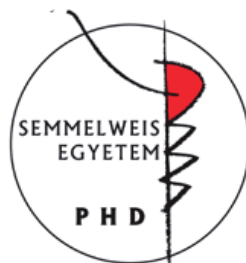# Morbidity of acute cardiovascular diseases in the light of various atmospheric parameters

Doctoral Thesis

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INTRODUCTION

In the age of anthropocene, the health effects of global climate change pose a real threat to public health. The natural system of ecosphera is also part of the human body, therefore the human body can be considered as a system that has a continuous interaction with environmental factors. The 2009 Lancet and University College London Institute for Global Health Commission reports that climate change is one of the greatest health challenges of the 21st century, putting billions of people at risk of morbidity and mortality. Global climate change has a direct effect on the human body through atmospheric parameters. The development of cardiovascular (CV) diseases can be attributed to multifactorial causes, in which environmental factors might play a role. According to the World Health Organization's (WHO) data, most of the natural environment-related mortality has an effect on CV diseases. Nowadays, the human body is exposed to such altered, stronger atmospheric effects due to climate change, which were not typical of the region providing the given living space.

The human body has not yet been adequately adapted to the extreme atmospheric parameter changes resulting from the effects of climate change. In the future, extreme atmospheric effects caused by global climate change, as minor CV risk factors, may further increase the already high morbidity and mortality of acute cardiovascular diseases (ACVD). Major CV risk factors identified by the Framingham Study are well known, but the impact of atmospheric parameters as minor CV risk factor is still underestimated. The 2009 WHO report, Protecting Health from Climate Change, drew attention to the importance of atmospheric parameters health effects related medical research in order to develop new prevention strategies. Reflecting on this WHO guideline, we began and created our research at the Department of Vascular Surgery at Semmelweis University.

In our study, we examined the effects of increasingly extreme atmospheric parameters due to climate change on ACVDs, especially in acute myocardial infarction (AMI), aortic aneurysm rupture (AAR), aortic dissection (AD), and thromboembolism. We examined the atmospheric sensitivity of major CV risk factors and specific haemostatic and inflammatory parameters. In addition, within the framework of a collaboration, the first comparative study in France and Hungary was carried out on the effects of atmospheric parameters on ACVDs.

OBJECTIVES

Our study results were intended to prove the minor CV risk factor role of atmospheric parameters. We aim to examine the characteristics of the effects of atmospheric parameters on ACVD morbidity. There is no official international or national medical prevention guidelines against atmospheric parameter effects, therefore our aim was to shed light on the fact that taking into account the atmospheric parameters CV effects, creating new CV prevention strategies are possible and necessary. In the future these strategies might help to reduce the negative CV effects of unfavourable meteorological factors caused by global climate change.

In my research, we aimed to answer the following questions:

1. Are the atmospheric parameters elevating the morbidity number of acute cardiovascular diseases?
2. Do changes in atmospheric parameters and their complex interaction have a greater CV effect than the individual CV effect of atmospheric parameters?
3. Do atmospheric parameters have different effects on different types of acute ACVDs?
4. Within atmospheric parameters, are front effects, due to their atmospheric complexity, have the most complex CV effect? Do certain front patterns increase the incidence of ACVDs?
5. Do the CV effects of the atmospheric parameters develop within a time lag?
6. For individuals with different demographic (sex, age) characteristics, do the atmospheric parameters have a different strength of CV effect?
7. Do individuals with major CV risk factors have different degrees of vulnerability to atmospheric parameters?
8. Do some haemostatic and inflammatory factors have a different value in the presence of defined atmospheric conditions?
9. Do atmospheric parameters have different CV effects in different geographic and social regions?
10. Can the Kérdő- meteoro-sensitivity questionnaire, specifically developed for Hungary, be used in other countries with different latitude?
11. Do some atmospheric parameters have a protective CV effect?

12. Can our results about atmospheric parameters as minor CV risk factor serve as a basis for developing CV prevention strategies?

METHODS

We conducted our multi-centre study in Budapest at the Semmelweis University-Heart and Vascular Centre, at the National Blood Transfusion Service and at the Centre Hospitalier Universitaire de Bordeaux, Département Cardiovasculaire. In our clinical study, the effects of atmospheric parameters were examined in several aspects. Our research can be divided into 6 main parts.

