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Unraveling the Environmental, Meteorological and Lifestyle Determinants of Hypertension Mortality in Türkiye

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ABSTRACT

Hypertension is a leading risk factor for cardiovascular diseases and a significant cause of mortality worldwide. This study investigates the association of environmental, meteorological, and lifestyle factors with hypertension mortality in Türkiye from 2010 to 2019. This study analyzed province-level hypertension mortality data for 81 provinces in Türkiye from 2010 to 2019. Predictors included air quality indicators (particulate matter 10, sulfur dioxide, carbon monoxide, nitrogen dioxide, ozone), meteorological variables (air pressure, humidity, temperature, wind speed), and lifestyle factors (smoking, alcohol consumption, exposure to second-hand smoke). An ordinal logistic regression approach was employed to model the likelihood of hypertension mortality, with adjustments for multiple testing using the Benjamini-Hochberg False Discovery Rate technique. In this study, it was found that significant associations are between hypertension mortality and several predictors. Air pressure, in terms of coefficient of variation and median levels, was significantly associated with hypertension mortality. Temperature and humidity showed strong associations, with median levels and variability impacting mortality rates. Lifestyle factors, notably smoking and alcohol consumption, were also significantly associated with increased hypertension mortality. Surprisingly, exposure to

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smoke at home showed a slight protective effect. The study highlights the complex interplay of environmental, meteorological, and lifestyle factors in terms of influencing hypertension mortality in Türkiye. These findings emphasize the need for multifaceted public health strategies that consider these diverse influences to manage and prevent hypertension-related mortality effectively.
Keywords: Environmental Factors, Hypertension, Lifestyle Factors, Meteorological Factors, Mortality, Türkiye

INTRODUCTION

Hypertension, a critical public health issue, is a leading risk factor for cardiovascular diseases and a significant cause of mortality worldwide. The global burden of hypertension has been escalating, with a notable increase in both diagnosis and mortality rates. This trend is not uniform across regions, reflecting a complex interplay of genetic, environmental, and lifestyle factors (Mills et al., 2016). In Türkiye, a country with diverse environmental and socioeconomic landscapes, hypertension mortality data across 81 provinces for 2010 and 2019 present a unique opportunity to explore these dynamics.

Environmental and meteorological factors have a recognizable effect on hypertension. Air quality, in particular, has been linked to cardiovascular morbidity and mortality, with pollutants such as particulate matter and nitrogen dioxide implicated in the exacerbation of hypertensive conditions (Rajagopalan et al., 2018). Additionally, meteorological variables like temperature and humidity have an impact on blood pressure and outcomes related to hypertension over the short and long terms (Yang et al., 2015).

Lifestyle factors, notably smoking and alcohol consumption, are well-established risk factors for hypertension. The relationship between these behaviors and hypertension is multifaceted, involving direct physiological impacts, socio-economic dimensions, and interactions with environmental factors (Roerecke et al., 2018; Virdis et al., 2010). In Türkiye, where smoking and alcohol consumption patterns vary significantly across regions, examining these be-haviors in conjunction with environmental and meteorological data can pro-vide valuable insights into their role in Hypertension mortality.

This manuscript aims to investigate the association of environmental, meteorological, and risky behavior markers with Hypertension mortality trajec-

tories in Türkiye over the years 2010 and 2019 over the years 2010 and 2019 controlling for the known factors of hypertension in general. By integrating data on air quality, meteorological conditions, and smoking and alcohol consumption across 81 provinces, we seek to elucidate the multifactorial nature of Hypertension mortality and its regional variations within Türkiye. This analysis not only contributes to the understanding of Hypertension epidemiology in Türkiye but also adds to the global discourse on the interplay of environmental, behavioral, and health outcomes in the context of non-communicable diseases, and thus help the public health authorities develop more timely and effective healthcare and disease prevention strategies.

METHODOLOGY

The primary focus of this study was on the trends (i.e., trajectories) in hypertension-related mortality at the provincial level. Data on hypertension-induced fatalities across 81 Turkish provinces from 2010 to 2019 were requested from Turkish Statistical Institute. These annual mortality rates were calculated relative to the population of each province and presented as the number of deaths per 100,000 individuals annually. With the current data, computing age-adjusted mortality rate was not possible to be computed.

