Extreme weather conditions influence the frequency of epistaxis-related emergency room visits*

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Abstract

Background: Climate change has been associated with an increase in extreme weather conditions. The aim of this study was to identify environmental factors and the effect of extreme weather events (<5th or >95th percentile) on the risk for epistaxis-related emergency room visits (EV).

Methods: A total of 2179 epistaxis-related EVs were identified between 2015 and 2018. A distributed lag non-linear model was fitted to investigate the relationship between extreme weather conditions and the total number of epistaxis-related EVs per day. Cumulative relative risk (cRR) is defined as the cumulated daily risk of EV for epistaxis within a stated period after an extreme weather condition compared to the risk of EV at the median value of that weather condition.

Results: At a mean daily temperature of 27°C (P_{95}), cRR for epistaxis-related EV was 2.00. At a relative humidity of 39% (P_5), cRR was highest on day 3 at 1.59, while extremely high humidity (92%, P_{99}) led to a decreased cRR of 0.7 on day 1. Intense precipitation of 24mm (P_{99}) reduced the cRR on day 3 to 0.38. For prolonged extreme conditions over three days, extremely low wind speed, as well as both high and low atmospheric pressure events, diminished cRR.

Conclusions: Extreme temperatures, relative humidity, and precipitation, as well as extended periods of extreme wind speeds and atmospheric pressure, significantly impact cRR for epistaxis-related EVs.

Key words: emergency service, hospital, epidemiology, epistaxis, nose, weather

Introduction

Climate change has been associated with increased frequency of extreme weather events. The negative effects of such events on human health are diverse, including an increase in overall and cause-specific mortality [1,2]. Epistaxis is one of the most common reasons for emergency room visits (EV) within otolaryngology. Epistaxis visits frequently require invasive procedures, which can be laborious and time-consuming. Identifying environmental factors and the effect of extreme weather events to better predict the risk for EV might improve health resource management and patient outcomes. Previous studies have shown that specific meteorological patterns might influence epistaxis-related EV frequency [3,4]. However, we currently lack an understanding of how extreme weather events affect epistaxis rates over time.

Epistaxis is a common occurrence and affects up to 60% of the population, with about 6% of these cases requiring medical attention. Overall, epistaxis is responsible for about 1 in 200 of all emergency department visits [5]. Etiologically, a wide range of traumatic and atraumatic risk factors contributes to the development of epistaxis. Cardiovascular diseases, such as hypertension and congestive heart failure, diabetes mellitus, and inflammatory conditions, including acute viral infections and chronic sinusitis, are known to increase the risk for epistaxis [6-10]. Patients suffering from coagulopathies such as hereditary hemorrhagic telangiectasia and von Willebrand disease also frequently present with epistaxis [11,12]. Other hematological reasons include thrombocytopenia, which may be autoimmune or due to hematological malignancies, such as leukemia [5,13]. Oncologic risk factors include squamous cell carcinoma of the sinonasal and nasopharyngeal area or benign tumors like juvenile angiofibroma [5]. Iatrogenic factors also play a significant role, in

particular the use of anticoagulation or antiplatelet agents, nasal corticosteroids, and SSRIs [14,15]. Importantly, EV and hospital admission rates for several risk factors, including hypertension and diabetes, have been associated with weather conditions [16,17]. From an environmental perspective, epistaxis cases have been shown to occur more frequently during the winter months [18-20]. Meteorological factors such as temperature, humidity, high precipitation, and wind speed have been correlated with risk for epistaxis [3,21-24]. Yet, due to conflicting results, there is currently no consensus on how weather affects epistaxis-related EVs [25].
The current literature has focused on the immediate effects of weather events on EV and hospital admission rates on the same day. However, this is likely to be an oversimplification, as it has been shown that weather variables such as temperature can have delayed effects on EVs and hospital admissions in other medical conditions [26,27]. The increased relative risk (RR) of EVs due to low-temperature events is higher when cumulated over four days compared to the same-day RR for asthma, as well as cerebrovascular and hypertensive diseases. In other words, disregarding delayed and cumulative effects over subsequent days would have led to an underestimation of EV risk related to low-temperature events. This observation exemplifies the limitations of the reductive assumption that weather only affects disease-related EVs on the same day.
To the best of our knowledge, currently, no data exists on the delayed effects of extreme weather events on epistaxis. Therefore, we analyzed epistaxis-related EVs at a tertiary hospital in Austria and applied a distributed lag non-linear model (DLNM) to investigate the cumulative effects of extreme weather events, including mean temperature, relative humidity, mean wind speed, precipitation, and atmospheric pressure over 14 days.

Methods

Study population and meteorological data

In this study, all epistaxis-related EVs from January 1st, 2015, to December 31st, 2018, were analyzed via the electronic medical record system of the Vienna General Hospital. For each epistaxis-related EV, basic patient information including age, sex, and date of visit, as well as clinical information such as active anticoagulant medication, systolic blood pressure at presentation, and performed treatment were extracted. This study was approved by the ethics committee of the Medical University of Vienna (Approval numbers: 2136/2019 and 2121/2019).
The Central Institution for Meteorology and Geodynamics, which is the national meteorological and geophysical service of Austria ("Zentralanstalt für Meteorologie und Geodynamik") provided daily meteorological data for Vienna from January 1st, 2015, to December 31st, 2018. The variables included daily mean temperature, relative humidity, precipitation, mean wind speed, and atmospheric pressure. Measurements were taken in Vienna's first district (latitude: 48.198°; longitude: 16.3669°) only three kilometers away from to the Vienna General Hospital at an elevation of 177m above sea level.

Statistical analysis

To assess the immediate and delayed effects of extreme weather variables on the frequency of epistaxis-related EVs, we fitted a distributed lag non-linear model (DLNM) [28]. This established model has previously been used to show the delayed effects of meteorological conditions and air pollution on morbidity and mortality [26,29].
Mean temperature, relative humidity, precipitation, mean wind speed, and atmospheric pressure were used as independent variables, whereas the number of daily EVs related to epistaxis served as the response variable. For all models, we chose two bases to describe the relationship between weather data and lags. Lags (or lag days) are the days following the initial exposure to a specific weather condition. We chose natural cubic splines with five degrees of freedom (df) at equally spaced quantiles for the daily weather variables and equal intervals on the logarithmic scale of lags [27]. The maximum lag was set to 14 days to account for potential harvesting effects [30]. Natural cubic splines of time with seven df per year were used to control for long-time trends and seasonality. Indicator variables for days of the week were set to account for varying demand during the week (e.g., due to closed doctor's offices on the weekend). Additionally, we controlled for public holidays using a dummy variable, as an increase in EVs is to be expected on these days. On Austrian public holidays, doctor's offices of general practitioners and ENT doctors, as well as outpatient departments of hospitals, are closed, leaving emergency rooms as sole providers for emergencies, just as they would be on weekend days, which increases visitation rates. Since public holidays may also fall on weekend days, which plausibly reduces the public holiday effect on those weekend days, we included an interaction between the day of the week indicators and the public holiday dummy. Coefficient estimates indicate a constant level of EVs over weekdays and a statistically significant increase of EV's on Saturdays, Sundays, and public holidays. As expected, the interaction between public holidays and weekend days is negative and not statistically significant. Additionally, we control for a policy change in the emergency room admission procedure, introducing a screening station in December 2016 with a dummy variable. The estimated coefficient was not statistically significant. We calculated the Pearson correlation coefficient for every combination of weather variables to determine possible correlations between weather conditions (Supplementary Table 1).
Extreme weather events were defined as the independent weather variables' 1st, 5th, 95th, and 99th percentile. RR for each lag day was calculated for extreme weather events using the median of each weather variable as a reference. cRR is defined as the risk of EV for epistaxis after an extreme weather condition

