environmental sciences proceedings

MDPI

Proceeding Paper

The Impact of Temperature Changes on Global Stroke Mortality—Ischemic Stroke, Intracerebral and Subarachnoid Hemorrhage †

Irena Ilic [1,*] and Milena Ilic [2]

1 Faculty of Medicine, University of Belgrade, 11000 Belgrade, Serbia
2 Department of Epidemiology, Faculty of Medical Sciences, University of Kragujevac, 34000 Kragujevac, Serbia
* Correspondence: ajrini10@gmail.com; Tel.: +381-11-3636300
† Presented at the 4th International Electronic Conference on Environmental Research and Public Health—Climate Change and Health in a Broad Perspective, 15–30 October 2022; Available online: https://ecerph-4.sciforum.net/.

Abstract: The percentage of stroke deaths attributable to low temperature was 7.23% in 2019, accounting for 474,002 stroke deaths globally, while about 48,030 of the stroke deaths were attributed to high temperature. Joinpoint regression analysis was applied to calculate the average annual percent change (AAPC) with 95% confidence interval (CI) to evaluate stroke mortality trends in 1990–2019. Trends from global stroke mortality attributed to low temperature significantly declined (AAPC = −2.5%; 95%CI = −2.6 to −2.3) in both sexes together. A significantly increased trend for stroke mortality attributed to high temperature was observed in both sexes together (AAPC = +1.0%; 95%CI = 0.6 to 1.3).

Keywords: stroke; global mortality; temperature changes

check for updates

Citation: Ilic, I.; Ilic, M. The Impact of Temperature Changes on Global Stroke Mortality—Ischemic Stroke, Intracerebral and Subarachnoid Hemorrhage. *Environ. Sci. Proc.* **2022**, *24*, 5. https://doi.org/10.3390/ECERPH-4-13107

Academic Editor: Jon Ø. Odland

Published: 26 October 2022

1. Introduction

Strokes are the second most common cause of death worldwide, after ischemic heart disease [1–3]. Strokes are responsible for approximately 11% of the world's total deaths in 2019 [1,2]. The Global Burden of Disease (GBD) 2019 study estimated that the total number of stroke deaths increased between 1990 and 2019 by 43.5% (or 2.0 million deaths, i.e., from 4.6 million to 6.6 million deaths, respectively) [1,3]. Ischemic stroke constituted 50.0% of all stroke deaths in 2019 (3.3 million), while intracerebral hemorrhage constituted 43.9% (2.9 million) and subarachnoid hemorrhage constituted 6.1% (0.4 million) [3]. The tremendous increasing number of stroke deaths could be due to ageing and increase of global populations, as well as the exposure to cardiovascular risk factors [3,4].

On the other hand, the age-standardized rates of global stroke mortality decreased sharply from 1990 to 2019 (by 36.0%) [1,3]. The percentage change of age-standardized rates of deaths from stroke globally in the same period by pathological types of stroke were −34.0% for ischemic stroke, −36.0% for intracerebral hemorrhage and −57.0% for subarachnoid hemorrhage [1,3]. A decreasing trend in global stroke mortality may be explained by better accessibility to improved treatment and implementation of strategies for prevention of non-communicable diseases (that led to decreasing prevalence of certain environmental, occupational, behavioral and metabolic risk factors for stroke) [4–6].

Some previous studies have indicated that the large increase in the global burden of stroke can be due to the increase in exposure not only to well-established risk factors, but perhaps also to some still insufficiently known risk factors, and suggested potential role of the effects of ambient temperature on the risk of stroke [3,7–9]. This study aimed to assess the link between stroke mortality and non-optimal temperature at the global level.

2. Materials and Methods

2.1. Study Design

An ecological trend study was conducted.

2.2. Data Source

Data on deaths due to overall stroke and stroke subtypes (ischemic stroke, intracerebral and subarachnoid hemorrhage) were derived from the GBD 2019 study database for the years 1990 to 2019 [10]. Age-standardized rates (ASRs) for stroke mortality were calculated by method of direct standardization and expressed per 100,000 persons. In addition, data about the effects of non-optimal temperature on stroke mortality were extracted from the GBD 2019 study: non-optimal temperature included low temperature (daily temperatures below the theoretical minimum risk exposure level) and high temperature (daily temperatures above the theoretical minimum risk exposure level).