A range of predictors was obtained from the databases of the Ministry of Environment and Urbanization, including environmental factors like particulate matters (PM_{10}, $PM_{2.5}$), sulfur dioxide (SO2), carbon monoxide (CO), nitrogen dioxide (NO2), ozone (O3), air pressure, humidity, and the number of rainy days per year. Meteorological variables were included, such as maximum, average, and minimum temperatures, wind speed, total sunlight, sun radiation, and electromagnetic field exposure. The median values recorded between 2010 and 2019 served as a representation of these factors. Additionally, to assess the impact of environmental variability on hypertension mortality, we calculated the standard deviations (SD) and coefficients of variation (CV) for these variables over the same period as variability markers. We have 15 environmental variables having longitudinal data and expressed as median, CV and SD, resulting in a total of 45 potential markers. We did not have a longitudinal measurement on the other three environmental markers namely, sunlight, electromagnetic field exposure, and sun radiation, and therefore we were not able

to obtain the variability measures SD and CV for them as additional markers. Lifestyle-related predictors, specifically smoking, alcohol consumption, and exposure to second-hand smoke, were also acquired as critical predictors. In terms of the population demographics, we also computed the proportion of elderly population and male population in each province as a potential predictor.

To analyze the temporal changes in hypertension mortality, we utilized the SAS TRAJ procedure, developed by Jones, Nagin, and Roeder (2001). This analysis identified a three-tier categorization (low, intermediate, and high) as the most fitting description of the mortality trends. An Ordinal Logistic Regression method was then applied to model the probability of a province falling into a higher category with each incremental increase in the predictor variables.

53 different markers were examined in total. To address the issue of multiple testing to reduce the likelihood of false positives, we applied the Benjamini-Hochberg False Discovery Rate (FDR) technique (Benjamini & Hochberg, 1995). For more explicit graphical depiction, the response and predictor variables were standardized to have a mean of zero and a variance of one. All statistical analyses were conducted using SAS® Version 9.4 (Cary, North Carolina, USA).

RESULTS

Trajectory analyses of hypertension mortality data across 81 provinces in Türkiye from 2010 to 2019 resulted in four trajectories, representing shallow/deficient and somewhat stable levels of hypertension mortality to very high levels and highly variable hypertension mortality over time (Figure 1).

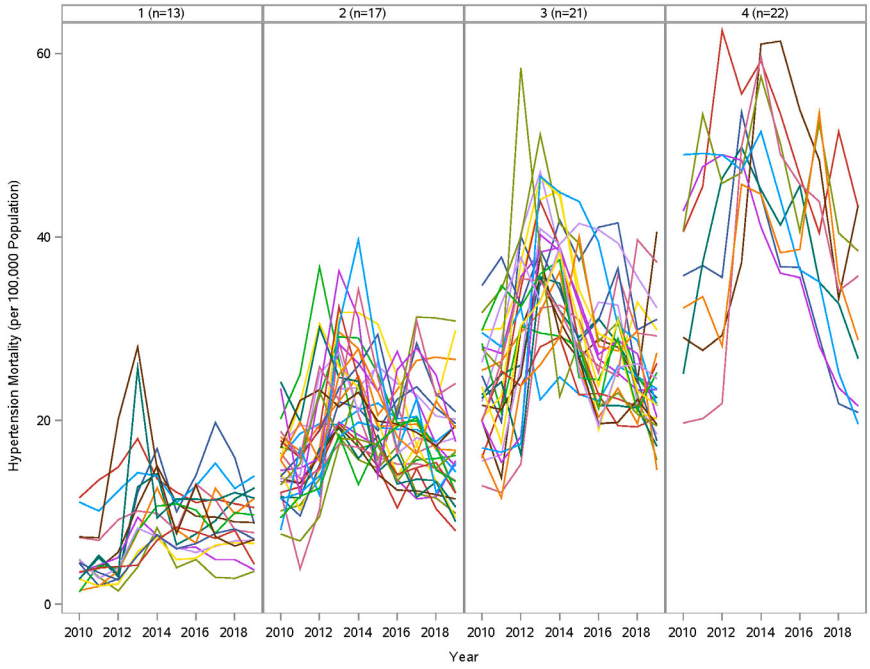

Figure 1. Profiles of Hypertension Mortality by SAS TRAJ procedure
(Numbers in the parentheses represent the number of provinces in the given cluster; each line represents the longitudinal profile of a province.)

We have identified several significant associations with various environmental, meteorological, and lifestyle factors. The results are shown in Table 1, which presents the odds ratios (OR), 95% confidence intervals (CI), p-values, and False Discovery Rate (FDR) corrected p-values for each predictor. Figure 2 depicts the association of these significant markers with hypertension mortality.

