THE COMBINED EFFECT OF MOON PHASES AND METEOROLOGICAL FACTORS ON OUR HEALTH

Ph.D. Dissertation

Horváth László

University of Pécs Faculty of Health Sciences
Doctoral School of Health Sciences
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UNIVERSITY OF PÉCS

FACULTY OF HEALTH SCIENCES

DOCTORAL SCHOOL OF HEALTH SCIENCES

Head of Doctoral School: Prof. Dr. Kiss István

Head of Programme: Prof. Dr. Verzár Zsófia

Supervisor: Dr. habil Pakai Annamária

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1. INTRODUCTION

The functioning of the human body is a set of chemical reactions, biochemical processes, which are influenced by the parameters of the reactions (pressure, temperature, pH, catalysts, degree of gravity, radiation, etc.). Even the average person can perceive that changes in meteorological parameters (temperature, pressure differences caused by frontal effects, humidity, UV radiation), external environmental factors (air pollution, impact of the built environment), geographical parameters (cyclical changes in the phase of the moon, solar flares, electromagnetism, etc.) result in a number of physiological and physiological effects. In patients with chronic diseases, especially cardiovascular diseases, these effects are even more measurable. Environmental factors affect complex physiological and physiological processes, blood pressure, the body's thermoregulatory capacity, hydration status, blood composition (oxidative processes e.g. smog, high ozone concentration), electrolyte concentration (Kriszbacher, 2006).

The health status of the Hungarian population is also worse than in other European countries (Németh et al. 2021). In Hungary, about 18,000 people die of stroke each year, with an estimated incidence of 50,000 (Németh et al., 2021). In Hungary, both the morbidity and mortality of cardiovascular and cerebrovascular diseases increase with age. Compared to Western European countries, the incidence of stroke in Hungary is two to three times higher, and the average age of patients is 5 to 10 years lower, so it is crucial to increase the effectiveness of prevention and care. The rising rate of heart and cerebral infarctions is also striking (Németh et al., 2021).

According to Eurostat reports, about 1.7 million people die from circulatory diseases every year in the European Union. Examining the causes of excess mortality, it was found that the number of deaths increases during heat waves appearing in the EU, with cerebrovascular accidents being the most prominent cause (Alghamdi et al., 2021). The two main types of acute cerebral circulation disorder (stroke) are cerebral infarction and stroke. The incidence of the disease has decreased in Hungary over the past four decades, but even so, nearly 30,000 hospitalizations are made annually due to stroke (Berczeli et al., 2018). Compared to Western European countries, the incidence rate of stroke in Hungary is still two to three times higher (Jánosi, 2017).

Hungary is located in Central Europe, with a population of 9.6 million people and an area of about 93,000 square kilometers. The World Bank classifies it as a high-income country and its health expenditure accounts for 7.38% of GDP (Current health expenditure (% of GDP) – Hungary, 2024). In 2022, the average life expectancy at birth was 79.05 years for women and

72.55 years for men (KSH, 2024). The seven main regions of Hungary have different levels of development. The value of the human development index is higher than the national average in two regions (Central Hungary: 0.922; Western Transdanubia: 0.857), while the lowest value can be found in the northern regions (Northern Hungary: 0.811, Northern Great Plain: 0.822) (Subnational HDI., 2024).

In Hungary, stroke care is provided by maintaining 39 stroke centers (and emergency care facilities in areas not close enough) and by a professional guideline renewed in 2023 (Hungarian Stroke Society, 2023), so that all patients can receive evidence-based treatment and care in a timely manner. Despite this, Hungary was ranked 20th among WHO member states in terms of mortality rate in 2016. In addition, compared to the countries examined in the research, the proportion of stroke cases treated in stroke departments was also low (30%) (Kim et al., 2020).

The influence of meteorological factors on stroke development is widely assessed, but little is known about the detailed impact of meteorological factors on stroke events. It has been found that the incidence of ischemic stroke is lower in summer, but the daily minimum temperature contributes significantly to its development (Nia et al., 2019).

Climate change also has a significant impact on the incidence of acute myocardial infarction, especially during the transition from cold to heat in March, April, and May (Ertl et al., 2019). Daytime temperatures have a significant impact on global stroke mortality. Overall, the number of environmental health problems is steadily increasing, and human health is increasingly threatened (Olisarova, 2021).

Hungary is located in Central Europe, in the temperate climate zone, which is characterized by significant temporal variability due to oceanic, continental and Mediterranean factors due to its geographical position. The number of hours of sunshine in the country ranges from 1900 to 2000 hours per year. Precipitation varies greatly both in space and time. In addition, heat waves that are harmful to human health and lead to increased mortality typically affect the entire country, with the exception of one southwestern county (Somogy). (Kiss et al., 2018)

The health status of the Hungarian population is also worse than in other European countries (Németh et al. 2021).

2. Objective

The central topic of the thesis was the analysis of the relationship between stroke cases and certain meteorological factors. We examined the effect of moon phase changes in relation to sroke cases in Baranya County in 2018-2019.

Our first research question was to investigate the epidemiology of ischemic and hemorrhagic stroke in Hungary between 2010 and 2023. Our goal was to analyze how the incidence and mortality data changed during the study period and to assess whether seasonality was observable.

In our second study, we aimed to assess the relationship between meteorological fronts, changes in moon phases and the number of stroke cases in Baranya County between 2018 and 2019.

The aim of our third analysis is to explore the relationship between meteorological fronts, changes in moon phases and the number of cases of different stroke disease groups in Baranya County, as well as the seasonality observed in the period between 2018 and 2019. Our further goal is to analyze what changes occur during the phases of the moon in relation to the occurrence of diseases. In our study, we also put emphasis on the relationship between frontline activities and diseases.

The objectives of the dissertation are summarized in detail in the following points:

1. Investigation of the epidemiology of ischemic and hemorrhagic stroke cases in Hungary.
2. To investigate the effect of weather variables on stroke cases in certain seasons.
3. We intend to investigate whether the alternation of the lunar cycle plays a role in the occurrence of stroke cases.
4. To investigate the detectability of seasonality in the appearance of stroke case numbers.

The main hypotheses of our research:

1. Investigation of the relationship between frontal effect and stroke case numbers.
2. It is hypothesized that frontal effects affect the frequency of ischemic stroke cases differently in each season.
3. It is assumed that air pressure and temperature change have an effect on the incidence of stroke cases.
4. We assume that there is a relationship between the full moon and the stroke evenings.

3. Detailed analyses

3.1 Epidemiology of ischemic and hemorrhagic stroke in Hungary between 2010 and 2023: a nationwide retrospective analysis of real data

Epidemiology of stroke

Between January 2010 and December 2023, a total of 2,772,009 patients were hospitalized in Hungary using one of the examined ICD codes. During the study period, 93.62% of cases were ischemic and 6.38% were haemorrhagic. In 2010, there were 224,379 stroke-related hospital admissions, this will decrease to 152,649 by 2023, which is a decrease of 31.97%. In terms of patient numbers, we observed fluctuations in stroke hospital admissions between 2020 and 2022. In 2020, there was a decrease of 27.32% compared to the previous year (146,781 patients). In 2021, there was a further decrease of 17.76% (120,718 patients), but in 2022, the number of hospital admissions increased by 11.15% compared to the previous year (134,173 patients).

The number of patients also shows a decrease in proportion to the population (-29.03%). The number of inpatient days decreased by -38.84% and the average length of stay per patient decreased by -10.08%. Taking all these factors into account, the prevalence of stroke in Hungary was 2.24% in 2010, which decreased to 1.59% by 2023. The national data are summarized in Table 1.

		Ischaemic		Haemorrhagic		Total	
		2010 (n=211,607)	2023 (n=140,928)	2010 (n=12,772)	2023 (n=11,721)	2010 (n=224,379)	2023 (n=152,649)
Sex %	*Male*	45.94	48.26	51.9	51.65	46.28	48.52
	Female	54.06	51.74	48.1	48.35	53.72	51.48
Patient's residence (Region) %	*Western Transdanubia*	8.90%	9.87%	9.97%	9.29%	8.96%	9.83%
	Central Transdanubia	12.99%	10.56%	11.09%	9.96%	12.88%	10.51%
	Southern Transdanubia	10.22%	8.90%	9.97%	9.62%	10.21%	8.96%
	Northern Great Plain	14.72%	14.94%	15.55%	15.01%	14.77%	14.95%
	Southern Great Plain	14.68%	15.57%	13.51%	14.83%	14.62%	15.51%
	Northern Hungary	13.72%	13.38%	12.75%	11.30%	13.67%	13.22%
	Central Hungary	24.55%	26.59%	26.60%	29.57%	24.66%	26.82%
	Unknown	0.20%	0.19%	0.56%	0.42%	0.22%	0.21%
Prevalence % (95%CI)		0.13 (0.07-0.19)	0.12 (0.06-0.19)	2.11 (2.052.17)	1.47 (1.41-1.53)	2.24 (2.18-2.30)	1.59 (1.53-1.65)
Mean age (SD)		66.90 (11.60)	69.56 (11.38)	59.46 (16.36)	62.85 (15.64)	68.97 (11.92)	70.67 (11.76)
Mean length of stay (days)		9.70	8.66	12.93	11.65	9.89	8.89
Hospital mortality rate % (95%CI)		7.71 (7.31-8.11)	7.62 (7.13-8.11)	28.91 (27.44-30.37)	23.60 (22.02-25.18)	8.86 (8.47-9.24)	8.76 (8.29-9.22)

Table 1: Characteristics of the patient population 2010,2023

Despite the decrease in average hospital stay and patient numbers, the average age of treated individuals increased from 68.97 years to 70.67 years. However, the average age of haemorrhagic patients decreased slightly during the study period: from 59.46 years to 62.85 years.

Mortality

The number of stroke deaths in hospitals is also on a downward trend: From 20,566 deaths in 2010, the number of deaths fell to 14,057 in 2023. However, in terms of mortality rate, this decrease is less significant: it represents a decrease of only -0.10%. During the COVID-19 pandemic, we observed an increase in mortality rates, with the highest rates observed between 2020 and 2022: 10.00% in 2020, 12.57% in 2021 and 10.54% in 2022.

