International Journal of Biometeorology (2023) 67:1353–1362
https://doi.org/10.1007/s00484-023-02503-6

ORIGINAL PAPER

Investigation the relationship between causes of death and thermal comfort conditions: the sample of Amasya Province

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Received: 19 March 2023 / Revised: 29 May 2023 / Accepted: 3 June 2023 / Published online: 9 June 2023

Abstract

Despite many advances in medicine, there is still a strong relationship between human health and atmospheric conditions. This study determines the effects of thermal comfort conditions on the causes of death in the province of Amasya, which is located in the Mediterranean basin. Meteorological data and monthly mortality data were used as material. As a method, thermal comfort conditions were determined by the Rayman model according to the PET index. Pearson correlation analysis and linear regression analysis methods were used to determine the effects of air temperature and thermal comfort conditions on the causes of death. In conclusion, it has been determined that thermal comfort conditions are effective on the total number of deaths, deaths due to external injuries and poisonings, deaths due to circulatory, and respiratory system diseases, but not for deaths due to other causes. These findings are important for early warning systems, preventive, and protective measures in health systems.

Keywords Amasya · Mortality · Air temperature (T) · Thermal comfort · PET (physiologically equivalent temperature)

Introduction

There is a close relationship between the natural environment and human life and activities. In the natural environment, the climate is the most important factor. The climate, which is expressed as the average of long-term weather conditions, directly or indirectly affects people's cultural activities such as nutrition, clothing, behavior, and habits, and economic activities such as agriculture, tourism, trade, etc., and, most importantly, health conditions.

Climatic conditions affect people's psychological and physiological health. In hot and humid climates, poisoning is high due to rapid growth of bacteria and microbes (drinking and utility water, food, etc. environments), infectious diseases shorten the average human lifespan in humid climates, psychological disorders, and respiratory diseases such as asthma, pneumonia, and bronchitis are common in regions where cold conditions persist, and in cool and humid regions, the frequent occurrence of joint diseases reveals the relationship between climatic conditions and the distribution of diseases (Epstein 2001; Verges et al. 2004; Atalay 2010; Türkeş 2010).

Despite many advances in medicine, there is still a strong relationship between human health and atmospheric conditions (Blazejczyk et al. 2018). Atmospheric stimuli significantly affect human health and well-being (Fers 1995; Kalkstein 1998). Since the human body is affected by climatic conditions for a long time, it can be a state of habituation. People choose food and clothing in accordance with their climate zones. At the same time, they design their dwellings according to their climatic conditions. However, the human body develops a sudden response to seasonal changes, especially cold air waves, heat waves, and sudden changes (Türkeş 2010; Blazejczyk et al. 2018). On days when such adverse weather conditions are experienced, there is an increase in hospital admissions and death rates (Desai 2002; Kuchcik 2001; Diaz et al. 2006; Knowlton et al. 2009; d'Ipoliti et al. 2010; Baccini et al. 2011; Aboubakri et al. 2018).

As a general opinion, deaths are more common among the elderly population. Vulnerable groups such as people with chronic diseases, the elderly, and infants are more affected by environmental changes (Çağlak 2021). The deaths of people, which are a natural process, show a trend in some periods depending on climatic conditions. In Amasya, people use expressions such as "Old age is like winter" and "The falling snow cover is likened to a shroud" to express that deaths are high in winter. In this study, it was aimed to examine the relationship between deaths and thermal comfort conditions.

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In recent years, the relationships between death events and atmospheric conditions have been studied by scientists from many disciplines. In the studies, the relationship between climatic elements (air temperature, humidity, wind speed, and precipitation) and mortality events were examined (Donaldson et al. 1998; Diaz et al. 2005; Hajat et al. 2007, 2014; Khanjani and Bahrampour 2013; Kalankesh et al. 2015; Burkart and Kinney 2016; Sharafkhani et al. 2017; Dadbakhsh et al. 2018). In studies dealing with the relationship between climatic elements and death events, only the changes in climatic conditions have been taken into account. However, the human body is under the influence of all climatic elements in the thermal environment. At the same time, human physiology, behavior, activities, and some complex metabolic processes should be taken into account. There are thermal comfort models that can evaluate both all atmospheric factors and personal factors (clothing, metabolic processes, activity, etc.) in the thermal environment where people live (Urban and Kysely 2014). Thermal comfort, in its most general form, is the state of people to feel comfortable/happy and fit in their thermal environment (mainly temperature, humidity, wind, solar radiation, cloudiness) (Çağlak 2021; Toy et al. 2022). When people are deprived of such comfort, many social, economic, and physical problems are observed, such as a decrease in their welfare and happiness, an increase in health problems (weakness, chronic diseases, fatigue, headaches, etc.), an increase in energy use, and a decrease in work efficiency. Thermal stresses are more effective in women compared to men and cause cardiovascular and respiratory diseases (Matzarakis et al. 2011).

