Original Article

Effect of Air Temperature and Universal Thermal Climate Index on Respiratory Diseases Mortality in Mashhad, Iran

Gholamabbas Fallah Ghalhari PhD•[1], Fatemeh Mayvaneh PhD[1]

Abstract

Objective: Climatic factors with desired and sometimes undesired effects lead to changes in the human body, such as hypothermia, influenza, heart disease, stroke, asthma, etc. The present study investigates the role of temperature in respiratory mortality in Mashhad, Iran.

Materials and Methods: Among the respiratory mortality data, daily temperature, wind speed and relative humidity from 2004 to 2013 were used. First, Tmrt parameter was calculated through Ray Man software and the values of UTCI index were obtained using Bioklima software. Finally, the correlation between the thresholds of the above-mentioned index and temperature as well as mortality was calculated. In addition, the mortality risk ratio in all of these thresholds was calculated.

Result: The results show that the UTCI index has changed from 32°C to 40°C in Mashhad. There is a strong and negative relationship between the maximum temperature (r = -0.90, *P*-value < 0.001) and mortality, and a positive relationship between the minimum temperature and mortality. In addition, the correlation between index and mortality shows that the highest positive and strong correlation is observed in negative temperature thresholds with cold stress. Thresholds with thermal stress are also inversely associated with mortality. The study of the mortality risk ratio in all thermal stress thresholds shows that in average cold stresses and a 10°C reduction, the mortality risk ratio increases by 1.36% in the significance level of 95%.

Conclusion: Generally, mortality increases with decreasing temperature and increasing cold stresses and the mortality risk increases by 1.36% per 10°C reduction.

Keywords: Heat stress, mortality, ratio risk, UTCI

Cite this article as: Fallah Ghalhari G, Mayvaneh F. Effect of air temperature and universal thermal climate index on respiratory diseases mortality in Mashhad, Iran. *Arch Iran Med*. 2016**; 19(9):** 618 – 624.

Introduction

Respiratory disease is a medical term that encompasses pathological conditions affecting the organs and tissues that make gas exchange possible in higher organisms. Respiratory diseases consist of a wide range of diseases such as acute respiratory infections, pneumonia, obstructive pulmonary disease, pneumoconiosis and malignant pleural disease, and respiratory devices. Respiratory diseases are considered as causes of morality all over the world.[1] In addition, lower respiratory tract infection, COPD, tuberculosis, and lung cancer are among the top 10 causes of morality worldwide.[2] In all situations, the human is affected by his surrounding heat[3] and has recognized the effect of climate on the incidence and spread of epidemic diseases since long ago. In the 5th century BCE, Hippocrates' observations regarding seasonal diseases formed the base of investigating epidemics in his epistle.[4, 5] Climate variability is one of the risk factors for mortality.[6, 7] Many studies have reported the side effects caused by cold and thermal stresses on mortality. Temperature or a simple measure such as experimental parameters showing the effects of temperature, humidity and wind speed are used in most of these studies.[8] Human thermal comfort results from the energy balance between body and environment affecting the human physiology, psychology and behavior.[9,10] On the other hand, thermal comfort models use complex metabolic processes including level of physical activity and dress in addition to atmospheric parameters (temperature, vapor pressure of water, wind speed and mean radiant temperature).[11] In addition, these models are useful tools to summarize the interactions of environmental stressors and human reactions expressed as empirical or logical classifications based on the human balance-related calculations.[12,13] The Fiala multi-node model of human thermoregulation and heat balance is one of the most advanced models based on the latest advances in all fields of thermal physiology, occupational health, physics, meteorology, biometeorology and environmental sciences.[14] This model is derived from the Universal Thermal Climate Index (UTCI). This index has been developed to create a standard measure for suitable thermal conditions in major fields of human biometeorology.[15] In comparison with other indices, UTCI is more sensitive to slight changes in temperature, solar radiation, humidity and wind speed and provides a better description of various climatic conditions.[16] Many epidemiological studies on the effects of temperature on mortality in Northern Europe and America are conducted due to increased temperature compared to previous decades.[17] In addition, various studies in other countries show that daily mortality depends on temperature.[18–21] There is evidence of a U or V shaped relationship between mean temperature and all mortalities in most world cities.[22–24] In cold and moderate regions, temperature-mortality curve shows a minimum of 18°C called the point of maximum comfort, higher

