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ORIGINAL ARTICLE

Evaluation of the Effects of Thermal Comfort Conditions on Cardiovascular Diseases in Amasya City, Turkey

Savaş Çağlak[1]

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Abstract

Aim Studies fall short when it comes to determining the relationship between thermal comfort and cardiovascular diseases. Studies examining the relationship between thermal comfort conditions and human health in Turkey, located in the transition zone of air masses at mid-latitudes, are quite limited. This is the first study conducted in Turkey that deals with thermal comfort conditions and CVDs, which is the leading cause of death. This study aimed to examine the relationship between thermal comfort conditions and CVDs of Amasya, a medium-sized exemplary Turkish city.

Subject and methods To determine the thermal comfort conditions in the study area between 2014–2019, the physiologically equivalent temperature (PET) index obtained from the Rayman model, which uses hourly air temperature (ºC), relative humidity (%), wind speed (m/s), and cloud cover (octa) data, was used. The relationship between PET values and CVDs was determined by Pearson correlation analysis and linear regression analysis.

Results The study indicated a negative, high, and moderate correlation between PET values and cardiovascular diseases ($p < 0.001$). The results show that when PET values increase by 1 ºC, patient admissions will decrease by about 104 to 108 patients (–104.737 to –108.619 units.)

Conclusion These results can be informative and guiding for both the protection of public health and studies on climate change and human health.

Keywords Thermal comfort · Cardiovascular diseases · Public health · Sustainable cities · PET · Turkey

Introduction

The relationship between climatic conditions and human health was examined by Hippocrates 2500 years ago, and it was stated that climate types affected human health (Greene and Depew 2004). Despite the great progress in medicine, the health of individuals and communities is strongly affected by atmospheric conditions (Blazejczyk et al. 2018). Extreme thermal conditions create physiological pressure on the human body, causing various ailments and death (Canoui-Poitrine et al. 2006; Gasparrini et al. 2015; Matzarakis et al. 2010; Zhang et al. 2017).

Thermal comfort is the state where people feel happy, peaceful, and fit in the atmospheric environment they are in (Auliciems and Szokolay 2007; Çağlak 2021). In other words, the state of thermal comfort occurs when there is no stimulation between the uncomfortable heat and the uncomfortable cold (Parsons 2003). It has been stated that the absence of thermal comfort conditions causes negativities in many social, economic, physiological, and health conditions of people, and even causes death (Baccini et al. 2011; Konefał et al. 2021; Nastos and Matzarakis 2012). Studies of scientists from many disciplines on thermal conditions reveal that it is an important indicator in human life and activities (Epstein and Moran 2006). It is stated that the frequency of experiencing extreme thermal conditions will increase with climate change, which will also cause an upsurge in the health burden (Peng et al. 2011). According to Global Burden Of Disease Study 2019, cardiovascular diseases (CVDs), especially ischemic heart diseases, constitute an important part of the global disease burden (Vos et al. 2020). In developing countries such as Turkey, the health burden due to CVDs is more evident.

CVDs are the most common cause of death in adults (Dülek et al. 2018). It was stated that 63% of the deaths (57

✉ Savaş Çağlak
savas_caglak@hotmail.com

[1] Ministry of Education, Amasya City, Turkey

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million) and 30% of the injuries occurred in the world in 2007 were due to CVDs (Mendis et al. 2011). It is estimated that CVD-related deaths will exceed 22 million in 2030 (World Health Organization 2014). Although most CVDs are preventable, they tend to increase worldwide (Costa et al. 2021). Causes of this increasing trend, especially in recent years, is due to change of lifestyles with urbanization, lack of movement, increased consumption of fatty and salty foods, and high consumption of processed foods (Turkey Cardiovascular Diseases Prevention and Control Program 2015–2020 2015). In addition to the abovementioned, factors such as exposure of people to noise, heat, and air pollution in urban areas, the decrease in the areas where they can spend their quiet time due to the decrease in the amount of green areas, and the restriction of fresh air and mobility increase the burden of disease (Sevgi 2020).

Previous studies examining CVDs with thermal conditions have associated CVD-related hospital admissions with cold weather (Analitis et al. 2008; Manfredini et al. 2009; Ornato et al. 1996; The Eurowinter Group 1997). It has been reported that 53% of CVD-related hospitalizations in Spain occur during the cold period (Santurtún et al. 2020). One probable explanation of linkage between myocardial infarction and cold weather is increased coronary vascular resistance caused by coronary vasoconstriction that could cause decreased oxygenation of heart and induce plaque fracture (Mohammad et al. 2018). The effect of cold thermal conditions on CVDs is more pronounced in temperate and warm climate countries (Barnett et al. 2005). As a result, countries such as Turkey, which is in the transition zone of air masses, are projected to be more affected by it.