In ischemic cases, the hospitalization mortality rate exceeded 10% in just one year (11.24% in 2021), which is also the peak of the observed time series. In contrast, mortality from haemorrhagic stroke did not show such a significant spike during the COVID period: the mortality rate in 2021 was 27.49%, lower than the maximum of 29.58% observed in 2011.

Significant improvements were observed in certain age groups, especially in the case of ischemic stroke, among children aged 0 to 4 years, where hospital-acquired mortality decreased from 21.43% to 0% during the study period. However, we saw a slight increase in three age groups (5–18 years: +1.75%, 51–60 years: +0.48%, 61–65 years: +1.05%). Mortality rates due to hemorrhagic stroke showed an improvement between 2010 and 2023 in all age groups, with the most significant improvement being seen among young children (0–4 years: –22.42%, 5–18 years: –10.36%). (Figure 1-2)

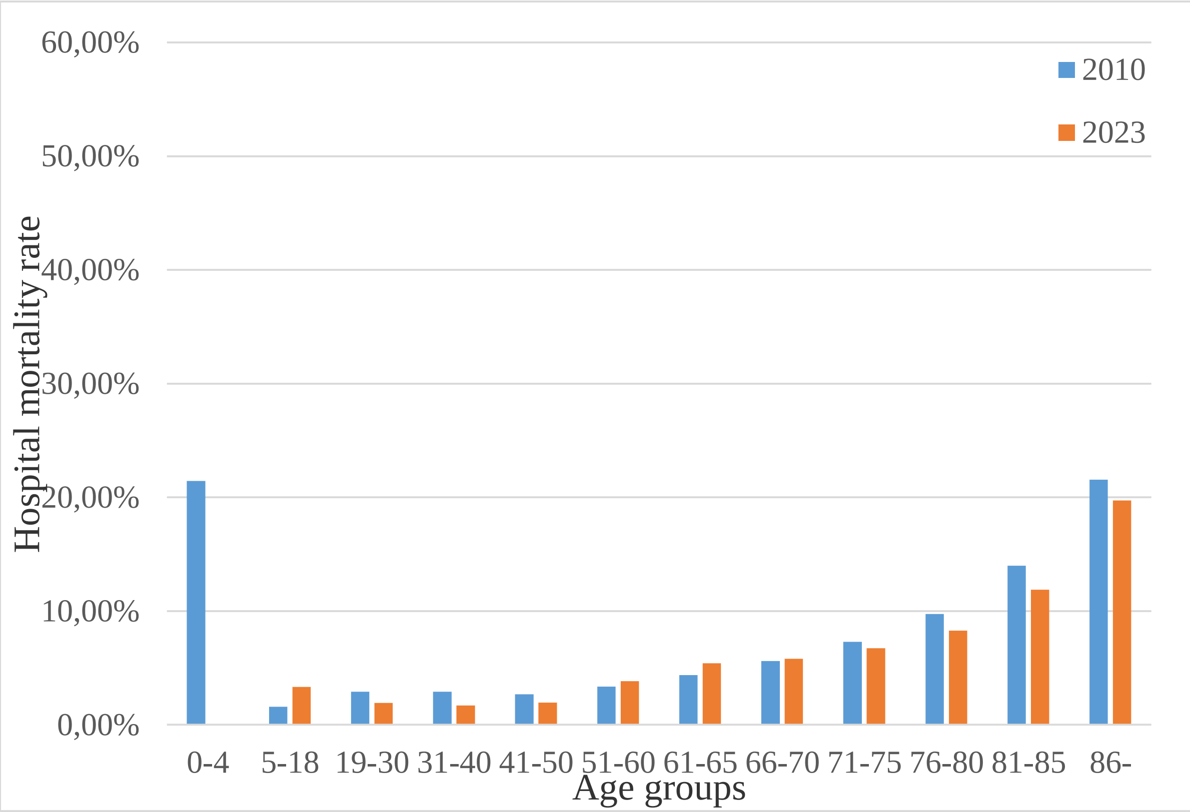


Figure 1: Mortality rates of ischemic stroke cases in 2010 and 2023

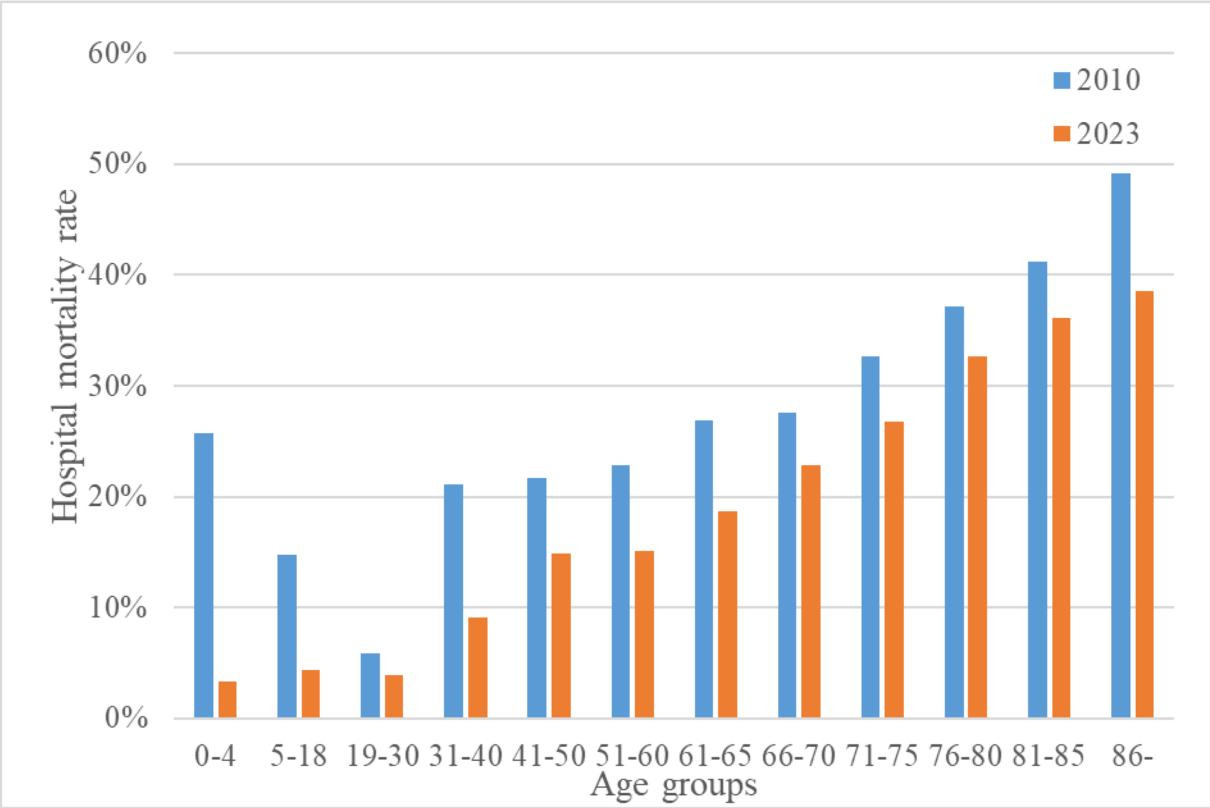


Figure 2: Mortality rates of hemorrhagic stroke cases in 2010 and 2023

Seasonality

When we aggregated the monthly patient numbers for all the years studied, we found that August consistently had a significantly lower incidence compared to other months. However, October and March show remarkable peaks in terms of patient numbers. In terms of mortality, the highest rates were observed in January–March (10.74%, 10.07% and 9.58%, respectively) and in December (8.84%), while the highest rates were observed in January–March (10.74%, 10.07% and 9.58%) respectively.

The lowest mortality rate was recorded in June (7.95%) (Figure 3).

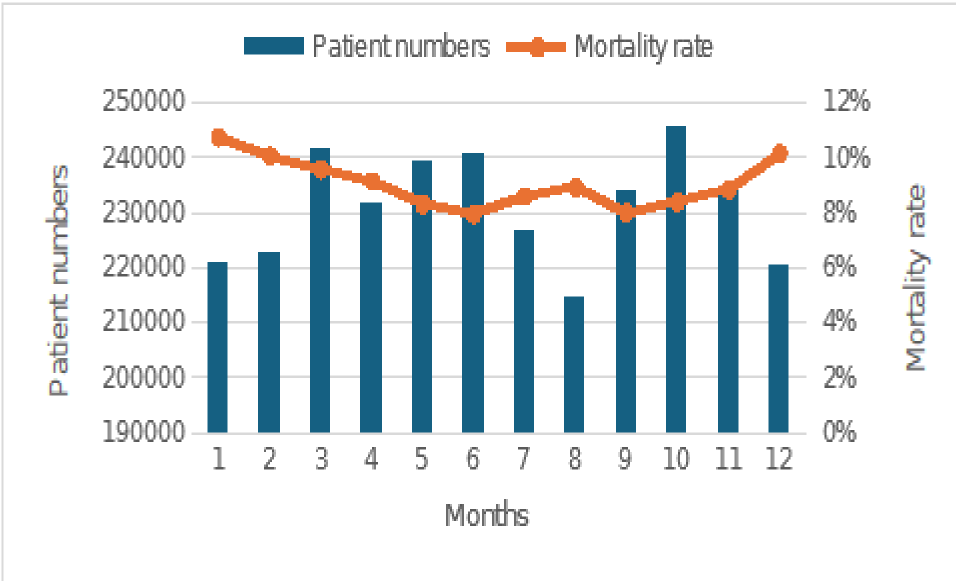


Figure 3: Seasonality 2010, 2023

The change in the average length of stay between 2010 and 2023 is illustrated in the figure. Based on our data, we observed an overall 1-day decrease during the 14-year study period, from 9.89 days to 8.89 days. This decrease was more significant in cases of haemorrhagic stroke, where the length of hospital stay decreased by 9.97% (from 12.93 days to 11.65 days). In the case of ischemic stroke, the average length of hospital stay was shortened from 9.70 days to 8.66 days (-9.70%). (Fig. 4)

