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TEMPERATURE-RELATED MORTALITY IN BELGRADE IN THE PERIOD 1888–2008

SMRTNOST V POVEZAVI S TEMPERATURAMI V BEOGRADU V OBDOBJU 1888–2008

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Civil registers of deceased.
Matična knjiga umrlih.

Temperature-related mortality in Belgrade in the period 1888–2008

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ABSTRACT: The paper uses air temperature and crude death rate data from Belgrade in the period from 1888 to 2008, in order to show expected correlation. Basic statistical analysis demonstrates statistically significant correlation values between these parameters. The starting assumption was that people in earlier times were more sensitive to extreme cold temperatures, particularly in the winter season. Statistical results confirm previous mentioned assumptionparticularly in the period before the First World War. Further analysis showed that in the last twenty years, air temperatures and death rates have opposite correlation outcomes. Statistical analysis points out that, in the last twenty years, death rates are increasing more rapidly in the summer season, due to increasing frequencies of extreme air temperature events.

KEY WORDS: geography, crude death rate, air temperature, seasonal impact, Belgrade, Serbia

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Contents

1 Introduction

The relationship between air temperature and mortality is a fairly well studied and available historical data show that seasonality of mortality has been of interest for a long time. But, the associations between climate and mortality have been extensively studied in the last twenty years pointing out mechanism of impact as well as various structural differences: social, regional, rural-urban.

According to Huynen et al. (2001) relationship between mortality and temperature appears graphically as a V shape, with an optimum temperature value. Curriero et al. (2002) analysed data about temperature and mortality in 11 cities of the eastern United States and found that mortality risk generally decreased as temperature increased from the coldest days to a certain threshold temperature, which varied by latitude, above which mortality risk increased as temperature increased. Pattenden et al. (2003) explored associations between mortality and temperature in two European capitals – Sofia and London and concluded that in London, for each degree of extreme cold mortality increased by 4.2%, and in Sofia by 1.8%. Luterbacher et al. (2004) concluded that European climate was very likely warmer than that of any time during the past 500 years and that 2003 was by far the hottest summer.

Carson et al. (2006) also indicated that the degree to which population vulnerability to outdoor temperature is reduced by improvements in infrastructure, technology, and general health has an important bearing on what realistically can be expected with future changes in climate. And because of that there was a progressive reduction in temperature-related deaths over the 20th century, despite an ageing population. According Hajat et al. (2007) most vulnerable group were elderly people, particularly those in nursing homes and the greatest risk of heat mortality was observed for respiratory and external causes, and in women.

The main result of international study of temperature, heat and urban mortality was that heat thresholds were generally higher in cities with warmer climates, while cold thresholds were unrelated to climate (McMichael et al. 2008).

Analitis et al. (2008) concluded that cold-related mortality is an important public health problem across Europe and because of that the health effects of hot weather are fast becoming a global public health challenge for the 21st century" (Hajat et al. 2010).

The objective of this study is to examine fluctuations of seasonal and annual air temeperatures and population ageing on crude death rate in Belgrade in the last 121 year. Results in this paper are generaly compared with similar researchers in other scientific articles.

2 Database and methods

The observed time span is 121 years long, i.e. from 1888 to 2008. Total number of deaths was taken from parish and civil registers. Instead of absolute numbers, the crude death rates (CDR) have been analyzed. Furthermore, yearly Ageing (Ag) (people aged 65 and more) have been calculated by applying linear interpolation for the period 1921–2008. Air temperature time series (in °C) of meteorological station in Belgrade for the period 1888–2008 were taken from Meteorological yearbooks of the Republic Hydrometeorological Service of Serbia. Seasonal and annual air temperature series (Tsr – annual, TsrW – winter, TsrSp – spring, TsrSm – summer, TsrA – autumn) were as well used, in order to show possible impacts of temperature-related deaths.

All parameters were split into three parts. The first part is from 1888 to 1913, according to assumption that people in times before the First World War were more sensitive to extreme cold and hot temperature spells. The second part, from 1919 to 1940, mostly characterized the beginnings of the industrialization process and the development of a modern society. The third part (1946–2008) is the period of the society industrialization and the period of constant air temperature increase, moreover, in the last twenty years.

The periods of the First and Second World Wars (1914–1918 and 1941–1945) have been excluded from the analysis due to missing data or poor quality of the observation procedures, which can probably provide some misleading in correlation outcomes.

In the various statistical analysis, 5-year moving average series was used in order to reduce the noise on the original raw Tsr, CDR and Ag variables. Given analysis results should be taken with certain consideration because this kind of approach lessens the number of cases and variability of time series, which inevitably influences the quality of the final results.

Pearson correlation coefficient (r) and Multiple Linear Regression (MLR) have been used to define correlations among analyzed variables. We performed the inspection of the residuals distribution of the dependant-criteria variable (CDR) and redundancy analysis, i.e. testing of the relationship between independentvariables (Tsr and Ag) as well as the correlation with dependent variable. In order to define significance of statistical test results the critical levels were 90%, 95% and 99%.

Belgrade, a city of approximately 1,6 million inhabitants, is settled in mid-latitudes between 44 φ °N and 45 φ °N and has four distinct seasons. At the end of the 19th and the first half of the 20th century, winters were mostly bitterly cold with often heavy snow. However, mostly mild winters with mean seasonal temperatures higher than 2 °C were noticed in the last twenty years of observed period. Summers are mostly arid and very hot with mean seasonal temperatures varying between 20 and 24 °C and in some years with extreme hot temperature spells higher than 40 °C.

3 Results

Figure 1 represents tendencies and linear trends of CDR and Ag on an annual level, as well as annual and seasonal range of mean air temperature according to defined time periods. The annual CDR at the end of the 19th and the beginning of the 20th century follows the tendency of a constant decline (Figure 1, A-C1). Furthermore, in the last twenty years it is noticeable a slight rise of CDR variable (Figure 1, D1). Annual values of Tsr show a smooth rising tendency in the last 111 years. The similar situation is in all three defined periods, while the last period (Figure 1, D2) shows a bit higher increasing trend. This kind of Tsr movement was probably influenced by seasonal fluctuations; the most expressed rise was recorded in the winter (Figure 1, A-D3) and summer (Figure 1, A-D4) seasons. In the last observed period (1946–2008), winter, spring and summer temperatures show a tendency of a constant rise (Figure 1, D3-5). Share of people old 65 and more in total population imply the increase of Ag variable (Figure 1, A7). This kind of tendency is particularly noticeable in the last two decades (Figure 1, D7).