It has been reported that CVDs increase in summer and winter seasons in Bangladesh (Miah et al. 2012). Another study reported that deaths from respiratory and cardiovascular diseases increased at high temperatures in Budapest, London and Milan (Ishigami et al. 2008).

Studies on the seasonality and duration of hot and cold thermal comfort conditions in a particular location and their ratios or relations with public health gain great importance in terms of revealing the disease patterns of a population (Abrignani et al. 2009; Conlon et al. 2011). Although there are many studies that determine the relationship between thermal comfort conditions and death events, studies on human health and diseases have been limited (Anderson and Bell 2009; Díaz et al. 2005; Donaldson and Keatinge 2002; Hajat et al. 2007; Nastos and Matzarakis 2012). In Turkey, which is located in the transition zone of air masses, studies dealing with the relationship between thermal comfort conditions and human health have been very limited and the relationship between cardiovascular diseases and thermal comfort conditions has not been studied. Climate change is closely related to all climate-related sectors and countries should develop some adaptation studies and measures. Determining the relationships between thermal comfort conditions and human health will be guiding for both the effects of climate change and sustainable healthy cities. The relationship between thermal comfort conditions and cardiovascular diseases has not been studied in Turkey, which is located between cold (polar) air masses from the north and warm (tropical air) masses from the south.

The aim of this study was to assess the relationship between thermal comfort conditions and policlinic admissions for CVDs in Amasya, a medium-sized sample Turkish city located in the Central Black Sea Part of Turkey's Black Sea Region. The study is important because it is the first study in Turkey that handles the relationship between thermal comfort conditions and CVDs. The findings of the study are expected to guide the measures and plans to be taken to reduce the negative effects of thermal conditions.

Materials and methods

According to NTUS, the city of Amasya, in the Samsun sub-region of the Western Black Sea Region (TRA83 Level), is located between 40°40′22"N—40°38′11"N latitudes and 35°47′3"E—35°51′24"E longitudes and is located behind Canik Mountains (Fig. 1). According to 2021 data, the total population of the city is 147,380 people, 50.2% of the population is female, 49.8% is male, 15.7% is 65 years old and over, 27.3% is child population ranging between 0–14 years.

Amasya is in the transition zone between the Black Sea Climate and the Continental Climate. According to the long annual measurements of the meteorology station no. 17085, which is located in the city center, the annual average temperature is 13.6 ˚C and the annual total precipitation is 460.8 mm. Precipitation falls the most in winter and early spring, the least in summer. The annual average relative humidity was 60% and the annual average wind speed was 1.6 m/s. Average and extreme values are given in Table 1.

The data on the number of patients who applied to the cardiology and cardiovascular surgery polyclinics in the tertiary health institution in Amasya Center were obtained from the local health authority as the monthly patient numbers between 2017 and 2019, based on residence (patients residing in the city center). Data up to 2019 were used due to the Covid-19 pandemic. According to the monthly number of patients, the most admissions were in January 2019, and the least admissions were in July 2018 (Table 2). Monthly mean numbers of patient admissions used in statistical analysis.

Meteorological parameters were obtained as hourly air temperature (ºC), relative humidity (%), wind (m/s), and cloudiness (octa) from meteorology station no. 17085 in the city center, between 2017 and 2019. The physiologically equivalent temperature (PET) index, which calculates a radiation model from both atmospheric factors (temperature,