A: Examination of individual and interaction effects of atmospheric parameters on ACVDs.
B: Examination of the effects of atmospheric fronts on ACVDs.
C: Identification of subpopulations with atmospheric vulnerability. Examination of the atmospheric sensitivity of major CV risk factors.
D: Examination of atmospheric sensitivity of haemostatic and inflammatory factors among ACV patients and healthy blood donors.
E: Examination of the effect of atmospheric parameters on ACVD in the Bordeaux region. Comparative study of the effects of atmospheric parameters on ACVD in Budapest and Bordeaux.
F: Atmospheric sensitivity test in Bordeaux region.

1. Geographic region, atmospheric parameters, and hospital sampling frames

1.1. Study population

In our multi-centre study, patients hospitalized with ACV were involved at the Semmelweis University-Heart and Vascular Centre, between 2009.01.01. and 2013.12.31 ((n:6499) and at the Centre Hospitalier Universitaire de Bordeaux, Département Cardiovasculaire between 2012.01.01. and 2013.12.31. (n:1357). Voluntary blood donors recruited in the National Blood Supply Service during the study periods (2009.01.01-2013.12.31) were also included in the study (n:686).

The ACVDs investigated in our study were determined on the basis of the International Classification of Diseases (ICD). Our study included ACVDs, registered in the clinical database, including acute myocardial infarction (I21), pulmonary embolism (I26), dissection of the aorta (I71.0), aortic aneurysm rupture (I71.1/I71.3/I71.5/I71.8), arterial embolism and thrombosis (I74), portal vein embolism and venous thrombosis (I82).

A separate database was created based on the patients' demographic characteristic (i.e., age), other major CRFs (e.g., hypertonia, diabetes, hyperlipidaemia, smoking, alcohol, previous CVDs, family history) and several haemostatic and inflammatory factors [Haemoglobin (Hgb), Haematocrit (Htc), red blood cell (RBC), white blood cell (WBC), thrombocytes (thr), C-reactive protein (CRP), lactate dehydrogenase (LDH), International Normalized Ratio (INR), Low-density lipoprotein (LDL), Cholesterine (Chol)].

The database of our research contains the atmospheric parameter data for a given day, as well as the number of patients hospitalized with ACVD on a given day, and a separate major CV risk factor and laboratory parameter for each patient. The laboratory parameter of the healthy donors (Hgb, WBC, Thr) was recorded by creating a separate database.

1.2. Geographic regions and atmospheric parameters

Our research project was conducted in Budapest at the Department of Vascular Surgery of Semmelweis University. Budapest, the capital of Hungary, is located in Central Europe in the Carpathian Basin (geographic location coordinates: 47°29′54″ North and 19°02′27″ East). Bordeaux is situated in Western Europe, France, in the region of Aquitaine 62 km from the Pacific Ocean (geographic location coordinates: 44° 50' 16" North and 0° 34' 46" West).

The atmospheric parameter data was collected of the closest synoptic meteorological station to the clinics. Data concerning atmospheric parameters, measured at the weather monitoring station, were obtained from the examined geographical regions by the Hungarian Meteorological Service in Hungary, and Météo-France, the French national meteorological service in France. Measurements from the meteorological service provided values for each parameter: minimum and maximum temperature (degrees Celsius); minimum and maximum relative humidity (percent); minimum and maximum atmospheric pressure (hPa); and wind speed (m/s), front effect (no front/ anticyclone; warm front; cold front; occluded front; stationary front).

1.3. Statistical analysis

The analysis was carried out in R version 3.4.3 (R Core Team, Vienna) with the mgcv and tscount package. The analysis of atmospheric parameters and the individual and interaction effects of fronts on ACVDs were modelled with a Poisson time-series Generalized Linear Model: Poisson tsGLM and Generalized Additive Model: GAM. The level of statistical significance was set at 5%.

RESULTS

Test „A":

The distribution of acute hospitalization was characterized by pronounced seasonality. (Figure 1.)
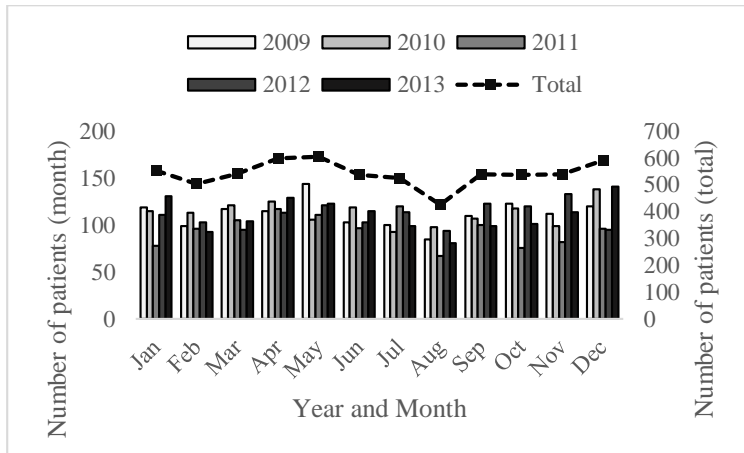
Figure 1.: The monthly and aggregated number of patients for each month in all years.