Table 1. Patient characteristics of the study cohort (n=2179).

	n (% missing)	count (%)
Age	2179 (0%)	-
0 to 18	-	264 (12.1%)
19 to 44	-	383 (17.6%)
45 to 64	-	472 (21.7%)
65-84	-	777 (35.7%)
85+	-	283 (13.0%)
Sex	2179 (0%)	-
male	-	1228 (56.4%)
female	-	951 (43.6%)
Referral by external provider or ambulance	2098 (3.9%)	-
yes	-	543 (25.9%)
no	-	1555 (74.1%)
Admission required	2179 (0%)	-
yes	-	203 (9.3%)
no	-	1976 (90.7%)
Laterality of epistaxis	2008 (8.5%)	-
one-sided	-	1869 (93.1%)
two-sided	-	139 (6.9%)
Primary location of epistaxis	1741 (20.1%)	-
anterior	-	1504 (86.4%)
posterior	-	237 (13.6%)
Current use of anticoagulants or antiplatelet agents	2065 (5.5%)	-
yes	-	915 (44.3%)
no	-	1150 (55.7%)
Systolic blood pressure at presentation	1319 (65.2%)	-
<140	-	437 (33.1%)
140-159	-	377 (28.6%)
160-179	-	285 (21.6%)
180+	-	220 (16.7%)
Treatment	2139 (1.9%)	-
bipolar cautery	-	943 (44.1%)
anterior nasal packing	-	374 (17.5%)
double balloon device *	-	226 (10.6)
topical vasoconstriction	-	187 (8.7%)
posterior nasal packing	-	7 (0.3%)
operative intervention	-	4 (0.2%)
not required #	-	398 (18.6%)

* intranasal tamponade with two separately inflatable balloons; # no active bleeding at the time of presentation.

compared to the risk of EV at the median value of that weather condition within the stated period. cRR was calculated and plotted by cumulating the RR from lag0 up to lag14. Numeric values for RR including confidence intervals and p-values were extracted for lag0, lag1, lag3, lag7, and lag14 (Supplementary Table 2), as well as for cRR for lag0-1, lag0-3, lag0-7, and lag0-14 (Supplementary Table 3). To account for prolonged extreme weather conditions, we also calculated a model for RR and cRR on lag0 to lag14 after prolonged extreme weather conditions over the previous three days. The three-day mean was used to calculate the 1st, 5th, 95th, and 99th percentile for mean temperature, relative humidity, mean wind speed, and atmospheric pressure. For precipitation, the sum over three days was used. Numeric values for RR (Supplementary Table 4) and cRR (Supplementary Table 5) are stated equivalently to our one-day model.

Statistical testing and model fitting was performed using R software (version 4.1.3) [31]. DLNMs were fitted using the "dlnm" package [32]. Heatmaps were drawn using the R package ggplot2.

Results

Study population and weather

Overall, 2179 epistaxis-related EVs occurred between January 1st, 2015 and December 31st, 2018 at the Vienna General Hospital in Vienna, Austria. Patient characteristics of the study population are shown in Table 1. Additional risk factors for epistaxis in the study population are reported separately (Supplementary Table 6). On average, more than one epistaxis-related EV occurred daily. Weekly epistaxis-related EVs followed a clear seasonal trend in 2015, 2017, and 2018 with higher rates of EV in the winter months with a peak in January and a trough in August (Figure 1A). Vienna's mean temperature and relative humidity followed expected seasonal trends (Figure 1B, C), whereas precipitation, mean wind speed, and atmospheric pressure did not show relevant seasonal changes (Figure 1D, E, F).

Mean temperature

In a first step, we wanted to know whether extreme temperatures affect epistaxis-related EVs. RR for EV according to mean temperature is visualized for each lag day in Figure 2A. Low temperature events at -5°C (P_1) and 0°C (P_5) showed a same-day RR (lag0) of 0.92 [0.51-1.65, confidence interval (CI) 95%] and 0.78 [0.53-1.14, CI 95%], respectively. Over the next 14 days (lag1 to lag14), daily RR ranged from 0.91 to 1.19 ($p>0.05$) for -5°C and from 0.78 to 1.25 ($p>0.05$) for 0°C. cRR was not significantly altered at -5°C and 0°C at any lag intervals (Figure 3A). High temperature events at 27°C (P_{95}) and 30°C (P_{99}) showed a same-day RR of 1.11 [0.69-1.76, CI 95%] and 1.3 [0.69-2.44, CI 95%], respectively. Daily RR was highest on the following day (lag1) with 1.47 ($p=0.24$) for 27°C and 1.54 ($p=0.34$) for 30°C. cRR was significantly increased within one day of high temperature events (lag0-1) to 1.63 ($p=0.036$) for 27°C and to 2.00 ($p=0.032$) for 30°C. For prolonged extreme temperatures over three days, the same trend was observed. In addition to the increased cRR for epistaxis after heatwaves, there was a significant decline in cRR to 0.72 within 14 days after prolonged extremely cold weather at mean temperatures of -4°C ($p=0.032$) and 0°C ($p=0.014$) (Supplementary Figure 1A).

In summary, the data shows that high mean temperatures of 27°C and above increased the risk of EVs for epistaxis within one day after the temperature event. At low temperatures, prolonged three-day cold spells reduced the EV risk within the following 14 days.