Authors' affiliations: [1]Faculty of Geography and Environmental Sciences, Hakim Sabzevari University, Sabzevar, Iran.
•Corresponding author and reprints: Gholamabbas Fallah Ghalhari PhD, Faculty of Geography and Environmental Sciences, Hakim Sabzevari University, Sabzevar, Iran. Tel: +98-51-44013309, Cell Phone: +98-913-2639881, E-mail: ab_fa789@yahoo.com.
Accepted for publication: 22 June 2016

and lower of which the mortality increases.[25,26] McGregor has investigated the association between the level of ischemic heart disease mortality (IHD) for three English counties and the winter North Atlantic Oscillation (NAO) and found that there is a clear and negative relationship between the increased mortality and the above-mentioned index. Analitis, et al.[27] studied the short-term effects of cold weather on mortality in 15 European cities and found that a 1°C decrease in temperature was associated with a 1.35% increase in daily mortalities in the elderly groups. In addition, studies show that in almost half the world, 1°C increase in temperature is associated with 1% – 3% increase in the risk of mortality.[28] Almeida, et al.[29] proved that, even without extremes in apparent temperature, there is a relationship between the average temperature and daily mortality in Lisbon and Porto, Portugal during the warm season (April to September). Miron, et al.[30] studied the time trend of the maximum and minimum temperature and its relationship with mortality in Central Spain during 1975 – 2003 and ascertained that mortality, especially in the elderly, increases with a decrease in temperature and thermal comfort. Nastosand Matzarakis[7] also studied the effect of temperature and thermal indices on mortality and the results showed a close relationship between mortality and the reduced temperature during cold periods, so that 10°C increase in temperature was associated with 6% – 13% increase in the risk of mortality. In addition, investigating the delay time showed that the significant effects (increased mortality) of 3-day delay during cold period appear against 1-day delay during warm period.

Considering the necessity of conducting studies on thermal comfort and its relationship with human health, this study examines the relationship between Universal Thermal Climate Index (UTCI) and temperature and respiratory mortality in Mashhad (Iran) from 2004 to 2013.

Study Area

In terms of topography, Mashhad is located in the southeast of Atrak-Kashafrud basin inside Mashhad plain. This city is located within the latitude and longitude of´ 36°14' to 36°48' N and 59°35' to 59°74' E in Khorasan Razavi province (Iran). Mashhad is the second largest city in Iran and the most important population center in north eastern Iran. According to the census of 2011, Mashhad's population was 3,069,941, showing an upward trend compared to the previous years. In addition, the total number of respiratory mortalities in this city in the study period was 17,523 subjects.

Methods

This study has used the meteorological data of temperature, wind speed, water vapor pressure, cloudiness, relative humidity (obtained from Mashhad synoptic meteorological station) and mortality due to respiratory diseases (pulmonary tuberculosis: 435 cases of death, flu and pneumonia: 6629 cases of death, lung cancer: 1334 cases of death, acute respiratory infection: 494 cases of death, acute and chronic bronchitis: 1116 cases of death, asthma and shortness of breath topically: 949 cases of death, other respiratory tract diseases: 6566 cases of death based on the international classification of disease[31]) in Mashhad (provided by Ferdows Municipality) during 2004 – 2013. In order to calculate the UTCI index, the mean radiant temperature (Tmrt) was first calculated using Ray Man software. The obtained values were entered to Bioklima software. Values of indices were calculation daily scale in Mashhad, and thresholds of thermal stress were extracted during the study period; then, the relationship between UTCI and temperature and daily mortality was assessed using the Pearson's correlation. In the next step, the ratio of mortality risk in all stress thresholds was calculated using STATA software at a level of 95%.

Universal thermal climate index (UTCI)

In 1999, the International Society of Biometeorology established a commission "On the development of a Universal Thermal Climate Index (UTCI)". The goal of this project was to derive a thermal index based on the most advanced thermo-physiological models. Since 2005, these efforts have been reinforced by Cooperation in Science and Technical Development (COST) which has brought together leading experts in the areas of human thermo-physiology, physiological modeling, meteorology and climatology. This index is known as the temperature of the reference condition yielding the same response in the same conditions. The UTCI value depends on temperature, wind speed, relative humidity and the mean radiant temperature and is written as follows:[32]