2.3. Statistical Analysis

Changes in stroke mortality between 1990 and 2019 were determined by using joinpoint regression analysis software [11]. Joinpoint regression analysis was applied to calculate the average annual percentage change (AAPC) with 95% confidence interval (CI) to evaluate trends in 1990–2019. The joinpoint regression model is consisting of segments joining at points (i.e., joinpoints) where a significant change in the trend occurs. The changes in temporal trends include changes in intensity and/or direction of stroke mortality trends. As the statistically significant level, $p < 0.05$ was taken.

3. Results

Globally, the percentage of stroke deaths attributable to non-optimal temperature was 7.95% in 2019, accounting for 521,031 stroke deaths in both sexes together (Figure 1). Globally, 401,624 stroke deaths (8.78% of total stroke deaths in the world) were attributed to non-optimal temperature in 1990.

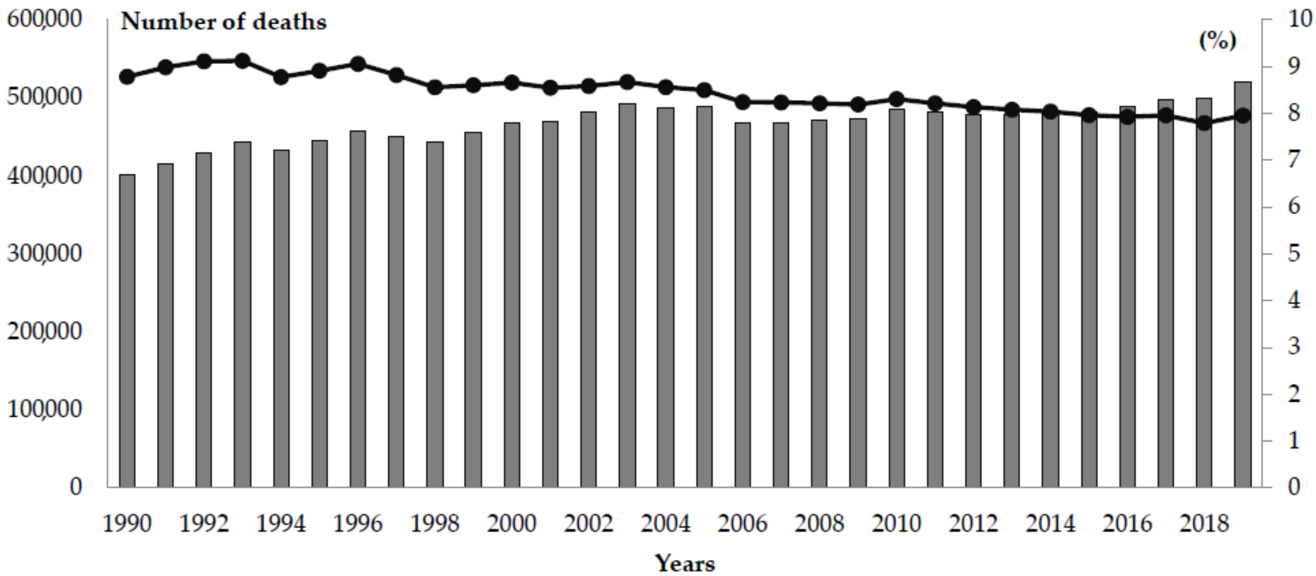

Figure 1. The global stroke deaths attributed to non-optimal temperature (number of deaths and percentage contribution in total stroke) in both sexes together, 1990–2019.

In both sexes together, the number of deaths for ischemic stroke, intracerebral hemorrhage and subarachnoid hemorrhage attributable to non-optimal temperature was 279.644, 212.194 and 29.194, respectively (Figure 2).