Between the examined atmospheric parameters temperature (1-day lag; p = 0.001), temperature change (0.000), air pressure (2-7-days lag; p = 0.002), humidity (0.039) and wind speed (1 day lag; p = 0.027) specific conditions increased the morbidity number of ACVDs. (Figure 2.)
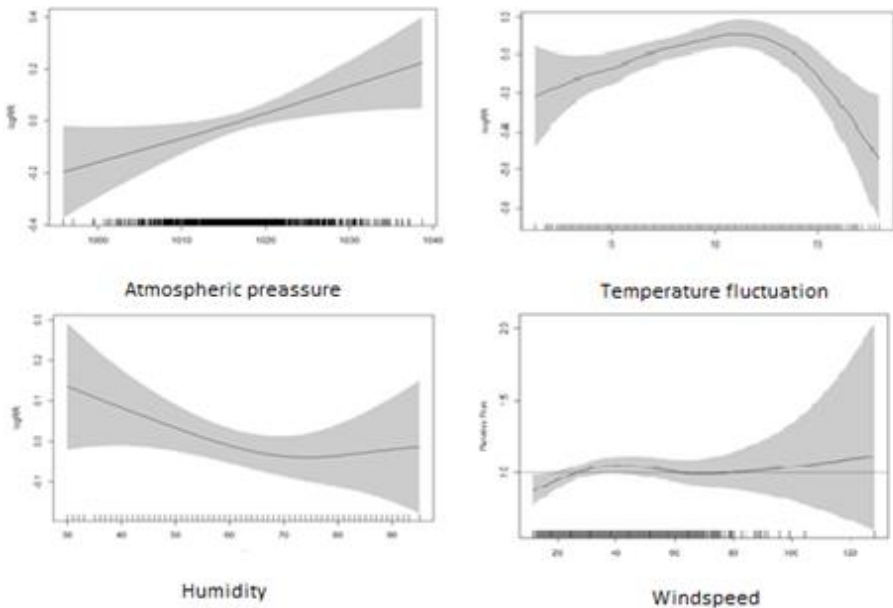
Figure 2. Effect of atmospheric Parameters on the relative risk

In our study we determined three interaction atmospheric condition complexes, which atmospheric conditions have increased the ACV hospitalization number: 1. high temperature (30 °C≤) + high humidity (40%≤) 2. daily temperature change (5 °C<) with humidity change (40%≤). 3. temperature change (≥5°C) + humidity change (≥40%)+ wind speed change (2 m/s ≤). The observed effects were independent of seasonality.

Test „B":

The front effects (2-day lag effect) significantly increased morbidity (p=0,005). Positive significant association was observed between ACV hospitalization and cold front (<0.001). In our study we detected 3-day front complexes, which increased the incidence of ACV disease: 1. anticyclone-anticyclone-warm front, 2. warm front-stationary front- stationary front, 3. cold front-occluded front- cold front, 4. anticyclone-cold front-occluded front. (Figure 3.) During our study we also detected CV protective factors. The occluded front effect (2-day

lag effect (p = 0.016) and cold front-occluded front-cold front (p = 0.031) detected as a protective factor, as the morbidity showed a decrease.
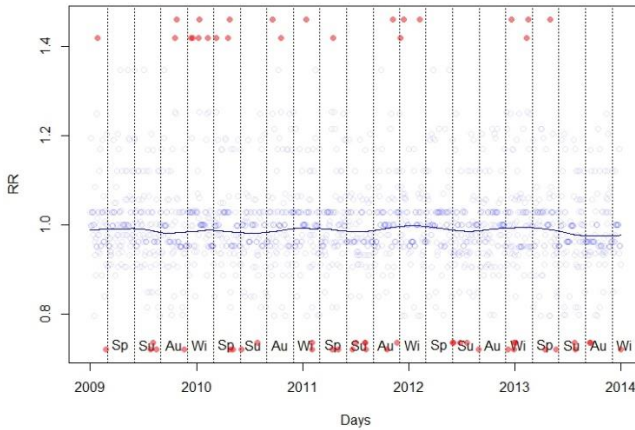
Figure 3. Timeline diagram of the relative risk of the effects of front patterns.