$$UTCI = f(Ta;Tmrt;Va;vp) = Ta + offset(Ta;Tmrt;Va;vp) \quad (1)$$

The offset, i.e. the deviation of *UTCI* from air temperature, depends on the actual values of air and mean radiant temperature (*Tmrt*), wind speed (*va*) and humidity, expressed as water vapor pressure (*vp*) or relative humidity (*RH*). This indicator aims to quantify the human physiological reactions to the one-dimensional thermal conditions, shows reflect actual index value will be calculated as multivariable dynamic model.[14,33] The UTCI ultimately aims to be a one-dimensional quantity adequately reflecting the human physiological reaction to the actual thermal condition. The index value will be calculated as a multivariate dynamic model. In addition, the model outputs include the thermoregulatory physiological processes as listed in Table 1. These outputs are significant for the human reaction to natural, moderate and extreme thermal conditions.[34,35]

An Assessment Scale of the UTCI

Different values of UTCI are categorized in terms of thermal stresses. These categorizations are based on the physiological responses to actual environmental conditions, so that these responses are caused by reference conditions and decreased thermal or cooling loads. Table 2 represents the categories of this index based on ecological and physiological criteria.[36]

Calculations of the UTCI made use of the mathematical equation (for more details, see the reference 36).[37] The mean radiative temperature (Tmrt) is one of the input factors used to calculate UTCI. This input shows the effect of solar radiation and temperature on human and represents a uniform surface temperature of an imaginary enclosure surrounding the person and calculable based on mathematical relationship.[38,39]

Estimation of relative risk (RR)

In Statistics and Epidemiology, the probability of occurrence of an event (developing a disease or death over a period of time) among the exposed group compared to the unexposed group is

Table 1. Variables available from the output of the thermophysiological model after exposure times of 30 and 120 min

Variable	Abbreviation	Unit
rectal temperature	Tre	°C
mean skin temperature	Tskm	°C
face skin temperature	Tskfc	km
sweat production	Mskdot	g/min
heat generated by shivering	Shiv	W
skin wittedness	wettA	% of body area
skin blood flow	VblSk	% of basal value

Table 2. Temperature thresholds (°C) of particular thermal sensations (of alert descriptions) used in bioclimatic indices

Stress category	UTCI range (°C)
Extreme heat stress	Above +46
Very strong heat stress	+38 to +46
Strong heat stress	+32 to +38
Moderate heat stress	+26 to +32
No thermal stress	+9 to +26
Slight cold stress	+9 to 0
Moderate cold stress	0 to −13
Strong cold stress	−13 to −27
Very strong cold stress	−27 to −40
Extreme cold stress	Below −40

[a]The UTCI subinterval +18 to +26°C within this category complies with the definition of the "thermal comfort zone" (The Commission for Thermal Physiology of the International Union of Physiological Sciences, 2003.

Table 3. the Mean Temperature, Mean of UTCI and Respiratory Mortality in Mashhad during the Period under Study

Months	Mean Temperature	Mean of UTCI	Respiratory Mortality
January	2.04	-9.65	1728*
February	3.92	-7.51	1604*
March	7.90	-2.47	1337
April	13.97	5.42	1308
May	20.14	15.03	1473
June	25.03	21.43	1422
July	27.91	24.55	1384
August	27.52	22.95	1384
September	23.42	15.64	1324
October	18.41	8.85	1283
November	11.80	2.35	1428
December	6.07	-4.8	1704*

*The Maximum Mortality in the Years

called risk ratio (relative risk) enjoying two important features of exposure and lack of exposure.[40,41] This parameter is to be exposed to something that can affect health[42,43] (For more details about the calculation of the risk ratio, see the reference 42).

Result

During 2004 to 2013, the total number of mortalities in Mashhad was 125262 subjects, among which 17523 respiratory mortalities were recorded. The average number of mortality in the study period is 2 to 8 deaths per day. Demographic-population descriptions of the rate of mortality are shown in Table 3. The highest and lowest rates of deaths were observed in January and October, respectively. January has the lowest index values and the highest strong cold stresses, and October has the lowest rate of mortality due to conditions without thermal stresses (Figure 1 and 2). The respiratory mortality rate is shown in Figure 3, and was used after fitting various curves. Finally, considering R^2 values the cubic curve showed the best fit with mortality data. As shown in the graph, mortality first followed a descending trend, and then increased over the time.