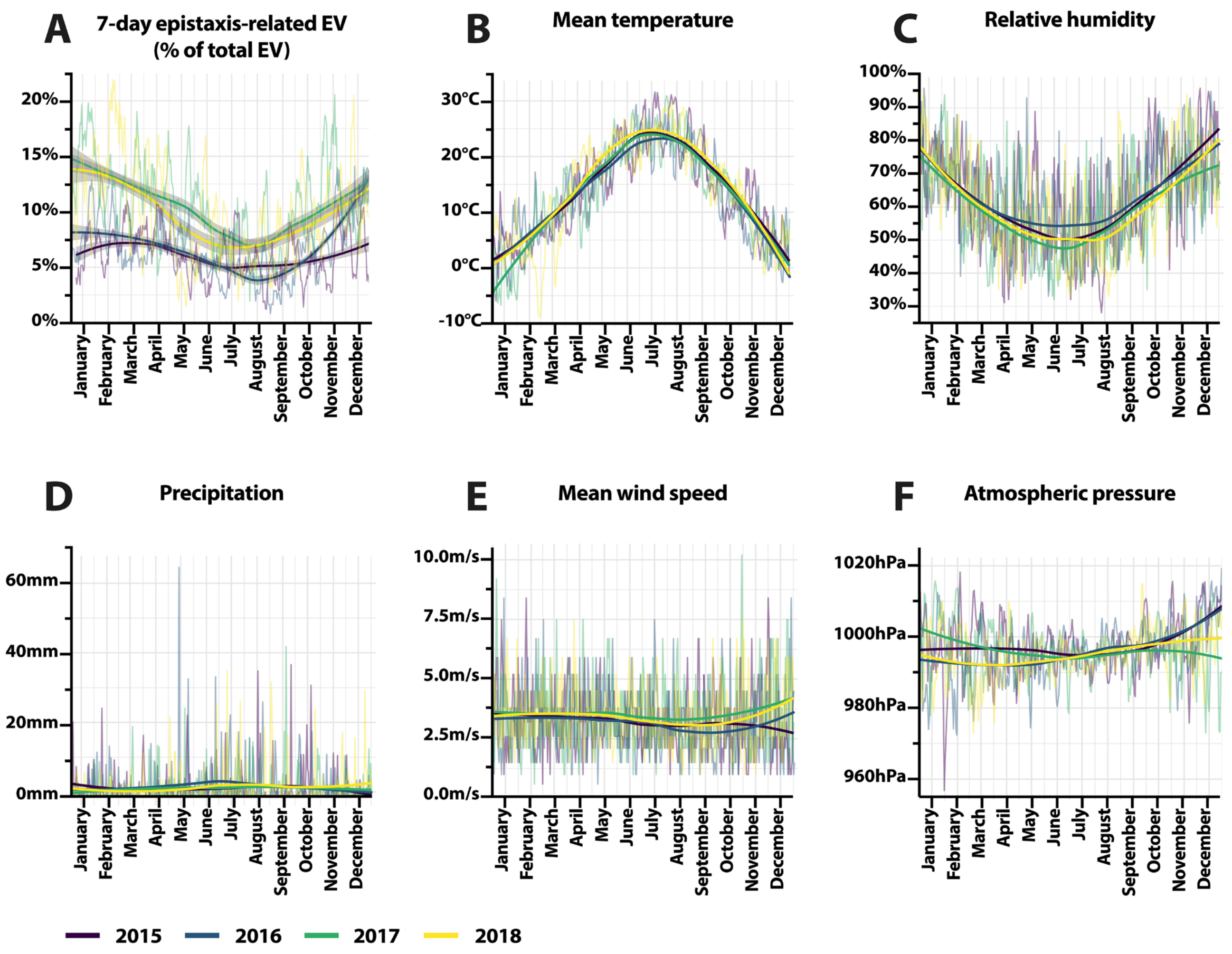

Figure 1. Weekly epistaxis-related EVs (% of total EVs from any cause) (A) and daily mean temperature in °C (B), relative humidity in % (C), precipitation in mm (D), mean wind speed in m/s (E), and atmospheric pressure in hPa (F), are shown as absolute values and as exponentially smoothed line plots from 2015-2018.

Relative humidity

In the next step, we were interested to know whether extreme relative humidity conditions impacted epistaxis-related EV rates. RR for EV according to relative humidity is visualized for each lag day in Figure 2B. Low relative humidity events at 34% (P_1) and 39% (P_5) showed a significant increase in RR for EV on the same day (lag0) to 1.49 [1.12-1.97, CI 95%] and 1.39 [1.15-1.68, CI 95%], respectively. RR was also at its highest on lag0 compared to the following 14-day period. On day 14, RR was decreased to 0.87 (p=0.024) at 39% relative humidity. cRR was significantly increased within three days (lag0-3) to 1.79 (p=0.002) and within one week (lag0-7) to 1.6 (p=0.05) for 34% relative humidity (Figure 3B). At 39% relative humidity, cRR was continuously elevated up until one week after the relative humidity event (lag0-7) with the highest cRR within three days (lag0-3) at 1.59 (p<0.001). High relative humidity events at 86% (P_{95}) and 92% (P_{99}) showed a RR on the same day (lag0) of 0.94 [0.79-1.13, CI 95%] and 0.76 [0.57-1.03, CI 95%], respectively. At both 86% and 92%, RR was at its lowest on the same day (lag0). cRR was significantly decreased at 92% relative humidity within one day (lag0-1) to 0.7 (p=0.05). The same trend in EV risk was shown for extended extremely high and low relative humidity conditions over three days (Supplementary Figure 1B).

These observations indicate an epistaxis-inducing effect of low relative humidity leading to an increased risk of EV both on the same day and within the following week. The decreased RR on day 14 may be interpreted as a harvesting effect after a period of increased risk for EV. On the contrary, very high relative humidity may alleviate epistaxis and decrease the risk of EV within one day after the weather event.

Precipitation

Due to the observed effect of extreme relative humidity on epistaxis-related EV, we then analyzed potential effects of

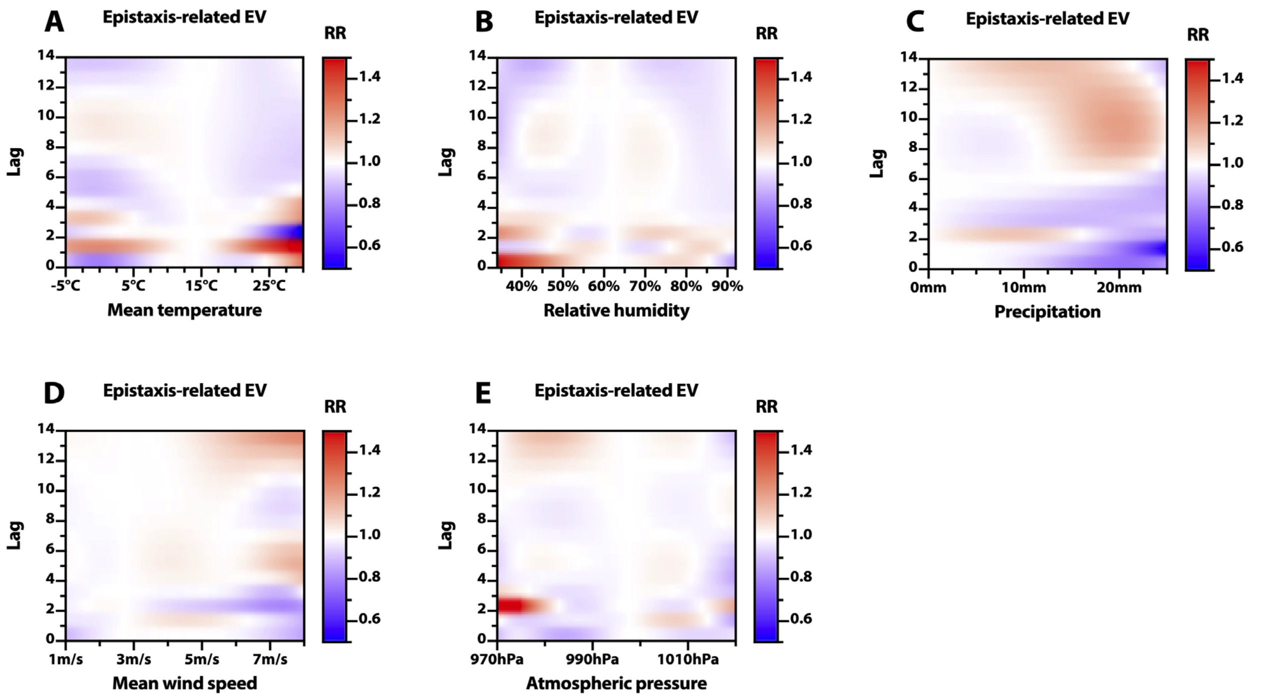

Figure 2. Heatmaps of relative risk for epistaxis-related EV from lag0 to lag14 according to mean temperature in °C (A), relative humidity in % (B), precipitation in mm (C), mean wind speed in m/s (D), and atmospheric pressure in hPa (E).