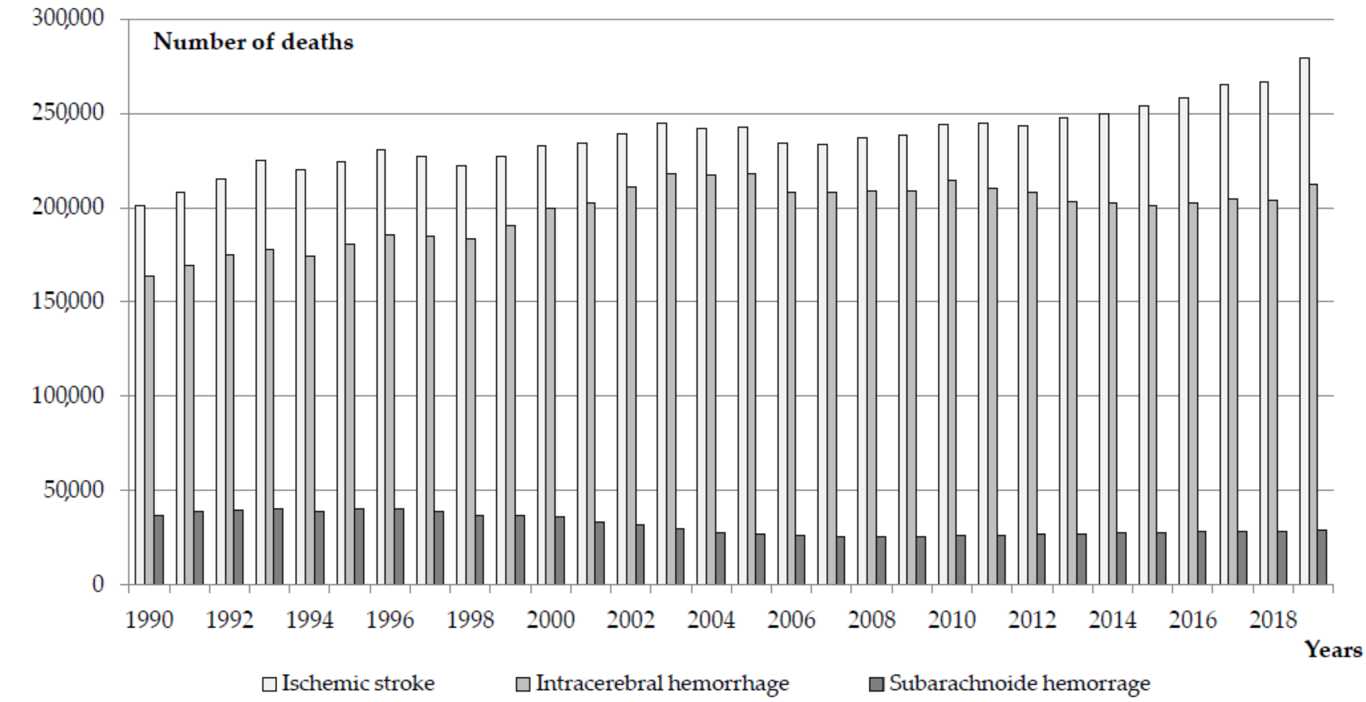

Figure 2. Number of global stroke deaths attributed to non-optimal temperature in both sexes together, by stroke types, 1990–2019.

Trend from global stroke mortality attributed to low temperature significantly declined (AAPC = −2.5%; 95%CI = −2.6 to −2.3) in both sexes together, with five joinpoints (Figures 3 and 4). A significantly increasing trend for stroke mortality attributed to high temperature was observed in both sexes together (AAPC = +1.0%; 95%CI = 0.6 to 1.3).

