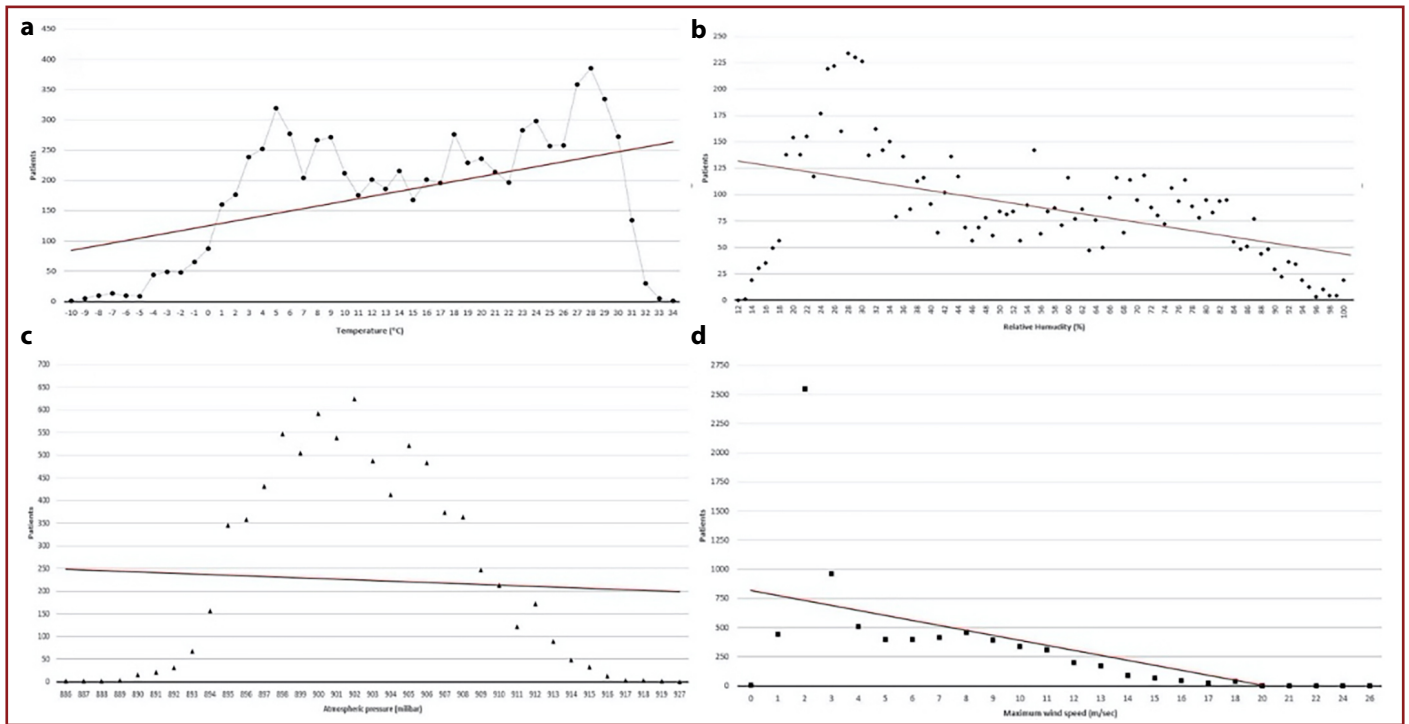
A positive correlation was found between the total number of patients admitted to the emergency department due to exposure to violence and mean temperature ( $r=0.139, p<0.001$ ) (Fig. 4a), whereas a significant negative correlation was found with mean relative humidity ( $r=-0.134, p<0.001$ ) (Fig. 4b), mean air pressure ( $r=-0.047, p=0.005$ ) (Fig. 4c), and mean maximum wind speed ( $r=-0.243, p<0.001$ ) (Fig. 4d).