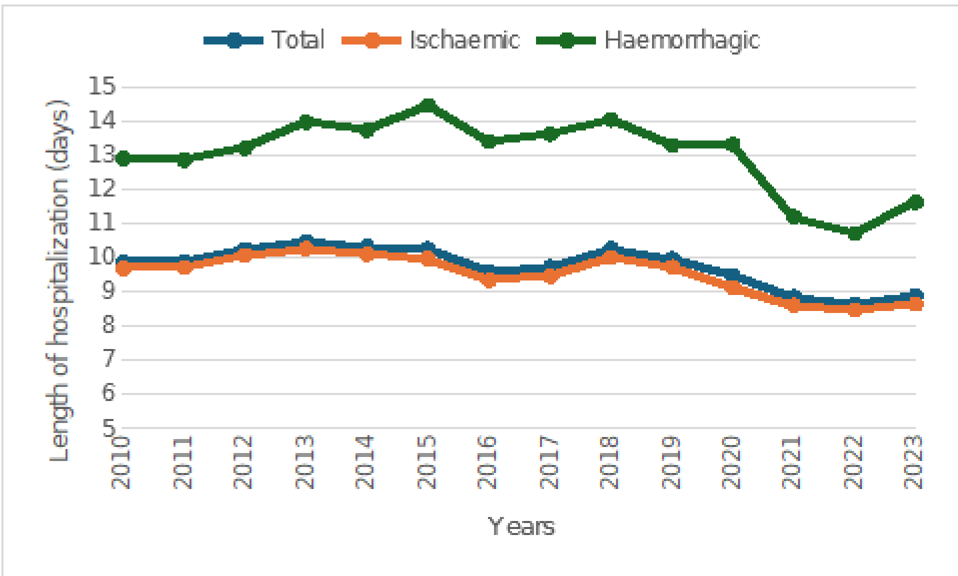
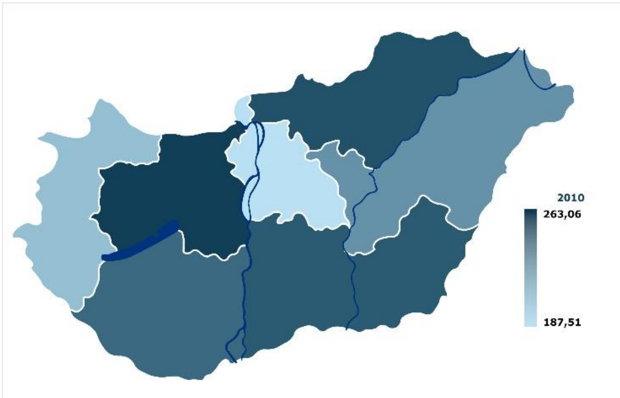


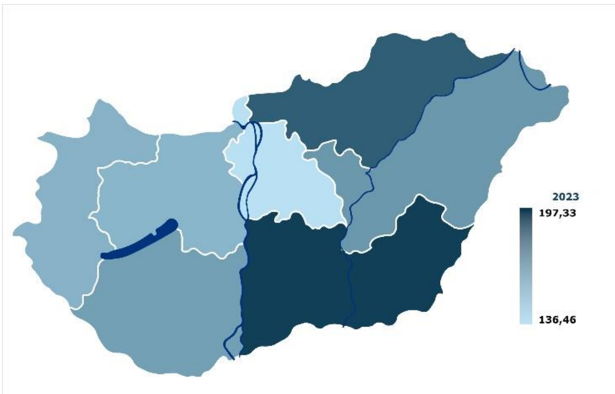
Figure 4: Average hospital stay 2010-2023

Regional disparities

The residence-specific prevalence per 100,000 inhabitants was as follows. In 2010, there was a significant difference between the highest (Central Transdanubia, 263/100,000) and the lowest (Central Hungary, 188/100,000) values among the seven regions of Hungary. One possible reason for this may be that Budapest, the capital, belongs to Central Hungary, where living conditions and access to health care are at a higher level. By contrast, by 2023, the prevalence rate was highest in the Southern Great Plain region (197/100,000), while it remained the lowest in Central Hungary (136/100,000). All seven regions show a decrease between 2010 and 2023, with the most significant improvement observed in Central Transdanubia (-42.42%).



5 (a)



5 (b)

Figure 5: Regional disparities 2010,2020

3.2 The effect of meteorological factors on the incidence of stroke in Hungary

The data were analyzed with descriptive statistical indicators (mean, standard deviation). In addition, normality was tested with the Shapiro-Wilk test, and then the differences and relationships between the variables were examined using Mann-Whitney U, Kruskall-Wallis test, Spearman's rank correlation and regression analysis. The results were considered significant at $p<0.05$.

In addition, a Cox proportional hazard model was used to analyze the relationship between temperature (°C) and atmospheric pressure change (hPa) in relation to the daily number of ischemic stroke cases, grouped by different seasons. In the case of haemorrhagic stroke, the model could not be run due to the low, narrow range of daily cases. As a first step of the analysis, we prepared the database and then created a CSV file for compatibility, as this format can be read by most analysis software. The data was then imported and processed using the Cox model. It is important to note that in the case of hemorrhagic stroke, zero values were excluded because they could not be treated by the Cox model. Calculations were made using SPSS 26.0 and R software.

Between 1 January 2018 and 31 December 2019, during the 730 days examined, a total of 1765 cases were treated in Baranya County, of which 834 were women (47.25%) and 931 men (52.75%). 89.92% of patients were hospitalized for ischemic stroke and 10.08% for hemorrhagic stroke. In terms of seasons, the incidence was broadly balanced, with men having a slightly higher incidence of stroke in autumn and winter (54.38% of cases in autumn and 56.23% in winter) (Figure 6).

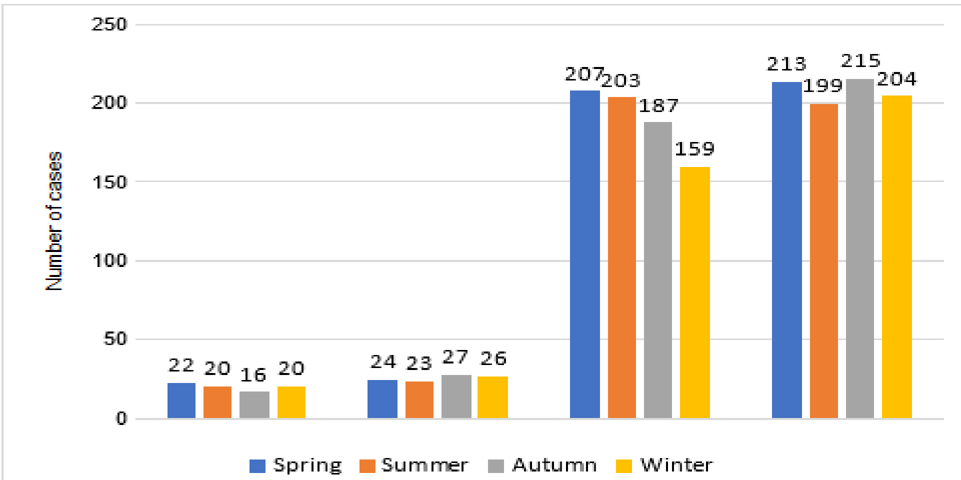
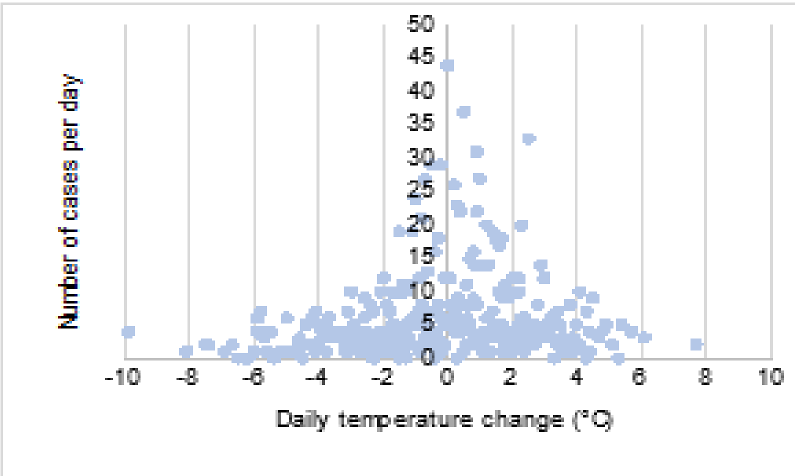


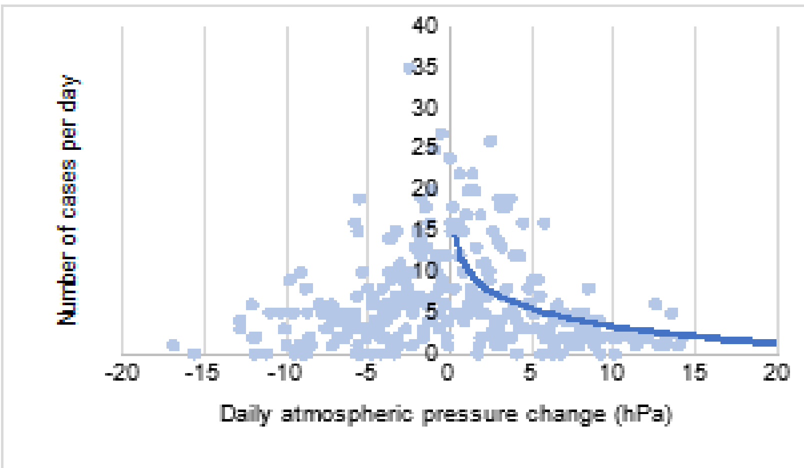
Figure 6: Number of stroke events in Baranya County, Hungary

The trends of the dependent variables (case numbers) listed in Figure 7 were examined as a function of the seasons, types of fronts, moon phases and mean daily temperature, but no significant differences were found ($p > 0.05$).

The relationship between daily temperature change, air pressure and the total number of cases per day is shown in Figure 6. In the case of daily temperature changes, a higher proportion of cases occur on days when the average daily temperature has risen compared to the previous day. A weak positive significant relationship with temperature change was found for the number of ischemic strokes in men ($r=0.088$, $p=0.018$) and the total number of ischemic strokes ($r=0.112$; $p=0.003$). In contrast, the number of hemorrhagic strokes, albeit weak, showed a significant negative relationship with daily temperature changes ($r=-0.073$; $p=0.049$). Changes in atmospheric pressure showed a weak positive correlation with hemorrhagic stroke cases.