Today, there are more than 100 thermal comfort indices. There have been bibliographic studies on these (Landsberg 1972; Driscoll 1992; Epstein and Moran 2006; Parsons 2014; de Freitas and Grigorieva 2015). Among the models used to determine thermal comfort conditions, the most widely used radiation model is the PET index, which is obtained using the RayMan model. PET (physiologically equivalent temperature) index calculates human thermal comfort according to body heat energy balance. Therefore, this index was preferred in the study.

Studies examining the relationship between thermal comfort conditions and death events have been limited. Matzarakis et al. (2011) in Vienna, using the PET (physiologically equivalent temperature) index, concluded that there is a relationship between thermal comfort conditions and death events, and that heat stress increases mortality rates. Nastos and Matzarakis (2012) used PET and UTCI (Universal Thermal Climate Index) indices in Greece and found a relationship between mortality rates and thermal comfort conditions. During periods of hot and cold thermal conditions, there was an increase in deaths. Schegel et al. (2020) reported that there are significant relationships between mortality rates and thermal comfort conditions in Germany. Aboubakri et al. (2020) concluded that cold stresses are more effective on death events than heat stresses in Iran. Studies examining the relationship between death events or diseases and thermal comfort conditions in Turkey are scarcely any.

In this study, the relationship between death events and thermal comfort conditions (PET) and air temperature in Amasya, a medium-sized Anatolian province, was investigated. Thermal comfort conditions were evaluated according to the PET index obtained from the RayMan model using hourly data. Air temperature was evaluated daily. Monthly death numbers for 2010–2019 (10 years) were used to circumvent the effects of the COVID-19 pandemic. The relationship between total number of deaths and causes of death, thermal comfort conditions, and air temperature was determined using Pearson correlation analysis and linear regression analysis methods. In Turkey, studies examining the relationship between mortality and thermal comfort have been conducted only in Şanlıurfa province, which is located in the warm climate zone of Turkey. In the study conducted, deaths were not analyzed according to their causes. The relationship between the number of all natural deaths and thermal comfort is discussed (Kolbüken and Aytaç, 2020). The study is the first study to examine the causes of deaths in Turkey and contributes to the literature in this respect.

Materials and methods

Many factors can be effective on death events. Many complex factors such as genetics of certain diseases, the effect of nutritional conditions, and epidemics affect death events. In addition, the ability of a person to travel can have effects in a different region. For this reason, Amasya, which is a medium-sized Anatolian province where there is not much population mobility, was chosen as the study area. In addition, death data from 2010 to 2019 were used in the study to disable the effects of the COVID-19 pandemic.

Amasya is located in the back region of the Canik Mountains in the Central Black Sea Region of the Black Sea Region. According to NUTS classification, it is located in the Samsun sub-region of the Western Black Sea Region. The province consists of 7 districts, namely Taşova, Suluova, Merzifon, Göynücek, Gümüşhacıköy, Hamamözü, and Amasya central district (Fig. 1). The total population of the province is 335,355 people, of which 50.2% are women and 49.8% are men. 15.7% of the population is the elderly population aged 65 and over (Şenol 2020).

Amasya has a transitional climate between the Black Sea climate and the continental climate (Çağlak 2017). When evaluated according to climate classifications, in Amasya, according to Köppen-Geiger; (Csa) climate with mild winters, very hot summers and dry climates; according to Erinç; steppe-semi-arid; according to de martonne; step-damp;