**Table 1.** Monthly meteorological data (9 years)

Months	Mean temperature (°C)	Mean relative humidity (%)	Mean pressure (millibar)	Mean wind speed
January	1.2	74.2	905.3	5.6
February	3.3	68.8	905.4	5.6
March	7.7	59.6	902.3	6.9
April	13.3	53.0	902.1	6.9
May	18.3	50.2	901.1	7.2
June	24.0	34.7	898.8	7.0
July	28.2	25.5	896.6	6.9
August	28.1	25.4	897.9	6.2
September	23.0	30.4	901.4	6.1
October	15.8	49.9	905.4	5.3
November	8.3	67.3	907.5	4.6
December	3.0	78.2	907.1	5.0

**Table 2.** Correlation between the number of patients admitted to the emergency room because of exposure to violence and meteorological parameters

	Mean temperature (°C)	Mean relative humidity (%)	Mean pressure (millibar)	Mean wind speed (m/s)
Stab wound				
r	0.050	-0.062	-0.036	-0.043
p	0.003	<0.001	0.031	0.010
Assault				
r	0.117	-0.106	-0.029	-0.268
p	<0.001	<0.001	0.083	<0.001
Firearm				
r	0.085	-0.090	-0.046	0.038
p	<0.001	<0.001	0.005	0.020
Total				
r	0.139	-0.134	-0.047	-0.243
p	<0.001	<0.001	0.005	<0.001



**Figure 4.** Relationship between daily meteorological parameters and number of patients exposed to violence. Relationship between mean air temperature (a), mean relative humidity (b), mean atmospheric pressure (c), mean maximum wind speed (d) and number of patients exposed to violence.

**Table 3.** Poisson regression analysis results of the relationship between patient admissions and daily meteorological parameters

Parameter	Stab wound			Assault			Firearm		
	p	Exp(B)	95% CI	p	Exp(B)	95% CI	p	Exp(B)	95% CI
Mean temperature (°C)	0.395	0.995	(0.983-1.007)	0.000	1.012	(1.007-1.017)	0.240	1.009	(0.994-1.025)
Mean relative humidity (%)	0.006	0.993	(0.989-0.998)	0.106	0.998	(0.996-1.000)	0.015	0.992	(0.986-0.998)
Mean Pressure (milibar)	0.102	0.988	(0.973-1.002)	0.414	0.997	(0.991-1.004)	0.562	1.006	(0.986-1.026)
Mean windy rate (m/sec)	0.001	0.974	(0.959-0.989)	0.000	0.916	(0.909-0.923)	0.026	1.021	(1.002-1.040)
	LH $\chi^2=29.907$ , $p<0.001^*$			LH $\chi^2=749.222$ , $p<0.001^*$			LH $\chi^2=45.223$ , $p<0.001^*$		

\*: Omnibus test. CI: Confidence interval; LH $\chi^2$ : Likelihood-ratio chi-square.

According to the results of Poisson regression analysis of the relationship between patient admissions and daily measurement parameters, mean relative humidity and mean wind speed for stab wounds and firearm injuries, and mean temperature and mean wind speed for assault were found to be independent predictors (Table 3).

### Discussion

In the present study, meteorological parameters appeared to have an effect on the number of patients admitted to the emergency department because of exposure to aggressive behaviour over a period of 9 years. All aggressive behaviours were positively correlated with air temperature but negatively correlated with relative humidity, wind speed, and

atmospheric pressure. No correlation was found between the cases exposed to assault and atmospheric pressure.

Global warming can increase violent behaviour by worsening children’s developmental environments and directly affecting human physiology. Ranson et al.<sup>[10]</sup> have suggested that climate change would increase murder cases by 2.2% and aggravated assault cases by 2.3% in the United States by the end of the century. The routine activities theory proposed to explain the relationship between heat and human behaviour claims that comfortable weather increases outdoor activities, thereby exposing more people to offenders by breaking their routines<sup>[18]</sup>. According to this theory, crime increases due to greater interpersonal interaction in mild climate conditions. Zacharias et al.<sup>[19]</sup> investigated the