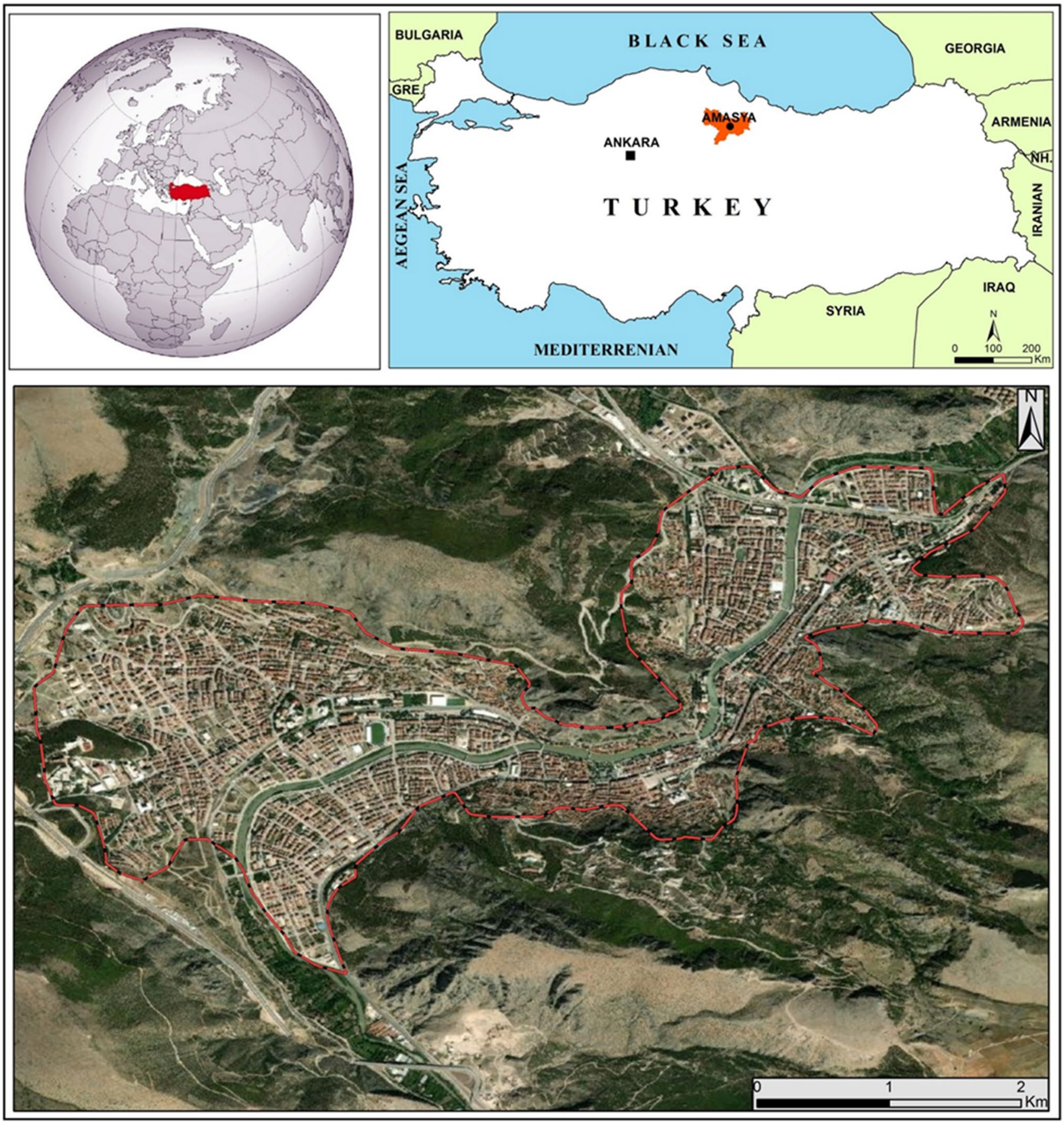

Fig. 1 Location map of the study area

relative humidity, wind speed, cloudiness, and solar radiation) and personal factors (clothing, activity, metabolic processes, etc.) to determine thermal comfort conditions, and RayMan software were used (Matzarakis et al. 1999). Details about RayMan software are given in the studies (Fröhlich et al. 2019; Matzarakis et al. 2007, 2010). The thermal sensation levels of the PET index were determined by taking into account a healthy person aged 35 years, 175 cm tall, weighing 75 kg, male, with a 0.9 clo load of clothing and 80 W workload (Höppe 1999; Matzarakis et al. 1999). PET values are classified according to sensation and stress levels (Table 3).

In order to perform statistical analysis, monthly average, maximum and minimum PET values and monthly variability of these values were calculated. In monthly PET values (mean, max., min.), the highest values are between June and

Table 1 Mean and extreme climatic values for Amasya city

Observation period: 1960–2021 Latitude: 40° 39″N Longitude: 35° 50″E Elevation: 409 m

Parameters	Value	Date/period
Mean temperature (˚C)	13.6 °C	Annual
Mean relative humidity (%)	% 60.0	Annual
Mean wind velocity (m/s)	1.6 m/s	Annual
Total precipitation (mm)	460.8 mm	Annual
Mean number of days covered with snow	11.9 days	Annual
Maximum temperature (˚C)	45.0 °C	30.07.2000
Minimum temperature (˚C)	−21.0 °C	15.12.2008
Highest rainfall in a day	60.9 mm	03.07.1981
The highest snow thickness	97 cm	05.03.2012
The fastest wind velocity (m/s)	36 m/s	24.09.1996

August, the lowest values are between November and February (Table 4).