7 (a)



7 (b)

Figure 7: Relationship between (a) daily temperature change and (b) atmospheric pressure with the total number of cases per day

In addition, we showed that on the day when the frontal effect changed compared to the previous day, the mean daily incidence of female ischemic stroke was higher (M: 1.13, SD: 1.04) than when the frontal effect did not change (M: 0.95, SD: 1.02, p=0.010). Frontal change can also significantly increase summer ischemic stroke events. A more detailed description is shown in Table 2.

Subtype	**Front change**			**No front change**			**p**
	Number of cases (mean per day)	**SD**	**Total number of cases**	**Number of cases (mean per day)**	**SD**	**Total number of cases**	
Spring (n=466)							
Haemorrhagic (female)	0,16	0,36	14	0,09	0,32	8	.366
Haemorrhagic (male)	0,12	0,36	11	0,14	0,35	13	.858
Haemorrhagic (total)	0,28	0,54	25	0,22	0,47	21	.723
Ischaemic (female)	1,02	1,07	92	1,22	1,03	115	.907
Ischaemic (male)	1,10	1,25	99	1,21	1,02	114	.994
Ischaemic (total)	2,12	1,60	191	2,44	1,35	229	.620
Total	2,40	1,68	216	2,66	1,41	250	***.622***
Summer (n=445)							
Haemorrhagic (female)	0,11	0,31	13	0,11	0,31	7	.372
Haemorrhagic (male)	0,12	0,33	14	0,14	0,35	9	.133
Haemorrhagic (total)	0,23	0,46	27	0,24	0,47	16	.150
Ischaemic (female)	1,08	1,15	127	1,15	1,01	76	.534
Ischaemic (male)*	1,12	1,06	132	1,02	0,90	67	.016
Ischaemic (total)*	2,19	1,45	259	2,17	1,41	143	.041
Total*	2,42	1,57	286	2,41	1,56	159	***.022***

Autumn (n=445)							
Haemorrhagic (female)	0,14	0,35	13	0,03	0,18	3	.128
Haemorrhagic (male)	0,11	0,31	10	0,20	0,50	17	.700
Haemorrhagic (total)	0,24	0,46	23	0,23	0,54	20	.702
Ischaemic (female)	0,91	0,92	86	1,16	1,11	101	.382
Ischaemic (male)	1,22	1,22	116	1,14	1,00	99	.250
Ischaemic (total)	2,13	1,50	202	2,30	1,57	200	.925
Total	2,37	1,56	225	2,53	1,67	220	.886
Winter (n=406)							
Haemorrhagic (female)	0,11	0,31	8	0,12	0,32	12	.562
Haemorrhagic (male)	0,20	0,43	15	0,11	0,31	11	.495
Haemorrhagic (total)	0,30	0,52	23	0,22	0,44	23	.458
Ischaemic (female)	0,71	0,83	54	1,00	1,02	103	.756
Ischaemic (male)	1,26	1,12	96	1,04	1,10	107	.914
Ischaemic (total)	1,97	1,41	150	2,04	1,42	210	.865
Total	2,28	1,48	173	2,26	1,48	233	.867

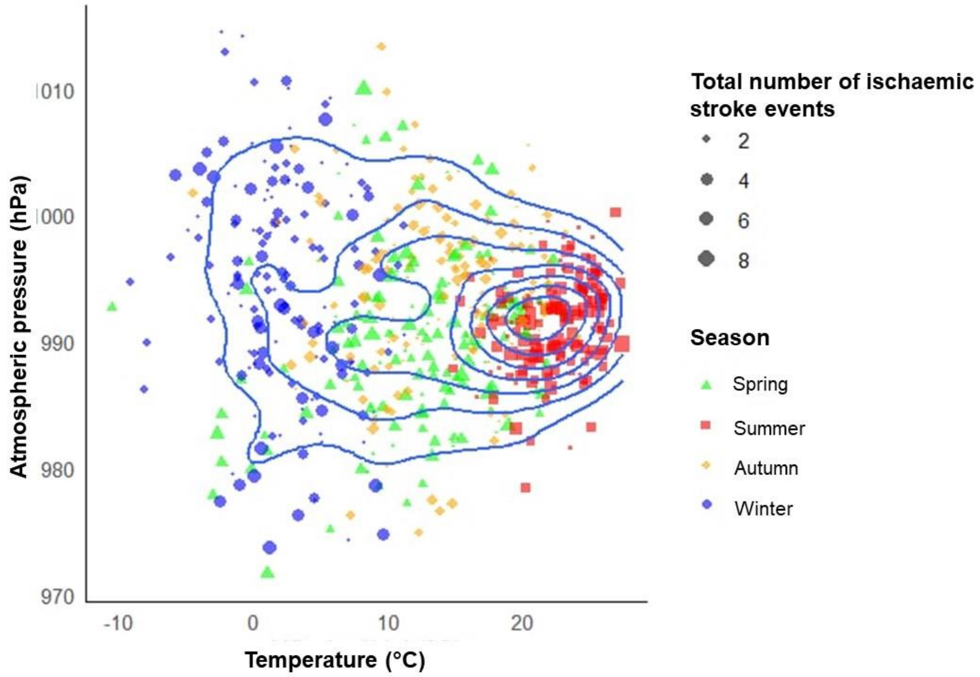
Table 2: Incidence of stroke and changes in frontal effect in different seasons

We were unable to demonstrate a significant difference in how the front changed - only in the number of female ischaemic cases in the fall did we see that a change in the frontal effect to a mixed or warm effect increased the number of cases on the day of the event (p=0.030).

We also examined the indicators separately for each season. We found that there is essentially no significant difference between stroke incidence and meteorological characteristics in spring and summer, except that in spring the change in air pressure is slightly positively correlated with hemorrhagic stroke events (r=.156; p=.034) and wind speed (r=.150, p=.041). In autumn, however, the number of ischemic cases increases when the temperature rises sharply overnight (r=.255, p=.002), and this correlation can be observed for all cases (r=.211, p=.004).

An increase in air pressure increases the likelihood of an ischemic stroke occurring. In summer, if the air pressure increases, the number of ischemic strokes increases significantly. Changes in air pressure significantly predicted the total number of strokes (β=-.168, [95%CI: -.972–-.075], p=.022), the number of male ischemic events (β=-.0145, [95%CI: -0.583–-.001] p=.049) also increased during this time of year.

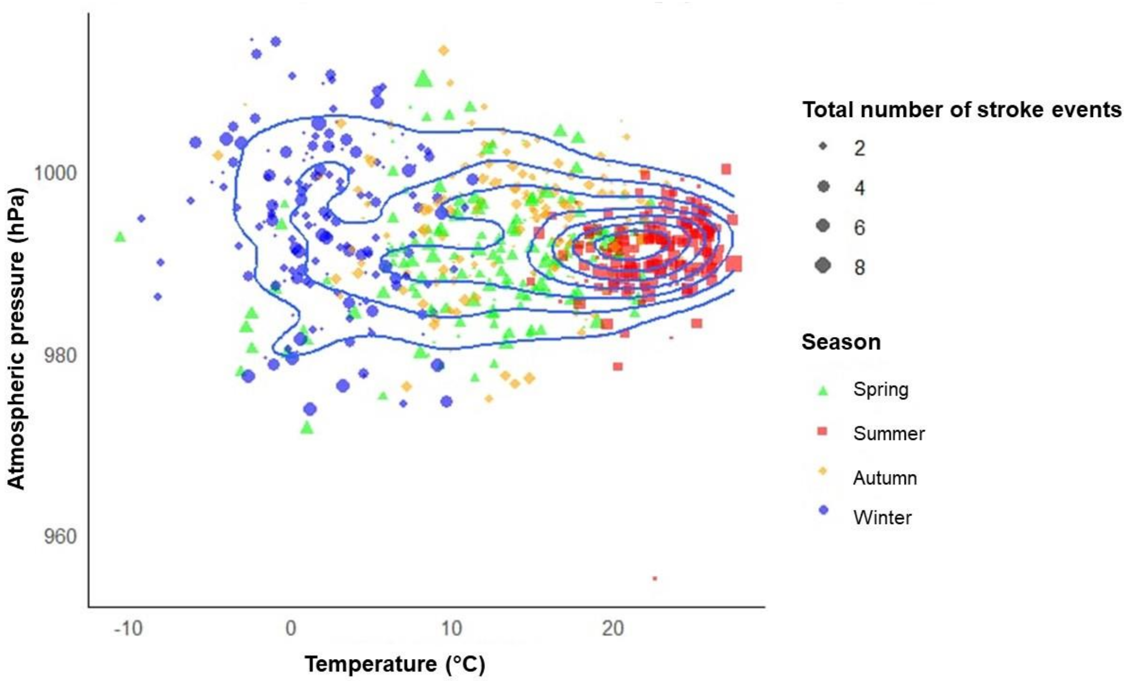
In autumn, the increase in temperature increases the incidence of stroke (r=0.210; p=0.004). Within this, the association is slightly stronger in ischemic cases (r=0.225; p=0.002; women: r=0.148; p=0.046, men: r=0.163; p=0.028). However, in men, the risk of ischemic stroke is increased by a decrease in air pressure (r=-0.183; p=0.013).



(a)

Figure 2: Predictors of the Cox model: seasonal changes in temperature and atmospheric pressure for a) ischemic and b) total stroke events

Figure 8 shows the results of the Cox model by season. The size of the dots indicates the number of ischemic stroke cases per day; Higher points mean a greater number of cases that occurred on a given day. One of the most important findings of the figure is that the area with the highest density is found at temperatures between 15-20°C and atmospheric pressure changes of around 990 hPa. This area is especially prevalent during the summer months (red squares). The data show that most cases of ischemic stroke occur in this range of temperature and atmospheric pressure changes. In both the spring (green) and autumn (orange) seasons, a significant number of stroke cases occur at temperatures between 15-20°C, but these are less concentrated than in the summer months. Winter data, although spread over a wider range, also show that the highest densities are observed around temperatures between 15-20°C and atmospheric pressure changes of around 990 hPa.