high precipitation, as heavy rainfall increases relative humidity through evaporation. RR for EV according to precipitation is visualized for each lag day in Figure 2C. High precipitation events at 10mm (P_{95}) and 24mm (P_{99}) showed a RR for EV on the same day (lag0) of 0.95 [0.8-1.13, CI 95%] and 0.77 [0.49-1.21, CI 95%], respectively. Over a 14-day period (lag1 to lag14), the RR for EV was lowest three days after high precipitation (lag 3) for 10mm at 0.9 (p=0.132) and on the following day (lag1) for 24mm at 0.63 (p=0.066). RR after precipitation of 10mm was at its highest after 14 days (lag14) with a minor, but significant increase to 1.13 (p=0.03). cRR at high precipitation events of 24mm was significantly decreased within one day (lag0-1) and within three days (lag0-3) to 0.48 (p=0.034) and 0.38 (p=0.044), respectively (Figure 3C). Sustained heavy precipitation over three days showed a similar reduction in cRR (Supplementary Figure 1C). These results point toward very high precipitation mitigating effect on the risk for epistaxis-related EV within three days after heavy rainfall. However, high precipitation did not show any significant same-day impact.

Mean wind speed

As we showed that extreme mean temperature, relative humidity, and precipitation were associated with epistaxis-related EV, we next investigated mean wind speed as a potential factor in EV rates. RR for EV according to mean wind speed is visualized for each lag day in Figure 2D. Low wind speed events at 1m/s (P_1) and 2m/s (P_5) showed a RR on the same day (lag0) of 0.85 [0.68-1.06, CI 95%] and 0.95 [0.89-1.01, CI 95%], respectively. Over the next 14 days (lag1 to lag14), daily RR for EV ranged from 0.85-1.02 (p>0.05) for 1m/s and 0.95-1.01 (p>0.05) for 2m/s. cRR at low wind speeds was non-significantly decreased over the entire 14-day observational period (Figure 3D). High wind speed events at 6m/s (P_{95}) and 8m/s (P_{99}) showed a RR on the same day (lag0) of 0.99 [0.83-1.18, CI 95%] and 0.86 [0.53-1.4, CI 95%], respectively. Daily RR for EV ranged from 0.99-1.12 (p>0.05) for 6m/s and 0.86-1.25 (p>0.05) for 8m/s over the following 14 days (lag1 to lag 14). cRR was not significantly altered at high wind speeds at any lag period. Low average wind speeds at 2m/s (P_5) over three days showed a significant decrease in cRR to 0.81 [0.65-0.99, CI 95%] within 14 days after the event (Supplementary Figure 1D).
Taken together, mean wind speed did not significantly affect the risk for EV after single-day events. However, prolonged low wind speeds were associated with a significantly lower risk for epistaxis-related EVs within the next 14 days.

Atmospheric pressure

Finally, we aimed to investigate the association between atmospheric pressure and epistaxis-related EV. RR for EV according to atmospheric pressure is visualized for each lag day in Figure 2E. Low atmospheric pressure events at 976 hPa (P1) and 983 hPa (P_5) showed a RR on the same day (lag0) of 0.95 [0.67-1.35, CI 95%] and 0.86 [0.7-1.06, CI 95%], respectively. Across the 14-day observational period, RR for EV was slightly increased

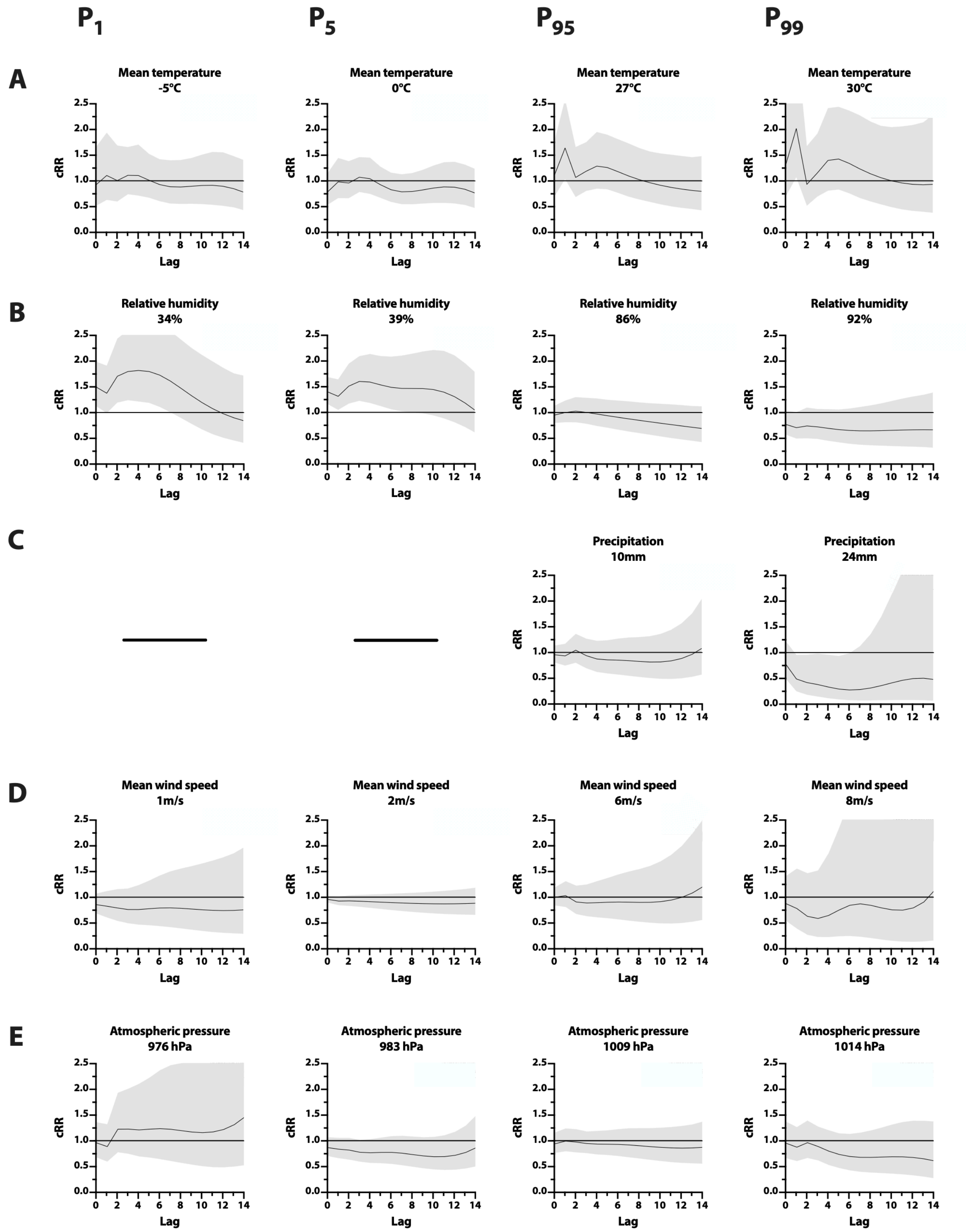

Figure 3. Line-plots (confidence interval 95%) of cumulative relative risk (cRR) from lag0 to lag14 for extreme weather events defined as the 1th, 5th, 95th, and 99th percentile of mean temperature in °C (A), relative humidity in % (B), precipitation in mm (C) [P_{95} and P_{99} only], mean wind speed m/s (D), and atmospheric pressure in hPa (E).