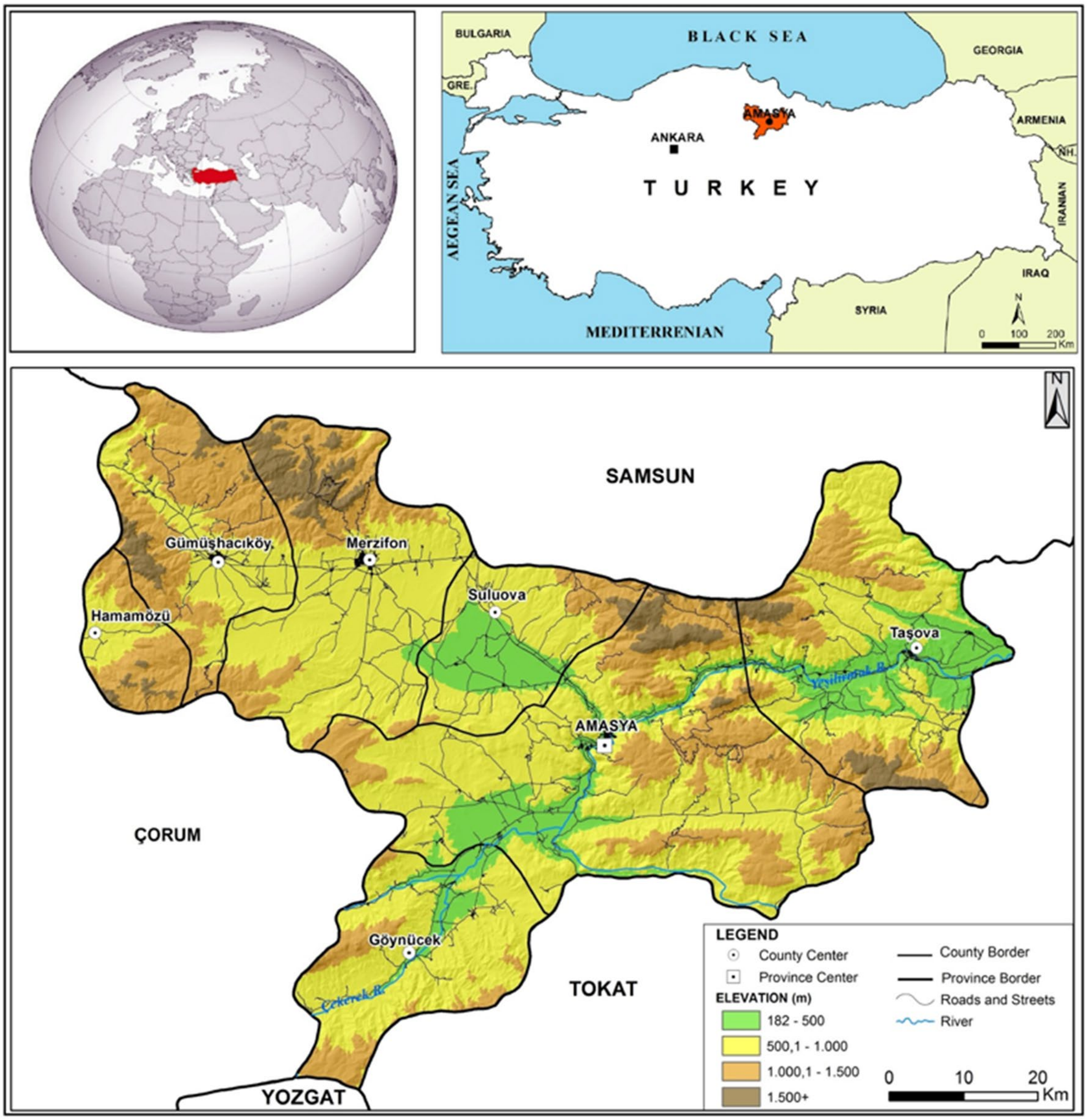

Fig. 1 Location map of Amasya Province

according to Thornthwaite; D,B′2,d,b′3 (D: semi-arid, B′2: mesothermal, d: with little or no excess water, b′3: summer evaporation rate: 53%) (Bölük 2016). According to long-term (1960–2022) measurement data, the annual average temperature of Amasya is 13.6 °C, the highest temperatures are in July and August, and the lowest temperatures are in January and February. The record maximum temperature was measured 45.0 °C on 30.07.2000, the record minimum temperature was – 21.0 °C on 15.01.2008 and 30.07.2000, and the extreme lowest temperature was – 21 °C on 15.01.2008. The average annual sunshine duration is 5.8 h, the maximum sunshine duration is 9.6 h in July, and the minimum sunshine duration is 2.1 h in December. The annual total precipitation is 461.6 mm, the highest precipitation is 54.7 mm in December, and the least precipitation is 10.1 mm in August (Table 1).

In the study, the meteorology station numbered 17,085, located at an altitude of 405 m, of the Amasya Meteorology Directorate, was calculated from 2010 to 2019 (10 years) hourly; air temperature (°C), relative humidity (%), wind (m/s), and cloud cover (octa) data were used. In addition, daily air temperature (°C) data were used. In the determination of thermal comfort conditions, the radiation model RayMan, which is widely used in the world and which calculates both atmospheric factors (temperature, relative humidity, wind speed, cloudiness and solar radiation) and personal factors (clothing, activity, metabolic processes, etc.) was used (Matzarakis et al. 1999; Gulyas et al. 2006).