(b)

3.3 Stroke in the shadow of the moon in Baranya county, Hungary, 2018-2019

We analyzed the data of a total of 1765 examined persons in 2018 and 2019. Among them were 834 female and 931 male patients. We divided the stroke cases into two groups, according to ischemic and hemorrhagic cases. 1587 patients suffered ischaemic stroke, of which 756 female and 831 male cases could be documented on the basis of ICD codes in the years under review. There were a total of 178 cases of bleeding type, of which 100 were women and 78 were men.

With the help of a radar chart, we illustrate the monthly case numbers broken down by month in the two years examined. In terms of the number of monthly cases, the lowest was in February (n=127) and the highest in May (n=163) (Figure 9).

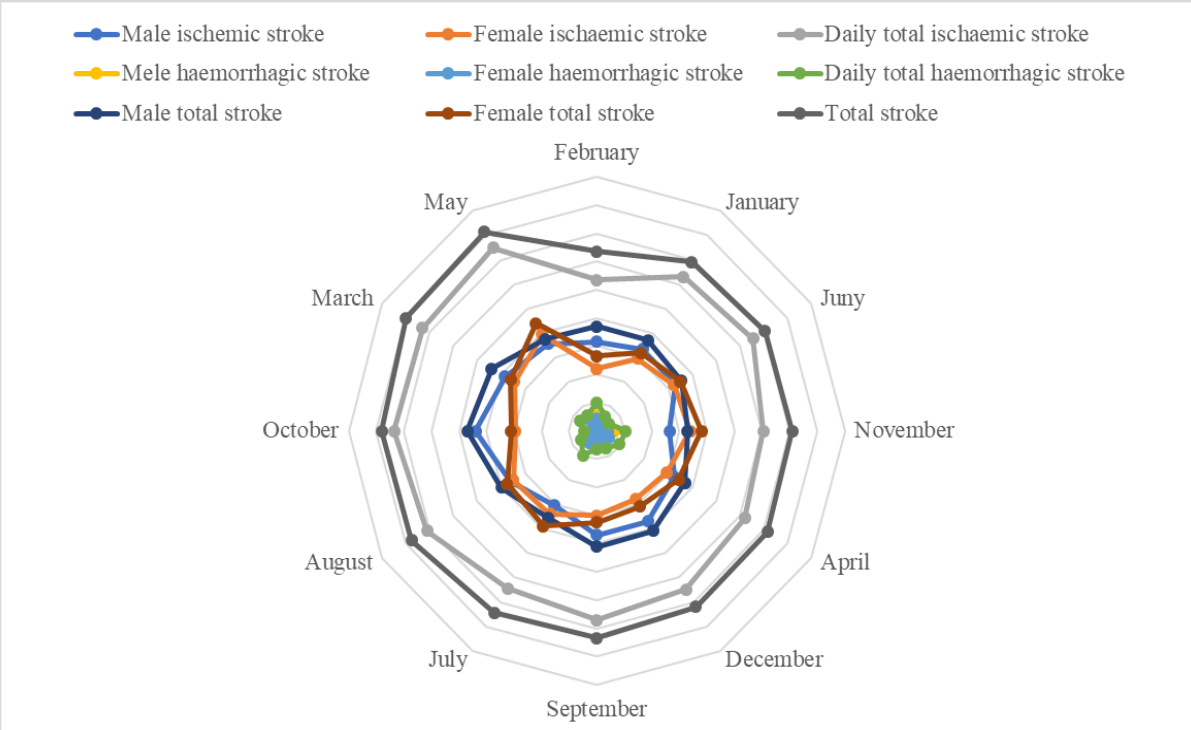


Figure 9: Monthly case numbers by stroke type and gender

In our research, we also examined the weekly rhythm of stroke cases. The second figure clearly shows that the number of cases decreases from the beginning of the week towards the weekend. The second figure illustrates that we were able to document 264 patients on Mondays, 238 cases on Tuesdays, and 255 patients on Wednesdays. It can be seen that we processed the data of 224 patients on Thursday and 237 cases on Friday. According to our investigation, 190 patients were detected on Saturdays and 179 cases of ischemic stroke on Sunday. In the case of bleeding evenings, however, the resulting curve is flat, due to the smaller number of cases. It can be stated as follows that there were 23 stroke cases on Monday and 22 on Tuesday, followed by Wednesday, where the data of 33 patients were recorded, 28 cases on Thursday and 25 cases on Friday. Regarding the weekend, 21 cases were documented on Saturday and 26 on Sunday in the period under review. A significant relationship can be detected between the average daily case numbers (p=0.001). The average number of cases on Monday is 2.51, and the average number of cases on Saturday is 1.83. On Mondays, the average number of cases is significantly higher than the average number of cases on Saturdays (p=0.011) (Figure 10).

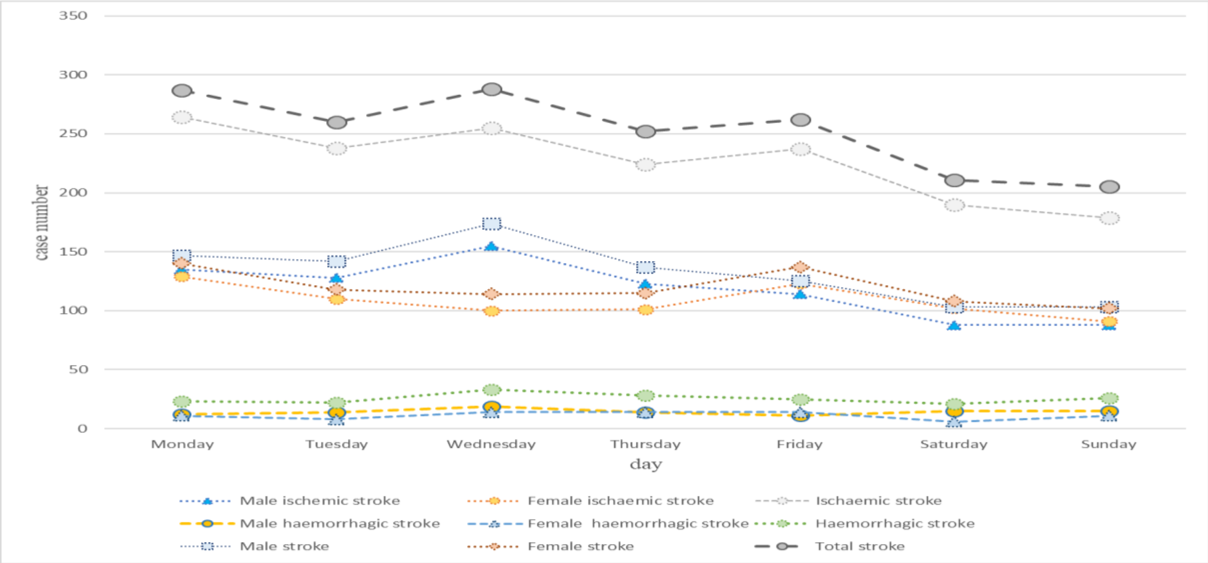


Figure 10: Daily order of case numbers sorted for all cases 2018-2019 (N=1765)

We also examined the incidence of stroke in terms of seasons. Figure 11 illustrates that there were a total of 466 cases in the spring and 445 in the summer. The diagram shows that there were 445 stroke cases in the autumn and 409 in the winter. No significant correlation was found between the seasons and the mean of case numbers in terms of ischemic (p=0.704) or hemorrhagic stroke cases (p=0.195) (Figure 11).

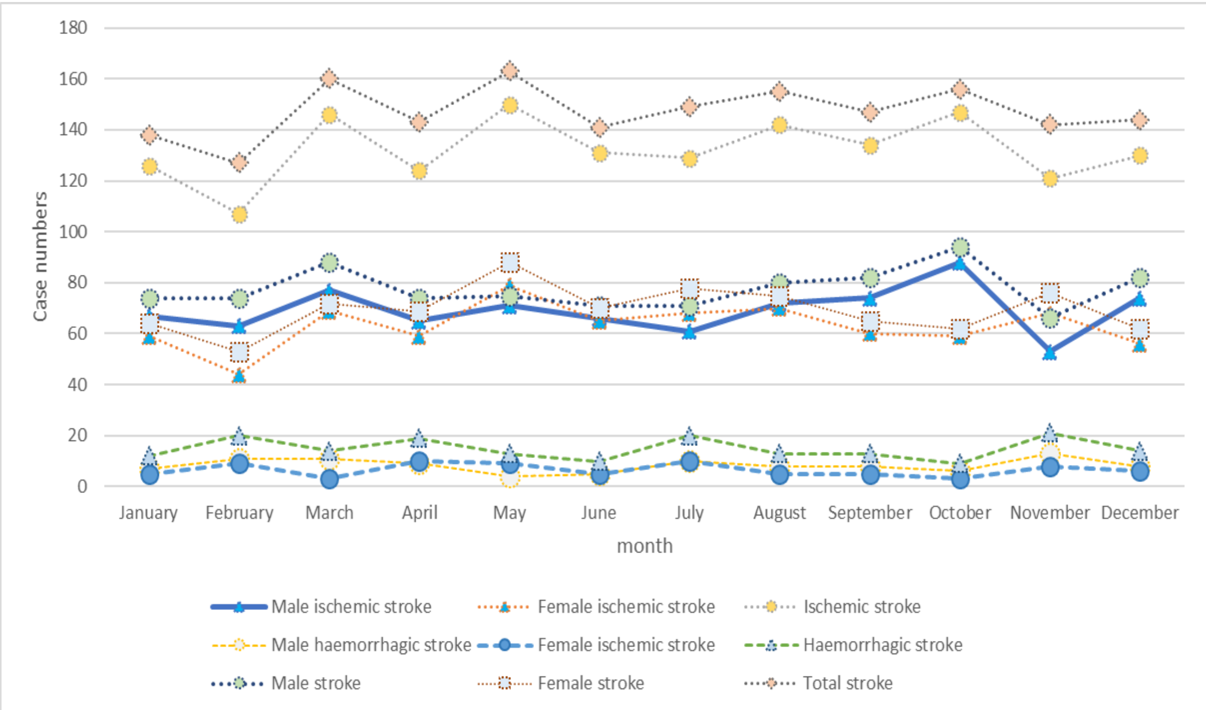


Figure 11: Comparison of months and stroke cases in the years 2018-2019 (N=1765)

Looking at the monthly stroke case numbers in 2018-2019, most stroke cases were detected in March (n=160) and May (n=163), the fewest patients (n=127) were documented in February. Cases of ischemic and hemorrhagic stroke are illustrated in Figures 12 and 13 in terms of gender distribution.