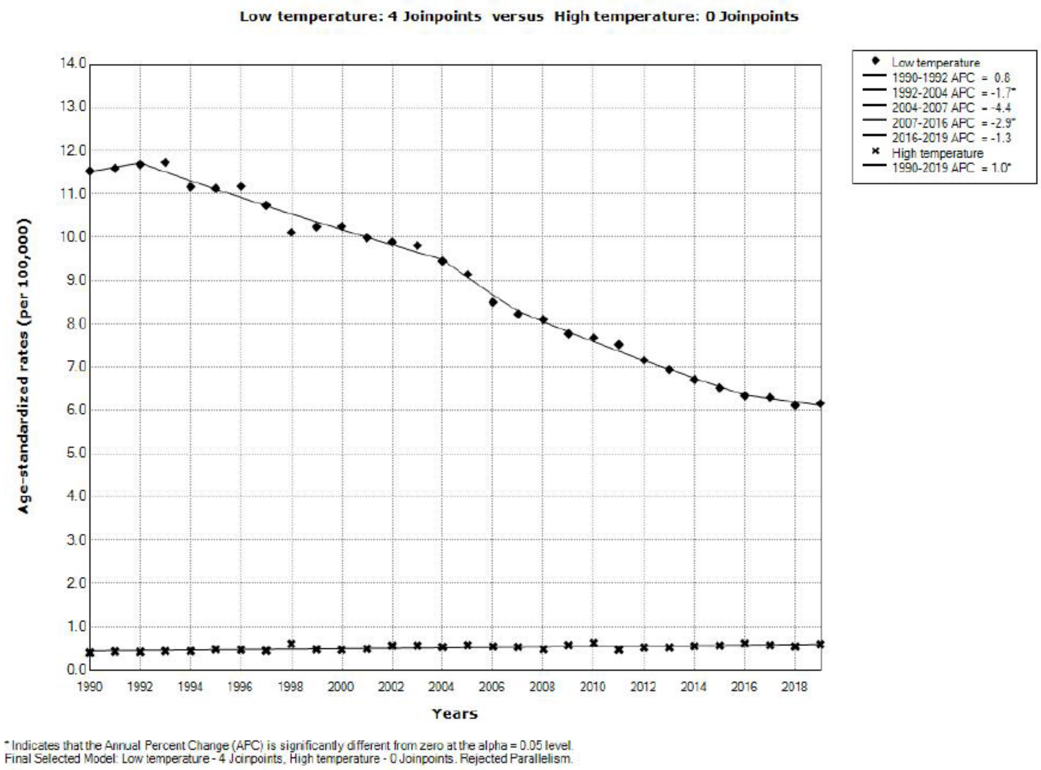

Figure 3. The global stroke mortality attributed to non-optimal temperature, in both sexes together, 1990–2019; a joinpoint regression analysis.

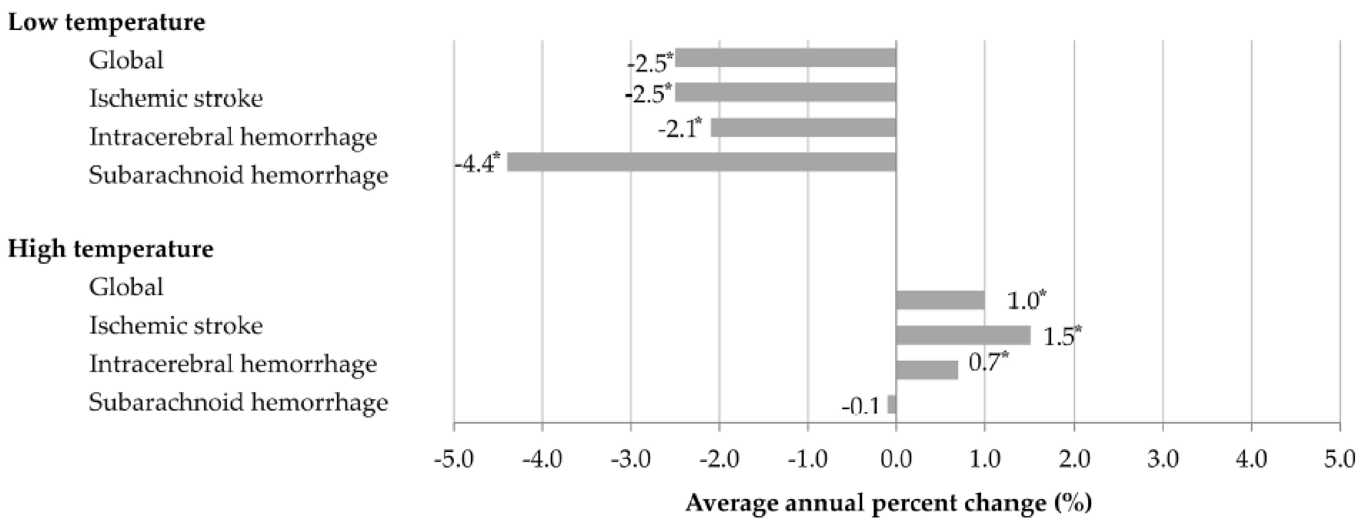

Figure 4. The global trends of stroke mortality attributed to low and high temperatute in both sexes together, by stroke types, 1990–2019; a joinpoint regression analysis. * statistically significant, $p < 0.05$.