In the next step, the relationship and correlation between mortality and temperature and UTCI were identified in all thresholds regarding the index thresholds and the results obtained from these correlations are shown in Table 4. There is a negative and significant correlation between the maximum temperature and the number of deaths, so that mortality decreases with the increase of temperature (r = -0.56, P = 0.03). This reverse and strong relationship with increased temperature is enhanced above 20°C (r = -0.90, P = 0.001). In addition, there is a strong and positive

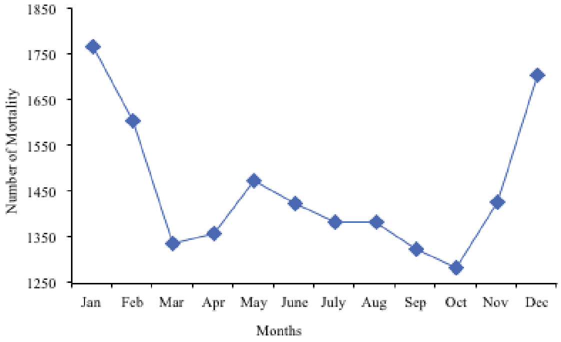

Figure 1. The Number of Mortality in different Months

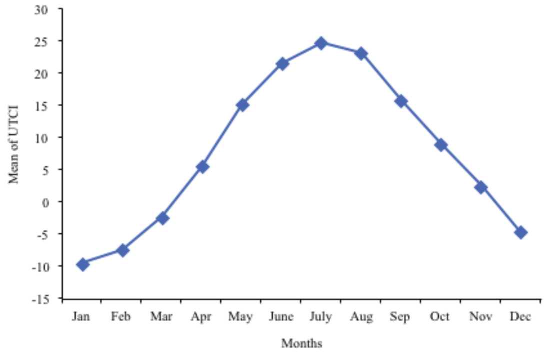

Figure 2. The Mean of UTCI Index In different Months

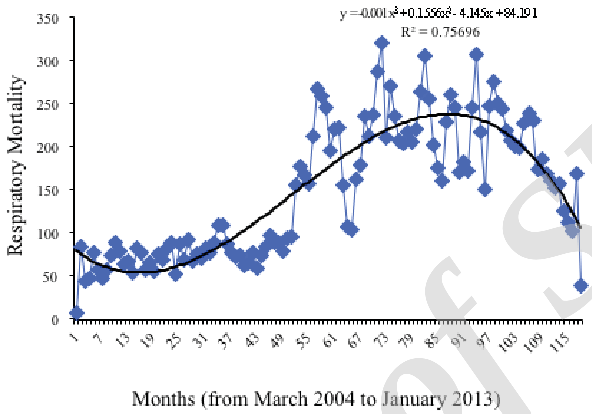

Figure 3. Time series of respiratory mortality in over 10 years

Table 4. Correlation between UTCI and Respiratory Mortality in the Threshold

UTCI Range (°C)	Stress Category	P	P-Value
26 to 32	Moderate heat stress	-0.92	0.003
9 to 26	No thermal stress	-0.49	0.03
0 to 9	Slight cold stress	-0.56	0.2
0 to -13	Moderate cold stress	0.83	0.001
-13 to -27	Strong cold stress	0.87	0.001
-27 to -40	Very strong cold stress	0.29	0.5

relationship between the minimum temperature and mortality at a significance level of $P < 0.01$, so that mortality increases with decrease of temperature ($r = -0.82$, $P = 0.0001$).

In addition, considering the thermal stress thresholds, the correlation between UTCI and mortality indicates that the highest strong and positive correlation is observed in thresholds with moderate and severe cold stresses, and thermal stress thresholds have reverse and strong relationship. The results of the risk ratio estimate (Figure 4) show that the relationship between mortality and UTCI has two maximum points of 17.5°C and -6.5°C; in other words, the highest risk of mortality is related to these two points. In general, in the threshold of 30°C to -10°C, the relative risk of respiratory mortalities per 10°C reduction in UTCI increases 1.4% at a confidence level of 95%. According to the obtained results (see Figure 5), the relationship between mortality and mean temperature and mean UTCI follows the third degree equation. In other words, by increasing temperature and UTCI index to a certain amount, the mortality rate increases and then decreases with further increases in mean temperature and mean UTCI index.

