Relationship Between the Activity of the Hypertension Program and the Number of Patients with Symptoms and Signs of Stroke

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Abstract

This paper investigates the possible relationship between the activity of Portugal's national hypertension program and the number of patients showing signs and symptoms of stroke. The objective was to confirm or not the general assumption that high blood pressure leads to increased stroke risk, using statistical and analytical methods applied to data from the Serviço Nacional de Saúde (SNS).

Results revealed age specific divergence: individuals under 65 showed a moderate negative correlation ($\rho = -0.43$) between hypertension control and stroke incidence, whereas those aged 65 and over exhibited a positive correlation ($\rho = 0.32$), consistent with international evidence on age related stroke risk.

Geographic analysis indicated a moderate negative relationship, despite notable regional disparities. Districts such as Évora and Coimbra demonstrated the effectiveness of localized cardiovascular health strategies, while others, like Viana do Castelo and Guarda, showed elevated stroke rates despite moderate hypertension control - suggesting the influence of environmental, lifestyle, or healthcare access factors. Notably the imputation strategy used for missing geographic data preserved spatial integrity, allowing for reliable district level comparisons. These findings highlight the need for tailored hypertension management strategies, such as improved secondary hypertension detection in younger adults, and region-specific interventions to address contextual health inequalities.

This work contributes to a better understanding how targeted chronic disease management can help reduce Portugal's disproportionately high stroke mortality.

Keywords: hypertension; stroke; hypertension program activity; health data; public health; prevention; Portugal.

1. Introduction

In recent years, the association between hypertension and stroke has been widely investigated, highlighting hypertension as the primary modifiable risk factor for stroke occurrence. The relevance of this research lies not only in its to inform preventive strategies and improve post-stroke recovery outcomes, but also in its role in confirming and validating a central focus of cardiovascular health policy.

Previous studies have established that hypertension is present in approximately 80% of stroke patients. Moreover, severe and uncontrolled forms of hypertension are associated with a higher risk of having both ischemic and hemorrhagic strokes, and poor blood pressure management is linked to significantly worse post-stroke recovery. However, the hypertensive population often exhibits coexisting risk factors such as advanced age, a family history of cardiovascular disease, unhealthy dietary habits (e.g., high intake of sugar and fat), and tobacco use - all of which contribute to stroke risk.

In Portugal, stroke remains one of the leading causes of mortality and long-term disability, such as understanding whether the national hypertension control program has contributed to measurable reductions in stroke incidence is of high clinical and public health importance.

This study seeks to explore this relationship by analyzing data from the Serviço Nacional de Saúde (SNS). Specifically, it assesses whether higher hypertension control rates are associated with lower rates of stroke symptoms and signs at the population level, using both temporal and geographic comparisons. The study also investigates how this relationship differs between individuals aged under 65 and those aged 65 and above, and across Portuguese districts with varying levels of hypertension control and healthcare system performance.

Through statistical correlation, regression modelling, and spatial data analysis - including imputation methods to preserve geographical validity - this study aims to produce statistically robust evidence on the effectiveness of national hypertension control efforts in preventing strokes. By identifying gaps in program performance and areas of disproportionate stroke burden, we hope to contribute to the optimization of chronic disease prevention strategies. Ultimately, the findings are intended to support a more equitable, data-driven public health approach to reduce Portugal's high stroke mortality and improve cardiovascular outcomes across diverse population groups.

2. Methods

2.1. Hypertension data analysis

We began analyzing the data provided by the SNS on hypertension by first investigating the presence of missing values, revealing that there are 24 missing values in the variable `ponto_ou_localizacao_geografica`, which indicates geographic coordinates. This variable proves to be of great importance in comparative and conclusive terms, as in Portugal, geographical diversity translates into significant sociocultural differences. The relevance of the variable was confirmed by the Likelihood Ratio Test, using Poisson regression, `anova` function and the chi-square test.

H_0: The reduced model is adequate, as the variable ponto_ou_localizacao_geografica does not provide a significant contribution

H_1: The full model is significantly improved by the inclusion of the variable ponto_ou_localizacao_geografica, which contributes significantly

$$p\text{-value} = 2.2 \times 10^{-16}$$

We reject the null hypothesis at a 1% significance level and observe that the model including the variable `ponto_ou_localizacao_geografica` presents a much lower residual deviance. Thus, we conclude that the variable in question substantially improves the model fit and should be retained.

We examine the percentage these values represent, their temporal distribution, and their proportion over time. We also assess whether the data lacking associated location are representative of the overall sample — that is, whether they are not outliers and whether their statistical metrics are consistent with those of the full dataset. To this end, we visually compare the values and perform the Welch two-sample t-test, since we verified that the samples have different variances.

$$H_0 : \mu_1 = \mu_2; \text{ the means of the two groups are equal}$$
$$H_1 : \mu_1 \neq \mu_2; \text{ the means of the two groups are different}$$

$$p\text{-value} = 0.6463$$

We fail to reject the null hypothesis, indicating that there is no significant difference between the means. Therefore, the values are representative of the sample, so we proceed with data imputation as the most appropriate option.

To support the imputation of location data, we converted the coordinates of each geographic point into their corresponding municipalities and districts using the shapefile `gadm41_PRT.shp`. The municipalities' imputation process will be carried out based on the similarity of metric values. That is, each municipality has x associated values, for which we calculate the mean and standard deviation, and we create a value range $[\text{mean} - \text{sd}, \text{mean} + \text{sd}]$. With this, we check which interval the value without a location falls into, and we assign it the corresponding municipality for that interval. The values that did not fall within any predefined interval were classified as outliers and subsequently excluded from the analysis. Afterwards, we examine the imputed municipalities and assign them to their respective districts.