Globally, a significantly decreasing trend for total stroke mortality attributed to low temperature was observed in both sexes together in 1990–2019 (by −2.5% per year), as well as decreasing trends that were observed for all stroke types, those being ischemic stroke (by −2.5% per year), intracerebral hemorrhage (by −2.1% per year), and subarachnoid hemorrhage (by −4.4% per year) (Figure 4). Globally, a significantly increasing trend for total stroke mortality attributed to high temperature was observed in both sexes together in 1990–2019 (by +1.0% per year); increasing trends were observed for ischemic stroke (by +1.5% per year) and intracerebral hemorrhage (by +0.7% per year), but not for subarachnoid hemorrhage, where a stable trend was observed.

4. Discussion

Stroke deaths attributed to the non-optimal temperature are a substantial issue worldwide, because they contribute by participation to about 8% to the global stroke mortality in the last decades. Rising temperature showed a substantial effect on total stroke mortality at the global level in 1990–2019, with a substantial increase in ASRs of mortality due to high temperature described for ischemic stroke and intracerebral hemorrhage.

Similar to our results, some other ecological studies suggested association between non-optimal temperature and stroke burden [7,12,13]. However, to the best of our knowledge, the GBD 2019 study is the first systematic analysis to estimate the global effect of non-optimal temperature on stroke burden and its subtypes and added high and low non-optimal temperatures as risk factors [3,5]. Some previous studies indicated that low temperature was one of the top ten risks in the oldest age group [13] and that older age seems to increase vulnerability to low temperature for both ischemic stroke and intracerebral hemorrhage [7]. Our results showed that the global burden of stroke (as measured by ASRs of mortality) attributable to low temperature was 10 times greater than the burden attributable to high temperature in 2019. On the other hand, a rise of temperature had a substantial effect in populations with a lesser ability to adapt to temperature changes, especially in countries with limited socio-economic resources, which can worsen health inequalities in the world [14,15]. Among others, based on the link between non-optimal temperature and stroke mortality, the Lancet Countdown on health and climate change concluded that the response to climate change could be "the greatest global health opportunity of the 21st century" [16].

Author Contributions: Conceptualization, I.I. and M.I.; methodology, I.I. and M.I.; software, I.I. and M.I.; validation, I.I. and M.I.; formal analysis, I.I. and M.I.; investigation, I.I. and M.I.; resources, I.I. and M.I.; data curation, I.I. and M.I.; writing—original draft preparation, I.I.; writing—review

and editing, I.I. and M.I.; visualization, I.I. and M.I.; supervision, M.I.; project administration, M.I.; funding acquisition, M.I. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Ethics Committee of the Faculty of Medical Sciences, University of Kragujevac (Ref. No.: 01-14321, 13 November 2017), entitled "Epidemiology of the most common health disorders".

Informed Consent Statement: Not applicable. No patient approvals were sought nor required for this study. Namely, as our model-based analysis used aggregated publicly available data, and patients were not involved in the research.

Data Availability Statement: Data is contained within the article.