14 days after a low-pressure event of 983 hPa to 1.12 (p=0.03), with non-significantly lowered RR for the previous days. cRR was not significantly altered over the 14-day lag period (Figure 3E). While trends at 976 hPa are difficult to interpret due to a large confidence interval, low atmospheric pressure events at 983 hPa showed a trend towards decreased cRR. High atmospheric pressure events at 1009 hPa (P_{95}) and 1014 hPa (P_{99}) showed a same-day RR of 0.93 [0.76-1.15, CI 95%] and 0.94 [0.65-1.36, CI 95%].

No significant effects on RR were observed over the following 14 days. cRR was non-significantly decreased across the entire lag period. For prolonged extreme atmospheric pressure over three days, cRR was significantly decreased within seven days at both 985 hPa (P_5) to 0.79 [0.67-0.94, CI 95%] and 1013 hPa (P_{99}) to 0.65 [0.49-0.88, CI 95%] (Supplementary Figure 1E).
Therefore, the only significant effect of single-day extreme atmospheric pressure events on EV was an increased risk on day 14, which stood in contrast to the non-significant trend towards lower risk for EV over the entire 14-day period after high pressure events and low pressure events at 983 hPa. For extended periods of extremely low and high atmospheric pressure, EV risk was significantly reduced.

Discussion

In this study, we analyzed immediate and delayed effects of extreme weather conditions on epistaxis-related EVs in Vienna, Austria. EVs for epistaxis were more frequent in the winter months (November to March) than in summer (June to September). The higher frequency of and web-based interest in epistaxis in the winter months has been well-described [33]. Yet there is still no consensus on the causative relationship between meteorological conditions and epistaxis-related EVs or hospital admissions due to heterogeneous results [34-36]. Recent studies have demonstrated a correlation between epistaxis-related EVs and mean temperature, relative humidity, total rainfall, and wind speed [3,4,23,37]. However, these studies either chose to correlate EV frequency with average monthly conditions, thereby disregarding weather variability within a given month, or only considered the same-day effects without regard for delayed effects over subsequent days. To better account for the complex, non-linear effects of weather on human physiology, we utilized a DLNM model to investigate the impact of extreme weather conditions on epistaxis-related EV over 14 days.

In our study population, very low mean daily temperatures had no significant same-day effect on EVs. In contrast, extremely high mean temperatures increased the risk of EV compared to the median yearly temperature. These results contrast several studies that have described an inverse correlation between temperatures and epistaxis-related EVs. For example, Mangussi-Gomes et al. showed that low mean monthly temperatures lead to a higher risk of epistaxis-related EVs in Sao Paulo, Brazil [23]. Comelli et al. showed the same trend with mean daily temperature in a study population of over 5000 patients in Parma, Italy [38]. However, this correlation may not be causative. Low temperatures occur in the winter months, when indoor heating leads to low relative humidity inside homes and offices, which, in turn, causes drying of the nasal mucosa with an associated increased vulnerability for epistaxis. It has also been suggested that higher frequencies of upper respiratory tract infections in winter increase susceptibility to epistaxis due to inflammation-related damage to the nasal mucosa [37]. Low outdoor temperature may therefore not be a direct causative factor for higher epistaxis frequency. Our results support this view by showing that extremely low temperatures did not increase the risk for epistaxis-related EV. On the contrary, cold spells over three days reduced the risk for EV, which may be the result of reluctance to seek medical attention for less severe cases of epistaxis during extremely cold weather conditions. Conversely, we did show an increased risk for EV within one day after high-temperature events. These temperatures mainly occur in Vienna during the drier summer months. They are therefore associated with a hot and dry climate that contributes to exsiccation of the nasal mucosa, which can promote epistaxis.
In support of this hypothesis, we further showed that very low relative humidity increased the risk of epistaxis-related EV both on the same day and within the following seven days. In contrast, extremely high relative humidity decreased the risk of EV within one day, but not on the same day. McMullin et al. reported a similar negative correlation between humidity and EVs in maritime climates [37]. Sowerby et al. described a negative correlation between mean daily temperature but not humidity in Alberta, Canada, which features a continental climate more similar to Vienna [21]. However, due to this study's disregard for effects on subsequent days, the influence of humidity on EVs may have been underestimated. Mangussi et al. demonstrated an inverse correlation between mean monthly humidity and epistaxis-related EV, as well as total monthly rainfall [23]. Our results confirm the observed effect of substantial precipitation on EV risk. While same-day precipitation showed a non-significant trend towards lower epistaxis-related EVs on the same day, EV risk was considerably and significantly decreased within three days after strong precipitation. After heavy rainfall, evaporation increases relative humidity, making it reasonable to assume a link between the effect of relative humidity and rainfall on epistaxis-related EV risk. In our study, the correlation between relative humidity and precipitation was moderate. Due to the nature of the available weather data, we could not distinguish between precipitation in the form of snow or rain. In Vienna, a large portion of precipitation in the winter months comes from snow. Snow will not lead to the same levels of evaporation as rain in higher temperatures, and, therefore, the effect of precipitation in the form of rainfall and its correlation with relative humidity might be underestimated by our study.

Few studies have reported on the effect of wind speed or atmospheric pressure on EV risk. Min et al. reported on a limited effect of higher wind speeds on elevated EV risk. The authors hypothesized that higher wind speeds could lead to increased air pollutants exposure. Yu et al. reported a weak correlation between high wind speeds and EV risk in a pediatric study population [39]. Kemal et al. found no correlation between wind speeds and epistaxis risk [25]. While our data does not show any significant effect of very low or high mean wind speeds on epistaxis-related EV risk for single-day events, prolonged low wind speeds were correlated with moderately reduced risk. These observations align with previous findings of increased risk during high wind speeds due to heightened levels of air pollutants. Extended periods of low wind speeds could reduce the dissemination of air pollutants, thereby subjecting the nasal mucosa to fewer irritants. Regarding atmospheric pressure, Reddy et al. did not find a correlation with hospital admissions for epistaxis [24]. While we saw a general trend towards lower epistaxis-related EV rates at very high and low atmospheric pressure, the results were insignificant for single-day events. However, for extended periods of extreme atmospheric pressure, we showed a significant reduction in EV risk both at low and high pressure conditions. Low atmospheric pressure is generally associated with cloudiness and higher precipitation, suggesting a link between the mitigating effect of extremely low atmospheric pressure and intense precipitation. However, the correlation between these two variables was weak in our study. Conversely, high atmospheric pressure usually leads to drier weather with higher temperatures, which were identified as risk factors, not mitigators, for epistaxis-related EV in our study. Other bleeding-related morbidities, such as subarachnoid hemorrhages and upper gastrointestinal bleeding, have been shown to occur more frequently during high atmospheric pressure conditions. In contrast, our study showed a mitigating effect of prolonged extremely high atmospheric pressure [40,41]. The current literature lacks a robust physiological explanation for the impact of high pressure events on epistaxis risk. Nevertheless, our study is the first to describe a link between atmospheric pressure and epistaxis rates and may act as a steppingstone for further investigation into the physiological effects of extreme atmospheric pressure on the nasal mucosa and its susceptibility to epistaxis.