Table 1 represents correlation values between CDR and annual and seasonal time series of air temperatures. The results show a statistically significant correlation, on the level of 99% between annual values of CDR and Tsr, as well as CDR-TsrW and CDR-TsrSm variables. Obtained statistically significant correlation values ($\rho < 0.01$) vary between ±0.3 and even over ±0.8. The beginning of the observed period (1888–1913) is characterized by statistically significant negative correlation between CDR with TsrW (Figure 2) and Tsr, and positive with TsrSm. In the period from 1946 to 2008, correlation between CDR and Tsr point at positive significant values especially with TsrSp and TsrSm temperatures (Figure 3).

Table 1: Pearson correlation coefficient (r) analysis between 5-year moving yearly CDR and annual and seasonal Tsr in Belgrade.

Time periods	CDR-Tsr	CDR-TsrW	CDR-TsrSp	CDR-TsrSm	CDR-TsrA
	r	r	r	r	r
1888–2008[a]	–0.60***	–0.53***	–0.43***	–0.27***	–0.37***
1888–1913	–0.80***	–0.86***	0.36*	0.57***	0.08
1919–1940	–0.12	0.35	0.34	–0.55**	–0.35
1946–2008	0.81***	0.48***	0.70***	0.73***	0.11

[a] Excluded the periods from 1914 to 1918 and from 1941 to 1945.
* Significant $\rho < 0.1$ (90%); ** Significant $\rho < 0.05$ (95%); *** Significant $\rho < 0.01$ (99%)

Correlation analysis of Ag with CDR and Tsr variables for the period 1946–2008, suggests high positive correlation with annual, winter, spring and summer values. The relationship between Ag-CDR and Ag-Tsr is 0.86, i.e. 0.65 and it represents statistically significant relations ($\rho < 0.01$). With seasonal air temperature variables, except for autumn, correlation of Ag in all cases exceeds 0.4 and shows statistical significant for level of 99%.

At the beginning of the analysis of MLR, the inspection of the residuals distribution of the dependant variable, i.e. of annual CDR has been performed. Results suggest the residual values of CDR generally have the characteristics of normal distribution, considering the fact that dots show a good distribution around the line of the best fit (Figure 4).

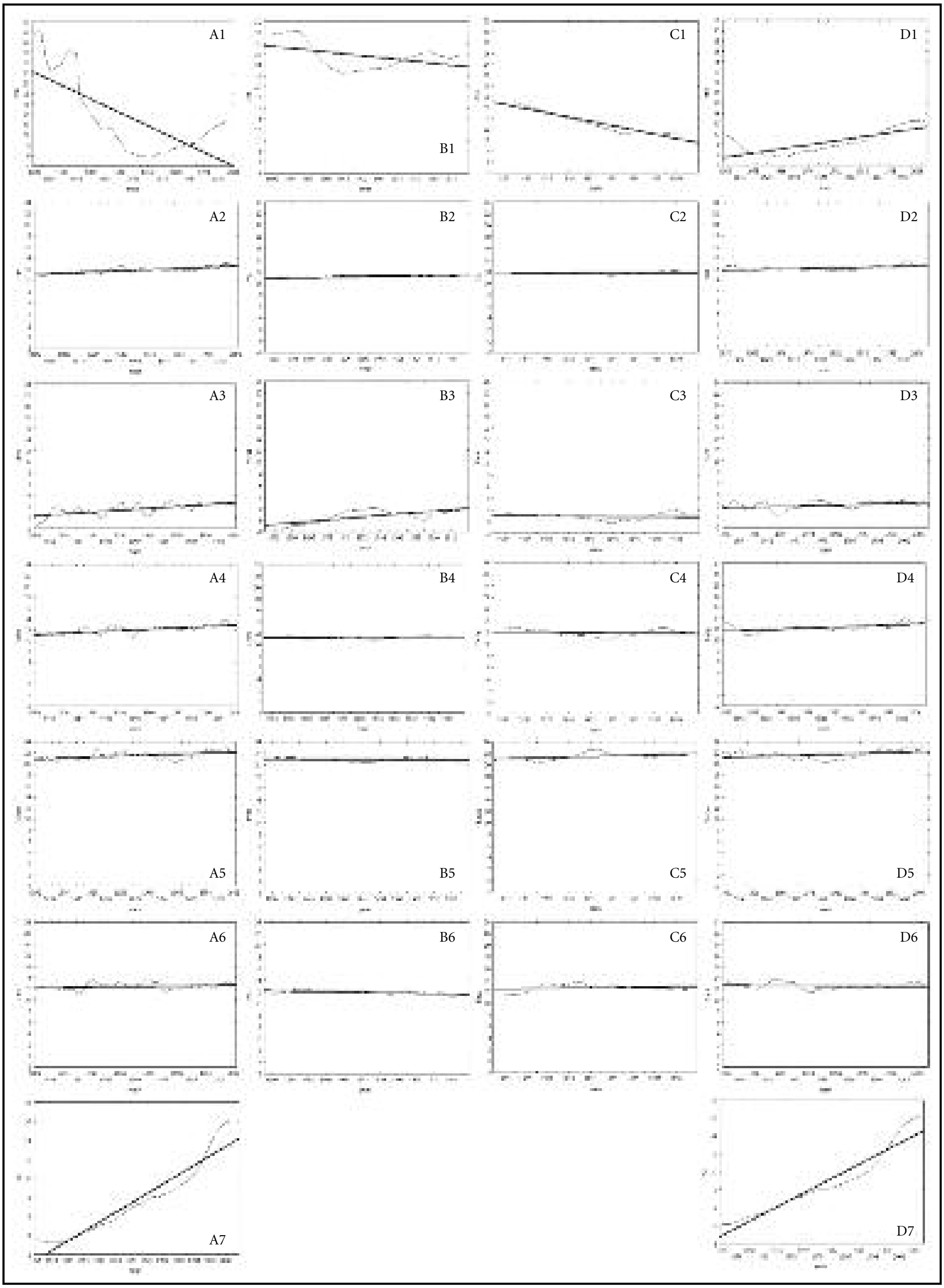


Figure 1: Changes in 5-year moving annual and seasonal A1-7: CDR, air temperature and Ag for the period 1888–2008; B1-6: CDR and air temperature from 1888 to 1913; C1-6: CDR and air temperature from 1919 to 1940; D1-7: CDR, air temperature and Ag from 1946 to 2008. Note: parameter variables are shown with thin line; linear trend is shown with bold line; The periods from 1914 to 1918 and from 1941 to 1945 have been excluded.