Finally, we validated the imputation and examined potential changes in the data. We compared the average values per municipality before and after imputation. Furthermore, we conducted a graphical analysis of the distance between the imputed values and the respective municipal means. We also compared the regional distribution of values lacking location data with those containing location information, in order to determine where most values were imputed. Additionally, we assessed whether the correlations among numerical variables were preserved following the imputation.

Correlation before imputation: 0.7432419 Correlation after imputation: 0.7427319

The correlation remains largely consistent, which was desirable and indicates that the imputation was appropriated. Additionally, to ensure the consistency of the numeric variables, we verify their stability using summary statistics and various ggplot visualizations. We also analyze the dispersion of the imputed values compared to the original values to confirm that the variability remains comparable. For a more comprehensive assessment, we perform a Principal Component Analysis (PCA), distinguishing between imputed and non-imputed values (Figure 1).

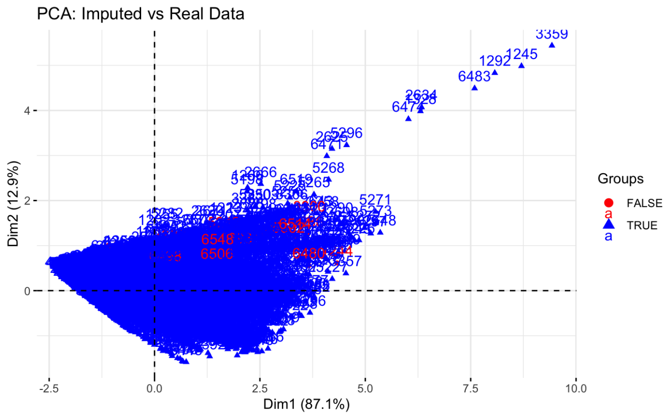

Figure 1: Principal Component Analysis

This PCA plot shows that the imputed data were well integrated into the overall dataset. The imputed observations (in red) are embedded within the same space as the real observations (in blue), indicating that the imputation process preserved the original data structure. There is no clear separation or clustering of imputed points, which means the imputed values do not behave like outliers or introduce distortions. The spread and variance of the imputed data are consistent with the real data, further supporting the quality and appropriateness of the imputation.

Upon completing the imputation process, we proceed with the temporal analysis of the hypertension dataset, assuming the dataset from this point onward contains the imputed values. We began by graphically examining the annual distribution of hypertension for all patients, for patients aged under 65, and by age group across years using stacked bar charts. Additionally, we explore the monthly distribution of hypertension within the same three categories. Later on, we proceed with the geographical analysis.

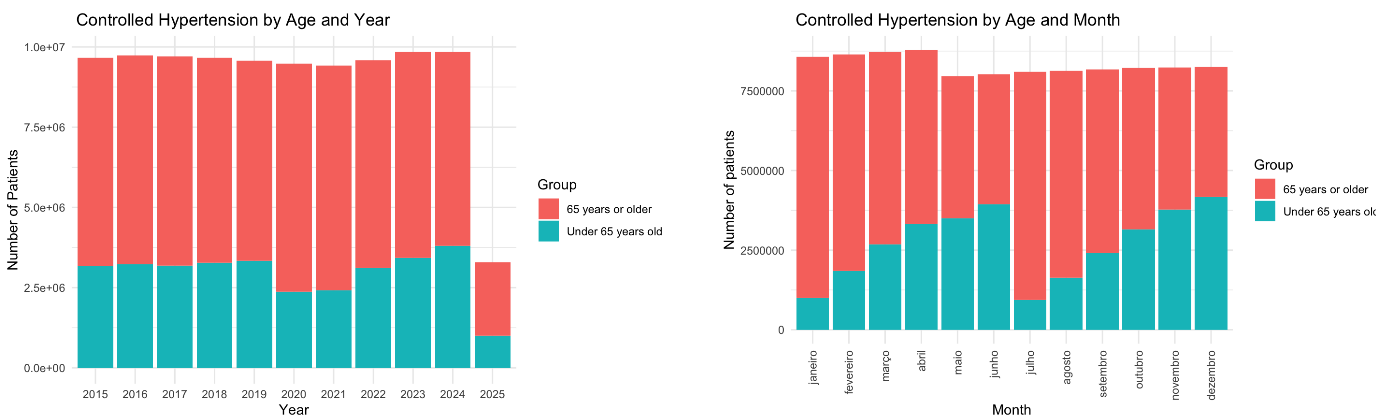

Figure 2: Controlled Hypertension by Age Group Across Years and Months

The bar plots illustrate that individuals aged 65 and older consistently represent the majority of patients with controlled hypertension across both months and years. This reflects the expected medical trend, as hypertension not only becomes more prevalent with age but also requires more consistent management in older populations. The distribution between age groups remains stable over time, indicating that the control of hypertension is consistently more common — or perhaps more prioritized — among older adults. The apparent drop in 2025 is due to incomplete data, as only part of the year was included in the dataset. These findings emphasize the importance of focusing hypertension management and control strategies on older populations, who bear the greatest burden and benefit most from effective blood pressure regulation. Furthermore, the monthly distribution confirms that the predominance of controlled hypertension in the 65+ age group persists throughout the year, with no strong seasonal variations. This highlights the chronic nature of hypertension and the need for continuous, year-round monitoring and control, especially among the elderly.