Table 1 Mean and extreme climatic values for Amasya city

Parameters	Months												Annual/date
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Mean temperature (°C)	2.6	4.5	8.3	13.4	17.6	21.3	23.8	23.9	20	14.6	8.5	4.6	13.6
Mean maximum temperature (°C)	7	9.8	14.5	20.4	25.1	28.7	31.1	31.5	27.9	21.9	14.6	8.8	20.1
Mean minimum temperature (°C)	−0.8	0.3	3.1	7.2	11.1	14.5	16.7	16.7	13	8.7	3.9	1.3	8.0
Highest temperature (°C)	23.5	24.8	31.2	35.8	37.9	41.8	45	42.2	43.5	36	29.7	22.9	45.0 30.07.200
Lowest temperature (°C)	−21.0	−20.4	−15.3	−5.1	−0.1	4.8	8.5	8.8	3	−2.9	−9.5	−12.7	−21.0 15.01.2008
Mean sunshine duration (hours)	2.2	3.3	4.5	6	7.4	8.8	9.6	9.2	7.5	5	3.4	2.1	5.8
Number of rainy days	12.3	11.1	12.5	13.0	13.0	9.1	3.3	2.7	4.7	7.9	9.2	12.6	110.1
Mean monthly total rainfall (mm)	51.1	37.2	48.1	53.4	53.8	40.1	16.2	10.1	19.7	34.5	42.7	54.7	461.6

In the classification of thermal comfort conditions, the PET (physiologically equivalent temperature) index obtained from the RayMan model and developed according to the body heat energy balance was used. PET index calculates human thermal comfort according to body heat energy balance. The index calculates all the effects of the thermal environment on humans (short- and long-wave solar radiation, air temperature, relative humidity, and wind speed) and the thermo-physiological conditions of the human body (type of clothing and activity) (Höppe 1999; Matzarakis et al. 1999; Gulyas et al. 2006). Thermal sensation levels of PET index were determined by considering a 35-year-old, 175 cm tall, 75 kg, male, healthy individual with 0.9 clo clothing load, and 80-W workload (Höppe 1999; Matzarakis et al. 1999; Toy and Kántor 2017; Table 2).

Mortality data were obtained from TURKSTAT on a monthly basis between 2010 and 2019 (10 years) according to the causes of death. These years were chosen in order not to take into account the impact of the COVID-19 pandemic on death rates.

The Pearson correlation analysis method was used to determine the direction of the relationship between thermal comfort conditions and air temperature, causes of death and total mortality rates, and linear regression analysis method was used to determine the effects of thermal comfort conditions on death events.

Table 2 Human thermal sensation and stress ranges for PET (Matzarakis et al. 1999)

PET (°C)	Thermal sensation	Level of thermal stress
<4	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	Slightly cold stress
18.1–23.0	Neutral (comfortable)	No thermal stress
23.1–29.0	Slightly warm	Slightly warm stress
29.1–35.0	Hot	Moderate heat stress
35.1–41.0	Very hot	Strong heat stress
>41.0	Extreme hot	Extreme heat stress

Results

According to the monthly average number of deaths in Amasya between 2010 and 2019, while the highest number of deaths occurred in January (227), December (198), March (196), and February (195), the least deaths occurred in October (164) and June (170). According to the causes of death, the highest number of deaths per month is due to circulatory system diseases, and the least deaths are due to external causes of injury and poisoning. Detailed information about the causes of death is given in Table 3.

According to the results of Pearson correlation analysis, between the monthly average number of deaths and thermal comfort conditions (PET): PET mean, max., min. ($r = -0.773$, $r = -0.770$, $r = -0.772$ ($p = 0.003$), respectively), negative correlation was found at a high level. Between air temperature and monthly death numbers: T mean, max., min. (respectively $r = -0.761$ ($p = 0.004$), $r = -0.778$ ($p = 0.003$), $r = -0.748$ ($p = 0.005$)), negative correlation was found at high level. According to the results of the regression analysis, approximately 60% of monthly deaths can be explained by thermal comfort conditions and air temperature. It has been determined that there will be a decrease of approximately 1.1 units in monthly deaths with an increase of 1 °C in thermal comfort conditions. It has been found that there will be a decrease of 1.3 to 1.7 units in monthly deaths with a 1 °C increase in air temperature (Table 4).

In Amasya, "very cold" and "cold" stresses in the first 50 days and last 50 days of the year, "cool" stress between the 60th and 90th days of the year, and between the 310th and 320th days of the year, and the "cool" stress between the 100th and

Table 3 Mean number of deaths in Amasya and monthly distribution of their causes (2010–2019)

Mortality causes\months	1	2	3	4	5	6	7	8	9	10	11	12	Total
Circulatory system diseases	102	85	86	81	80	74	74	75	66	80	81	91	975
Benign and malignant tumors diseases	39	37	37	34	36	33	38	40	36	42	37	37	446
Respiratory system diseases	28	27	23	18	19	14	16	15	16	19	20	20	235
Nervous system and sensory organs diseases	10	9	8	10	8	8	10	12	8	9	11	10	113
Diseases related to endocrine, nutrition, and metabolism	13	10	10	10	9	11	12	12	10	10	10	10	127
External causes of injury and poisoning	5	5	5	8	6	6	8	9	7	9	5	6	79
Other	30	22	27	20	24	24	22	20	21	21	23	24	278
Total	227	195	196	181	182	170	180	183	164	191	187	198	2254

130th days of the year between the days and the 270th and 300th days, "slightly cool" stress and "comfortable" conditions are experienced. Between the 140th and 170th days of the year and the 260th days of the year, "slightly warm" stress is experienced, and between the 180th and 250th days of the year, "warm" stress is experienced (Fig. 2).