Taken together, this is the first study to show that daily mean temperature, relative humidity, and precipitation had delayed effects on presentation rates for epistaxis in the emergency room setting. For extended extreme conditions over three days, we, furthermore, showed delayed effects for mean wind speed and atmospheric pressure. A same-day effect was observed only for very low relative humidity, highlighting the importance of prolonged consequences of extreme weather events on epistaxis. These results could help inform resource allocations in health care management in similar climates and contribute to information and education for patients with epistaxis predispositions on environmental factors that warrant increased protective measures, such as saline nasal spray or nasal irrigation, to decrease the risk for episodes of epistaxis. Further investigation into the immediate and delayed meteorological effects on epistaxis in other climates and more extensive study populations, as well as such effects on other ENT-related diseases requiring emergency room presentation, is warranted.

This study has several limitations. The retrospective and single-center study design poses limitations on data availability and generalizability. Since Vienna has a dry and continental climate, the conclusions should be interpreted carefully for locations with deviating weather conditions. Furthermore, our results stem from a tertiary care center, which often treats more severe epistaxis cases that are associated with other medical conditions. The findings may therefore not be applicable to the overall incidence of epistaxis cases, most of which do not require EV. Lastly, this study focused on extreme weather events and does not allow conclusions related to moderately lower or higher than average conditions.

Conclusions

Extremely high temperatures and low relative humidity increase the risk of epistaxis-related EV. On the other hand, extreme precipitation and high relative humidity mitigate the risk for EV. For prolonged extreme conditions over three days, low wind speed and both high and low atmospheric pressure events diminished EV risk. Only very low relative humidity exerted a significant same-day effect. In contrast, the other meteorological conditions impacted EV risk over a subsequent period of up to 14 days.

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Authorship contribution

MH: concept of study, analysis of results, write up of manuscript, critical review of all contents; ML, FP, and MO: concept of study, collection of data, critical review of all contents; FFB, DR, and CAM: concept of study, critical review of all contents; DTL: concept of study, collection of data, analysis of results, write up of manuscript, critical review of all contents.

Conflicts of interest

The authors declare that there are no conflicts of interests regarding the publication of this paper.

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Availability of data and materials

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

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This manuscript contains online supplementary material

SUPPLEMENTARY MATERIAL

Supplementary Table 1. Pearson correlation coefficients for every combination of the independent weather variables.

	Mean temperature	Relative humidity	Precipitation	Mean wind speed	Atmospheric pressure
Mean temperature	1.00	-0.62	0.05	-0.09	-0.19
Relative humidity	-0.62	1.00	0.25	-0.02	0.05
Precipitation	0.05	0.25	1.00	0.11	-0.19
Mean wind speed	-0.09	-0.02	0.11	1.00	-0.14
Atmospheric pressure	-0.19	0.05	-0.19	-0.14	1.00

Supplementary Table 2. Relative risk for epistaxis-related EV under extreme weather conditions (1st, 5th, 95th, and 99th percentile) compared to median conditions of mean temperature, relative humidity, precipitation, mean wind speed, and atmospheric pressure. Confidence intervals (95%) and p-values are shown in brackets. Significant results (p≤0.05) are highlighted in bold print.

	Relative risk (RR)			
Mean temperature	-5°C (P_1)	0°C (P_5)	27°C (P_{95})	30°C (P_{99})
lag0	0.92 [0.51-1.65; p=0.778]	0.78 [0.53-1.14; p=0.202]	1.11 [0.69-1.76; p=0.67]	1.3 [0.69-2.44; p=0.408]
lag1	1.19 [0.51-2.8; p=0.682]	1.25 [0.74-2.11; p=0.404]	1.47 [0.77-2.8; p=0.238]	1.54 [0.63-3.75; p=0.344]
lag3	1.1 [0.73-1.66; p=0.646]	1.12 [0.85-1.46; p=0.42]	1.11 [0.81-1.52; p=0.5]	1.24 [0.81-1.91; p=0.328]
lag7	0.95 [0.85-1.07; p=0.418]	0.95 [0.88-1.03; p=0.216]	0.93 [0.84-1.02; p=0.14]	0.92 [0.81-1.05; p=0.206]
lag14	0.91 [0.75-1.12; p=0.38]	0.91 [0.78-1.05; p=0.196]	0.98 [0.82-1.16; p=0.774]	1.01 [0.8-1.27; p=0.938]
Relative humidity	34% (P_1)	39% (P_5)	86% (P_{95})	92% (P_{99})
lag0	**1.49 [1.12-1.97; p=0.006]**	**1.39 [1.15-1.68; p<0.001]**	0.94 [0.79-1.13; p=0.524]	0.76 [0.57-1.03; p=0.08]
lag1	0.92 [0.66-1.28; p=0.618]	0.94 [0.76-1.16; p=0.546]	1.05 [0.87-1.26; p=0.594]	0.92 [0.67-1.25; p=0.584]
lag3	1.05 [0.85-1.31; p=0.638]	1.06 [0.91-1.23; p=0.446]	0.98 [0.85-1.12; p=0.746]	0.98 [0.78-1.21; p=0.828]
lag7	0.93 [0.85-1.03; p=0.17]	0.99 [0.92-1.05; p=0.664]	0.97 [0.91-1.02; p=0.246]	0.99 [0.9-1.08; p=0.8]
lag14	0.93 [0.78-1.12; p=0.44]	**0.87 [0.78-0.98; p=0.024]**	0.96 [0.87-1.07; p=0.48]	1 [0.86-1.16; p=0.974]
Precipitation	-	-	10mm (P_{95})	24mm (P_{99})
lag0	-	-	0.95 [0.8-1.13; p=0.552]	0.77 [0.49-1.21; p=0.256]
lag1	-	-	0.98 [0.82-1.16; p=0.788]	0.63 [0.39-1.03; p=0.066]
lag3	-	-	0.9 [0.78-1.03; p=0.132]	0.91 [0.63-1.32; p=0.624]
lag7	-	-	0.99 [0.92-1.06; p=0.72]	1.03 [0.83-1.27; p=0.796]
lag14	-	-	**1.13 [1.01-1.27; p=0.03]**	0.95 [0.69-1.31; p=0.76]
Mean wind speed	1m/s (P_1)	2m/s (P_5)	6m/s (P_{95})	8m/s (P_{99})
lag0	0.85 [0.68-1.06; p=0.154]	0.95 [0.89-1.01; p=0.124]	0.99 [0.83-1.18; p=0.926]	0.86 [0.53-1.4; p=0.556]
lag1	0.96 [0.78-1.19; p=0.736]	0.97 [0.91-1.03; p=0.33]	1.03 [0.86-1.23; p=0.744]	0.89 [0.54-1.48; p=0.664]
lag3	0.96 [0.8-1.16; p=0.678]	0.99 [0.94-1.05; p=0.796]	0.98 [0.84-1.14; p=0.776]	0.94 [0.64-1.38; p=0.734]
lag7	1 [0.91-1.11; p=0.946]	0.99 [0.96-1.02; p=0.56]	1 [0.92-1.08; p=0.948]	1.03 [0.85-1.27; p=0.744]
lag14	1.02 [0.87-1.19; p=0.838]	1.01 [0.96-1.06; p=0.738]	1.12 [0.98-1.27; p=0.096]	1.25 [0.92-1.69; p=0.154]
Atmospheric pressure	976 hPa	983 hPa	1009 hPa	1014 hPa
lag0	0.95 [0.67-1.35; p=0.774]	0.86 [0.7-1.06; p=0.154]	0.93 [0.76-1.15; p=0.52]	0.94 [0.65-1.36; p=0.75]
lag1	0.93 [0.62-1.38; p=0.7]	0.97 [0.76-1.23; p=0.782]	1.05 [0.81-1.38; p=0.698]	0.92 [0.57-1.48; p=0.732]
lag3	1 [0.78-1.28; p=0.99]	0.95 [0.82-1.1; p=0.492]	0.97 [0.84-1.12; p=0.698]	0.92 [0.73-1.16; p=0.498]
lag7	0.99 [0.88-1.12; p=0.876]	0.98 [0.92-1.04; p=0.516]	0.99 [0.94-1.04; p=0.682]	0.98 [0.89-1.07; p=0.6]
lag14	1.12 [0.93-1.34; p=0.234]	**1.12 [1.01-1.25; p=0.03]**	1.01 [0.92-1.11; p=0.774]	0.94 [0.81-1.08; p=0.392]