2.2. Stroke data analysis

Following the completion of the hypertension analysis, we began our examination of the stroke dataset (`avc`). It is important to note that from this point forward, when we refer to "stroke cases", we are specifically referring to individuals who presented with signs or symptoms suggestive of stroke.

As a preliminary step, we conducted a thorough check for missing values across all variables, considering both NA entries and empty strings. This verification confirmed that the dataset was complete, with no missing values detected. The main objective of this phase was to explore the distribution of stroke cases across key demographic dimensions. We began by aggregating the total number of stroke cases by gender, which allowed us to assess differences in stroke incidence between men and women. To understand how these patterns evolved over time, we extended the analysis to show annual and monthly trends in stroke cases by gender. We then turned our focus to age groups, calculating the total number of stroke cases across predefined age ranges. These results were presented both in total and disaggregated by year and month, providing a clearer picture of how age-related stroke incidence changes over time and potentially follows seasonal patterns (Figures 3 and 4).

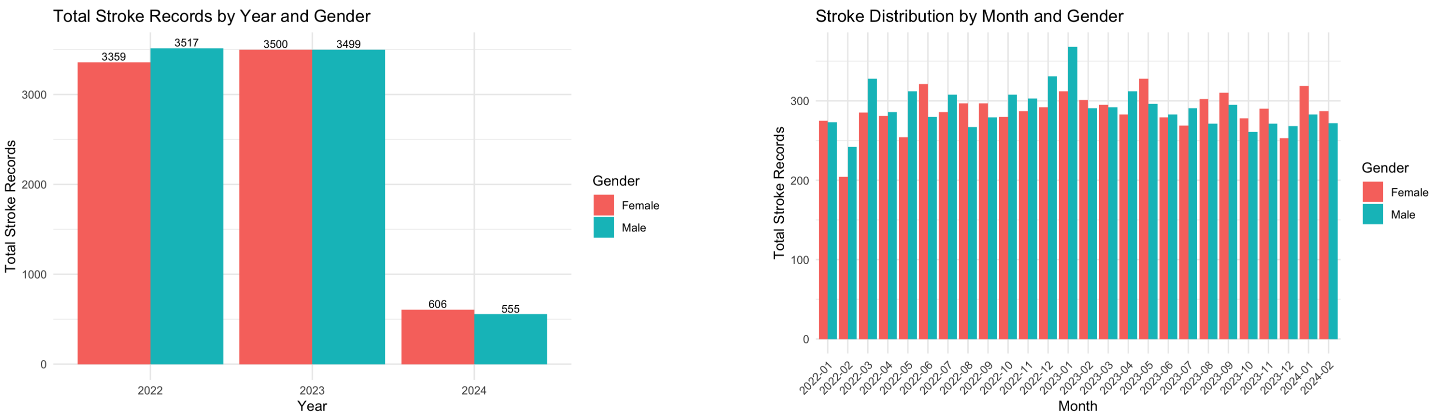

Figure 3: Stroke Records by Gender Across Years and Months

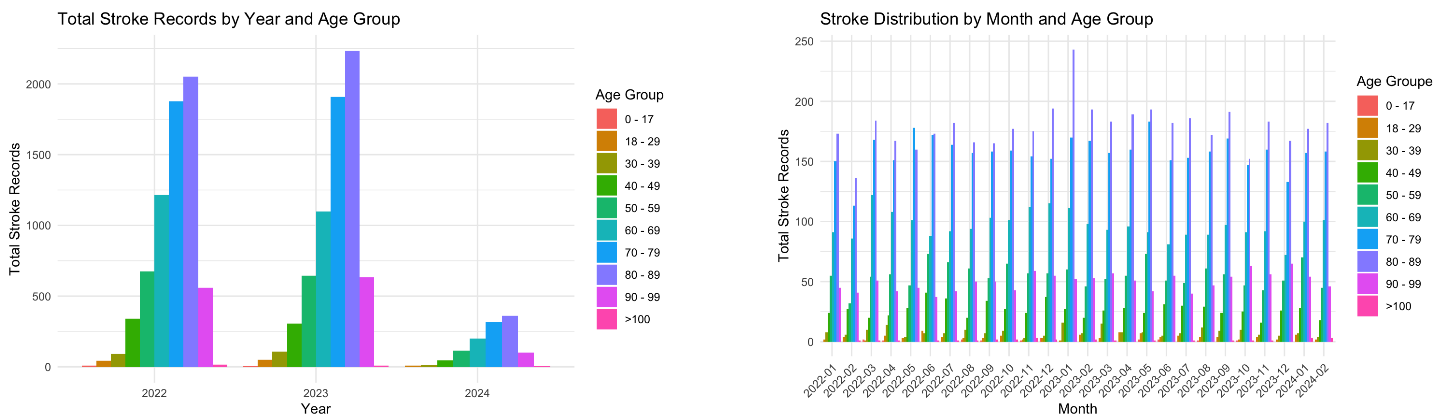

Figure 4: Stroke Records by Age Group Across Years and Months

Through the observation of the plots, it is clear that stroke incidence increases significantly with age, particularly from 60 years onward, with the highest number of cases occurring in the 70–79 and 80–89 age groups. This is medically explained by the higher prevalence of risk factors such as hypertension, diabetes, and atherosclerosis in older adults, along with age-related vascular changes that increase the brain's vulnerability to stroke. This trend is consistent with our earlier analysis of the hypertension dataset, which showed that the number of individuals with controlled hypertension is also higher among people aged 65 and older. In contrast to the strong age-related pattern, gender distribution appears fairly even, showing only minor differences between male and female cases across both annual and monthly periods. There is no strong seasonal pattern in stroke incidence related to either gender or age group. The decrease in total cases in 2024 is due to the fact that the analysis includes only the first two months of that year.