Test "C":

The morbidity number of patients with diabetic, hyperlipidemic, hypertensive, and previous CV disease increases during specified atmospheric parameter changes. The strongest significant relationship was observed in the subpopulation with diabetes. (Table 1.)

Table 1. Regression results to determine the atmospheric sensitivity of subpopulations with different major risk factors.

Relative risk estimates for atmospheric parameters from Poisson model to estimate daily event counts for the hypertensive subsample (n=2'886)				
Parameter*	Relative risk	CI95% lower	CI95% upper	p-value
Average daily atmospheric pressure, hPa	**1.006**	**1.000**	**1.012**	**0.036**
Average daily humidity, %	**0.992**	**0.989**	**0.996**	**<0.001**
Relative risk estimates for atmospheric parameters from Poisson model to estimate daily event counts for the diabetic subsample (n=1'074)				
Parameter*	Relative risk	CI95% lower	CI95% upper	p-value

Parameter	Relative risk	CI95% lower	CI95% upper	p-value
Daily atmospheric temperature change ≥5°C	**1.480**	**1.062**	**2.062**	**0.020**
Daily humidity change ≥ 40%	**0.351**	**0.159**	**0.773**	**0.009**
Average daily atmospheric temperature, °C	**0.987**	**0.978**	**0.997**	**0.009**
Average daily humidity, %	**0.992**	**0.987**	**0.998**	**0.005**
Average daily wind velocity over 2 m/s	**1.693**	**1.214**	**2.360**	**0.002**
Interaction of daily atmospheric temperature change ≥5°C and humidity change ≥ 40	**2.429**	**1.088**	**5.424**	**0.030**

Relative risk estimates for atmospheric parameters from Poisson model to estimate daily event counts for the CVD subsample (n=1'004)

Parameter*	Relative risk	CI95% lower	CI95% upper	p-value
Daily humidity change ≥ 40%	**1.659**	**1.045**	**2.633**	**0.031**
Average daily humidity, %	**0.993**	**0.988**	**0.999**	**0.021**
Interaction of daily atmospheric temperature change ≥5°C and humidity change ≥ 40%	**0.511**	**0.314**	**0.830**	**0.007**

Relative risk estimates for atmospheric parameters from Poisson model to estimate daily event counts for the hyperlipidemia subsample (n=1'967)

Parameter*	Relative risk	CI95% lower	CI95% upper	p-value
Average daily atmospheric pressure, hPa	**1.008**	**1.002**	**1.015**	**0.015**
Average daily humidity, %	**0.991**	**0.987**	**0.995**	**<0.001**
Interaction of daily atmospheric temperature change ≥5°C and wind velocity ≥ 2 m/s	**1.317**	**1.046**	**1.658**	**0.019**

* Parameters are adjusted for seasonality. Bold rows indicate parameters significantly associated with daily event counts (p≤0.05)

Specific front patterns also increased the morbidity risk of patients with specified major CV risk factors (Table 2.)

Table 2. Regression results to determine the front sensitivity of subpopulations with different major risk factors (max. 2-days lag).

Relative risk estimates† for atmospheric parameters from Poisson model to estimate daily event counts for the hypertensive subsample (n=2'886)

Lag	Weather front	Relative risk	CI95% lower	CI95% upper	p-value
	4[*]	**1.154**	**1.026**	**1.297**	**0.017**
1 day	3[*]	**0.847**	**0.750**	**0.957**	**0.008**
	4[*]	**0.889**	**0.799**	**0.990**	**0.032**

Relative risk estimates† for atmospheric parameters from Poisson model to estimate daily event counts for the diabetic subsample (n=1'074)

Lag	Weather front	Relative risk	CI95% lower	CI95% upper	p-value
	3[*]	**1.251**	**1.012**	**1.547**	**0.038**
	4[*]	**1.246**	**1.029**	**1.509**	**0.024**
2 day	3[*]	**0.790**	**0.649**	**0.961**	**0.018**