Figure 2: CDR (full line) and TsrW (dotted line) 5-year moving averages for Belgrade in the period 1888–1913

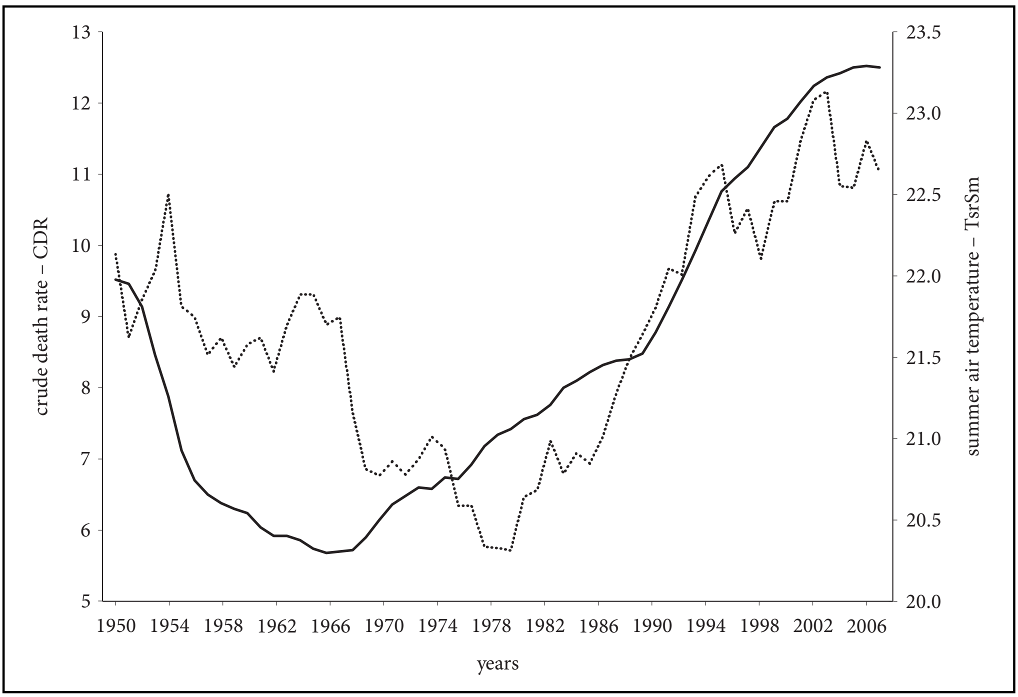
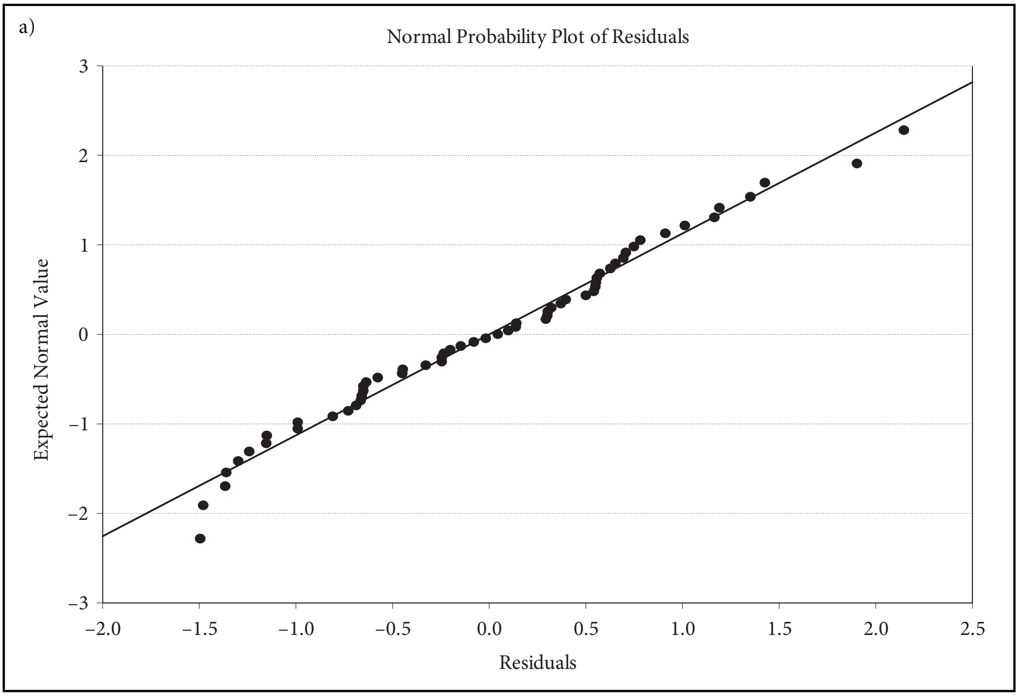


Figure 3: CDR (full line) and TsrSm (dotted line) 5-year moving averages for Belgrade from 1946 to 2008