Discussion

The Fiala model has been subject to general as well as application-specific validation studies regarding human thermal and regulatory behaviors,[44] occupant comfort in buildings,[45] transient indoor climate conditions in cars,[46] asymmetric radiation scenarios and exposures to high intensity sources,[47] but also anesthesia. Studies and clinical trials show that there is a close relationship between temperature and respiratory and cardiac mortality.[48] This study investigates the relationship between temperature and mortality and showed that the mortality has decreased above 20°C and

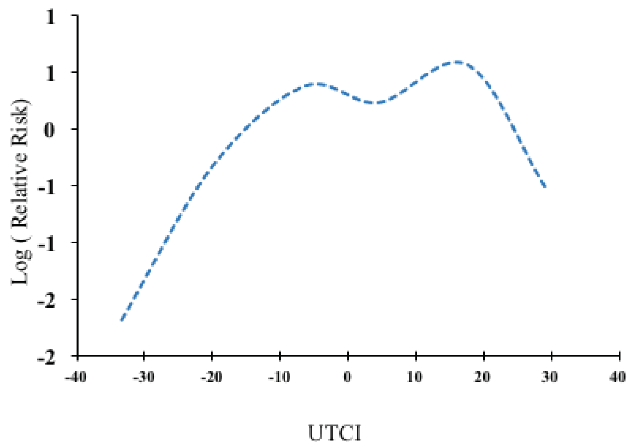

Figure 4. exposure-response relationships for UTCI (◦c) mortality respiratory and trend of respiratory mortality in Mashhad

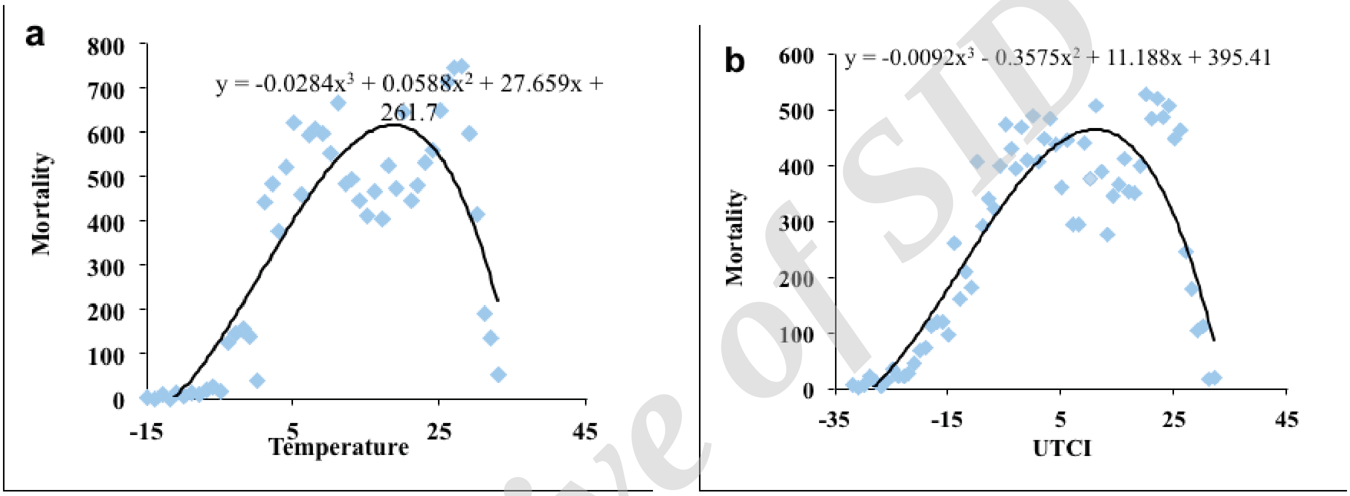

Figure 5. Scatterplots and fitted curves of respiratory disease mortality and mean temperatures and mean UTCI

there is a strong and reverse relationship between them, while the effects of the minimum temperature and thermal stresses have the highest positive and strong relationship with mortality. Previous and similar studies show that thermal stresses have the highest relationship with mortality.[45–47] The effects of cold weather on respiratory and cardiovascular diseases and mortality have been confirmed.[48–50] In addition, studies conducted by Marchant, et al.[51] and Beyerbach, et al.[52] at the North Pole show the increased mortality due to cardiovascular diseases during severe winters. Considering the studies conducted by Braga, et al.[53] and Hampel, et al.[54] regarding the existence of strong relationships between respiratory diseases (viral pneumonia, influenza, pneumonia) and cold temperature, the results of this study show that there is a strong and positive relationship between minimum temperatures and cold stress thresholds. In addition, researchers believe that there is a reverse relationship between the level of fibrinogen and temperature, and the incidence of seasonal respiratory infections increases with the increase of fibrinogen.[55] This study also investigates the relationship between the Universal Thermal Climate Index (UTCI)–a thermo-physiological model of human comfort–and respiratory mortality in Mashhad. Findings showed that there is a strong and positive relationship between cold stresses and mortality. Like the present study, Nastos and Matzarakis[7] investigated the relationship between the above-mentioned model and several other climatic parameters and mortality in Athens. In general, it is concluded that the existence of climatic elements and its effects on health, disease, and mortality are significant. This study also has shown that low temperatures and cold stresses caused by them had the strongest relationship with mortality in Mashhad. It is recommended to consider the relationship between environmental factors and the incidence of diseases and mortality while conducting similar studies. In addition, using similar thermo-physiological models will be a useful guideline to inform vulnerable and sick people about unsuitable times of environmental conditions (severe cold and thermal stresses).