Relative risk estimates† for atmospheric parameters from Poisson model to estimate daily event counts for the hyperlipidemia subsample (n=1'967)

| Lag	Weather front	Relative risk	CI95% lower	CI95% upper	p-value
2 day	3[*]	**0.782**	**0.674**	**0.907**	**0.001**
	4[*]	**0.866**	**0.76**	**0.986**	**0.030**

Relative risk estimates† for atmospheric parameters from Poisson model to estimate daily event counts for the previous history of CVD subsample (n=1'004)

Lag	Weather front	Relative risk	CI95% lower	CI95% upper	p-value
2 day	3[*]	**0.802**	**0.652**	**0.986**	**0.036**

† Parameters are adjusted for seasonality *p<0.05 [2: warm front, 3: occluded front, 4: cold front, 5: stationary front]

Overall, based on the demographic analysis, we found that for total ACVDs, the men were more vulnerable than women. The data of descriptive statistics show that men have the highest mean of morbidity during every front type and showed the highest front sensitivity during cold weather front (78%), whereas women had the highest front sensitivity when stationary front occurred (40.1%). Regarding age groups, people over 55 year have the highest mean of morbidity during every front type. (Figure 4.)
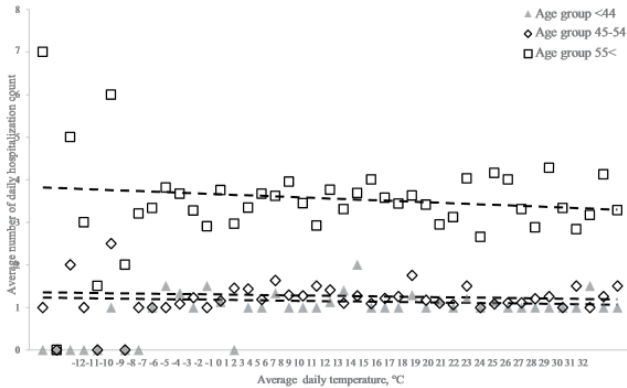
Figure 4. Average daily hospitalization rate based on average daily temperature, taking into account age distribution.

Test „D":

In healthy blood donors, the Hgb parameter showed a significant relationship with daily mean temperature (8-14-day lag effect; p=0,008). In terms of WBC and Thr, there were no significant correlation. All examined parameters (Fvs, Hgb, Thr) in ACV patients showed significant correlation with certain atmospheric parameters. The Hgb level correlated with the atmospheric conditions of mean daily temperature (15-21-days lag effect; $p = 0.006$), daily temperature fluctuation (2-7-days lag effect; $p = 0.000$) and average humidity (0-days lag effect; $p = 0.005$). There was a correlation between WBC and atmospheric pressure (1-day lag effect; $p = 0.015$). The Thr level correlated with average daily mean temperature (15-21-days lag effect; $p = 0.029$) and atmospheric pressure (1-day lag effect; $p = 0.007$) conditions. The CRP, LDH, INR, LDL, CHOL level showed a significant correlation with specific atmospheric parameter conditions. The above mentioned parameters have changed with the same tendency to the effects of daily temperature fluctuations, daily average temperatures, and atmospheric pressure atmospheric conditions. (Table 3.)

CRP, LDH, INR, LDL, CHOL values increased in terms of daily temperature fluctuations, low temperatures, high atmospheric pressure. Front effect (independent of the type) increased INR and LDL parameters.

Table 3. Regression values for laboratory parameters and atmospheric parameters that represent CV risk.

CRP	(estimated) degrees of freedom	F	P-value
Mean Temperature	1,50	0,742	0,002
Atmospheric Pressure, Mean of 2-7 Day Lag	2,44	1,547	0,000
Maximum Wind Speed	1,36	0,879	0,004
Maximum Wind Speed, Mean of 2-7 Day Lag	2,16	1,141	0,003
LDH	**(estimated) degrees of freedom**	**F**	**P-value**
Mean Temp., Mean of 15-21 Day Lag	1,27	0,807	0,004
Maximum Wind Speed	1,13	1,119	0,001
INR	**(estimated) degrees of freedom**	**F**	**P-value**
Mean Temperature	2,41	0,848	0,013
Mean Temp., Mean of 8-14 Day Lag	2,81	2,215	0,000
Daily Temp. Diff.	1,55	0,641	0,016
Daily Temp. Diff., Mean of 2-7 Day Lag	2,27	1,491	0,000
Atmospheric Pressure	2,70	1,055	0,008
Atmospheric Pressure, 1 Day Lag	5,16	2,442	0,000
Maximum Wind Speed, Mean of 2-7 Day Lag	0,99	0,457	0,022
Front-type	4,00	4,747	0,001
LDL	**(estimated) degrees of freedom**	**F**	**P-value**
Mean Temperature	3,19	1,736	0,000
Mean Temp., Mean of 8-14 Day Lag	2,79	2,016	0,000
Mean Temp., Mean of 15-21 Day Lag	4,78	1,156	0,031
Daily Temp. Diff.	1,16	0,484	0,024
Daily Temp. Diff., 1 Day Lag	3,15	1,203	0,007
Daily Temp. Diff., Mean of 8-14 Day Lag	1,01	0,442	0,023