effect of microclimate conditions (i.e., temperature, sun, and wind speed) on the use patterns of open fields in a business district and concluded that increases in temperature lead to greater use of these open fields. The increase in interpersonal interaction may vary according to the structure of society. Studies have generally shown that aggressive behaviour increases at weekends<sup>[20,21]</sup>. However, our study found that the attacks were mostly on Fridays and at least Sundays. This situation is related to the social structure and may be attributable to the fact that people tend to spend more time at home on weekends, especially because of the closure of workplaces, and that interaction between people is reduced even more on holidays. Furthermore, the increase in violent behaviour on Friday, the last day of the week, may be a reflection of the increased stress on weekdays. In addition, heat aggression theory argues that changes in temperature affect crimes by increasing irritability and anger and that there is a positive linear relationship between temperature and aggressive behaviour<sup>[5,6]</sup>. Both theories suggest that aggressive behaviour increases with the increase in air temperature. In our study, a positive linear correlation was detected between air temperature and aggressive behaviour. To test the theory of heat aggression and to examine the shape of the dose-response, Bell and Baron<sup>[7]</sup> conducted human experiments and found that there was no positive linear relationship between temperature and aggressive behaviour, and that aggression increased with temperature until the temperature reached a certain threshold, following which it showed a further decrease. Two studies on this topic suggested that the positive correlation between ambient temperature was not linear and that the incidence of violent crime did not increase further when the ambient temperature was higher than 27°C–32°C<sup>[13,14]</sup>. In our study, it was determined that aggressive behaviours were more common when the air temperature was between 5°C and 29°C, but less aggressive behaviours were observed when the air temperature was <5°C and >29°C. This result supports that aggressive behaviours decrease when the air temperature is below or above a certain threshold value. Harsh weather conditions increase the likelihood of staying at home or lead to a further decrease in socialisation. Different populations in different parts of the world adapt to the temperature increases of their respective regions; thus, what one population considers a high temperature may be within the normal range for another population. Therefore, each population may have varying responses to different temperatures. In addition, the fact that aggressive behaviours decreased in the winter season in our study suggests that temperatures below the normal levels have a

reducing effect on aggressive behaviours that are typically observed in temperatures above certain thresholds.

In studies based on patients who applied to the emergency department as victims of aggressive behaviour, different results were obtained regarding the effect of air temperature. The analysis conducted by Lemon et al.<sup>[15]</sup> with the data of patients who were admitted in 3 hospital emergency departments because of assault injuries between 2014 and 2016 showed that there was a 1% increase in the attack rate for each degree increase in the maximum daily temperature. They also found no significant correlation between the weekend and the number of attacks. However, in this study, those who applied to the emergency department but had minor injuries were not included in the study; only serious attacks were interpreted. Sivarajasingam et al.<sup>[16]</sup> did not find such a relationship in the study regarding the emergency admissions because of violence and ambient temperature. In our study, a significant relationship was found between emergency room admissions because of injuries from aggressive behaviour and air temperature.

The effect of meteorological parameters on aggressive behaviours may have emerged by affecting the biological rhythm. There are studies on substances related to biological rhythm, one of which is serotonin. Among the biological factors, the serotonergic system has an important role in regulating violent behaviours<sup>[22]</sup>. In the study by Tiihonen et al.<sup>[23]</sup> on violent crimes (homicide, attempted murder, grievous bodily harm, attempted grievous bodily harm, assault and attempted assault), air temperature and serotonin levels between 1996 and 2013, low serotonin concentration and high ambient temperatures were associated with violent crime rates in Finland. They reported that the seasonal variation in violent crime is affected by natural fluctuations in the serotonergic system and that a 2°C increase in ambient temperature can increase the violent crime rate by more than 3% if other contributing factors remain constant. Therefore, it has been stated that a decrease in serotonin level may also play a role in aggravating aggressive behaviour in humans by an increase in temperature.

Furthermore, other weather parameters other than air temperature affected aggressive behaviours. However, conclusions regarding the effect of these parameters have varied. Michel et al.<sup>[11]</sup> found in their study that wind speed had no significant independent relationship with any of the crime or trauma variables examined. Similarly, wind speed reportedly showed no significant independent relationship with any of the crime or trauma variables examined<sup>[24-26]</sup>. In our study, we found a negative correlation between

maximum wind speed and aggressive behaviour. In addition, it was found that there was a negative correlation between mean humidity and air pressure and emergency room admissions after exposure to aggressive behaviour. This may be related to the decrease in violence cases when meteorological parameters reach extreme values.

## Conclusion

In conclusion, our study suggests that meteorological parameters such as air temperature, relative humidity, air pressure, and maximum wind speed have an effect on aggressive behaviour in our region and increase the need for emergency care and treatment due to aggressive behaviour.

**Ethics Committee Approval:** The study was approved by the Firat University Non-Interventional Clinical Research Ethics Committee (no: 2022/02-14, date: 10/02/2022).

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**Conflict of Interest:** None declared.

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