2.3. Data-driven analysis of the link between hypertension and stroke by District

In this part of the analysis, we examined the distribution and evolution of both stroke cases and controlled hypertension across Portuguese districts, using a consistent and comparable methodology to better understand regional patterns in cardiovascular health.

We began by analyzing stroke data (`avc`), calculating the total number of cases per district and tracking their evolution over time. To ensure fair comparisons across regions with different population sizes, we normalized the data by estimating the monthly stroke rate per 100,000 inhabitants. We obtained the population of each district from the Portuguese National Statistics Institute (INE), and we used the average population between 2022 and 2023, as demographic growth during this period was minimal and did not significantly affect regional proportions. This allowed us to identify not just where the highest number of stroke cases occurred in absolute terms, but also where the relative incidence was highest. We further explored the temporal dimension by analyzing both monthly and annual trends in stroke rates, and we visualized the results through bar plots, line graphs, and a heatmap showing the evolution of stroke incidence by district and year. Statistically, we tested for normality of distribution using the Shapiro-Wilk test and assessed the homogeneity of variances between districts using Levene's test. The Shapiro-Wilk results showed that only Coimbra ($p < 0.05$) deviated from normality, while the distributions in all other districts did not ($p > 0.05$), suggesting that the overall data could be considered approximately normal. However, Levene's test revealed a highly significant difference in variances across districts

($p < 2.2 \times 10^{-16}$). Given this, we opted to use the one-way ANOVA to see if there are significant differences in stroke rates between districts.

Using the same structure, we then analyzed controlled hypertension data from January 2022 to February 2024—the same period used for the stroke analysis—to ensure direct comparability. We followed exactly the same approach as in the stroke analysis. To verify the assumptions for subsequent statistical analysis, we also applied the Shapiro-Wilk test to assess normality across districts and the Levene's test to evaluate the homogeneity of variances. The Shapiro-Wilk test indicated that while most districts exhibited approximately normal distributions (e.g., Lisboa: $p = 0.873$, Évora: $p = 0.976$), several districts—including Aveiro ($p \approx 5.9 \times 10^{-6}$), Leiria ($p \approx 8.6 \times 10^{-8}$), and Vila Real ($p \approx 3.5 \times 10^{-7}$)—deviated significantly from normality. Additionally, the Levene's test showed a statistically significant difference in variances across districts ($p = 0.014$). As both assumptions were violated, we again applied the Kruskal-Wallis test, which revealed statistically significant differences in controlled hypertension rates between districts.