| Atmospheric Pressure	2,40	2,600	0,000
Atmospheric Pressure, 1 Day Lag	1,39	0,578	0,016
Atmospheric Pressure, Mean of 2-7 Day Lag	1,55	3,475	0,000
Front-type	4,00	2,996	0,018
Front-type, 1 Day Lag	4,00	2,723	0,028
CHOL	**(estimated) degrees of freedom**	**F**	**P-value**
Mean Temperature	1,80	0,903	0,003
Mean Temp., Mean of 8-14 Day Lag	2,10	1,235	0,000
Daily Temp. Diff., 1 Day Lag	2,31	0,864	0,015
Atmospheric Pressure, Mean of 2-7 Day Lag	1,55	1,301	0,000
Maximum Wind Speed, Mean of 2-7 Day Lag	0,95	0,401	0,030

Test „E"

Seasonality could not be detected in the area of Bordeaux. (Figure 5.)
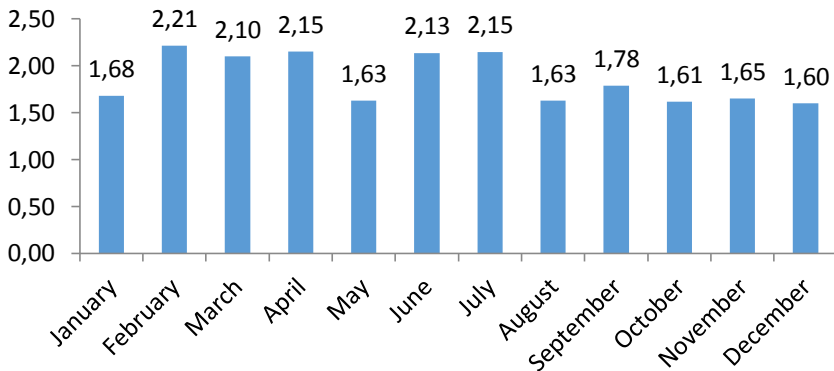
Figure 5. Daily average number of ACVB cases per month.

There was no significant difference in the demographic profile in Bordeaux and Budapest [Budapest: mean age 67.7±13.1; mean age in males 66.5±13.0, mean age in females 69.8±12.9; Bordeaux: mean age 66.9 ±17.7; mean age in males
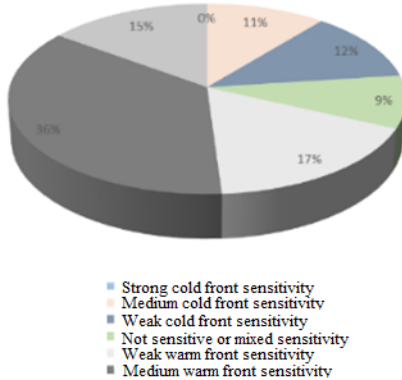
64.6±15.6, mean age in females 70.2±19.9).]. In Bordeaux and Budapest, the proportion of patients with hypertension, diabetes, and previous CV patients was 10% or less. There was a significant difference in the case number of hyperlipidaemia. In Bordeaux, the number of patients with hyperlipidaemia was 25.3% lower. In Bordeaux, the atmospheric pressure (8-14 days lag effect; 0.004), atmospheric pressure (1 day lag effect; 0.004) and wind velocity (p = 0.016) increased the case number. (Figure 6.)