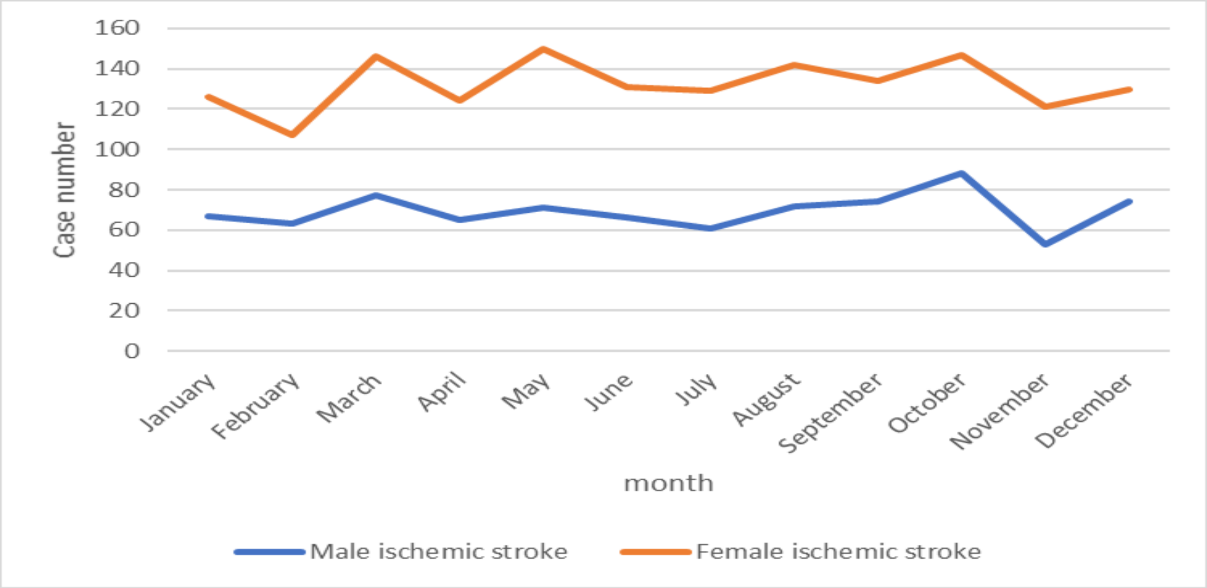


Figure 12: Distribution of ischemic stroke cases by gender

The highest number of cases can be seen among men in October (n=88), while the incidence among women was highest in May (n=79). In men (n=53), the lowest number of cases occurred in the months of November. There were 44 cases among women in February, which was the lowest compared to other months.

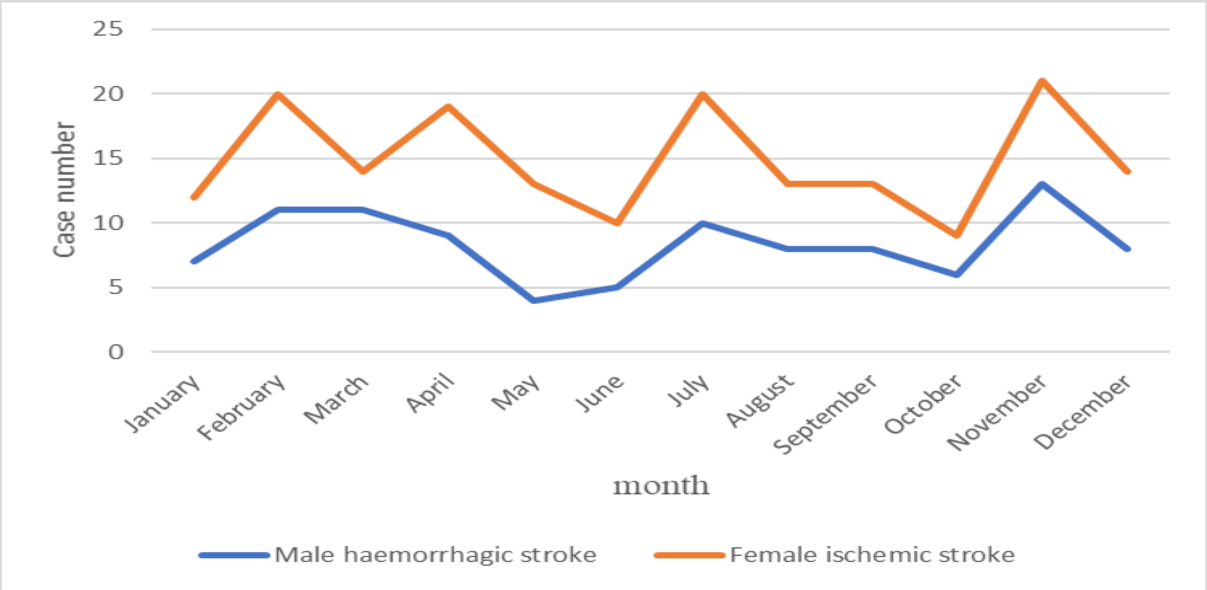


Figure 13: Distribution of haemorrhagic stroke cases by sex in the years examined

Most stroke cases involving men with hemorrhagic disorders occurred in November (n=13), while in women it peaked in April and July with the same number of cases - 10 cases. The lowest number of cases can be observed among men (n=4) in May, and in the case of women, this number can be documented with 3 people in May and October.

Examining the seasonal appearance, we can conclude that there is no significant difference in the number of cases when examining ischemic cases. In the spring, we were able to document 420 cases, and in the summer period, 402 cases occurred, which was the same as the case numbers in the autumn (n=402). In winter, there were slightly fewer cases (n=363). Examining the cases of hemorrhagic stroke, we can conclude that 46 cases were documented in the spring, followed by 43 cases in the summer, which showed the same number of cases as in the autumn period (n=43). In winter, it can be seen that 46 cases occurred. There is no significant difference in the incidence of the number of cases (p>0.05).

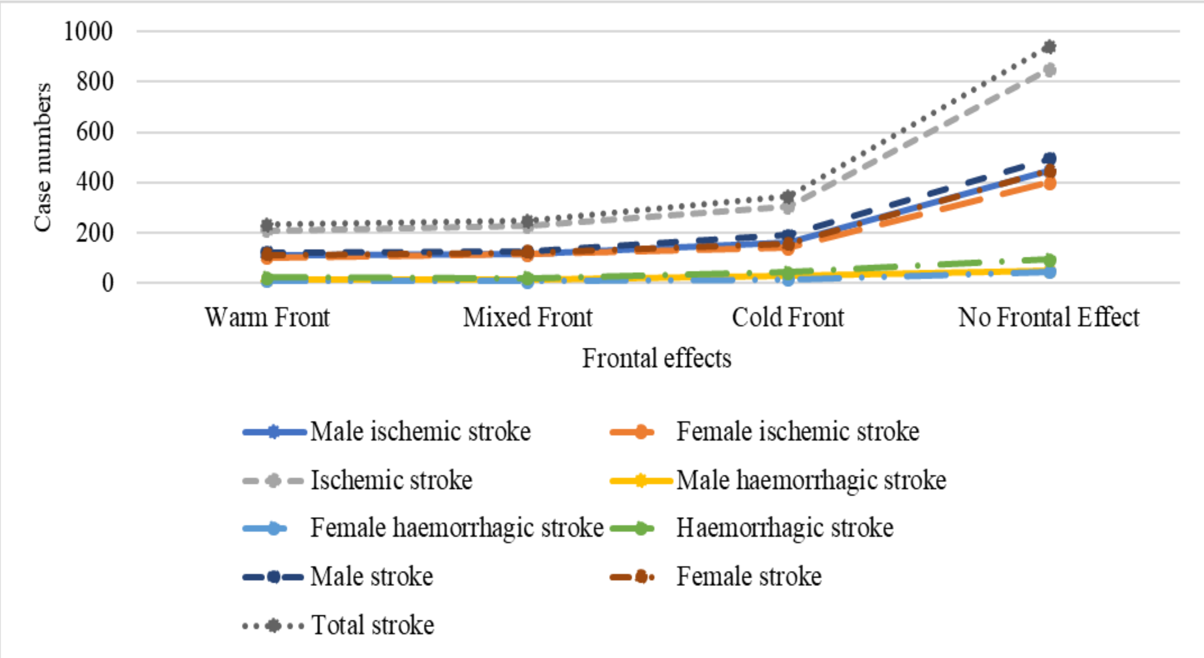


Figure 14 illustrates the relationship between cases and fronts in the two years under review.

It can be stated that during the front-free period, 942 cases were recorded, and 345 cases occurred during the cold front effect. During the warm front effect, 232 stroke cases were detected, and during the mixed front effect, 246 stroke cases were detected. The number of cases was outstanding in the absence of fronts compared to other frontal effects. We could not prove a significant difference between the front-pairs and the mean of the case numbers (p=0.869). Our study shows that there were much more front-free days in the period under review than days affected by any fronts, so the number of cases is significantly higher due to the front-free time. The examination of the daily incidence of the averages does not show a significant difference from the daily average of stroke cases occurring on frontal and frontless days (Figure 14).

Since there were many more front-free days than front-effect days, the number of cases is also much higher. However, the average number of cases on front-free days did not differ significantly from the average number of cases on front-effect days ($p>0.05$). We also examined the mean stroke compared to the frontal effects. The daily average of stroke cases was 2.40 in the case of a warm front, 2.46 in the case of a double front effect, and 2.39 in the case of a cold front. On front-free days, the daily average of cases is 2.42. No significant difference can be established in terms of the average number of daily cases ($p>0.05$).

Next, we examined the effect of lunar positions on the incidence of stroke, for which we prepared a categorized data table according to the phases of the moon with the help of the lunar calendar published by the Hungarian Meteorological Service.