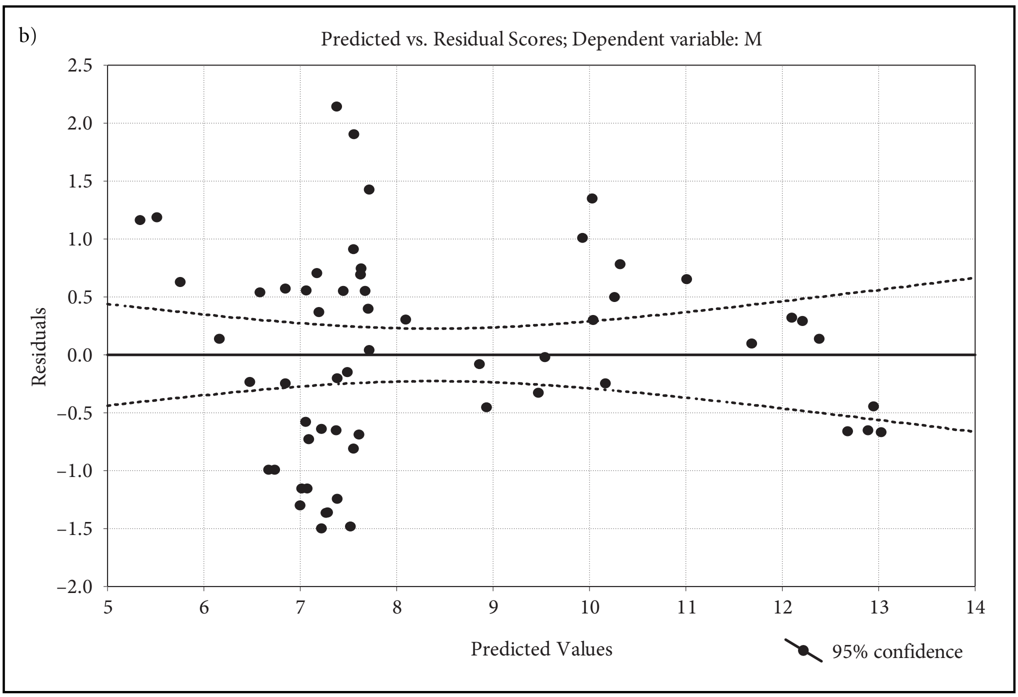


Figure 4: Normal probability plot of residuals (a) and predicted vs. residual scores (b) for dependent variable CDR in the period 1946–2008

Redundancy analysis of independent variables (annual and seasonal air temperatures and yearly ageing-Ag) is presented in Table 2. Obtained results point at high values of the tolerance between temperature and population ageing, which range in all cases between 0.58 and 1.0. At the same time, what can be noticed are perceptible differences in the value levels of partial correlation between independent variables, except in the case of Tsr-Ag, where the difference is somewhat smaller. It can be concluded that independent variables most probably can explain the movement tendency of CDR variable.

Table 2: Redundancy analysis of indenpendent variables – annual and seasonal Tsr and Ag from 1946 to 2008.

Dependent variable	Independent variables	T	R^2	P. C.	SP. C.
CDR	Tsr	0.58	0.42	0.65	0.33
	Ag			0.75	0.44
	TsrW	0.83	0.17	0.29	0.15
	Ag			0.83	0.73
	TsrSp	0.58	0.42	0.36	0.19
	Ag			0.75	0.53
	TsrSm	0.71	0.29	0.61	0.31
	Ag			0.81	0.56
	TsrA	1.00	0.0	0.18	0.1
	Ag			0.86	0.86

Note: T – tolerance; R^2 – squared correlation coefficient; P. C. – partial correlation; SP. C. – semipartial correlation

Table 3 shows results of MLR aimed at detecting possible correlation of annual and seasonal Tsr oscillations and Ag with the tendencies of the annual CDR in the period 1946–2008. In all cases, temperatures and Ag explain over 70% of variance (adjusted R^2) of the dependant CDR variable, and Tsr-Ag and TsrSm-Ag variables of even over 80%. Values of F and p statistics point at the reliability of the gained results, i.e. at a certain correlation between dependent and independent variables. *Beta* coefficients of the independent variables show, in most cases, statistical significant on the level of 99%, while only TsrA variable, does not sufficiently explain the movement of CDR variable.

Table 3: MLR between CDR and independent variables (annual and seasonal Tsr and Ag) for the period 1946–2008.

Dependent variable	Independent variables	adjusted R^2	F statistica	p statistica	beta coefficient
CDR	Tsr	0.8437	157.561	0.0000	0.432^{***}
	Ag				0.582^{***}
	TsrW	0.7533	89.575	0.0000	0.159^{**}
	Ag				0.796^{***}
	TsrSp	0.7669	96.439	0.0000	0.243^{***}
	Ag				0.703^{***}
	TsrSm	0.832	144.623	0.0000	0.370^{***}
	Ag				0.661^{***}
	TsrA	0.7405	83.766	0.0000	0.094
	Ag				0.859^{***}

Note: * Significant $\rho<0.1$ (90%); ** Significant $\rho<0.05$ (95%); *** Significant $\rho<0.01$ (99%)

4 Discussion

By analyzing CDR variable in the period between 1888 and 2008, it can be concluded that Tsr and Ag represent factors that influence the tendency of CDR movement in Belgrade.

In the period from 1888 to 1913, extremely cold winters caused greater mortality, which can most probably be connected with a greater occurrence of respiratory and cardiovascular diseases (Bom et al. 1997;

Keatinge and Donaldson 2004; Nakaji et al. 2004). According to the results, the rise in temperatures in the summer periods also points at the rise in mortality rate as a result of thermal stress when the body is not able to cool itself especially within the older population. This kind of situation in the summer period especially effects population in humid-continentalclimate regions (Keatinge and Donaldson 2004), such as Belgrade.

Observing the analysis results for the period from 1946 to 2008, it is necessary to emphasis to reverse influence of TsrW upon the CDR. It is noticed statistically important correlation between CDR and TsrW, which undoubtedly can represent an indicator of a negative influence of above average high TsrW upon population health condition (Ballester et al. 1997). Obviously, the society modernisation enabled that almost every household has a possibility of an adequate heating system and appropriate clothing (Kunst et al. 1991; Lerchl 1998; Nafstad et al. 2001), which means that the risk due to mortality rise as a result of above average cold winters, is reduced to minimum (Keatinge and Donaldson 2004). Above average high air temperatures in the winter period, especially if a sudden appearance of a heat temperature wave occurs, disable adequate adaptation of a body to a temperature change. In the last twenty years, a number of mild winters are increasing. Therefore, a number of different cardiovascularand respiratory diseases appear, especially within the older part of the population, as a result of virus and bacterial infections which favour warmer temperature conditions.

In the period from 1946 to 2008, TsrSp and TsrSm show a constant rise on the area of Belgrade. A constant rise of annual CDR is as well occurring. It can be concluded that the rise in temperatures in this periods of a year, i.e. appearance of above average warm springs and summers, probably leads to the rise in mortality (Keatinge and Donaldson 2004; Ekamper et al. 2009). This kind of situation is mostly expressed during the summer heat waves (Baccini et al. 2008; Huynen et al. 2001), because the researches have shown that high temperatures influence the number of deaths caused by heat waves and cardiovascular diseases (Sartor et al. 1995). The appearance of heat waves in Belgrade (for instance, in 2003 and 2007) (Anđelković 2007; Unkašević and Tošić 2009), can have even a stronger temperature influence because the city represents a metropolitan area with 1,6 million inhabitants, which enables the creation of urban heat island (Ballester et al. 1997; Haines et al. 2006; McMichael et al. 2008).