After determining that the mean patient admissions of CVDs and overall thermal comfort conditions (PET) values were normally distributed, statistical analyzes were performed with Pearson Correlation to determine the direction and strength of the relationship and linear regression analyses to assess the effects of thermal comfort conditions and monthly changes on cardiovascular diseases.

Pearson Correlation Analysis is a statistical method that examines the direction and strength of the relationship between two variables (Çubukçu 2019). The correlation coefficient takes a value between +1 and –1 and its negative or positive state indicates the direction of the relationship. The closer it is to 1, the stronger the relationship. The interpretation of the relationship is shown in Table 5 (Hayran and Özbek 2017).

Linear regression analysis involves creating an equation that allows estimating the value of the dependent variable from the independent variable based on the relationship between two variables. It is expressed by the following equation;

$$''y = \mathrm{a} + bx''$$

y: Dependent variable, x: Independent variable, a: Constant, x: Regression coefficient.

Results

According to the results of the analysis, between cardiovascular disease patient admissions and PET values, with PET Mean –.606 ($p < 0.001$) and PET Min –.605 ($p < 0.001$) a high negative correlation; with PET Max –.591 ($p < 0.001$) a moderate negative correlation was seen (Table 6). According to the results of linear regression analysis; 36.8% of cardiovascular diseases can be explained by mean PET values, 35.0% by maximum PET values, and 36.7% by minimum PET values. Even if the mean PET values are ineffective, 8572.675 patients will apply for cardiovascular diseases, 9032.152 patients if the maximum PET values are ineffective, and 8092.086 patients if the minimum PET values are ineffective according to the coefficients obtained. When PET values increase by 1 ˚C; with mean PET values 107 (-107.965 units), with max PET values 108 (-108.619 units), and with min PET values 104 (-104.737 units) fewer patient admissions should be expected (Table 6).

As seen on the average PET values, "very cold" and "cold" stress is experienced in the first 50 days and the last 30 days of the year in Amasya city. "Cool" stress is experienced between the 50th and 90th days of the year and between the 310th and 330th days of the year. "Comfortable" conditions are perceived between Day 120 and Day 150 and between Day 280 and Day 300 of the year. From the 160th to the 180th day of the year and between the 250th and 270th days of the year, "slightly warm" stress is experienced,

Table 3 Human thermal sensation and stress ranges for PET (Gulyás et al. 2006; Matzarakis et al. 1999)

PET (°C)	Thermal sensation	Level of thermal stress
< 0.0	Extreme cold	Freezing cold stress
0.1–4.0	Very cold	Extreme cold stress
4.1–8.0	Cold	Strong cold stress
8.1–13.0	Cool	Moderate cold stress
13.1–18.0	Slightly cool	Slight cold stress
18.1–23.0	**Neutral (comfortable)**	**No thermal stress**
23.1–29.0	Slightly warm	Slight warm stress
29.1–35.0	Warm	Moderate heat stress
35.1–41.0	Hot	Strong heat stress
> 41.0	Very hot	Extreme heat stress

Table 2 Monthly number of patients admitted to cardiovascular diseases in Amasya city center

Years	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
2017	6.315	5.731	6.568	5.416	6.095	4.686	5.810	4.789	5.617	6.102	6.311	6.216
2018	7.315	7.908	9.001	6.034	4.699	5.195	1.427	3.585	4.527	5.665	8.815	8.149
2019	9.501	9.019	8.729	9.182	9.093	5.821	6.357	6.065	8.187	7.930	7.776	9.300
Mean	7.710	7.553	8.099	6.877	6.629	5.234	4.531	4.813	6.110	6.566	7.634	7.888