Table 1: Predictors significantly associated with Hypertension Mortality

Predictor	OR (95% CI)	p-value	FDR Corrected p-value
Age >=65 Ratio (%)	2.91 (2.12,4.01)	<.0001	2.399E-9
Ever Alcohol Use	1.08 (1.03,1.14)	0.0013	0.00554
Ever Smoking	1.12 (1.04,1.21)	0.0019	0.007159
Humidity (CV)	0.88 (0.84,0.93)	<.0001	0.00002
Humidity (Median)	1.13 (1.07,1.19)	<.0001	0.000059
Humidity (SD)	0.79 (0.71,0.88)	<.0001	0.000072
Male Ratio (%)	0.51 (0.31,0.83)	0.0064	0.022473
Manual Rainy Days (CV)	0.94 (0.92,0.97)	0.0002	0.001212
Maximum Temperature (CV)	0.94 (0.90,0.99)	0.0125	0.036846
Maximum Temperature (SD)	0.66 (0.51,0.85)	0.0014	0.005743
Mean Temperature (Median)	0.83 (0.72,0.96)	0.0095	0.029536
Mean Temperature (SD)	0.40 (0.27,0.60)	<.0001	0.000059
Minimum Temperature (SD)	0.49 (0.33,0.71)	0.0002	0.001212
Particulate Matter-10 (SD)	0.88 (0.82,0.95)	0.0005	0.002183
Rainy Days (CV)	0.92 (0.89,0.95)	<.0001	0.000059
Rainy Days (Median)	1.25 (1.06,1.47)	0.0068	0.022473
Sun Radiation (Per 10 units)	0.91 (0.87,0.95)	<.0001	0.000104
Sunlight (Per 50 units)	0.84 (0.77,0.91)	<.0001	0.000152

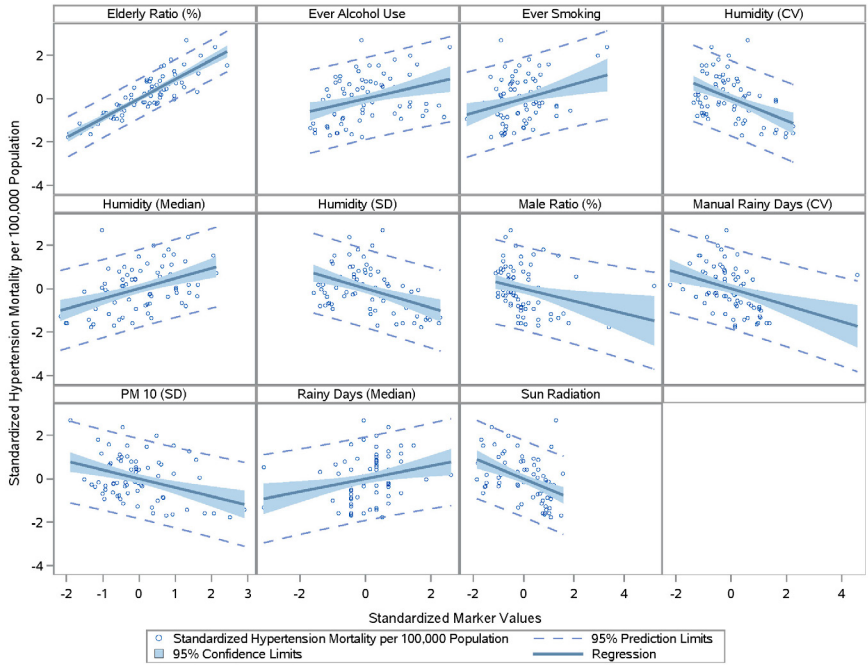

Figure 2. Predictors significantly associated with Hypertension Mortality

Known Factors

All factors known to be associated with Hypertension were also found to be associated with the hypertension mortality. Each percentage point increase in the elderly population in a province increased the odds of being in a higher cluster of hypertension mortality by about three times (OR=2.91, 95% CI: 2.12, 4.01, FDR-adjusted p-value<0.0001). Similarly, smoking and alcohol consumption were found to be positively associated with hypertension mortality. In addition, each 1-percentage point increase in male population in a province decreased the odds of being in a higher cluster of hypertension mortality by about 50% (OR=0.51, 95% CI: 0.31, 0.83, FDR-adjusted p-value=0.0022).

Environmental and Meteorological Factors

Most significant predictor of hypertension mortality was humidity and its variation markers. Each one-unit increase in average humidity increased the odds of being in a higher cluster of hypertension mortality by about 13% (OR=1.13, 95% CI: 1.07, 1.19, FDR-adjusted p-value<0.0001) while each one-

unit increase in the humidity CV resulted in a 12% reduction, and each one-unit increase in the humidity SD resulted in a 21% reduction in the odds of being in a higher cluster of hypertension mortality. An associated variable to humidity, rainy days showed similar association with hypertension mortality.

Standard Deviation of Particulate Matter-10 (PM_{10}) reduced the odds of being in a higher cluster of hypertension mortality by 12%, suggesting that the provinces with higher variation of PM_{10} concentration over time reported reduced number of hypertension related deaths.