In November, December, January, February, and March, when cold stress conditions are experienced, where PET values are below 18 °C, monthly death numbers were above the monthly average. In the months of May, June, July, August, and September, when the PET values are above 23 °C and hot-stressful perceptions are experienced, the number of deaths occurred below the monthly average. Monthly deaths in April and October, when "comfortable" conditions are experienced, are at the level of averages (Fig. 2).

According to Pearson correlation analysis between circulatory system disease-related deaths and thermal comfort conditions: PET mean, max., min. ($r = -0.849$, $r = -0.840$, $r = -0.843$ ($p = 0.003$), respectively), negative correlation was found at a very high level. T mean, max., and min. very high level of negative correlation were found ($r = -0.843$, $r = -0.859$, $r = -0.831$ ($p = 0.000$) respectively). It is understood that approximately 70% of circulatory system disease-related deaths can be explained by thermal comfort conditions and air temperature. It has been found that with an increase of 1 °C in the variables, monthly circulatory system disease-related deaths will decrease by approximately 0.7 units according to PET, and there will be a decrease of 0.8 to 1.0 units according to air temperature (T) (Table 4).

While circulatory system disease-related deaths occurred above the average from December to March, when cold thermal detections were experienced, deaths occurred below the monthly average from May to September, when hot thermal detections occurred. In April and October, when "comfortable" conditions are experienced in terms of thermal conditions, circulatory system disease-related deaths are at the average level (Fig. 2).

According to Pearson correlation analysis between respiratory disease-related deaths and thermal comfort conditions (PET) and air temperature: PET mean, max. min. ($r = -0.851$, $r = -0.850$, $r = -0.853$ ($p = 0.000$) respectively) and T mean, max., and min. very high level of negative correlation were found ($r = -0.873$, $r = -0.875$, $r = -0.875$ ($p = 0.000$) respectively). It is understood that approximately 70% of respiratory system disease-related deaths can be explained by thermal comfort conditions and air temperature. It has been determined that with an increase of 1 °C in the variables, monthly respiratory system disease-related deaths will decrease by approximately 0.35 units according to PET, and there will be a decrease by 0.45 units according to air temperature (T) (Table 4).

Respiratory system disease-related deaths occurred above the monthly average in November, December, January, February, and March when PET values were below 13 °C, when "very cold," "cold," and "cool" stresses were experienced, while PET values were 18 °C it occurs below the average in "comfortable" conditions and lightly warm, warm periods (Fig. 2).

Between thermal comfort conditions and air temperature and external causes of injury and poisoning-related deaths: PET mean, max., min. ($r = 0.658$, $r = 660$, $r = 656$ ($p = 0.020$) respectively) and T mean, max., min. ($r = 0.682$, $r = 680$, $r = 687$ ($p = 0.014$), respectively), positive correlation was found at high level. According to regression analysis, approximately 43% of external causes of injury and poisoning-related deaths can be explained by PET values and approximately 46% by air temperature. In a 1 °C increase in PET values and air temperature, external causes of injury and poisoning-related deaths will decrease by about 0.1 unit per month (Table 4).

While external causes of injury and poisoning-related deaths occur below the monthly average on days of cold thermal sensations, they occur above the monthly average on days of hot thermal sensations (Fig. 2).

There was no statistical relationship between thermal comfort conditions (PET) and air temperature (T) and benign and malignant tumors disease-related deaths, nervous system and sensory organs disease-related deaths, diseases related to endocrine, nutrition, and metabolism-related deaths (Table 4; Fig. 2).

Table 4 Results of Pearson correlation and linear regression analyses between thermal comfort conditions and causes of deaths