Ag, apart from Tsr, was analysed for the last observed period. The results show that the number of the old population from the World War II up to today is getting bigger. Ag influences the rise of CDR due to an increase in expected life expectancy. The results show that, in the last twenty years, the share of the people aged 65 and more, overcomes 10%, while in the first years of the 21st century it exceeds even 14%. Tsr values, for the same period, show above average values, i.e. it exceeds 12 °C, while the same situation occurs for winter, spring and summer temperatures. These two factors have the important influence on CDR increasing. Furthermore, since the beginnings of 1990s, CDR exceeds value 9‰, and even value 12‰ in the last few years.

The results of MLR confirm that both factors have an influence upon CDR movement. However, Ag probably has stronger influence compared to air temperature. Weaker correlation of the population compared to temperature conditions in the last ten years can be explained by the more widely use of air-conditioning systems, which enable cooling and greater body resistance to high temperatures and few-day long heats. It is expected that mortality caused by medical complications due to heat waves is constantly decreasing (Donaldson et al. 2003; Keatinge and Donaldson 2004).

5 Conclusions

According to the analyses and results of cold and heat-related deaths in Belgrade, the main conclusions of this study are as follows:

- it can be concluded that climate changes have a negative influence upon the health of the population, i.e. rise of the CDR;
- in the period from 1888 to 1913, the level of mortality are greatly depended on extremely cold winter and hot summer occurrences;
- in the last research period (1946–2008), population is less sensitive to cold periods. CDR has increasing trend according to the increase of temperatures both in winter and in summer periods. This result is probably related with heat waves which as a consequence have respiratory and cardiovascular diseases with the older population;

- in the period between 1946 and 2008, the old population is constantly increasing and significantly contributed to the movement of CDR. Our researches do not diminish the importance of temperature changes, which influence is probably lessened due to a wider use of air conditioning systems, both in offices and private households;
- further researches of climate changes and other factors that influence population mortality proved to be necessary both for Belgrade and entire Serbia, with an aim of gaining precise conclusions and detailed pattern of mutual relationship of all the relevant factors.

6 Acknowledgements

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Smrtnost v povezavi s temperaturami v Beogradu v obdobju 1888–2008

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IZVLEČEK: V članku smo uporabili podatke o temperaturi zraka in stopnji umrljivosti v Beogradu v obdobju od 1888 do 2008, da bi prikazali pričakovano soodvisnost. Osnovna statistična analiza pokaže statistično značilne vrednosti korelacij med temi parametri. Začetna predpostavka je bila, da so bili v preteklosti ljudje bolj občutljivi za izredno nizke temperature, zlasti v zimskem času. Statistični rezultati so potrdili to domnevo, še zlasti za čas pred 1. svetovno vojno. Rezultati nadaljnjih analiz pa so pokazali, da sta temperatura zraka in stopnja umrljivosti v zadnjih dvajsetih letih negativno povezani. Statistična analiza je namreč izpostavila, da stopnja umrljivosti v zadnjih dvajsetih letih hitreje narašča v poletnem obdobju zaradi vedno pogostejših pojavov ekstremnih temperatur zraka.

KLJUČNE BESEDE: geografija, stopnja umrljivosti, temperatura zraka, vpliv letnega časa, geografija, Beograd, Srbija

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Vsebina

1 Uvod

Razmerje med temperaturo zraka in smrtnostjo je precej dobro obdelana tema in razpoložljivi zgodovinski podatki povedo, da se že dolgo kaže zanimanje za sezonski značaj smrtnosti. Natančnejše raziskave razmerij med podnebjem in smrtnostjo v zadnjih dvajsetih letih pa so izpostavile mehanizme vplivov, pa tudi razne strukturne razlike: družbene, regionalne, ruralno-urbane.

Razmerje med smrtnostjo in temperaturo se ob optimalni temperaturni vrednosti v grafični predstavitvi pokaže v obliki črke V (Hunyen in ostali 2001). Analizira podatkov o temperaturah in smrtnosti v enajstih mestih v vzhodnem delu Združenih držav je pokazala, da nevarnost smrti na splošno upada z rastjo temperatur od najhladnejših dni do določenega temperaturnega praga, ki se z geografsko širino spreminja, nad njim pa se nevarnost smrti z naraščanjem temperature spet poveča (Curriero in ostali 2002). Pattenden in ostali (2003) so raziskovali povezave med smrtnostjo in temperaturami v dveh evropskih prestolnicah, Sofiji in Londonu, ter prišli do sklepa, da je v Londonu z vsako dodatno stopinjo izrednega mraza smrtnost narasla za 4,2%, v Sofiji pa za 1,8%. Luterbacher in ostali (2004) so ugotovili, da je podnebje v Evropi zelo verjetno toplejše, kot je bilo kdajkoli v zadnjih 500 letih, in da je bilo leta 2003 daleč najbolj vroče poletje.

Carson in ostali (2006) navajajo, da je stopnja občutljivosti prebivalstva za zunanje temperature zmanjšana zaradi izboljšav v infrastrukturi in tehnologiji, in da splošno zdravstveno stanje v veliki meri vpliva na to, kakšni bodo dejanski učinki prihodnjih podnebnih sprememb. In zaradi tega se je kljub staranju prebivalstva število smrti, povezanih s temperaturami, v 20. stoletju močno zmanjšalo. Hajat in ostali (2007) ugotavljajo, da so najbolj ogrožena skupina starejši ljudje, zlasti tisti v domovih za starejše občane. Največjo nevarnost za smrt zaradi vročine pa predstavljajo bolezni dihal in zunanji vzroki, in to za ženske.

Glavni rezultat mednarodne študije o temperaturah, vročini in smrtnosti v mestih je pokazal, da so v mestih s toplejšim podnebjem vročinski pragovi na splošno višji, medtem ko pragovi mraza niso povezani s podnebjem (McMichael in ostali 2008).

Analitis in ostali (2008) ugotavljajo, da je smrtnost, povezana z mrazom, velik problem javnega zdravstva po Evropi. Sicer pa postajajo vplivi vročega vremena na zdravje vedno večji globalni izziv za javno zdravstvo 21. stoletja (Hajat in ostali 2010).