In conclusion, the performed analysis revealed that there is a significant relation between the daily mortality and mean temperature and thermal indices such as UTCI in Mashhad, Iran. The relationship is U-shaped indicating that both the cold and hot components account for increased daily mortality, but cold conditions affect the daily mortality frequencies more than hot conditions. Another notable finding of our study is that the daily variations of temperature and UTCI index affect more mortality frequency during the cold period than the warm period of the year.

List of abbreviations

UTCI: Universal Thermal Climate Index; Mrt: Mean Radiant Temperature; RR: Relative Risk; IHD: Ischemic Heart Disease; NAO: North Atlantic Oscillation.

Competing interest

The authors declare that they have no competing interests.

Acknowledgments

This research received no grants from any funding.

References

1. Organization WH, Organization WH. Prevention and control of chronic respiratory diseases at country level: Towards a global alliance against chronic respiratory diseases (GARD): Based on the WHO Meeting on Prevention and Control of Chronic Respiratory Diseases, *Geneva*, Switzerland, 17 – 19 June 2004.
2. Desalu OO, Oluwafemi JA, Ojo O. Respiratory diseases morbidity and mortality among adults attending a tertiary hospital in Nigeria. *Jornal Brasileiro de Pneumologia*. 2009; 35: 745 – 752.
3. Kunst AE, Groenhof F, Mackenbach JP. The association between two windchill indices and daily mortality variation in The Netherlands. *American Journal of Public Health*. 1994; 84: 1738 – 1742.
4. Parsons K. Human thermal environments: The effects of hot, moderate, and cold environments on human health, comfort, and performance: Crc Press; 2014.
5. Meade MS. Medical geography: Wiley Online Library; 2010.
6. Cheng X, Su H. Effects of climatic temperature stress on cardiovascular diseases. European *Journal of Internal Medicine*. 2010; 21: 164 – 167.
7. Nastos PT, Matzarakis A. The effect of air temperature and human thermal indices on mortality in Athens, Greece. *Theoretical and Applied Climatology*. 2012; 108: 591 – 599.
8. Basu R. High ambient temperature and mortality: A review of epidemiologic studies from 2001 to 2008. *Journal of Environmental Health*. 2009; 8: 1 – 13.
9. Jendritzky G, de Dear R, Havenith G. UTCI-Why another thermal index? *International Journal of Biometeorology*. 2012; 56: 421 – 428.
10. McGregor GR. Human biometeorology. *Progress in Physical Geography*. 2012; 36: 93 – 109.
11. Kántor N, Unger J. The most problematic variable in the course of human–biometeorological comfort assessment—the mean radiant temperature. *Central European Journal of Geosciences*. 2011; 3: 90 – 100.
12. Blazejczyk K, Epstein Y, Jendritzky G, Staiger H, Tinz B. Comparison of UTCI to selected thermal indices. *International Journal of Biometeorology*. 2012; 56: 515 – 535.
13. Steadman RG. The assessment of sultriness. Part II: effects of wind, extra radiation and barometric pressure on apparent temperature. *Journal of Applied Meteorology*. 1979; 18: 874 – 885.
14. Fiala D, Havenith G, Bröde P, Kampmann B, Jendritzky G. UTCI–Fiala multi–node model of human heat transfer and temperature regulation. *International Journal of Biometeorology*. 2012; 56: 429 – 441.
15. Błażejczyk K, Broede P, Fiala D, Havenith G, Holmér I, Jendritzky G, et al. UTCI–nowy wskaźnik oceny obciążeń cieplnych człowieka. *Przegląd Geograficzny*. 2010; 82: 49 – 71.
16. Urban A, Davídkovová H, Kyselý J. Heat– and cold–stress effects on cardiovascular mortality and morbidity among urban and rural populations in the Czech Republic. *International Journal of Biometeorology*. 2014; 58: 1057 – 1068.
17. Ishigami A, Hajat S, Kovats RS, Bisanti L, Rognoni M, Russo A, et al. An ecological time–series study of heat–related mortality in three European cities. *Environ Health*. 2008; 7: 1 – 7.
18. Kunst AE, Looman CW, Mackenbach JP. Outdoor air temperature and mortality in the Netherlands: A time–series analysis. *American Journal of Epidemiology*. 1993; 137: 331 – 341.
19. Saez M, Sunyer J, Castellsague J, Murillo C, Anto JM. Relationship between weather temperature and mortality: A time series analysis approach in Barcelona. *International Journal of Epidemiology*. 1995; 24: 576 – 582.