Supplementary Table 3. Cumulative relative risk for epistaxis-related EV under extreme weather conditions (1st, 5th, 95th, and 99th percentile) compared to median conditions of mean temperature, relative humidity, precipitation, mean wind speed, and atmospheric pressure. Confidence intervals (95%) and p-values are shown in brackets. Significant results (p≤0.05) are highlighted in bold print.

Cumulative relative risk (cRR)				
Mean temperature	-5°C (P_1)	0°C (P_5)	27°C (P_{95})	30°C (P_{99})
lag0	0.92 [0.51-1.65; p=0.778]	0.78 [0.53-1.14; p=0.202]	1.11 [0.69-1.76; p=0.67]	1.3 [0.69-2.44; p=0.408]
lag0-1	1.1 [0.63-1.92; p=0.744]	0.97 [0.66-1.43; p=0.896]	**1.63 [1.03-2.57; p=0.036]**	**2 [1.07-3.77; p=0.032]**
lag0-3	1.1 [0.74-1.65; p=0.642]	1.06 [0.78-1.45; p=0.698]	1.18 [0.8-1.74; p=0.404]	1.15 [0.69-1.91; p=0.592]
lag0-7	0.88 [0.56-1.39; p=0.584]	0.78 [0.54-1.12; p=0.18]	1.09 [0.69-1.72; p=0.714]	1.23 [0.66-2.26; p=0.514]
lag0-14	0.77 [0.43-1.39; p=0.39]	0.75 [0.47-1.22; p=0.25]	0.79 [0.42-1.47; p=0.456]	0.93 [0.38-2.28; p=0.868]
Relative humidity	34% (P_1)	39% (P_5)	86% (P_{95})	92% (P_{99})
lag0	**1.49 [1.12-1.97; p=0.006]**	**1.39 [1.15-1.68; p<0.001]**	0.94 [0.79-1.13; p=0.524]	0.76 [0.57-1.03; p=0.08]
lag0-1	1.37 [0.98-1.9; p=0.064]	**1.3 [1.04-1.63; p=0.02]**	0.99 [0.81-1.22; p=0.948]	**0.7 [0.49-1; p=0.05]**
lag0-3	**1.79 [1.23-2.59; p=0.002]**	**1.59 [1.22-2.08; p<0.001]**	1 [0.78-1.28; p=0.98]	0.72 [0.48-1.06; p=0.096]
lag0-7	**1.6 [1-2.57; p=0.05]**	**1.46 [1.02-2.09; p=0.04]**	0.87 [0.63-1.21; p=0.412]	0.64 [0.37-1.1; p=0.106]
lag0-14	0.83 [0.41-1.7; p=0.614]	1.03 [0.6-1.76; p=0.926]	0.68 [0.42-1.11; p=0.126]	0.66 [0.31-1.38; p=0.272]
Precipitation	-	-	10mm (P_{95})	24mm (P_{99})
lag0	-	-	0.95 [0.8-1.13; p=0.552]	0.77 [0.49-1.21; p=0.256]
lag0-1	-	-	0.93 [0.74-1.16; p=0.508]	**0.48 [0.25-0.95; p=0.034]**
lag0-3	-	-	0.93 [0.69-1.26; p=0.646]	**0.38 [0.15-0.97; p=0.044]**
lag0-7	-	-	0.84 [0.54-1.28; p=0.41]	0.28 [0.07-1.12; p=0.072]
lag0-14	-	-	1.08 [0.57-2.05; p=0.806]	0.47 [0.07-3.46; p=0.462]
Mean wind speed	1m/s (P_1)	2m/s (P_5)	6m/s (P_{95})	8m/s (P_{99})
lag0	0.85 [0.68-1.06; p=0.154]	0.95 [0.89-1.01; p=0.124]	0.99 [0.83-1.18; p=0.926]	0.86 [0.53-1.4; p=0.556]
lag0-1	0.82 [0.61-1.11; p=0.202]	0.92 [0.84-1; p=0.064]	1.02 [0.8-1.3; p=0.86]	0.77 [0.39-1.54; p=0.466]
lag0-3	0.76 [0.49-1.16; p=0.202]	0.91 [0.81-1.04; p=0.16]	0.88 [0.63-1.24; p=0.462]	0.58 [0.22-1.51; p=0.264]
lag0-7	0.79 [0.42-1.49; p=0.466]	0.88 [0.72-1.07; p=0.196]	0.9 [0.54-1.49; p=0.67]	0.86 [0.23-3.26; p=0.828]
lag0-14	0.75 [0.29-1.96; p=0.56]	0.88 [0.65-1.18; p=0.378]	1.2 [0.56-2.58; p=0.644]	1.12 [0.16-7.98; p=0.908]
Atmospheric pressure	976 hPa	983 hPa	1009 hPa	1014 hPa
lag0	0.95 [0.67-1.35; p=0.774]	0.86 [0.7-1.06; p=0.154]	0.93 [0.76-1.15; p=0.52]	0.94 [0.65-1.36; p=0.75]
lag0-1	0.88 [0.59-1.31; p=0.526]	0.83 [0.66-1.05; p=0.116]	0.98 [0.79-1.23; p=0.892]	0.87 [0.6-1.25; p=0.45]
lag0-3	1.22 [0.74-2; p=0.438]	0.77 [0.59-1; p=0.054]	0.94 [0.75-1.17; p=0.574]	0.88 [0.61-1.27; p=0.494]
lag0-7	1.21 [0.6-2.45; p=0.59]	0.75 [0.52-1.09; p=0.13]	0.91 [0.67-1.23; p=0.544]	0.67 [0.39-1.15; p=0.146]
lag0-14	1.45 [0.52-4.04; p=0.474]	0.86 [0.5-1.49; p=0.59]	0.87 [0.55-1.36; p=0.532]	0.6 [0.27-1.36; p=0.224]