Cilj pričujoče raziskave je pregledati nihanja sezonskih in celoletnih temperatur zraka in staranje prebivalstva v povezavi s stopnjo umrljivosti v Beogradu v zadnjih 121 letih. Rezultati v tem prispevku so na splošno primerljivi s podobnimi raziskavami v drugih znanstvenih člankih.

2 Podatkovna baza in metodologija

Opazovano obdobje je dolgo 121 let, to je od leta 1888 do 2008. Podatke za celotno število smrti smo pridobili iz župnijskih in občinskih mrliških knjig. Namesto absolutnih ševilk smo analizirali stopnjo umrljivosti (CDR). S pomočjo linearne interpolacije smo izračunali tudi letno staranje (Ag) (prebivalstvo nad 65 let) za obdobje 1921–2008. Časovne nize temperatur zraka (v °C) za meteorološko postajo v Beogradu za obdobje 1888–2008 smo vzeli iz Meteorološkega letopisa Republiške hidrometeorološke službe Srbije. Uporabljeni so bili tudi sezonski in letni nizi temperatur zraka (Tsr – letni, TsrW – zimski, TsrSp – pomladni, TsrSm – poletni, TsrA – jesenski), da bi lahko pokazali možne vplive na smrti, povezane s temperaturo.

Vsi parametri so bili razdeljeni na tri dele. Prvi del obsega obdobje od 1888 do 1913 v skladu z domnevo, da so bili ljudje v času pred 1. svetovno vojno bolj občutljivi za obdobja z izredno nizkimi oziroma izredno visokimi temperaturami. Drugi del zajema čas, od 1919 do 1940, za katerega so najbolj značilni začetki industrializacijein razvoj moderne družbe. Tretji del (1946–2008) je obdobje industrializacije družbe in obdobje stalnega naraščanja temperatur zraka, še zlasti v zadnjih dvajsetih letih.(vir)

Zaradi manjkajočih podatkov ali slabe kakovosti postopkov opazovanja smo iz analize izločili obdobji prve in druge svetovne vojne (1914–1918 in 1941–1945), ker bi sicer zelo verjetno dobili zavajajoče rezultate za korelacije.

V različnih statističnih analizah je bila uporabljena metoda 5-letnih drsečih povprečij, da bi tako zmanjšali motnje na izvirnih neobdelanih spremenljivkah Tsr, CDR in Ag. Dobljene rezultate analiz je treba upoštevati z določeno rezervo, ker sta pri takem pristopu zmanjšana število primerov in spremenljivost časovnih nizov, kar neizogibno vpliva na kakovost končnih rezultatov.

Za določanje korelacij med analiziranimi spremenljivkami sta bila uporabljena Pearsonov korelacijski koeficient (r) in multipla linearna regresija (MLR). Proučili smo porazdelitve napak napovedi odvisne spremenljivke (CDR), izvedli redundančno analizo, tj. testiranje povezav med neodvisnimi spremenljivkami (Tsr in Ag), pa tudi korelacijo z odvisno spremenljivko. Za določitev značilnosti rezultatov statističnih preizkusov so bile vzete ravni 90%, 95% in 99%.

Beograd je mesto z okrog 1,6 milijona prebivalcev; leži v zmernih geografskih širinah, tj. med 44° in 45° severne geografske širine, in ima štiri izrazite letne čase. Ob koncu 19. in v prvi polovici 20. stoletja so bile zime v glavnem zelo mrzle in pogosto z obilico snega. Vendar pa so bile v zadnjih dvajsetih letih opazovanega obdobja zabeležene v glavnem mile zime, s povprečnimi sezonskimi temperaturami nad 2 °C. Poletja so v glavnem suha in zelo vroča, s povprečnimi sezonskimi temperaturami med 20 in 24 °C, v nekaterih letih pa z izredno vročimi kratkimi vmesnimi obdobji, ko so temperature višje od 40 °C.

3 Rezultati

Slika 1 prikazuje težnje in linearne trende stopnjo umrljivosti (CDR) in številom/deležem prebivalstva nad 65 let (Ag) na letni ravni, kot tudi letni in sezonski razpon srednje temperature zraka glede na opredeljena časovna obdobja. Letni CDR ob koncu 19. in v začetku 20 stoletja teži k stalnemu upadanju (slika 1, A–C1). V zadnjih dvajsetih letih pa je opaziti rahel dvig spremenljivke CDR (slika 1, D1). Letne vrednosti Tsr težijo k blagemu dviganju v zadnjih 111 letih. Podobna situacija se kaže v vseh treh opredeljenih obdobjih, vendar se v zadnjem obdobju (slika 1, D2) kaže trend za spoznanje večjega naraščanja. Na to vrsto gibanja Tsr so verjetno vplivala sezonska nihanja; najbolj izrazito rast so zabeležili pozimi (slika 1, A–D3) in poleti (slika 1, A–D4). V zadnjem opazovanem obdobju (1946–2008) pa zimske, poletne in pomladne temperature težijo k stalnemu dvigovanju (slika 1, D3–5). Delež prebivalcev nad 65 let v celotnem prebivalstvu pa pomeni rast spremenljivke Ag (slika 1, A7). Taka težnja je zlasti opazna v zadnjih dveh desetletjih (slika 1, D7).

Slika 1: Spremembe 5-letnih drsečih letnih in sezonskih povprečij: A1–7: CDR, temperatur zraka in Ag za obdobje 1888–2009; B1–6: CDR in temperatur zraka od 1888 do 1913; C1–6: CDR in temperatur zraka od 1919 do 1940; D1–7: CDR, temperatur zraka in Ag od 1946 do 2008. Opomba: parametrske spremenljivke (tanka črta); linearni trend (debela črta); izključeni sta obdobji od 1914 do 1918 in od 1941 do 1945.
Glej angleški del prispevka.

Preglednica 1 predstavlja vrednosti korelacij med CDR in letnimi ter sezonskimi časovnimi nizi temperatur zraka. Rezultati kažejo statistično značilno korelacijo, in to na ravni 99%, med letnimi vrednostmi CDR in Tsr, kot tudi med spremenljivkami CDR–TsrW in CDR–TsrSm. Dobljene vrednosti statistično značilnih korelacij (ρ < 0,01) nihajo med ±0,3 in celo več kot ±0,8. Začetek opazovanega obdobja (1888–1913) je označen s statistično značilno negativno korelacijo med CDR in TsrW (slika 2) ter Tsr, in pozitivno pri TsrSm. Korelacija med CDR in Tsr v obdobju od 1946 do 2008 pokaže na pozitivne značilne vrednosti, še zlasti pri temperaturah TsrSp in TsrSm (slika 3).