Table 4 Monthly PET values

Years	2017			2018			2019			Overall		
Months	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min
Jan	1.5	7.9	−4.5	5.0	8.4	2.0	2.0	5.7	−0.5	2.4	7.4	−2
Feb	6.9	10.7	3.7	8.5	12.0	5.5	5.2	10.8	−1.0	6.6	10.8	2.9
Mar	9.3	12.9	5.7	14.3	19.3	9.2	12.2	18.3	6.4	11.7	16	7.3
Apr	15.6	21.6	9.2	18.6	21.8	12.9	14.2	18.6	10.7	16.6	21.5	10.8
May	24.4	30.7	19.9	25.0	28.9	20.3	22.6	29.0	16.5	23.6	29	18.9
Jun	30.6	33.0	27.8	29.1	33.1	26.0	28.1	32.9	23.8	29.2	32.3	25.4
Jul	28.8	32.2	25.1	32.2	34.9	29.6	32.2	36.0	28.6	31.2	35.1	27.9
Aug	30.3	34.9	25.7	32.1	35.2	28.9	30.3	33.4	27.3	31.8	35.5	27.7
Sep	25.0	28.0	21.7	27.0	30.0	22.6	29.5	32.9	26.6	27.1	30.6	22.9
Oct	20.7	23.3	17.1	19.1	23.6	14.2	22.2	25.7	20.0	18.6	22.3	14.9
Nov	9.6	13.5	6.0	9.3	12.1	5.5	9.4	13.4	5.3	9.2	13.3	5.5
Dec	5.2	11.4	1.2	5.8	10.4	0.7	3.6	7.3	0.4	5.5	10.9	0.9

Table 5 Pearson correlation coefficients and expressed comment (Hayran and Özbek 2017)

Correlation coefficients (R)	Expressed comment
R < 0.2	No correlation
0.2–0.4	Low correlation
0.4–0.6	Moderate correlation
0.6–0.8	High correlation
0.8 >	Very high correlation

and from the 180th to the 250th day of the year, "warm" stress is encountered (Fig. 2).

As thermal comfort (PET) values increase, the number of applications to policlinics due to cardiovascular diseases decreases. On days when the mean PET values were below 18 ℃, patient admissions were higher than the averages (Fig. 2).

Subsequent to the analysis, it was seen that there is an inverse relationship between thermal comfort conditions and cardiovascular diseases. As PET values increase, the number of admissions due to cardiovascular diseases decreases. From November to April, monthly average patient admissions were above average, and from June to September, monthly patient admissions were below average. In May and October, there were average patient admissions (Figs. 2, 3, and 4).

According to the maximum PET values; Patient admissions were higher than the monthly average in all thermal comfort ranges from "very cold" stress to "comfortable" conditions (PET < 23 ˚C). During the periods when PET values were above 29 ℃, patient admissions were below the average (Fig. 3).

While patient admissions to cardiovascular diseases are above the average in all cold thermal perceptions from "extreme cold" stress to "cool" stress (PET < 13 ˚C), patient admissions are below the monthly average during periods of hot thermal perceptions with PET values above 23 ℃ (Fig. 4).

Discussion

In this study, the relationships between the thermal comfort conditions and cardiovascular patient admissions of Amasya, a medium-sized exemplary Turkish city in the Western Black Sea Region of Turkey, are explained by statistical methods. It has been determined that cold thermal

Table 6 Results of pearson correlation and linear regression analyzes between thermal comfort conditions cardiovascular diseases

Variable	Pearson correlation coefficient	Significance level (2-tailed) (P)	R square	F	B (unstandardized coefficients)	
					(Constant)	Independent variable (PET)
PET Mean (˚C)	–.606**	0.000	.368	19.776	8572.675	–107.965
PET Max. (˚C)	–.591**	0.000	.350	18.276	9032.152	–108.619
PET Min. (˚C)	–.605**	0.000	.367	19.681	8092.086	–104.737

Dependent variable, Cardiovascular diseases predictors, PET **. Correlation is significant at the 0.01 level (2-tailed)