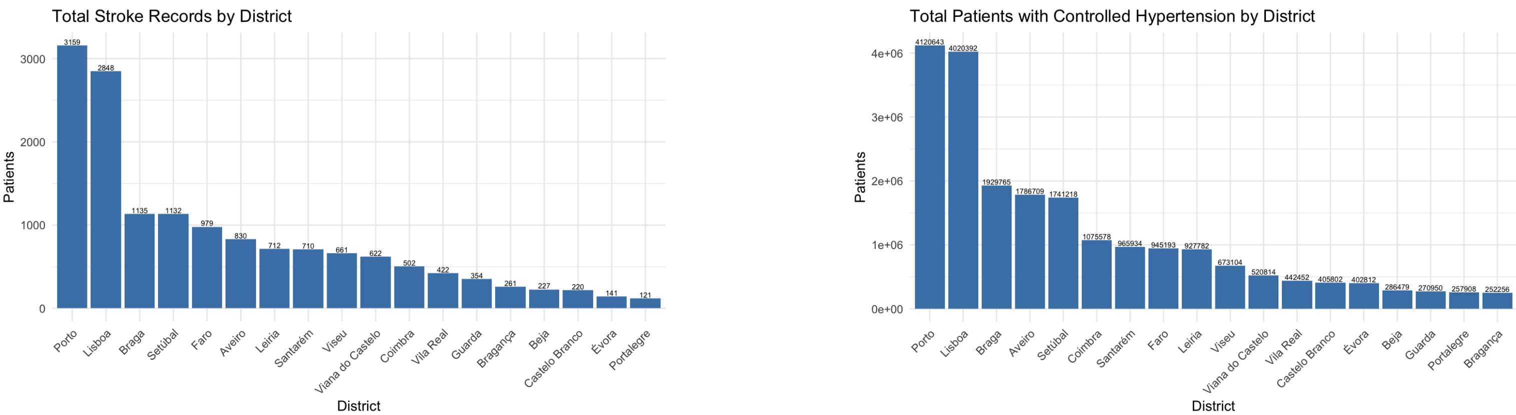

Figure 5: Total of Stroke Records and Controlled Hypertension by District

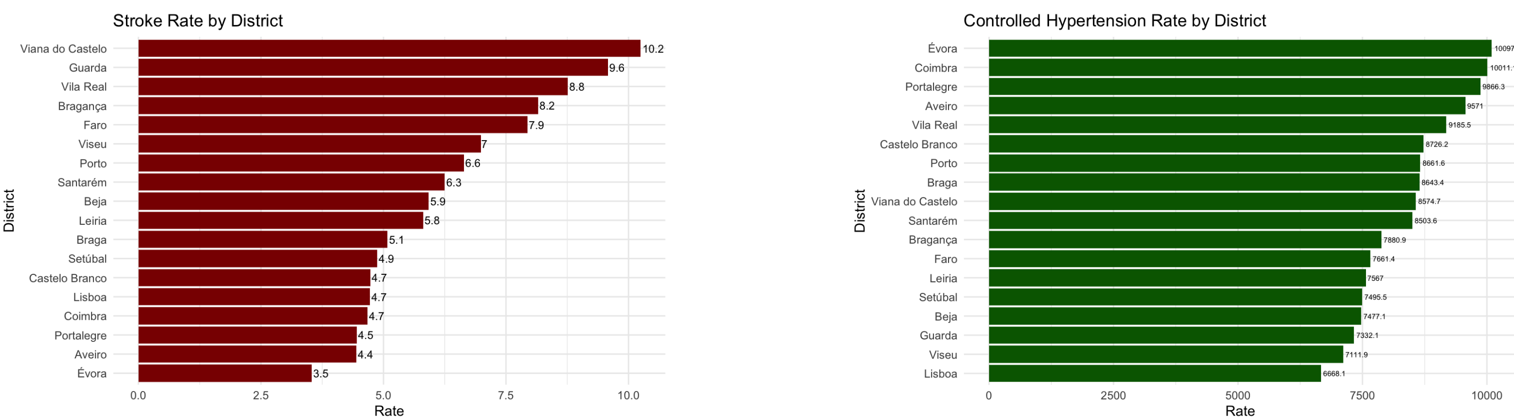

Figure 6: Stroke and Controlled Hypertension Rates by District

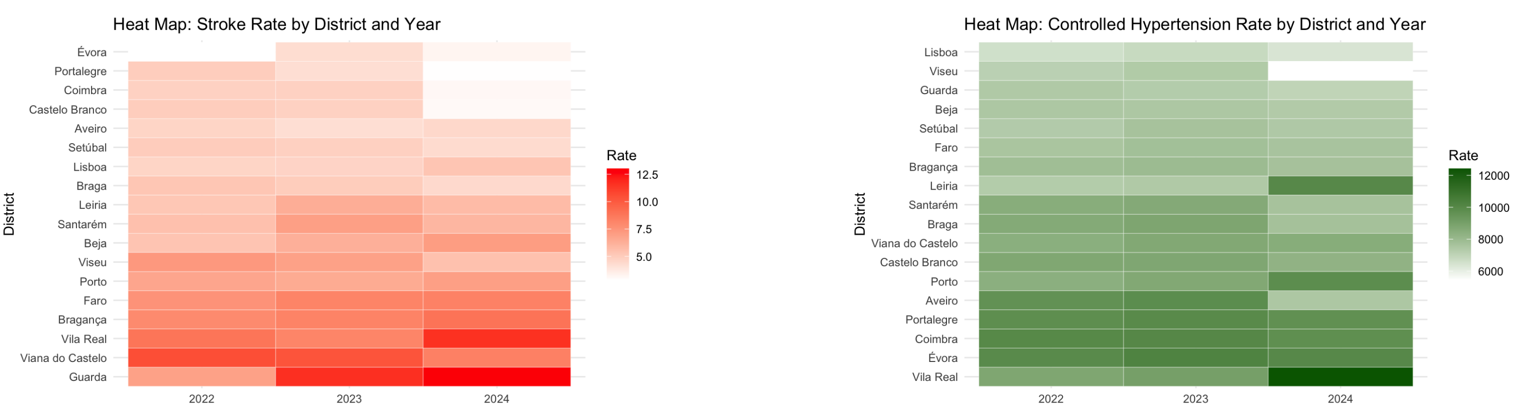

Figure 7: Heat Maps of Stroke and Controlled Hypertension Rates by District and Year

The analysis of both stroke incidence and hypertension control across Portuguese districts highlights important regional disparities and the value of using population-adjusted rates to interpret public health data effectively. In absolute numbers, Porto and Lisboa lead

in total stroke cases and in the number of individuals with controlled hypertension, which is expected given their larger populations. However, when adjusting for population size, a different reality emerges. For stroke cases, districts such as Viana do Castelo, Guarda, Vila Real, and Bragança exhibit the highest average stroke rates, despite recording fewer total cases. This pattern may be attributable to factors identified in 2022 studies, which highlight a higher prevalence of tobacco consumption and childhood obesity in the northern region. Similarly, for hypertension control, the highest average rates are found in Évora, Coimbra, and Portalegre, indicating more efficient management of this condition in less populous regions. These findings underscore that absolute figures can mask important inequalities and that normalized rates provide a clearer picture of regional performance.
The heatmaps for both conditions show consistent trends over time. Stroke rates remain high in districts like Viana do Castelo and Guarda throughout 2022 to 2024, while Évora and Portalegre maintain low rates. In contrast, for hypertension control, Évora, Coimbra, and Vila Real demonstrate strong and improving performance, whereas Lisboa and Viseu consistently rank lower relative to their population.