Preglednica 1: Analiza Pearsonovega koeficienta korelacij (r) med 5-letnim drsečim letnim CDR ter letnimi in sezonskimi Tsr v Beogradu.

Obdobja	CDR-Tsr	CDR-TsrW	CDR-TsrSp	CDR-TsrSm	CDR-TsrA
	r	r	r	r	r
1888–2008[a]	-0.60^{***}	-0.53^{***}	-0.43^{***}	-0.27^{***}	-0.37^{***}
1888–1913	-0.80^{***}	-0.86^{***}	0.36^{*}	0.57^{***}	0.08
1919–1940	–0.12	0.35	0.34	-0.55^{**}	–0.35
1946–2008	0.81^{***}	0.48^{***}	0.70^{***}	0.73^{***}	0.11

[a] Izločeni sta obdobji od 1914 do 1918 in od 1941 do 1945
[*] Značilen $\rho < 0.1$ (90%); [**] Značilen $\rho < 0.05$ (95%); [***] Značilen $\rho < 0.01$ (99%)

Slika 2: CDR (polna črta) in TsrW (pikčasta črta) 5-letna drseča povprečja za Beograd v odbobju 1888–1913.
Glej angleški del prispevka.

Slika 3: CDR (polna črta) in TsrSm (pikčasta črta) 5-letna drseča povprečja za Beograd od 1946 do 2008.
Glej angleški del prispevka.

Analiza korelacije Ag s spremenljivkama CDR in Tsr za obdobje 1946–2008 pokaže visoko pozitivno korelacijo pri letni, zimski, pomladni in poletni vrednosti. Povezavi med Ag–CDR in Ag–Tsr sta 0,86 oz. 0,65 in predstavljata statistično značilne povezave ($\rho < 0{,}01$). Korelacija Ag je s spremenljivkami sezonskih temperatur zraka, razen jesenskih, v vseh primerih večja od 0,4 in se kaže kot statistično značilna na ravni 99%.

Na začetku analize MLR smo proučili porazdelitev napak napovedi odvisne spremenljivke, tj. letnega CDR. Rezultati kažejo, da so napake napovedi odvisne spremenljivke CDR na splošno normalno frekvenčno porazdeljene, kar sklepamo na podlagi dobre porazdelitve okoli črte najboljšega prileganja (slika 4).

Slika 4: Verjetnostni grafikon normalne porazdelitve napak napovedi (a) ter primerjava napovedanih vrednosti z napakami napovedi (b) za odvisno spremenljivko CDR v obdobju 1946–2008.
Glej angleški del prispevka.

Redundančna analiza neodvisnih spremenljivk (letnih in sezonskih temperatur zraka in letnega Ag, tj. staranja) je predstavljena v preglednici 2. Dobljeni rezultati pokažejo visoke vrednosti tolerance med temperaturo in staranjem prebivalstva, ki se v vseh primerih uvršča med 0,58 in 1,0. Istočasno lahko opazimo znatne razlike v vrednostnih ravneh parcialne korelacije med neodvisnimi spremenljivkami, razen v primeru Tsr–Ag, kjer je razlika manjša. Sklepamo lahko, da neodvisne spremenljivke najverjetneje lahko pojasnijo smer gibanja spremenljivke CDR.

Preglednica 2: Redundančna analiza neodvisnih spremenljivk – letna in sezonske Tsr in Ag od 1946 do 2008.

odvisna spremenljivka	neodvisne spremenljivke	T	R^2	P. C.	SP. C.
CDR	Tsr	0.58	0.42	0.65	0.33
	Ag			0.75	0.44
	TsrW	0.83	0.17	0.29	0.15
	Ag			0.83	0.73
	TsrSp	0.58	0.42	0.36	0.19
	Ag			0.75	0.53
	TsrSm	0.71	0.29	0.61	0.31
	Ag			0.81	0.56
	TsrA	1.00	0.0	0.18	0.1
	Ag			0.86	0.86

Opomba: T – toleranca; R^2 – kvadrat korelacijskega koeficienta; P. C. – parcialna korelacija; SP. C. – semi-parcialna korelacija.

Preglednica 3: MLR med CDR in neodvisnimi spremenljivkami (letne in sezonske Tsr in Ag) za obdobje 1946–2008.

odvisna spremenljivka	neodvisne spremenljivke	prilagojeni R^2	statistika F	statistika p	*beta* koeficient
CDR	Tsr	0.8437	157.561	0.0000	0.432***
	Ag				0.582***
	TsrW	0.7533	89.575	0.0000	0.159**
	Ag				0.796***
	TsrSp	0.7669	96.439	0.0000	0.243***
	Ag				0.703***
	TsrSm	0.832	144.623	0.0000	0.370***
	Ag				0.661***
	TsrA	0.7405	83.766	0.0000	0.094
	Ag				0.859***

Note: * Značilen $\rho < 0.1$ (90%); ** Značilen $\rho < 0.05$ (95%); *** Značilen $\rho < 0.01$ (99%)

Preglednica 3 prikazuje rezultate MLR s ciljem, da se zaznajo možne korelacije pri letnih in sezonskih nihanjih Tsr in Ag s težnjami letnega CDR v obdobju 1946–2008. V vseh primerih temperature in Ag razložijo več kot 70% variance (prilagojeni R^2) odvisne spremenljivke CDR ter celo več kot 80% spremenljivk Tsr–Ag in TsrSm–Ag. Vrednosti statistik *F* in *p* kažeta na zanesljivost dobljenih rezultatov, tj. na določeno korelacijo med odvisno in neodvisnimi spremenljivkami. *Beta* koeficienti neodvisnih spremenljivk kažejo v večini primerov statistično značilnost na ravni 99%, medtem ko spremenljivka TsrA ne pojasni zadovoljivo gibanja spremenljivke CDR.

4 Razprava

Na osnovi analize spremenljivke CDR v obdobju med 1888 in 2008 lahko sklepamo, da Tsr in Ag predstavljata dejavnika, ki vplivata na smer gibanja CDR v Beogradu.