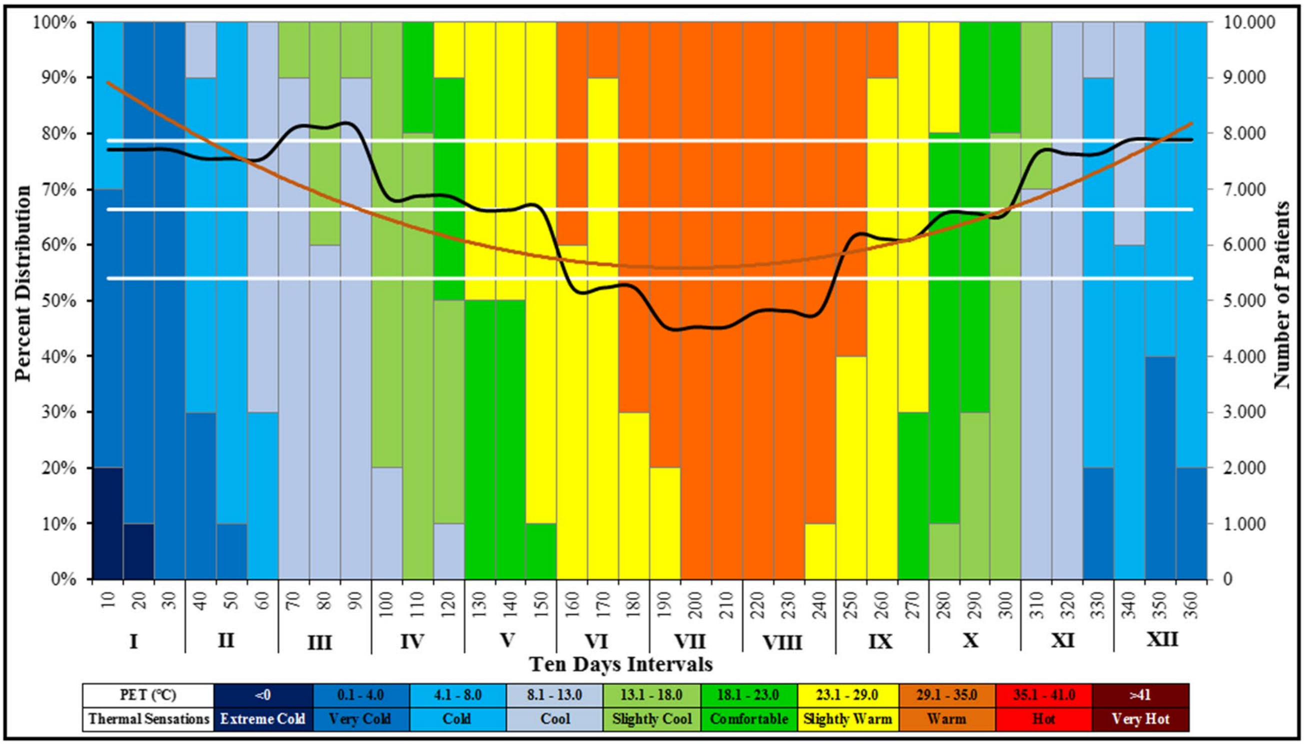

Fig. 2 Distribution of 10-day mean thermal comfort conditions (PET mean) with total number of patients per month for cardiovascular diseases (black line) and the polynomial fitting (brown line). Three reference lines (white lines) represent the mean, the mean + SD, and the mean − SD