Statistical analysis using the one-way ANOVA and Kruskal-Wallis tests confirms that the differences observed between districts are statistically significant for both stroke (p-value $< 2.2 \times 10^{-16}$) and hypertension control (p-value $< 2.2 \times 10^{-16}$), respectively. This indicates that regional disparities are not due to random variation but reflect meaningful differences in health outcomes and the quality or effectiveness of care provided across districts.

3. Results

Firstly, we analyzed the relationship between hypertension and stroke incidence, focusing on two age groups: individuals under 65 years and those aged 65 and over. The analysis was limited to the period between January 2022 and February 2024, as this was the only time frame shared by both datasets, ensuring a valid and comparable basis for the analysis. After organizing the data by month and age group, we began by creating boxplots to identify possible outliers in both variables (Figure 8). Since the boxplots clearly showed the presence of outliers in both the number of hypertensive patients and stroke cases, we decided to use Spearman's correlation instead of Pearson's, as it is more robust in the presence of non-normal distributions and extreme values (Figure 9).

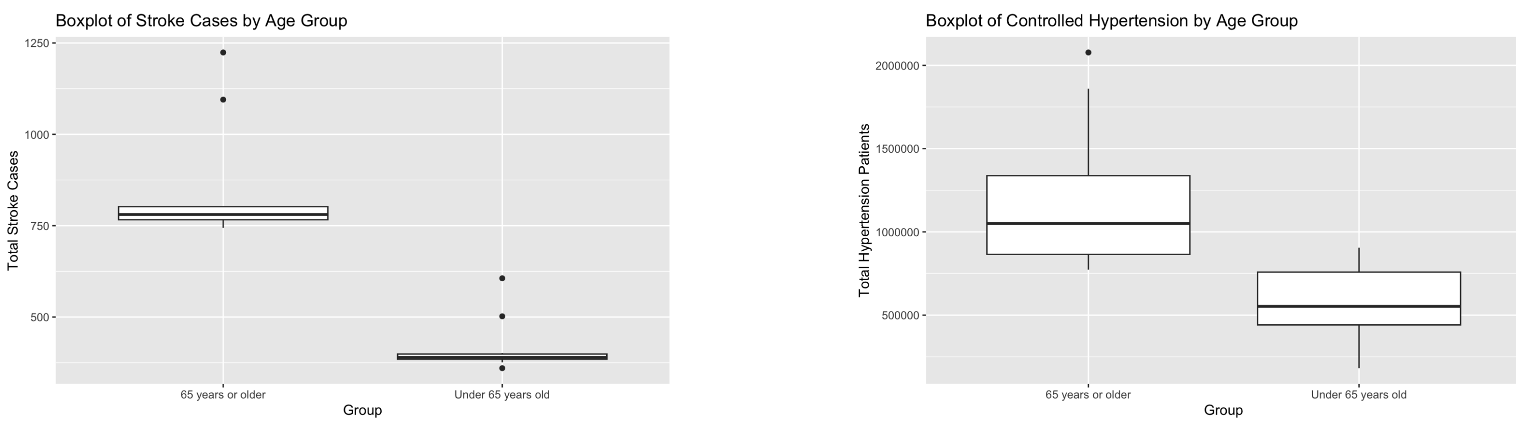

Figure 8: Boxplots of Stroke and Controlled Hypertension by Age Group

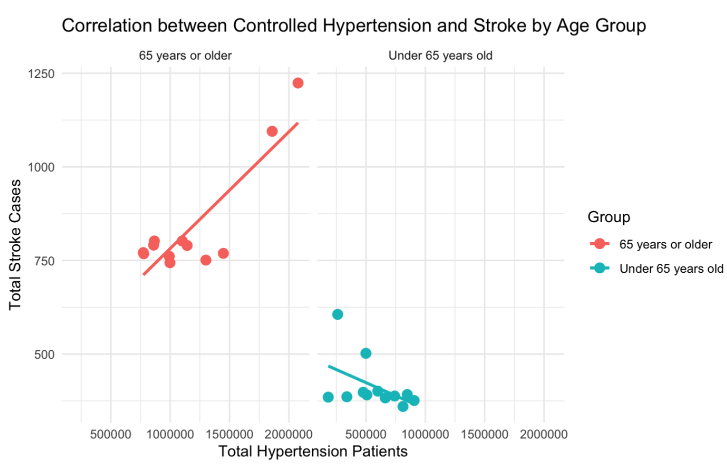

Figure 9: Correlation between Hypertension and Stroke by Age Group

The scatter plot and correlation coefficients, calculated using Spearman's method, show a distinct difference in the relationship between hypertension and stroke across age groups. For individuals aged 65 years or more, the Spearman correlation coefficient is approximately 0.32, indicating a weak to moderate positive correlation—as the number of hypertensive patients increases, so does the number of stroke cases. In contrast, for those under 65, the Spearman coefficient is approximately –0.43, suggesting a moderate negative correlation. These findings align with earlier bar chart analyses by age group, which also showed a significantly higher number of stroke cases in older age brackets, particularly between ages 70–79 and 80–89.

To better understand these associations, simple linear regressions were performed for each age group. For those under 65, the model did not reveal a statistically significant relationship (p = 0.124), with an adjusted R^2 of 0.14, indicating that only 14% of the variance in stroke cases could be explained by controlled hypertension levels in this group. The slope was negative, suggesting that as the number of controlled hypertensive patients increases, stroke cases slightly decrease, though the result is not significant. For individuals aged 65 and above, the regression model showed a statistically significant relationship ($p < 0.001$), with an adjusted R^2 of 0.71, meaning that 71% of the variability in stroke incidence could be explained by controlled hypertension in this age group. The slope was positive, indicating a clear upward trend. Interestingly, this contrasts with the Spearman correlation result for the younger group, where a negative correlation was found, but the regression revealed a strong positive and significant association. This suggests that the relationship may be non-monotonic or influenced by confounding factors, particularly in younger populations.