20. Díaz J, García R, López C, Linares C, Tobías A, Prieto L. Mortality impact of extreme winter temperatures. *International Journal of Biometeorology*. 2005; 49: 179 – 183.
21. Laaidi M, Laaidi K, Besancenot JP. Temperature–related mortality in France, a comparison between regions with different climates from the perspective of global warming. *International Journal of Biometeorology*. 2006; 51: 145 – 153.
22. Armstrong B. Models for the relationship between ambient temperature and daily mortality. *Epidemiology*. 2006; 17: 624 – 631.
23. Curriero FC, Heiner KS, Samet JM, Zeger SL, Strug L, Patz JA. Temperature and mortality in 11 cities of the eastern United States. *American Journal of Epidemiology*. 2002; 155: 80 – 87.
24. Farajzadeh M, Darand M. Analysis of air temperature influence on mortality in Tehran. *Hakim Res J*. 2008; 11: 27 – 34. [In Persian].
25. Donaldson G, Ermakov S, Komarov Y, McDonald C, Keatinge W. Cold related mortalities and protection against cold in Yakutsk, eastern Siberia: Observation and interview study. *BMJ*. 1998; 317: 978 – 982.
26. Hajat S, Kovats RS, Atkinson RW, Haines A. Impact of hot temperatures on death in London: A time series approach. *Journal of Epidemiology and Community Health*. 2002; 56: 367 – 372.
27. Analitis A, Katsouyanni K, Biggeri A, Baccini M, Forsberg B, Bisanti L, et al. Effects of cold weather on mortality: Results from 15 European cities within the PHEWE project. *American Journal of Epidemiology*. 2008; 168: 1397 – 1408.
28. Hajat S, Kosatky T. Heat–related mortality: A review and exploration of heterogeneity. *Journal of Epidemiology and Community Health*. 2010; 64: 753 – 760.
29. Almeida SP, Casimiro E, Calheiros J. Effects of apparent temperature on daily mortality in Lisbon and Oporto, Portugal. *Environ Health*. 2010; 9: 12.
30. Miron IJ, Criado–Alvarez JJ, Diaz J, Linares C, Mayoral S, Montero JC. Time trends in minimum mortality temperatures in Castile–La Mancha (Central Spain): 1975–2003. *International Journal of Biometeorology*. 2008; 52: 291 – 299.
31. Eisfeld J. International Statistical Classification of Diseases and Related Health Problems. *TSQ*. 2014; 1: 107 – 110.
32. Blazejczyk K, Jendritzky G, Bröde P, Fiala D, Havenith G, Epstein Y, et al. An introduction to the Universal Thermal Climate Index (UTCI). *Geographia Polonica*. 2013; 86: 5 – 10.
33. Havenith G, Fiala D, Błazejczyk K, Richards M, Bröde P, Holmér I, et al. The UTCI–clothing model. *International Journal of Biometeorology*. 2012; 56: 461 – 470.
34. Bröde P, Fiala D, Błażejczyk K, Holmér I, Jendritzky G, Kampmann B, et al. Deriving the operational procedure for the Universal Thermal Climate Index (UTCI). *International Journal of Biometeorology*. 2012; 56: 481 – 494.
35. Kampmann B, Bröde P, Havenith G, Jendritzky G, editors. Der Entwicklungsstand des klimatischen Belastungs-Index UTCI (Universal Thermal Climate Index). Produkt-und Produktions-Ergonomie-Aufgabe für Entwickler und Planer, 54 Kongress der Gesellschaft für Arbeitswissenschaft 2008 March 4 – 6; Technischen Universität Dortmund: GfA-Press; 2009. p. 709 – 712.
36. Blazejczyk K, Jendritzky G, Bröde P, Fiala D, Havenith G, Epstein Y, et al. An introduction to the Universal Thermal Climate Index (UTCI). 2013.
37. Błażejczyk K. Mapping of UTCI in local scale (the case of Warsaw). *Prace i Studia Geograficzne WGSR UW*. 2011; 47: 275 – 283.
38. Błażejczyk K. Assessment of regional bioclimatic contrasts in Poland. *Miscellanea Geographica–Regional Studies on Development*. 2011; 15: 79 – 91.
39. Błażejczyk K. Radiation balance in man in various meteorological and geographical conditions. *Geographia Polonica*. 2004; 77: 63 – 76.
40. Medina LS, Zurakowski D. Measurement Variability and Confidence Intervals in Medicine: Why Should Radiologists Care? *Radiology*. 2003; 226: 297 – 301.
41. Sistrom CL, Garvan CW. Proportions, Odds, and Risk. *Radiology*. 2004; 230: 12 – 19.
42. Giesecke J. Modern infectious disease epidemiology: Edward Arnold (Publisher) Ltd.; 1994.
43. Rothman KJ, Greenland S, Lash TL. Modern epidemiology: Lippincott Williams & Wilkins; 2008.
44. Fiala D, Lomas KJ, Stohrer M. Computer prediction of human thermoregulatory and temperature responses to a wide range of