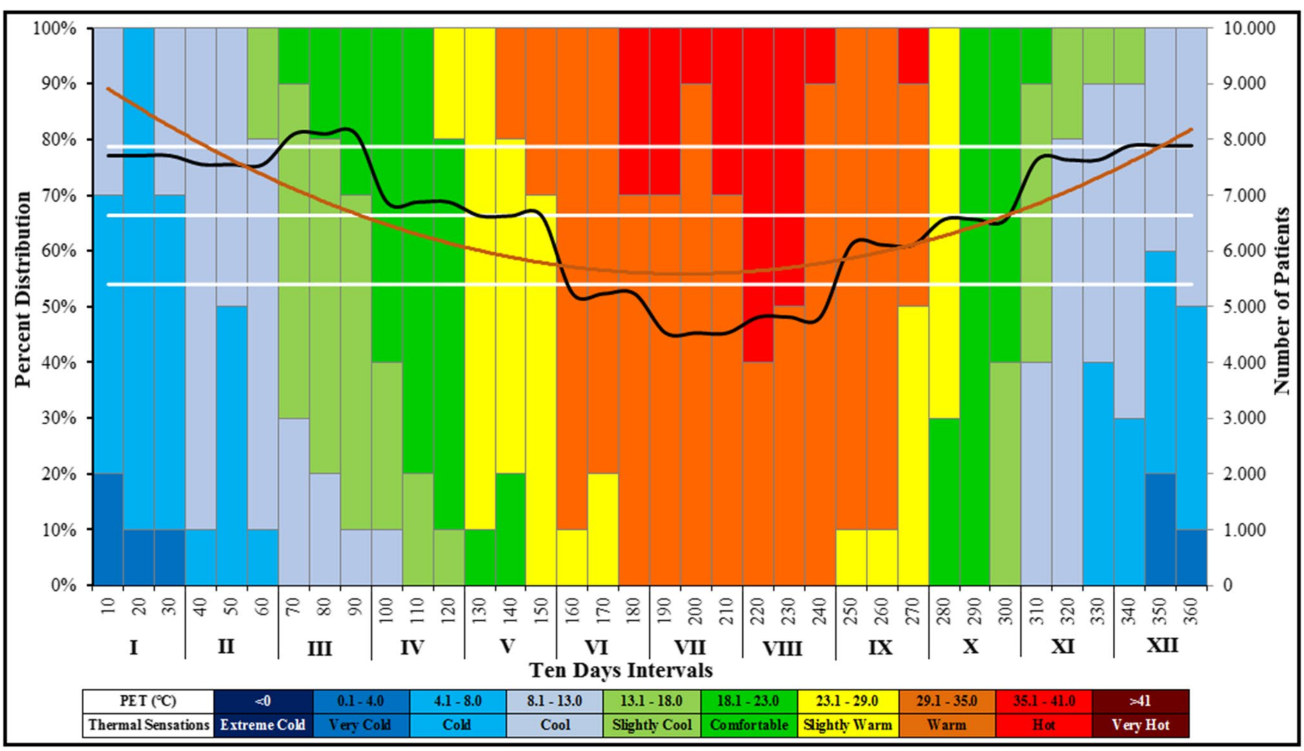

Fig. 3 Distribution of 10-day maximum thermal comfort conditions (PET max) with total number of patients per month for cardiovascular diseases (black line) and the polynomial fitting (brown line). Three reference lines (white lines) represent the mean, the mean + SD, and the mean − SD

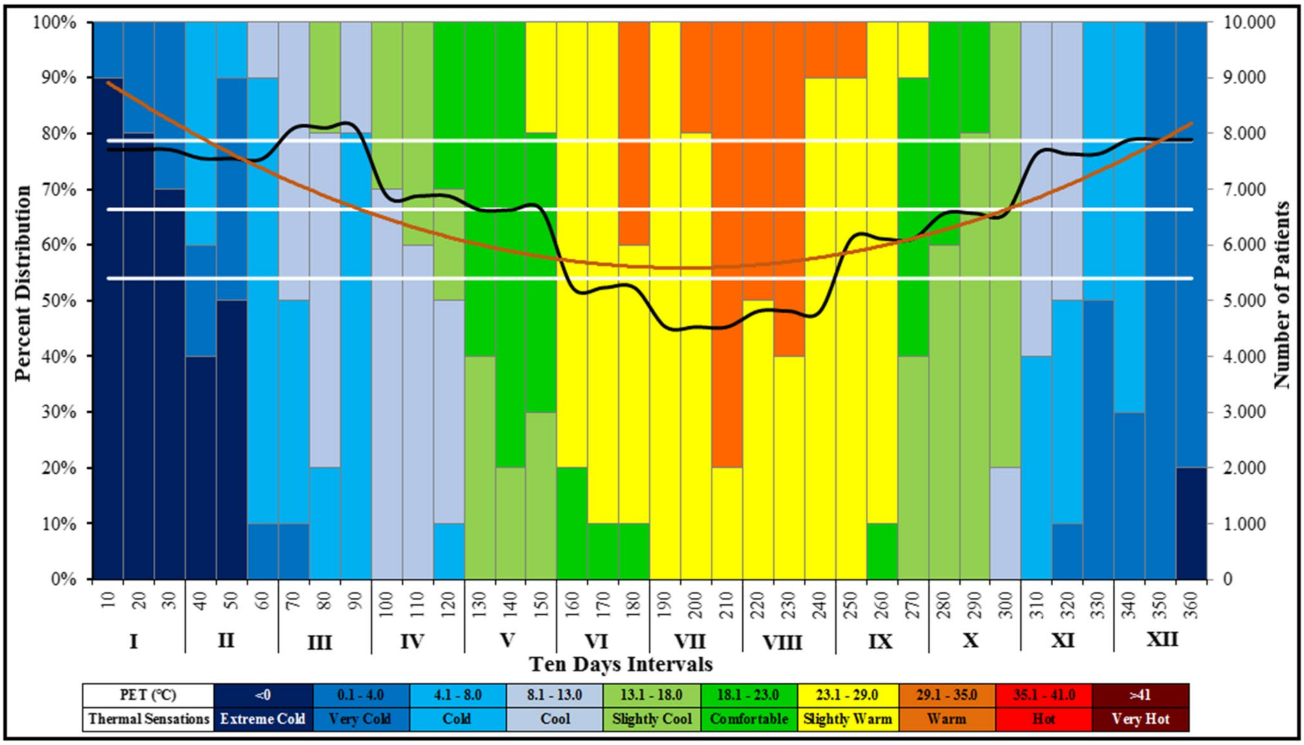

Fig. 4 Distribution of 10-day minimum thermal comfort conditions (PET min) with total number of patients per month for cardiovascular diseases (black line) and the polynomial fitting (brown line). Three reference lines (white lines) represent the mean, the mean + SD, and the mean – SD