Acknowledgments: This study is conducted as the part of project No 175042 supported by Ministry of Education, Science and Technological development, Republic of Serbia, 2011–2022.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. GBD 2019 Diseases and Injuries Collaborators. Global burden of 369 diseases and injuries in 204 countries and territories, 1990–2019: A systematic analysis for the Global Burden of Disease Study 2019. *Lancet* **2020**, *396*, 1204–1222. [CrossRef] [PubMed]
2. World Health Organization (WHO). *WHO Methods and Data Sources for Global Burden of Disease Estimates 2000–2019*; Global Health Estimates Technical Paper WHO/DDI/DNA/GHE/2020.3; WHO: Geneva, Switzerland, 2020.
3. GBD 2019 Stroke Collaborators. Global, regional, and national burden of stroke and its risk factors, 1990–2019: A systematic analysis for the Global Burden of Disease Study 2019. *Lancet Neurol.* **2021**, *20*, 795–820. [CrossRef] [PubMed]
4. Roth, G.A.; Mensah, G.A.; Johnson, C.O.; Addolorato, G.; Ammirati, E.; Baddour, L.M.; Barengo, N.C.; Beaton, A.Z.; Benjamin, E.J.; Benziger, C.P.; et al. Global Burden of Cardiovascular Diseases and Risk Factors, 1990–2019: Update From the GBD 2019 Study. *J. Am. Coll. Cardiol.* **2021**, *77*, 1958–1959.
5. GBD 2019 Risk Factors Collaborators. Global burden of 87 risk factors in 204 countries and territories, 1990–2019: A systematic analysis for the Global Burden of Disease Study 2019. *Lancet* **2020**, *396*, 1223–1249. [CrossRef] [PubMed]
6. Moryson, W.; Stawińska-Witoszyńska, B. Trends in premature mortality rates among the Polish population due to cardio-vascular diseases. *Int. J. Occup. Med. Environ. Health* **2022**, *35*, 27–38. [CrossRef] [PubMed]
7. Wang, X.; Cao, Y.; Hong, D.; Zheng, D.; Richtering, S.; Sandset, E.C.; Leong, T.H.; Arima, H.; Islam, S.; Salam, A.; et al. Ambient Temperature and Stroke Occurrence: A Systematic Review and Meta-Analysis. *Int. J. Environ. Res. Public Health* **2016**, *13*, 698. [CrossRef] [PubMed]
8. Li, T.; Horton, R.; Bader, D.A.; Liu, F.; Sun, Q.; Kinney, P.L. Long-term projections of temperature-related mortality risks for ischemic stroke, hemorrhagic stroke, and acute ischemic heart disease under changing climate in Beijing, China. *Environ. Int.* **2018**, *112*, 1–9. [CrossRef] [PubMed]
9. Achebak, H.; Devolder, D.; Ballester, J. Trends in temperature-related age-specific and sex-specific mortality from cardio-vascular diseases in Spain: A national time-series analysis. *Lancet Planet. Health* **2019**, *3*, e297–e306. [CrossRef] [PubMed]
10. Global Burden of Disease Collaborative Network. Global Burden of Disease Study 2019 (GBD 2019) Results. Seattle, United States: Institute for Health Metrics and Evaluation (IHME). 2020. Available online: http://ghdx.healthdata.org/gbd-results-tool (accessed on 29 August 2022).
11. Kim, H.-J.; Fay, M.P.; Feuer, E.J.; Midthune, D.N. Permutation tests for joinpoint regression with applications to cancer rates. *Stat. Med.* **2000**, *19*, 335–351. [CrossRef]
12. Çevik, Y.; Doğan, N.Ö.; Daş, M.; Ahmedali, A.; Kul, S.; Bayram, H. The association between weather conditions and stroke admissions in Turkey. *Int. J. Biometeorol.* **2015**, *59*, 899–905. [CrossRef] [PubMed]
13. Zhang, Y.; Li, S.; Pan, X.; Tong, S.; Jaakkola, J.J.; Gasparrini, A.; Guo, Y.; Wang, S. The effects of ambient temperature on cerebrovascular mortality: An epidemiologic study in four climatic zones in China. *Environ. Health* **2014**, *13*, 24. [CrossRef] [PubMed]
14. Hartley, A.; Marshall, D.C.; Salciccioli, J.D.; Sikkel, M.B.; Maruthappu, M.; Shalhoub, J. Trends in Mortality From Ischemic Heart Disease and Cerebrovascular Disease in Europe: 1980 to 2009. *Circulation* **2016**, *133*, 1916–1926. [CrossRef] [PubMed]
15. Barreca, A.; Clay, K.; Deschenes, O.; Greenstone, M.; Shapiro, J.S. Adapting to climate change: The remarkable decline in the US temperature mor-tality relationship over the twentieth century. *J. Political Econ.* **2016**, *124*, 105–159. [CrossRef]
16. Watts, N.; Amann, M.; Arnell, N.; Ayeb-Karlsson, S.; Belesova, K.; Boykoff, M.; Byass, P.; Cai, W.; Campbell-Lendrum, D.; Capstick, S.; et al. The 2019 report of The Lancet Countdown on health and climate change: Ensuring that the health of a child born today is not defined by a changing climate. *Lancet* **2019**, *394*, 1836–1878. [CrossRef] [PubMed]