Causes of death	Variable	Pearson correlation coefficient	Significance level (2-tailed) (*P*)	*R* square	*F*	*B* (unstandardized coefficients)	
						Constant	Independent variable
All-cause deaths	PET mean (°C)	−.773**	0.003	.598	14.9	207.626	−1.142
	PET Max. (°C)	−.770**	0.003	.594	14.6	213.657	−1.195
	PET Min. (°C)	−.772**	0.003	.596	14.7	202.443	−1.102
	T mean (°C)	−.761**	0.004	.580	13.7	205.856	−1.432
	T Max. (°C)	−.778**	0.003	.605	15.3	211.826	−1.306
	T Min. (°C)	−.748**	0.005	.560	12.7	200.043	−1.673
Circulatory system disease-related deaths	PET mean (°C)	−.849**	0.000	.720	25.7	93.814	−.725
	PET Max. (°C)	−.840**	0.001	.706	24.1	97.536	−.754
	PET Min. (°C)	−.853**	0.000	.727	26.6	90.581	−.704
	T mean (°C)	−.843**	0.000	.711	24.6	92.790	−.917
	T Max. (°C)	−.859**	0.000	.738	28.1	96.570	−.834
	T Min. (°C)	−.831**	0.001	.690	22.2	89.090	−1.074
Respiratory system disease-related deaths	PET mean (°C)	−.851**	0.000	.724	26.2	25.656	−.350
	PET Max. (°C)	−.850**	0.000	.723	26.1	27.526	−.368
	PET Min. (°C)	−.853**	0.000	.727	26.6	24.082	−.339
	T mean (°C)	−.873**	0.000	.762	32.1	25.344	−.458
	T Max. (°C)	−.875**	0.000	.765	32.5	27.102	−.409
	T Min. (°C)	−.875**	0.000	.766	32.8	23.566	−.546
External causes of injury and poisoning-related deaths	PET mean (°C)	.658*	0.020	.433	7.6	4.938	.095
	PET Max. (°C)	.660*	0.020	.435	7.7	4.422	.100
	PET Min. (°C)	.656*	0.021	.430	7.5	5.371	.091
	T mean (°C)	.682*	0.014	.466	8.7	5.005	.125
	T Max. (°C)	.680*	0.015	.462	8.6	4.533	.112
	T Min. (°C)	.687*	0.014	.472	8.9	5.488	.150
Benign and malignant tumors disease-related deaths	PET mean (°C)	−.088	0.785	.008	0.1	37.511	−.020
	PET Max. (°C)	−.100	0.757	.010	0.1	37.678	−.024
	PET Min. (°C)	−.067	0.837	.004	0.1	37.359	−.015
	T mean (°C)	−.043	0.895	.002	0.1	37.321	−.012
	T Max. (°C)	−.050	0.877	.003	0.1	37.403	−.013
	T Min. (°C)	−.029	0.928	.001	0.1	37.239	−.010
Nervous system and sensory organs disease-related deaths	PET mean (°C)	−.047	0.884	.002	0.0	9.515	−.006
	PET Max. (°C)	−.064	0.843	.004	0.0	9.593	−.008
	PET Min. (°C)	−.024	0.941	.001	0.0	9.454	−.003
	T mean (°C)	−.005	0.988	.000	0.0	9.407	−.001
	T Max. (°C)	−.013	0.969	.000	0.0	9.449	−.002
	T Min. (°C)	−.021	0.948	.000	0.1	9.388	−.004
Endocrine, nutrition and metabolism-related deaths	PET mean (°C)	.125	0.698	.016	0.1	10.350	.013
	PET Max. (°C)	.122	0.730	.012	0.1	10.311	.013
	PET Min. (°C)	.130	0.687	.017	0.2	10.404	.014
	T mean (°C)	.144	0.655	.021	0.2	10.335	.020
	T Max. (°C)	.115	0.722	.013	0.1	10.325	.014
	T Min. (°C)	.165	0.609	.027	0.3	10.388	.027
Other causes related deaths	PET mean (°C)	−.551	0.063	.304	4.3	25.766	−.150
	PET Max. (°C)	−.542	0.069	.294	4.1	26.516	−.155
	PET Min. (°C)	−.559	0.059	.313	4.5	25.116	−.143
	T mean (°C)	−.556	0.061	.309	4.4	25.591	−.193
	T Max. (°C)	−.568	0.054	.323	4.7	26.397	−.176
	T Min. (°C)	−.548	0.065	.301	4.2	24.815	−.226

*Correlation is significant at the 0.05 level (2-tailed)