conditions are experienced from November to March in Amasya, and warm thermal comfort conditions are experienced from June to September. Comfortable thermal conditions are experienced between May and October. The highest number of patients admitted for cardiovascular diseases was between November and April, and the lowest number of patient admissions was between June and August. Between thermal comfort conditions (PET mean, max, and min) and cardiovascular diseases, a negative, high, and moderate correlation was determined (–.606, –.591, –.605 respectively) according to Pearson correlation analysis. According to the results of linear regression analysis, 35.0% to 36.8% of cardiovascular diseases can be explained by PET values. When PET values increase by 1 ºC, patient admissions will decrease by about 104 to 108 patients (–104.737 to –108.619 units.)

Although the meteorological parameters are accessible, the inaccessibility of patient data is one of the main limitations of this study. Parameters such as ICD-10 codes or demographic characteristics could not be evaluated in patient admissions to outpatient clinics. However, the fact that the patient applications were obtained according to the residence information allowed the evaluation of the relationship between the outpatient clinic applications and the thermal comfort conditions of the city.

In studies carried out in the countries around Turkey, Manfredini et al. (2009) showed an increase in CVD applications in cold thermal conditions in Italy, and Santurtun et al. (2020) stated that 53% of CVD-related hospitalizations in Spain occur during the cold period. Another study found cold stress is linked with higher hospital admissions due to hypertension and ischemic heart diseases (Shiue et al. 2014). In Japan, hospitalizations due to CVD are higher in the winter season (Yoneyama et al. 2021). In literature, cold stress is also linked with CVD mortality. One study conducted in Greece found ambient temperature below 6 °C and above 39 °C is associated with CVD deaths in the elderly population (Tsoutsoubi et al. 2021). A Hong Kong study using the PET index has shown that deaths from CVDs are associated with both cold stress and heat stress (Thach et al. 2015). Contrary to these findings, Ishigami et al. (2008) stated that CVD applications increased in hot weather conditions in three European cities (Budapest, London and Milan). It is thought that the emergence of different results in some studies is due to the differences in the period of the study, the population structure, nutrition, and housing opportunities.

Studies examining the relationship between thermal comfort conditions and human health evaluate the interaction between thermal stress, cold–hot spells or diurnal temperature changes and health outcomes. The literature also mentions a J or U curve between CVD-related mortality and morbidity and atmospheric temperatures, and it is stated that cardiovascular health outcomes due to cold weather are more pronounced than warm weather (Achebak et al. 2018; Guo et al. 2011; Hajat et al. 2007; Tsoutsoubi et al. 2021; Xu et al. 2020). The health effects of both cold and hot weather can be explained by the limitations of the human body in adapting (Anderson and Bell 2009; Mohammad et al. 2018). The fact that health consequences due to cold weather are more pronounced in regions more accustomed to hot climates supports this theory (Barnett et al. 2005). The responsive mechanisms of the cardiovascular system to thermal changes help us understand the vulnerable groups such as the elderly, children, people with low socioeconomic status, outdoor workers, people with comorbid diseases, and undiagnosed individuals with CVDs (Kysely et al. 2009; Liu et al. 2015).

Thermal comfort conditions are the determination of how people are affected by atmospheric conditions in their environment. In Amasya, a medium-sized city in Turkey, located in the transition zone of air masses in the Mediterranean basin, a high negative correlation was determined between thermal comfort conditions (PET) and cardiovascular diseases.

Conclusion

In conclusion, this study presents the important relationship that cold thermal comfort conditions increase hospital admissions for cardiovascular diseases in Amasya, a medium-sized city in Turkey. The results are valuable in terms of drawing attention to the health consequences that may develop due to thermal conditions. Sensitive groups in the population such as the elderly population of 65 and over, children, and citizens with chronic diseases are more likely to be affected by adverse thermal conditions. The findings of the study can be a guide in the planning of health services in Amasya province by drawing attention to the importance of using atmospheric data in the planning of health care. These results can also be informative and guiding for studies related to public health protection, climate change, and human health.

Author contributions All of the work (material preparation, data collection and analysis) was done by the author (Savaş Çağlak).

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Data availability Data and materials are available by request from the corresponding author or from relevant organizations.

Code availability None.

Declarations

Ethics approval Since only numerical data were used in the study and no personal information was used, ethical approval was not required.

Consent to participate No person was included in the study.

Consent for publication Since there was no private data or information in the study, no permission was required.

Conflicts of interest There is no conflict of interest with any person or institution.

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