Temperature change (8-14 day lag)
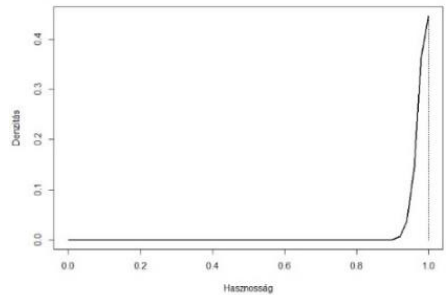
Atmospheric pressure (1 day lag)

Maximum wind speed
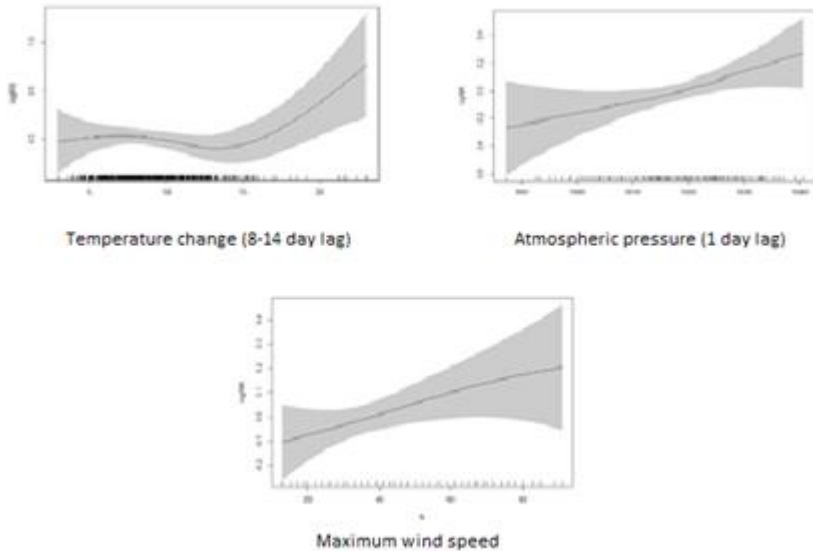
Figure 6. Effect of Atmospheric Parameters on RR.

Test „F":

The Kérdő-test showed a warm front sensitivity in the examined population (Figure 7.) Perfect applicability of the questionnaire was detected. (Figure 8.)

Figure 7. Kérdő meteorosensitivity test results.

- Strong cold front sensitivity
- Medium cold front sensitivity
- Weak cold front sensitivity
- Not sensitive or mixed sensitivity
- Weak warm front sensitivity
- Medium warm front sensitivity

Figure 8. Kernel Density Curve

Conclusion

During my research, I sought answers to the following hypotheses, for which the following conclusions can be drawn:

1. We have confirmed those results of studies that show there is a seasonality in the incidence of acute CV diseases. We have shown that extreme weather conditions can be determined as CV risk factors which might increase the number of ACVDs due to the increasing average temperature as a result of global climate change. High atmospheric pressure, strong wind speed and high humidity were detected as CV risk factors. Daily fluctuation of specified atmospheric parameters are CV risk factors. Temperature, atmospheric pressure and wind speed increased the number of ACV hospitalization. Given that global climate change is also causing increased frequency fluctuations in the short term, taking this into account this fact is an important factor in CV care.

2. As a new result, we found that complex atmospheric conditions can be considered as stronger CV risk factor than individual atmospheric parameters. We determined three atmospheric condition complexes which increased CV morbidity.

3. Based on our research results, atmospheric parameters can play a trigger role in each type of the examined ACVDs.

4. We have shown that cold season, regardless of seasonality, is a strong minor CV risk factor. Cold and extreme cold atmospheric conditions are becoming more common as a result of global climate change, therefore taking our results into account in the field of CV care may be a necessary step in the future. 3-day front pattern complexes were identified which increased the incidence of ACVDs.

5. In our results, we have shown the time lag effect of each atmospheric parameter.

6. In the demographics characteristic, we showed front sensitivity in men. Men showed front sensitivity to the cold front and women on the stationary front. In line with other international research results, our study also confirmed the more pronounced atmospheric sensitivity of the older generation. The possible using of our results in prevention is significant due to the climate threat of vulnerable groups.

7. We have successfully determined, as first in the scientific literature, a subpopulation with pronounced atmospheric vulnerability. Patients with diabetes, hyperlipidaemia, hypertension, and previous CV disease have a higher risk of developing morbidity in certain atmospheric conditions. Patients with diabetes have the highest vulnerability. This result will provide an opportunity to focus on future attention and apply appropriate prevention measures within a population with increased vulnerability.