We have divided the lunar cycles as follows: first quarter, ascendant, full moon, waning, last quarter, new moon. These six stages were examined in comparison with the stroke database. During the first quarter of the moon, 62 cases were observed, while at the waning lunar position, 630 cases occurred. At the waxing lunar position, 648 stroke cases were documented, while during the full moon there were 177 cases. There were 194 stroke cases during the new moon, while there were 54 strokes at the last quarter of the moon. We found that the number of cases is outstanding during waning and increasing lunar positions, but we cannot prove a significant difference between the lunar position pair and the average of the case numbers ($p=0.638$).

In terms of the relationship between front effects and moon position, 11 patients were registered during the cold front effect at the first quarter of the moon position and 101 patients at the waning moon position. During the increasing lunar position, 101 cases occurred, while 24 cases were recorded at the full moon and 61 cases at the new moon. At the last quarter of the moon's position, five cases were observed. During the mixed front effect, we were able to record four cases at the first quarter of the moon, and 90 patients at the waning moon. At the increasing lunar position, 70 cases were detected, at the full moon 24 cases, at the new moon 25 cases, and at the last quarter of the moon 14 patients. According to our results, the incidence of ischemic stroke is outstanding during the increasing and waning lunar position in the absence of fronts. There are many more days with increasing lunar cycles, but no significant difference can be verified between the daily occurrence averages of the case numbers (p>0.05) (Figure 15).

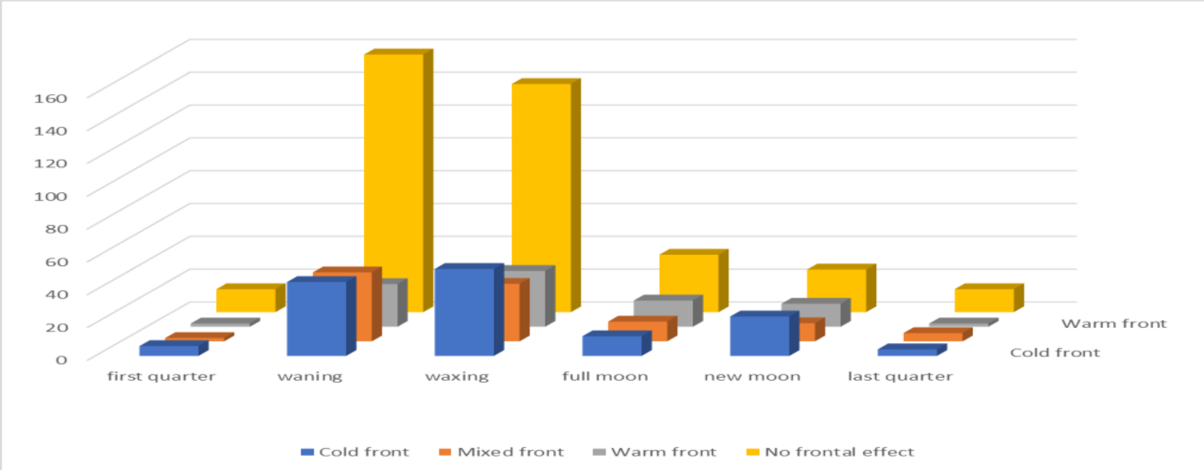


Figure 15: Examination of lunar cycles with the daily average of case numbers (N=1765)

During the first quarter of the moon, the daily average of cases was 2.58, and during the waning lunar position, the average daily incidence of stroke was 2.33. We can observe that at the increasing lunar position, the daily average of the case numbers was 2.48, and at the full moon, the daily average of the case numbers was 2.36. The daily average of cases was 2.59 during the new moon, and 2.16 during the last quarter of the moon. The differences between the averages are negligible. Our study shows that several days with increasing lunar positions can be observed, which distorts the study, but the daily incidence averages do not prove a significant difference (p>0.05) (Figure 16).

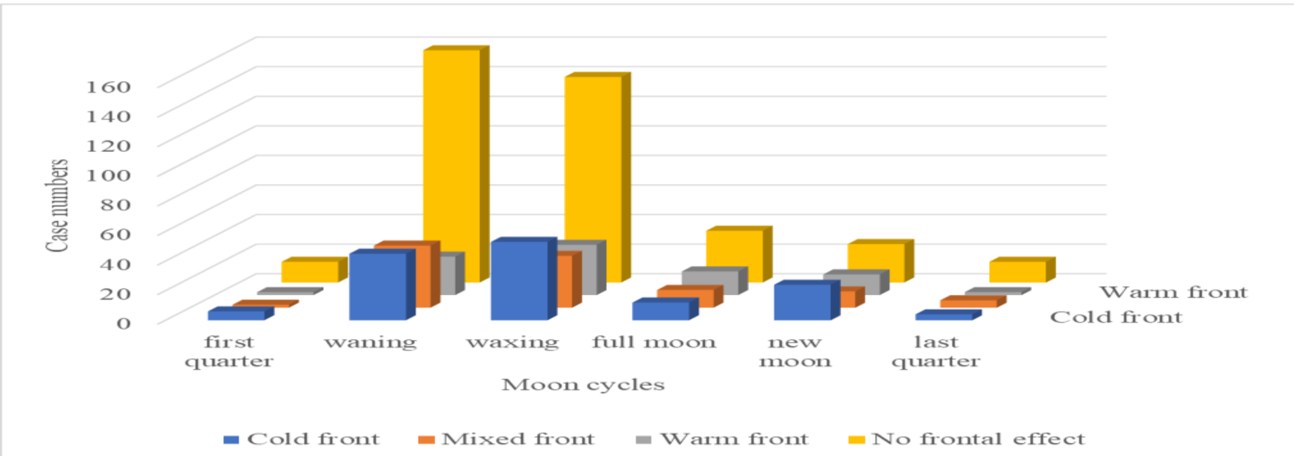


Figure 16: Number of ischemic stroke cases in the lunar position-front dimension (N=1587)

We also examined cases of hemorrhagic stroke, the results of which are presented in Figure 17. In frontless weather, there were two incidents at the first quarter of the moon. There were 40 patients at the waning lunar position, while there were 36 patients at the increasing lunar position. According to our research, eight cases were documented at the full moon, six at the new moon, and only two at the last quarter of the moon. In the case of the warm front effect, two patients were treated at the first quarter of the moon, and seven cases were treated at the waning lunar position. At the increasing position of the moon, seven patients were recorded, and at the full moon, six patients were recorded. At the new moon, one case was detected, while in the last quarter there was no patient admission with the examined codes. In the case of a cold front effect, two patients were admitted at the first quarter of the moon, 11 cases were observed at the waning lunar position, while 18 patients were admitted at the increasing lunar position, and one patient at the full moon. There were 10 cases at the new moon, and 0 cases at the last quarter of the moon. During a mixed front effect, one case was observed at the first quarter of the moon, and 8 cases at the waning lunar position. We can see that there were six patients at the waxing moon position, while two cases were observed at the full moon. During the new moon, two patients were treated, and at the last quarter of the moon, none were treated.

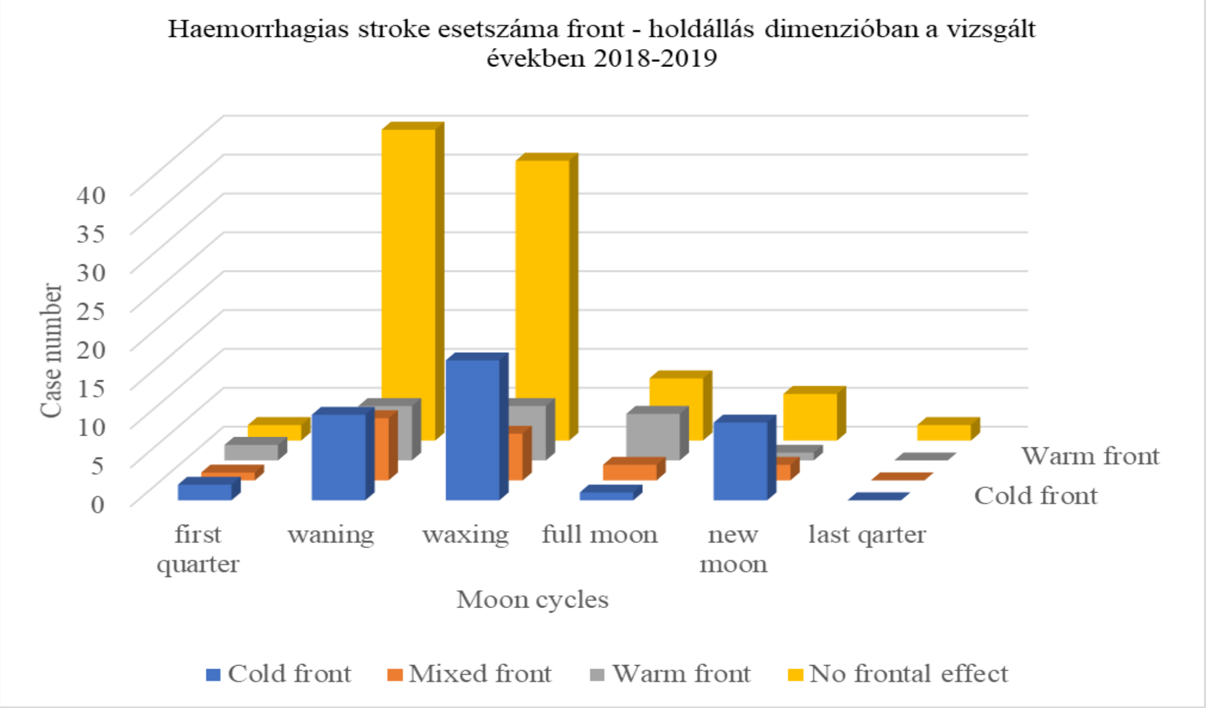


Figure 17: Number of cases of hemorrhagic stroke in front-moon position dimension (N=178)

We examined the changes in the number of stroke cases occurring during air pressure changes, according to which a change in the number of cases can be observed in the case of air pressure changes. At the time of decreasing air pressure, there were 763 cases of ischemic stroke and 74 cases of hemorrhagic stroke. During the increasing air pressure change, 797 cases of ischemic stroke were documented and 103 patients with hemorrhagic stroke were treated during the study period. In the absence of a change in air pressure, there were 26 cases of ischemic stroke and 1 case of haemorrhagic stroke.