Following that, to better understand the relationship between stroke incidence and hypertension control across Portuguese districts, we conducted two complementary correlation analyses using data from the period between January 2022 and February 2024, ensuring temporal alignment between the datasets. To ensure comparability across districts with different population sizes, we used rates—specifically, the number of stroke cases and the number of patients with controlled hypertension per 100,000 inhabitants. Prior to selecting the correlation method, we also generated boxplots to check for the presence of outliers in both variables (Figure 10). Since no significant outliers were detected, we proceeded with Pearson's correlation, which assumes linearity and is appropriate when the data distribution is approximately normal and free from extreme values (Figure 11). In addition to the Pearson correlation, we also performed a simple linear regression to quantify the potential association and assess the explanatory power of hypertension control over stroke rates.

Figure 10: Boxplots of Stroke and Controlled Hypertension Rates by District

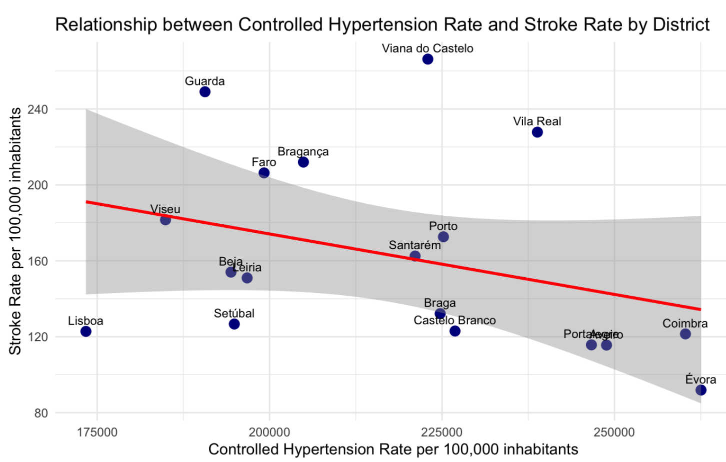

Figure 11: Relationship between Controlled Hypertension Rate and Stroke Rate by District

This last plot, which results from the first analysis comparing stroke rates and controlled hypertension rates per 100,000 inhabitants across Portuguese districts, reveals several important conclusions. There is a moderate negative relationship between the rate of controlled hypertension and the rate of stroke. The downward trend of the regression line suggests that, in general, districts with higher rates of hypertension control tend to have lower stroke incidence. This aligns with medical understanding: effective hypertension management reduces the risk of stroke, as high blood pressure is one of the leading modifiable risk factors. The plot also shows that while this relationship exists, it is not perfect—some districts deviate from the trend. For example, Viana do Castelo and Guarda have high stroke rates despite moderate hypertension control, which may indicate the influence of other factors like age distribution, healthcare access, socioeconomic status, or lifestyle. Conversely, districts like Évora, Coimbra, and Aveiro combine high hypertension control with low stroke rates, supporting the effectiveness of their local cardiovascular health strategies.

Statistical analysis supports this general trend but also highlights its limitations. The Pearson correlation coefficient between hypertension control and stroke rate was -0.3342, indicating a weak negative relationship. Also, the 95% confidence interval (-0.6929 to 0.1572) includes zero, meaning the correlation is not statistically significant and no reliable linear association can be confirmed. Similarly, in the linear regression analysis, the intercept was 301.6—though this has little practical meaning, as a scenario with zero hypertension control is unrealistic. The coefficient for hypertension control was -0.000637, showing a very weak and non-significant negative association ($p = 0.1753$). The model explained only 11.17 % of the variation in stroke rates ($R^2 = 0.1117$) and had a high residual error (49.4). Overall, the regression model is not statistically significant and has low explanatory power. While the visual trend supports the idea that better hypertension control may reduce stroke risk, the statistical evidence is weak and inconclusive. This suggests that stroke incidence cannot be explained by hypertension control alone, especially when analyzed at the population level. Other factors—like demographic structure, socioeconomic disparities, and quality of healthcare services—likely play a substantial role. Therefore, while promoting hypertension control remains essential, stroke prevention requires a broader, multifactorial public health approach.

4. Discussion

Among individuals aged 65 years or older, we observed a moderate positive correlation between the number of hypertensive patients and stroke incidence, consistent with established medical understanding. As people age, the cumulative effects of chronic conditions such as hypertension, diabetes, and atherosclerosis—combined with decreased vascular elasticity and increased arterial stiffness—contribute to a higher risk of stroke.

In contrast, among patients under 65, we identified a moderate negative correlation. This may reflect the generally lower burden of comorbidities and greater cardiovascular resilience in younger populations, leading to more inconsistent or weaker associations between hypertension and stroke incidence. Furthermore, the presence of undiagnosed or masked hypertension in this demographic—particularly in Portugal—may result in overestimations of "controlled" status, obscuring the true relationship. Nevertheless, these findings reinforce the critical importance of targeted hypertension management in older adults, where the potential impact on stroke prevention is greatest.