**Correlation is significant at the 0.01 level (2-tailed)

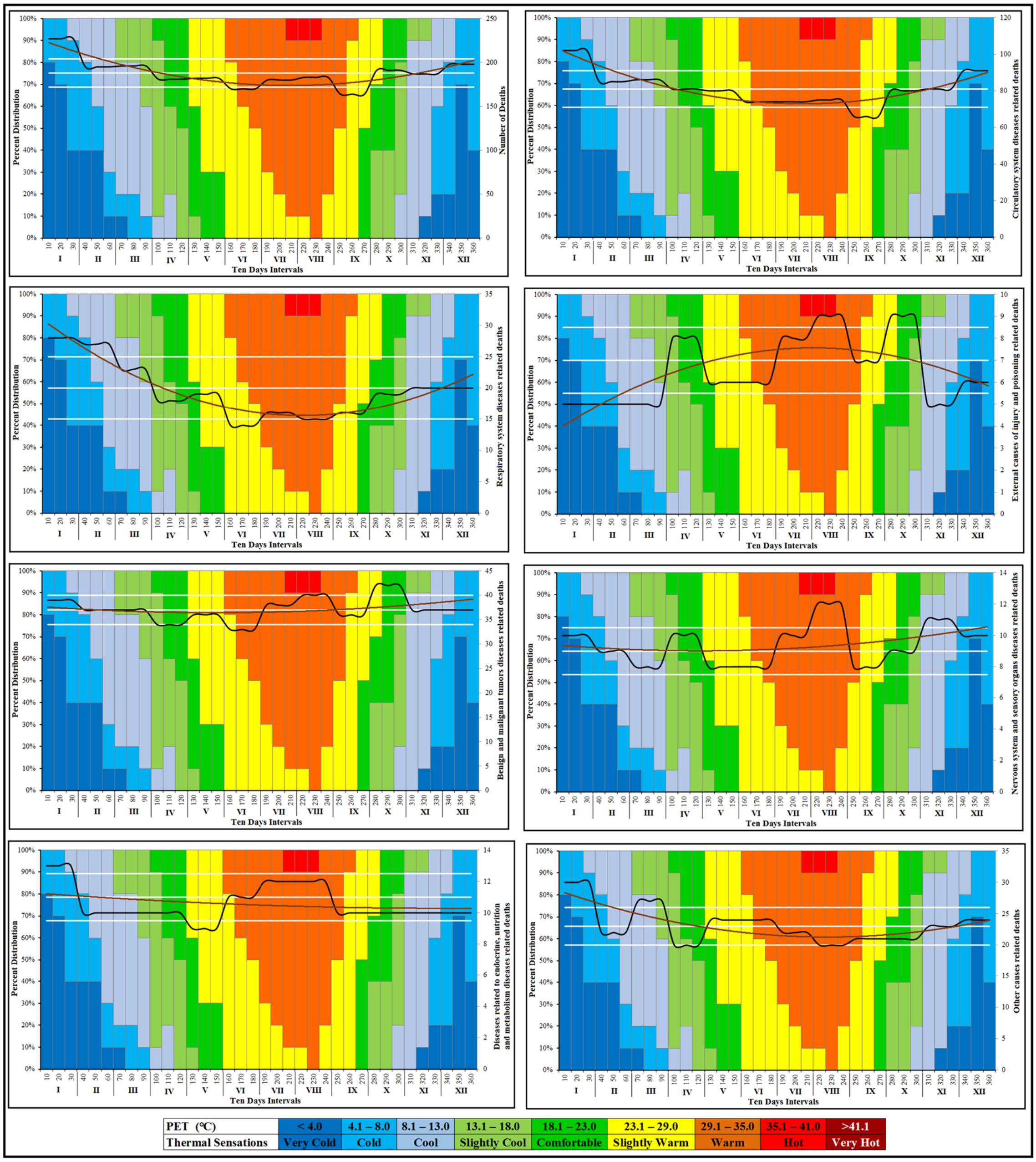

Fig. 2 Distribution of 10-day mean thermal comfort conditions (PET) with total numbers of death per month (black line) and the polynomial fitting (brown line). Three reference lines (white lines) represent the mean, the mean + SD, and the mean − SD

Although not significant, a moderate negative correlation was found between other causes related deaths and thermal comfort conditions and air temperature. According to the regression results, it was determined that there would be a decrease in deaths between approximately 0.15 and 0.20 with an increase of 1 °C in the variables (Table 4).

While other causes related to deaths are higher on days with cold thermal detections, they occur below average on days with hot thermal detections (Fig. 2).

Discussion

In Amasya, which is a medium-sized province of Anatolia, thermal comfort conditions and the relationship between air temperature and deaths were examined according to the causes of death. In this context, the thermal comfort conditions of the field were determined according to the PET index obtained from the Rayman model. The relationship between thermal comfort conditions and air temperature and the number of deaths according to their causes was determined by Pearson correlation analysis, and the number of deaths according to the causes of thermal comfort conditions and air temperature was determined by linear regression analysis.

As a result of the analysis, negatively high level between thermal comfort conditions and air temperature and total number of deaths due to all causes, very high negative level in circulatory system disease-related deaths and respiratory system disease-related deaths, positive in external causes of injury and poisoning-related deaths high level of directional relations, and a medium level of negative correlations were detected in other causes related deaths. There was no statistical relationship between benign and malignant tumors disease-related deaths, nervous system and sensory organs disease-related deaths, diseases related to endocrine, nutrition and metabolism-related deaths, and thermal comfort conditions and air temperature. However, in cold thermal conditions where PET values are below 18 °C, more deaths occur in monthly average numbers, in the number of deaths due to circulatory system, respiratory system, and other diseases, compared to other months. In hot thermal conditions where PET values are above 18 °C, deaths from external causes of injury and poisoning are higher than in other months.