environmental conditions. *International Journal of Biometeorology*. 2001; 45: 143 – 159.
45. Lomas K, Fiala D, Stohrer M. First principles modeling of thermal sensation responses in steady-state and transient conditions. *ASHRAE Transactions*. 2003; 109: 179 – 186.
46. Fiala D, Bunzl A, Lomas KJ, Cropper PC, Schlenz D. A new simulation system for predicting human thermal and perceptual responses in vehicles. In: Schlenz D, editor. PKW-Klimatisierung III: Klimakonzepte, Regelungsstrategien und Entwicklungsmethoden, Haus der Technik Fachbuch, Expert Verlag, Renningen. 27 ed: Haus der Technik Fachbuch; 2004. p. 147 – 162.
47. Richards M, Fiala D. Modelling fire–fighter responses to exercise and asymmetric infrared radiation using a dynamic multi–mode model of human physiology and results from the Sweating Agile thermal Manikin. *European Journal of Applied Physiology*. 2004; 92: 649 – 653.
48. Anderson BG, Bell ML. Weather–related mortality: How heat, cold, and heat waves affect mortality in the United States. *Epidemiology*. 2009; 20: 205.
49. Aylin P, Morris S, Wakefield J, Grossinho A, Jarup L, Elliott P. Temperature, housing, deprivation and their relationship to excess winter mortality in Great Britain, 1986–1996. *International Journal of Epidemiology*. 2001; 30: 1100 – 1108.
50. Gómez–Acebo I, Llorca J, Dierssen T. Cold–related mortality due to cardiovascular diseases, respiratory diseases and cancer: a case–crossover study. *Public Health*. 2013; 127: 252 – 258.
51. Marchant B, Ranjadayalan K, Stevenson R, Wilkinson P, Timmis AD. Circadian and seasonal factors in the pathogenesis of acute myocardial infarction: the influence of environmental temperature. *British Heart Journal*. 1993; 69: 385 – 387.
52. Beyerbach DM, Kovacs RJ, Dmitrienko AA, Rebhun DM, Zipes DP. Heart rate–corrected QT interval in men increases during winter months. *Heart Rhythm*. 2007; 4: 277 – 281.
53. Braga AL, Zanobetti A, Schwartz J. The effect of weather on respiratory and cardiovascular deaths in 12 US cities. *Environmental Health Perspectives*. 2002; 110: 859.
54. Hampel R, Breitner S, Rückerl R, Frampton MW, Koenig W, Phipps RP, et al. Air temperature and inflammatory and coagulation responses in men with coronary or pulmonary disease during the winter season. *Occupational and Environmental Medicine*. 2010; 67: 408 – 416.
55. Halonen JI, Zanobetti A, Sparrow D, Vokonas PS, Schwartz J. Associations between outdoor temperature and markers of inflammation: A cohort study. *Environmental Health*. 2010; 9: 42.