At the district level, as previously noted, we obtained a moderate negative relationship between the rate of controlled hypertension and the rate of stroke. The downward trend of the regression line suggests that, in general, districts with higher rates of hypertension control tend to have lower stroke incidence. This aligns with medical understanding: effective hypertension management reduces the risk of stroke, as high blood pressure is one of the leading modifiable risk factors.

However, this relationship is not uniformly observed across all districts. For example, Viana do Castelo and Guarda presented a higher stroke rate despite moderate hypertension control, which may indicate the influence of other factors like age distribution, healthcare access, socioeconomic status, or lifestyle. Interestingly, these findings mirror previous studies, which noted a higher stroke rate in northern regions of Portugal. One plausible environmental explanation may be the mineral-rich groundwater (pH ¿ 8.5) prevalent in these regions, which has been associated with worsened hypertension control outcomes. In Contrast, districts like Évora, Coimbra, and Aveiro combine high hypertension control with low stroke rates, supporting the effectiveness of their local cardiovascular health strategies.

Together, these results highlight the importance of regionalized approaches in public health. While urban centers such as Porto and Lisboa bear the largest absolute burden of cases due to population size, smaller districts often perform better on a per capita basis, suggesting more effective healthcare delivery and prevention strategies. At the same time, these differences may not be fully explained by healthcare infrastructure alone. Regional characteristics such as climate, lifestyle, dietary habits and environmental exposures could also contribute to higher rates of stroke or hypertension in certain districts. This reinforces the need for targeted policies that not only consider healthcare infrastructure but also address local environmental and cultural conditions, to promote equity in cardiovascular health outcomes.

Several confounding variables were not controlled in this analysis, for example: Sodium intake in Portugal, which exceeds the recommendations; therapeutic inertia and low treatment adherence; and diagnostic underreporting in rural districts, where neuroimaging rates are substantially lower. These limitations could have influenced the observed associations and emphasize the need for more detailed datasets in future studies.

These findings have direct implications for public health policy and clinical practice in Portugal. Given the divergent patterns observed between age groups, hypertension management strategies must be tailored accordingly. For example, for individuals under 65, where a negative correlation was observed, routine screening for secondary causes of hypertension should be implemented to avoid misclassification of patients as "controlled." On the other hand, older adults, who showed a positive correlation, would benefit from more intensive blood pressure management. At the district level, targeted interventions are needed to address the disparities. Districts like Guarda and Viana do Castelo may benefit from public education campaigns focused on reducing sodium intake, improving medication adherence, and addressing environmental risks, such as high water mineral content. To finalize, in the future some public health strategies that should be incorporated are pharmacy-linked follow-up, adherence tracking technologies, and biomarkers to better identify patients at residual risk of stroke. These approaches are essential to achieve a more equitable and effective stroke prevention across Portugal.

5. Conclusion

This study examined the relationship between the activity of the national hypertension program and the number of patients presenting with symptoms and signs of stroke, with focus on age group differences and Portuguese districts. The analysis revealed that the effectiveness of hypertension control programs is significantly shaped by both age and geographic context.

Regarding age specific analysis, one of the most important findings was the contrasting correlation pattern between groups, where individuals under 65 exhibited a moderate negative correlation, while those aged 65 and above showed a positive association between controlled hypertension and stroke incidence. For older adults, the results align with previews studies that highlights hypertension as a leading modifiable risk factor for stroke and supports the advantage of maintaining stricter blood pressure thresholds in this demographic. Conversely, for younger individuals, the results suggest that hypertension management may be insufficient, possibly due to undiagnosed secondary hypertension, low adherence to treatment, or other unmeasured cardiovascular risk factors.

At the regional level, the analysis revealed a moderate negative relationship between stroke incidence and controlled hypertension rates, but this trend was complicated by geographic disparities. Districts such as Viana do Castelo and Guarda showed stroke rates higher than coastal regions despite achieving moderate levels of hypertension control. These elevated rates are likely influenced by a combination of environmental exposures, lifestyle habits, and unequal access to healthcare. In addition, districts such as Évora, Coimbra, and Aveiro reported high hypertension control rates and lower stroke incidence, suggesting the positive impact of integrated local public health strategies.

Despite these encouraging patterns, the study also revealed limitations that must be addressed. The statistical models applied had low explanatory power, and several relevant confounding variables - such as smoking, obesity, sodium intake, and therapeutic inertia - were not included. Also, Portugal's average salt consumption remains considerably above World Health Organization (WHO) recommendations, and nearly 40% of hypertensive patients in primary care present poor medication adherence, which further complicates the interpretation of program outcomes. Additionally, rural underdiagnosis and limited access to neuroimaging may lead to underreporting of minor strokes and distort the district patterns. These factors highlight the need for more detailed data to better assess the true impact of hypertension control on stroke prevention.

In conclusion, while Portugal's hypertension control program has demonstrated measurable success, a one-size-fits-all strategy is insufficient. Taking in consideration that the relationship between controlled hypertension and stroke is influenced by age, geographic disparities, behavioural risk factors, and systemic inequalities. To effectively reduce the national burden of stroke, future public health strategies must include screening for secondary hypertension in younger adults, enforce stricter blood pressure targets for older populations, and implement regional interventions that address environmental and cultural factors. By addressing these multifaceted challenges through targeted and data-driven public health approaches, Portugal can move closer to achieving equity in cardiovascular outcomes and reducing one of the highest stroke mortality rates in Europe.

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