V obdobju od 1888 do 1913 so bile izredno mrzle zime vzrok za večjo smrtnost, kar se najverjetneje lahko poveže z večjo pojavnostjo bolezni dihal ter srca in ožilja (Bom in ostali 1997; Keatinge in Donaldson 2004; Nakaji in ostali 2004). Iz rezultatov je razvidno, da dvig temperatur v poletnem času prav tako povzroči večjo stopnjo umrljivosti kot posledico toplotnega šoka, ko se telo ni več samo sposobno ohlajati, še zlasti pri starejših ljudeh. Take razmere v poletnem času prizadenejo predvsem ljudi v območjih vlažnega celinskega podnebja (Keatinge in Donaldson 2004), kakršno je v Beogradu.

Ob pregledu rezultatov analiz za obdobje od 1946 do 2008 je treba izpostaviti obratni vpliv TsrW na CDR. Opaziti je statistično pomembno korelacijo med CDR in TsrW, kar nedvomno lahko predstavlja kazalnik negativnega vpliva nadpovprečno visokega TsrW na zdravstveno stanje prebivalstva (Ballester in ostali 1997). Očitno je modernizacija družbe omogočila, da ima skoraj vsako gospodinjstvo možnost ustreznega sistema ogrevanja, ljudje pa primerna oblačila (Kunst et al. 1991; Lerchl 1998; Nafstad in ostali 2001), kar pomeni, da je nevarnost za dvig smrtnosti kot posledice nadpovprečno mrzlih zim zmanjšana na minimum (Keatinge in Donaldson 2004). Problematične pa so nadpovprečno visoke zimske temperature zraka, ki onemogočijo ustrezno prilagoditev telesa temperaturnim spremembam, še zlasti če tak dvig temperature nastopi nenadoma. Zadnjih dvajset let so mile zime vse pogostejše. Zato se zlasti pri starejšem delu prebivalstva pojavlja veliko različnih srčno-žilnih bolezni in bolezni dihal, in to v obliki viroz in bakterijskih infekcij, za razvoj katerih so toplejše temperaturne razmere zelo ugodne.

V obdobju od 1946 do 2008 se na območju Beograda pri TsrSp in TsrSm kaže konstantna rast. Prav tako se pojavlja konstantno dvigovanje letnega CDR. Lahko sklepamo, da dvig temperatur v teh letnih časih, oz. pojav nadpovprečno toplih pomladi in poletij, verjetno vodi k naraščanju smrtnosti (Keatinge in Donaldson 2004; Ekamper in ostalial. 2009). Taka situacija v glavnem nastopi med poletnimi vročinskimi valovi (Baccini in ostali 2008; Huyen in ostali 2001), saj so raziskave pokazale, da visoke temperature vplivajo na število smrti, ki jih povzročijo vročinski valovi in srčno-žilne bolezni (Sartor in ostali 1995). Pojav vročinskih valov v Beogradu (na primer leta 2003 in 2007) (Anđelković 2007; Unkašević in Tošić 2009) ima lahko še večji temperaturni vpliv, ker je to mestno območje, metropola z okrog 1,6 miljona prebivalcev, kar lahko povzroči nastanek mestnega toplotnega otoka (Ballester in ostali 1997; Haines in ostali 2006; McMichael in ostali 2008).

Za zadnje opazovano obdobje je bila neodvisno od Tsr analizirana spremenljivka Ag. Rezultati kažejo, da se je od 2. svetovne vojne pa do danes število starejših prebivalcev povečalo. Ag vpliva na dvig CDR zaradi podaljšanja življenjske dobe. Rezultati kažejo, da je bil delež prebivalcev nad 65 let v zadnjih dvajsetih letih večji od 10 %, v prvih letih 21. stoletja pa je ta delež celo presegel 14 %. Vrednosti Tsr za isto obdobje kažejo nadpovprečne vrednosti, tj. presegajo 12 °C, in enaka situacija se pojavi pri zimskih, pomladnih in poletnih temperaturah. Ta dva dejavnika imata pomemben vpliv na naraščanje CDR. Polega tega je že od začetka devetdesetih let 20. stoletja CDR presegala vrednost 9 ‰, v zadnjih nekaj letih pa celo vrednost 12 ‰.

Rezultati MLR potrjujejo, da imata oba faktorja vpliv na gibanje CDR. V primerjavi s temperaturami zraka pa ima Ag verjetno močnejši vpliv. Šibkejšo korelacijo med prebivalstvom in temperaturnimi razmerami v zadnjih desetih letih lahko pojasnimo z bolj razširjeno rabo klimatskih naprav, ki omogočajo hlajenje in večjo odpornost telesa do visokih temperatur in nekajdnevne vročine. Pričakovati je, da bo smrtnost zaradi medicinskih zapletov, povzročenih z vročinskimi valovi, konstantno upadala (Donaldson in ostali 2003; Keatinge in Donaldson 2004).

5 Sklep

Na temelju analiz in rezultatov raziskave o smrtnosti v Beogradu, povezani z mrazom in/ali vročino, smo prišli do naslednjih temeljnih sklepov:

- lahko sklenemo, da spremembe podnebja negativno vplivajo na zdravje prebivalstva, tj. na dvig CDR;
- v obdobju od 1888 do 1913 je bila raven smrtnosti močno odvisna od nastopa izredno mrzle zime oz. vročega poletja;
- v zadnjem raziskanem obdobju (1946–2008) je bilo prebivalstvo manj občutljivo za mrzla obdobja. Težnja naraščanja CDR se ujema z naraščanjem temperatur v obeh letnih časih, pozimi in poleti. Ta rezultat je verjetno povezan z vročinskimi valovi, ki posledično povzročijo bolezni dihal in srčno-žilne bolezni pri starejših prebivalcih;
- v obdobju med 1946 in 2008 je število starejših prebivalcev konstantno naraščalo in je pomembno prispevalo h gibanju CDR. Rezultati naših raziskav nič ne zmanjšujejo pomembnosti temperaturnih sprememb, katerih vpliv pa je verjetno manjši zaradi širše uporabe klimatskih naprav tako na delovnih mestih kot doma.
- potrebno bo opraviti še nadaljnje raziskave o podnebnih spremembah in drugih dejavnikih, ki vplivajo na smrtnost prebivalstva tako v Beogradu kot v celotni Srbiji, in to s ciljem, da pridemo do natančnih sklepov in dobimo podrobne vzorce medsebojnih povezav vseh vplivnih dejavnikov.

6 Zahvala

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7 Literatura

Glej angleški del prispevka.