Temperature: Variability and median values of maximum, mean, and minimum temperatures were all significantly associated with hypertension mortality. For example, higher variability measured through SD of temperature substantially decreased the odds of hypertension mortality (OR = 0.40, 95% CI: 0.27, 0.60, FDR-adjusted p-value<.0001).

Both sun radiation and sunlight were found to be associated with lower likelihood of hypertension mortality.

Other environmental and meteorological markers were not found to be significantly associated with hypertension mortality.

We have constructed a multivariable logistic regression controlling the effects elderly population size and smoking rate, the only predictor which still showed some level of significance was humidity with an OR of 1.067 (95% CI: 0.995, 1.114, p=0.071). The predictive ability of this model was quite high with a AUC of 0.927.

DISCUSSIONS AND CONCLUSIONS

This study's findings, as outlined in Table 1 and Figure 2, provide a comprehensive view of the multifactorial nature of hypertension mortality in Türkiye. Our analyses confirmed the known lifestyle factors in relation to hypertension mortality such as smoking, alcohol consumption, male and elderly sizes of population (Bufford, 2016; Virdis et al., 2010; Brown et al., 2009). Our models also identified several significant environmental and meteorological markers and thus offer insights into the complex interplay of these elements.

Humidity seemed to be the most critical air quality marker in predicting hypertension mortality. Both median humidity and its variation measures through CV and SD were significant even after multiplicity correction. While

increasing humidity resulted in increased likelihood of hypertension mortality, contrary to what Chen and Zhang (2015) reported, the increasing variation measures of humidity (CV and SD) decreased the likelihood. Chen et al. (2014) discusses the association of PM_{10} with hypertension mortality. Our analyses did not confirm these positive associations as both PM_{10} and $PM_{2.5}$ in our models were not significant while we have shown that the variation of PM_{10} was negatively associated with hypertension mortality.

The significant impact of temperature variability on hypertension mortality underscores the vulnerability of hypertensive individuals to climatic changes. Such a variability aligns with global trends indicating increased cardiovascular risks associated with extreme temperatures (Jones et al., 2001). Jehn et al. (2002) discuss the increased blood pressure variability in winter months, which is indirectly in line with what we conclude in our study as well. The relationship of temperature and humidity with hypertension mortality adds to the growing evidence of the role of meteorological factors in cardiovascular health (Lee et al., 2019).

We have also identified sunlight and sun radiation as significant predictors of hypertension mortality; in fact, such significant findings are not very surprising as these two environmental markers are highly negatively correlated with humidity overall and our model results are in this anticipated direction. Interestingly, in line with our findings, Rostand et al. (2016) suggests a nega-tive association of insolation (i.e., exposure to solar radiation) with increased blood pressure.

Strengths and Weaknesses

The study's primary strength lies in its comprehensive approach, integrating a wide range of predictors across a large geographical area over an extended period. Such a strength provides a robust framework for understanding regional variations in hypertension mortality.

The study's observational nature limits its ability to infer causality. Potential confounders and biases inherent in the data sources could also affect the results. The lack of individual-level data also limits the ability to account for personal health behaviors and genetic predispositions.

Public Health Implications

The findings highlight the importance of considering environmental and meteorological factors in public health strategies for managing hypertension. Policies aimed at reducing air pollution and mitigating the impacts of climate change could be beneficial. The study underscores the need for continued efforts in tobacco and alcohol control, particularly in regions with high consumption rates.

Future Research

Future studies should incorporate individual-level data to better understand the interactions between personal health behaviors, genetic factors, and environmental exposures. Investigating the mechanisms underlying the observed associations, particularly the protective effect of exposure to smoke at home, could provide valuable insights. Longitudinal studies exploring the impact of climate change on hypertension mortality would be beneficial in guiding future public health policies.

In conclusion, this study contributes significantly to understanding hypertension mortality in Türkiye, highlighting the complex interplay of environmental, meteorological, and lifestyle factors. The findings emphasize the need for developing public health strategies that take into account the size of elderly population, smoking rate and high-risk behavior rates, and environmental markers especially humidity.

Ethical Approval: We have obtained the umbrella ethics approval from Istanbul Medipol University IRB for our TUBITAK Directorate of Science Fellowships and Grant Programmes (BIDEB)-2232 International Fellowship for Outstanding Researchers project titled “Feasibility assessment and utility of combining streaming national healthcare data with environmental and food intake data to improve health policy and outcomes” and this particular manuscript was part of our research under this application (Approval Date: September 09, 2019, Application number: 10840098-604.01.01-E.53819)

Authors’ Contributions: MK developed the research idea, acquired the relevant data, conducted data analyses and modelling, provided the final interpretations and final editing of the manuscript. OAK carried out the literature search, initial and final editing of the manuscript.

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Conflict of Interest Statement: The authors declare NO conflict of interest.

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