8. First in Hungary and in line with international literature we detected some haemostatic and inflammatory factor levels increase in correlation with atmospheric parameters. Temperature fluctuations, low temperatures and high atmospheric pressure have increased the level of CRP, LDH, INR, LDL, CHOL. Certain atmospheric parameters also increased Fvs, Hgb, and Thr levels. We first detected in the international literature, that front effects increased the level of INR and LDL.

9. In the international literature, we conducted the first study between Hungary and France on the CV effect of atmospheric parameters. We have shown that in the Bordeaux region the temperature, atmospheric

pressure and wind speed had a significant CV effect. Seasonality was not detectable in Bordeaux, unlike Budapest. This is a possible explanatory factor of the "French paradox". In the Bordeaux region, a warm-front sensitivity was detected, whereas, in the Budapest region, a cold front sensitivity was detected.

10. Based on our research results, the Kérdő-test can be applied in other countries with different latitude.

11. In our research cardiovascular meteorological comfort zones were determined, these atmospheric conditions were protective against ACVD.

12. Based on our results, the current medical meteorological forecasting system can be expanded taking into account front-patterns, atmospheric conditional complexes, and detected lag-effects. Preventive strategies based on our research results can be used in clinical practice in the future, these prevention programs should also focus on the prevention of the detected vulnerable groups.

List of publications:

Publications

- **Boussoussou N,** Boussoussou M, Merész G, Rakovics M, Entz L, Nemes A. Complex effects of atmospheric parameters on acute cardiovascular diseases and major cardiovascular risk factors: data from the CardiometeorologySM study. Sci. Rep. Nature 2019, 23;9(1):6358. **IF: 4,525**
- **Boussoussou N,** Boussoussou M, Nemes A. Historical overview of medical meteorology - the new horizon in medical prevention. *Orv Hetil*. 2017. 158(5):187-191. **IF: 0,322**
- **Boussoussou N**, Boussoussou M, Entz L, Nemes A. Occurrence of acute cardiovascular diseases under different atmospheric parameters. *Orv Hetil*. 2014. 6;155(27):1078-82.
- Boussoussou M, **Boussoussou N**, Entz L, Nemes A Cardiogen thromboembolia kockázati tényező: légköri paraméterek hatása korunk "cardiovascularis járványára", a pitvarfibrillációra. *Érbetegségek*, 2015. (1). 13-17.
- Boussoussou M, **Boussoussou N**, Merész G, Rakovics M, Entz L, Nemes A. Atmospheric fronts as minor cardiovascular risk factors, a new approach to preventive cardiology. Journal of Cardiology.2019.75(2):196-202. **IF:2,289**

Book chapter

- **Boussoussou N,** Boussoussou M. Climate Change is one of the biggest threats to global health. It is time for new horizons in preventive medicine - review of the latest knowledge on the health effects of climate change on acute cardiovascular diseases. In: Leon V. Berhardt, Advances in Medicine and Biology. New York, 2018: 180-203.

Posters and presentations

- World Congress of Cardiology 2019 (Paris, 2019. 08. 31.-09. 04.) „Associations between atmospheric parameters and haemostatic factors: a case control study."
- World Congress of Cardiology 2019 (Paris, 2019. 08. 31.-09. 04.) „Atmospheric front patterns and acute cardiovascular diseases, a new perspective in the cardiovascular threat of global climate change."
- 12th International Meeting of the French Society of Hypertension conference (Paris, 13-15. december 2018.) "Association between atmospheric parameters and acute cardiovascular diseases' demographic characteristic. "
- 11th International Meeting of the French Society of Hypertension conference (Paris, 14-15. december 2017.) "The effects of atmospheric parameters on the elderly population with cardiovascular diseases-vulnerability to meteorology"
- 10th International Meeting of the French Society of Hypertension conference (Paris, 14-15. december 2016.) "Major cardiovascular risk factors and atmospheric parameters: Evidence for an increased meteorosensitivity risk. A dangerous liaison?"
- 9th International Meeting of the French Society of Hypertension conference (Paris, 17-18. december 2015.) "Hypertension induced acute cardiovascular risk and atmospheric parameters: 2670 population based meteorosensitivity study"
- National meteorological conference "Relationship between weather fronts and acute cardiovascular diseases." (Budapest, 23. may 2013.)
- European Society of Cardiology -Eurothrombosis Summit 2014. conference (Paris, 28-30. september 2014.) "Association between acute coronary syndromes and different meteorological parameters: 1330 patients based, retrospective study"