As a result of the regression analysis, in the 1 °C increase that will occur in the variables (PET and T) 1.1 to 1.7 units per month for all-cause deaths, 0.7 to 1.0 units for circulatory system disease-related deaths, 0.35 to 0.45 units for respiratory system disease-related deaths, and 0.15 to 0.20 units for other causes related deaths, there will be a decrease. It has been determined that there will be an increase of 0.1 unit in causes of external injury and poisoning-related deaths.

In studies conducted in Amasya, it was reported that cold thermal comfort conditions increased hospital admissions for cardiovascular diseases and respiratory diseases (Çağlak 2022; Çağlak and Matzarakis 2023). This confirms the conclusion that circulatory system disease-related deaths and respiratory system disease-related deaths also increase during the period when cold thermal conditions are effective.

When the studies in the literature are examined, Nastos and Matzarakis (2012) found increases in mortality in cold thermal conditions in Greece. Aboubakri et al. (2020) reported that more deaths occurred in "cool" and "cold" stresses in a study conducted in Iran compared to other stress categories. Donaldson et al. (1998) in the study conducted in the Yakutsk region, it was stated that the total number of deaths increases in deaths due to ischemic heart, cerebrovascular, and respiratory disease, and decreases in deaths due to accidents, due to the decrease in air temperature. Urban and Kysely (2014) reported that cold conditions increase deaths in a study conducted in the Czech Republic. Meng et al. (2022) reported that there was an increase in death rates due to cold stresses and especially deaths due to circulatory system diseases in Shenzhen, China. In the Netherlands, cold and hot conditions have been reported to cause increases in deaths from circulatory and respiratory diseases and overall deaths (Kunts et al. 1993). When the results of this study were compared with the studies in the literature, it was seen that similar results were obtained.

It is thought that cold thermal conditions cause conditions such as increased blood pressure, increased cholesterol levels, increased fibrinogen, and erythrocyte counts in the blood, which pose a risk for circulatory system diseases (Thakur et al. 1987; Diaz et al. 2005). Again, the number of respiratory system diseases related to deaths is increasing because low temperatures because bronchoconstriction that poses a risk for respiratory system diseases, trigger existing lung diseases and cause infectious respiratory diseases to occur (Hajat and Haines 2002). Among the causes of death, circulatory system diseases and respiratory system diseases related to deaths are high, and cold thermal conditions, especially affecting the elderly population, cause the general number of deaths to be negatively correlated with thermal comfort conditions and air temperature. In heat stress, it is thought that external causes of injury and poisoning related to deaths increase because people have a lack of attention and cause injuries and accidents for people working in jobs that require attention.

In some studies, it has been stated that heat stresses rather than cold thermal conditions increase deaths. Matzarakis et al. (2011) stated in a study conducted in Vienna that there was an increase in deaths due to circulatory system and respiratory system diseases during periods of heat stress. Błażejczyk et al. (2018) reported an increase in mortality (compared to days without thermal stress) of 12% and 47%, respectively, on days of strong and very strong heat stress in Poland. Schlegel et al. (2020) stated that there are significant relationships between death rates and heat stress in Germany. However, in this study, a positive relationship was seen only in deaths due to external causes of injury and poisoning. Although the causes of illness and the results may differ according to the period examined in such studies, it is generally understood that thermal comfort conditions, extreme heat, or extreme cold stresses are effective on deaths.

In obtaining different results between studies, it is thought that the population structure (young, old, etc.) is different, geographical differences, nutrition and shelter differences, health investments, and differences in the development level.

Conclusion

In the study, it was found that in Amasya, a medium-sized Anatolian city, there was a high level of negative relationship between thermal comfort conditions and total number of deaths due to all causes, deaths due to circulatory system diseases and deaths due to respiratory system diseases, and a high level of positive relationship between thermal comfort conditions and deaths due to injuries and poisoning due to external causes. These findings scientifically confirm the statements such as “Old age is like winter” and “Falling snow is like a shroud” in the folk sayings in the Amasya region that deaths increase in winter.

With climate change, the frequency of cold and heat waves is increasing. Although the human body has an adaptable structure, it is difficult to adapt to thermal comfort conditions that occur suddenly and last for a long time. Especially the elderly 65 and over, children in the 0–14 age group and people in the sensitive group with chronic diseases should take some precautions on days when such negative comfort conditions are experienced. Findings from the study provide important information for establishing early warning systems in health systems, developing preventive and protective measures and protecting the population in the vulnerable group.

In addition, it is thought that the study will provide a guide for health-climate studies and climate-resilient healthy community planning.

Author contribution All stages of the study were prepared by Savaş Çağlak.

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

Code availability Not applicable.

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 Not applicable.

Consent for publication Not applicable.

Conflict of interest The author declares no competing interests.

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