4. Discussion

Epidemiology of ischemic and hemorrhagic stroke in Hungary between 2010 and 2023

The aim of our study is to retrospectively examine the incidence and mortality of stroke in Hungary between 2010 and 2023, with special regard to the differences between ischemic and haemorrhagic types, seasonal and regional trends, and the characteristics of hospital care. Stroke remains one of the most significant acute circulatory diseases, with significant morbidity and mortality, as well as long-term economic and social burdens on the health system and families. The data analysis is based on aggregated data from the Hungarian Central Statistical Office and the Pulvita Health Data Warehouse. The methodology used used a retrospective, nationwide approach, examining only inpatient care data. Stroke cases were grouped based on the ICD I60–I66 codes. The study did not contain any personal data, so ethical permission was not required. During the 14-year study period, a total of 2,772,009 stroke hospitalizations were identified. The vast majority of stroke cases were of ischemic origin (93.62%), while the proportion of haemorrhagic cases was 6.38%. The total number of stroke cases decreased by 31.97%, with 224,379 cases registered in 2010, compared to only 152,649 in 2023. Prevalence also showed a downward trend, from 2.24% to 1.59%. The duration of hospital stay decreased by an average of 1 day during the period (from 9.89 days to 8.89 days), with a significant reduction (-9.97%) in particular in cases of haemorrhagic. At the same time, the average age of stroke patients has increased: from 68.97 years to 70.67 years. The proportion of males increased slightly, from 46.28% to 48.52% in the total patient population. The number of hospital deaths decreased from 20,566 to 14,057 (-31.65%). At the same time, the mortality rate has barely changed (-0.10%), indicating that although there are fewer stroke cases, the effectiveness of care in terms of mortality has stagnated. During the COVID-19 period (2020–2022), mortality rates have increased significantly: in 2021, for example, the mortality rate from ischemic strokes reached 11.24%. In the case of hemorrhagic stroke, the mortality rate decreased in all age groups, especially in children, there was a dramatic improvement. According to the analysis of the seasonal pattern, the incidence of stroke cases is lowest in August, while peaks were observed in March and October. Mortality is highest in winter and early spring (January: 10.74%, February: 10.07%), and lowest in June (7.95%). Significant differences were also observed from a regional point of view. In 2010, the prevalence was the highest in Central Transdanubia (263/100,000 people), while it was the lowest in Central Hungary (188/100,000). By 2023, the Southern Great Plain took the lead (197/100,000), while Central Hungary maintained its favourable position (136/100,000). There was a decrease in all regions, the largest in Central Transdanubia (-42.42%).

Key findings:

- The number of stroke cases and hospital days decreased, but the death rate changed little.
- The impact of the COVID period can be detected in the mortality data.
- The effectiveness of haemorrhagic stroke care improved in all age groups.
- A seasonal pattern is observed in case numbers and mortality.
- Regional variations persist, but improving trends can be observed.

The effect of meteorological factors on the occurrence of stroke in Hungary (Baranya County, 2018–2019)

The main results of a retrospective, quantitative analysis carried out in Baranya County between 2018–2019, which examined the relationship between meteorological factors and stroke cases. The research was based on the assumption that weather conditions –especially temperature, air pressure, frontal effects and their daily changes – may play a role in triggering acute stroke events. During the study, we analyzed 1,765 stroke cases at the Clinical Center of the University of Pécs, of which 89.92% were of the ischemic type and 10.08% of the haemorrhagic type. During the analysis, weather data from the National Weather Service were matched with stroke cases. In addition to temperature and air pressure changes, we also took into account the type of fronts, the phases of the moon, and the wind speed. Based on the results, a weak but significant positive relationship can be demonstrated between the daily temperature increase and the increase in the number of ischemic stroke cases ($r=0.112$; $p=0.003$). This correlation was especially evident in men. The number of haemorrhagic stroke cases, on the other hand, showed a negative relationship with temperature changes, i.e. the occurrence was more frequent on colder days ($r=–0.073$; $p=0.049$). The increase in air pressure also showed a weak positive correlation with cases of haemorrhage. An extremely important result was that the change in the frontal effect increased the incidence of female ischemic stroke, especially if the nature of the front changed compared to the previous day. In the summer, during the frontal effect change, we also observed a significantly higher number of ischemic cases in men (p=0.016), and this trend was also detected in the aggregated summer data (p=0.041). In autumn, the increase in temperature significantly increased the number of ischemic stroke cases (r=0.225; p=0.002). The results of Cox regression models confirmed that most stroke cases occurred in the range of temperatures between 15–20°C and air pressure changes around ~990 hPa – especially in summer. Based on the data examined in the seasonal breakdown, they were also observed in autumn and spring rising trends, but these were less concentrated than in the summer months. Changes in wind speed and air pressure showed a weak but significant positive relationship with the number of haemorrhagic stroke cases, especially in spring. However, there was no significant difference between stroke case numbers related to moon phases and front types (p>0.05). Although weather factors alone do not cause stroke, our results indicate that certain changes in temperature and air pressure, as well as frontal effects, may increase the likelihood of ischemic stroke cases, especially in summer and autumn. Such data can help to better define risk periods and plan targeted prevention interventions.

Important points:

• How can weather forecasts and meteorological changes be incorporated into stroke prevention strategies? – It would be worth considering providing targeted information to the public in extreme weather conditions.

• Are further studies covering a longer period necessary? – The analysis of the two years creates a valuable basis, but studies at the national level, lasting several years, would strengthen the generalizability of the results.

• Is it possible to apply more differentiated prevention in a seasonal breakdown? – Especially in autumn and summer, increased supervision and awareness of stroke risk would be justified.

• What additional environmental factors should be investigated? – For example, including air pollution data, UV index or pollen data in the models.

Stroke in the shadow of the moon: The effect of meteorological and lunar phases on the occurrence of stroke in Baranya county (2018–2019)

The purpose of this discussion is to evaluate the results of a retrospective quantitative study conducted between 2018–2019 in Baranya County, which examined the frequency of stroke events in the context of various meteorological factors and moon phases. The special feature of the study is that it analyzed the potential effects of not only weather changes, but also the cyclical states of celestial bodies on the pattern of stroke occurrence.

Based on the detailed analysis of the 1,765 stroke cases, it can be concluded that the distribution of events shows certain temporal regularities, but at the same time, from a statistical point of view, no significant correlation was confirmed in the case of several investigated factors. Among the days of the week, the average of stroke cases that occurred on Monday was significantly higher compared to other days of the week (p=0.011), especially for ischemic stroke. This „Monday effect" is also consistent with previous international observations that suggest a link between stress responses and circulatory events. Based on the monthly distribution, the largest number of stroke cases occurred in May and March, while the fewest occurred in February. There were no significant differences in the incidence of either ischemic or haemorrhagic stroke events, broken down by season. Examining the relationship between frontal effects and stroke events, it was found that most cases occurred on front-free days, which, however, does not necessarily mean a causal relationship, since the number of such days was higher in itself. Among the types of frontal effects (cold, hot and mixed fronts), the mean daily incidence of stroke showed no significant variation (p>0.05).

In the analysis of the relationship with lunar phases, the highest number of stroke cases was recorded during the increasing and decreasing lunar positions, however, there was no statistically significant difference between the daily average of the case numbers (p=0.638). According to the combined analyses, neither the combination of fronts and lunar positions nor the type of air pressure changes showed a convincing effect on the occurrence of stroke.

Based on the breakdown by gender, slight differences can be observed: most ischemic strokes occurred in May among women and in October among men. In the case of haemorrhagic stroke, due to the smaller number of cases, there was less of a regular trend that could be drawn.

Important points:

• Is there a meaningful biological or psychological explanation for the „Monday effect"? Is it possible to deal with this with preventive programs and awareness campaigns?

• Do lunar cycles have relevance in clinical practice, or are the observed differences more likely to be explained by statistical bias?

• Is it worth conducting further investigation in another geographical area or over a longer time interval?

• How can data from weather reports or front forecasts be integrated into a future early warning system in case of stroke risk?

Our results can therefore benefit the individual, the state and the health sector and contribute to a healthier life and a sustainable society and care system.

The strength of our research is that the observed case numbers and the presented meteorological data come from the same region. The patients treated in the health care provider we studied are most likely to come from the area due to the need for acute care of the disease, while the observation station of the National Meteorological Service, from which we obtain the data, is only 14 km from the provider. In addition, a total of six dependent variables were studied by sex and stroke subtype, considering nine independent variables of different meteorological nature.

As a limitation of our analysis, we highlight that our results are not national, only county-level, and are based on data from only two years (2018-2019). Nor have we examined mortality indicators, which may also be worth examining in terms of the independent variables listed above. In addition, we did not have any other information about the patients, but presumably their age and the presence of other diseases could have influenced the daily case numbers. For example, lower mean daily temperatures in hospitalized patients were associated with better quality of life than on warmer days. However, it has been suggested that humidity as a meteorological factor may also influence the occurrence of stroke (Ertl et al, 2019), for which we also did not have data.

The impact of climate change can also be felt in Hungary, where global warming is changing the weather. Frontline activity increases, and storms and sudden temperature changes have a great impact on the human body.

5. New results

1) In the climatic and weather conditions examined in Baranya county, the number of ischemic and haemorrhagic stroke cases increases in both women and men in March and October.

2) Air pressure increase ($p=0.010$) and daily mean temperature increase ($p=0.018$) as changes have an effect on the frequency of ischemic stroke.

3) We found that the highest frequency of ischemic stroke cases can be observed in the summer months, with temperatures between 15-20 °C and air pressure changes around 990 hPa.

4) Among the days of the week, the mean of stroke cases occurring on Monday was significantly higher compared to other days of the week ($p=0.011$), especially for ischemic stroke, which suggest a relationship between stress responses and circulatory events.

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7. Publication list

Csákvári, T.; Verzár, Zs.; Balint, C. Elmer, D**., Horváth, L**. & Pakai, A. Epidemiology of ischemic and haemorrhagic stroke in Hungary between 2010 and 2023: a nationwide, retrospective analysis of real-world data. BMC Health Services Research, 12(10), 160; https://doi.org/10.3390/cli12100160 Impact Factor: 2.4.

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Overall impact factor from publications: 5.4

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