Supplementary Table 4. Relative risk for epistaxis-related EV under extreme weather conditions over three days (1st, 5th, 95th, and 99th percentile) compared to median conditions of mean temperature, relative humidity, precipitation, mean wind speed, and atmospheric pressure. The percentiles for extreme conditions were calculated using the three-day average for mean temperature, relative humidity, mean wind speed, and atmospheric pressure or the three-day sum for precipitation. Confidence intervals (95%) and p-values are shown in brackets. Significant results (p≤0.05) are highlighted in bold print.

	Relative risk (RR) after prolonged extreme conditions (3 days)			
Mean temperature over 3 days (mean)	-4°C (P_1)	0°C (P_5)	26°C (P_{95})	30°C (P_{99})
lag0	0.65 [0.33-1.26; p=0.2]	**0.51 [0.31-0.82; p=0.006]**	1.13 [0.63-2.02; p=0.686]	1.61 [0.7-3.69; p=0.264]
lag1	1.48 [0.4-5.47; p=0.558]	2.07 [0.83-5.2; p=0.12]	1.76 [0.59-5.21; p=0.31]	1.54 [0.31-7.56; p=0.594]
lag3	0.93 [0.63-1.37; p=0.704]	1.04 [0.8-1.36; p=0.76]	1.32 [0.96-1.81; p=0.084]	1.44 [0.91-2.29; p=0.118]
lag7	0.98 [0.89-1.07; p=0.598]	0.95 [0.89-1.02; p=0.15]	**0.9 [0.83-0.97; p=0.006]**	**0.89 [0.8-1; p=0.044]**
lag14	0.97 [0.86-1.09; p=0.634]	0.96 [0.87-1.05; p=0.334]	0.97 [0.86-1.08; p=0.548]	1.01 [0.87-1.18; p=0.872]
Relative humidity over 3 days (mean)	37% (P_1)	41% (P_5)	82% (P_{95})	89% (P_{99})
lag0	1.08 [0.85-1.37; p=0.522]	1.07 [0.9-1.29; p=0.438]	0.88 [0.74-1.05; p=0.16]	0.83 [0.64-1.08; p=0.168]
lag1	1.28 [0.9-1.83; p=0.174]	1.21 [0.92-1.59; p=0.164]	1.05 [0.81-1.37; p=0.692]	1.02 [0.69-1.5; p=0.926]
lag3	1.08 [0.93-1.27; p=0.312]	1.04 [0.93-1.17; p=0.468]	0.99 [0.89-1.11; p=0.924]	0.99 [0.84-1.17; p=0.914]
lag7	**0.94 [0.9-0.99; p=0.026]**	1 [0.97-1.04; p=0.916]	1 [0.97-1.03; p=0.966]	0.95 [0.91-1; p=0.056]
lag14	0.94 [0.86-1.03; p=0.196]	**0.9 [0.85-0.96; p=0.002]**	0.98 [0.93-1.04; p=0.47]	1.01 [0.93-1.09; p=0.87]
Precipitation over 3 days (sum)	-	-	24mm (P_{95})	40mm (P_{99})
lag0	-	-	1.12 [0.96-1.32; p=0.15]	1.09 [0.81-1.46; p=0.586]
lag1	-	-	0.83 [0.68-1.02; p=0.076]	0.82 [0.56-1.19; p=0.292]
lag3	-	-	0.96 [0.85-1.08; p=0.47]	1 [0.81-1.22; p=0.962]
lag7	-	-	0.98 [0.93-1.03; p=0.366]	1 [0.92-1.09; p=0.926]
lag14	-	-	1.02 [0.94-1.09; p=0.692]	1.06 [0.92-1.23; p=0.408]
Mean wind speed over 3 days (mean)	1m/s (P_1)	2m/s (P_5)	5m/s (P_{95})	6m/s (P_{99})
lag0	0.79 [0.57-1.08; p=0.138]	**0.91 [0.84-1; p=0.04]**	0.98 [0.87-1.11; p=0.784]	1.1 [0.89-1.35; p=0.374]
lag1	1.05 [0.73-1.52; p=0.782]	1 [0.9-1.11; p=1]	0.95 [0.81-1.12; p=0.562]	0.9 [0.68-1.19; p=0.456]
lag3	0.97 [0.77-1.21; p=0.764]	0.98 [0.93-1.04; p=0.548]	0.94 [0.87-1.02; p=0.126]	0.91 [0.79-1.05; p=0.198]
lag7	1.02 [0.93-1.11; p=0.676]	0.98 [0.96-1; p=0.124]	0.99 [0.96-1.03; p=0.71]	1.05 [0.98-1.12; p=0.138]
lag14	1.1 [0.94-1.28; p=0.238]	1.03 [0.99-1.06; p=0.18]	1.05 [1-1.11; p=0.064]	1.08 [0.98-1.19; p=0.106]
Atmospheric pressure over 3 days (mean)	980 hPa	985 hPa	1008 hPa	1013 hPa
lag0	0.85 [0.63-1.15; p=0.29]	0.89 [0.73-1.08; p=0.23]	0.92 [0.73-1.16; p=0.47]	0.85 [0.57-1.27; p=0.424]
lag1	0.98 [0.59-1.62; p=0.942]	0.96 [0.69-1.35; p=0.826]	1.05 [0.69-1.58; p=0.828]	1.02 [0.51-2.03; p=0.964]
lag3	1.01 [0.85-1.19; p=0.952]	0.99 [0.89-1.11; p=0.914]	0.95 [0.84-1.08; p=0.43]	0.9 [0.73-1.1; p=0.302]
lag7	0.97 [0.92-1.03; p=0.316]	0.98 [0.94-1.01; p=0.144]	1 [0.96-1.03; p=0.796]	0.99 [0.93-1.04; p=0.628]
lag14	**1.1 [1.01-1.19; p=0.034]**	**1.07 [1.01-1.13; p=0.016]**	1.01 [0.96-1.07; p=0.64]	0.93 [0.85-1.02; p=0.112]

Supplementary Table 5. Cumulative relative risk for epistaxis-related EV under extreme weather conditions over three days (1st, 5th, 95th, and 99th percentile) compared to median conditions of mean temperature, relative humidity, precipitation, mean wind speed, and atmospheric pressure. The percentiles for extreme conditions were calculated using the three-day average for mean temperature, relative humidity, mean wind speed, and atmospheric pressure or the three-day sum for precipitation. Confidence intervals (95%) and p-values are shown in brackets. Significant results ($p \leq 0.05$) are highlighted in bold print.

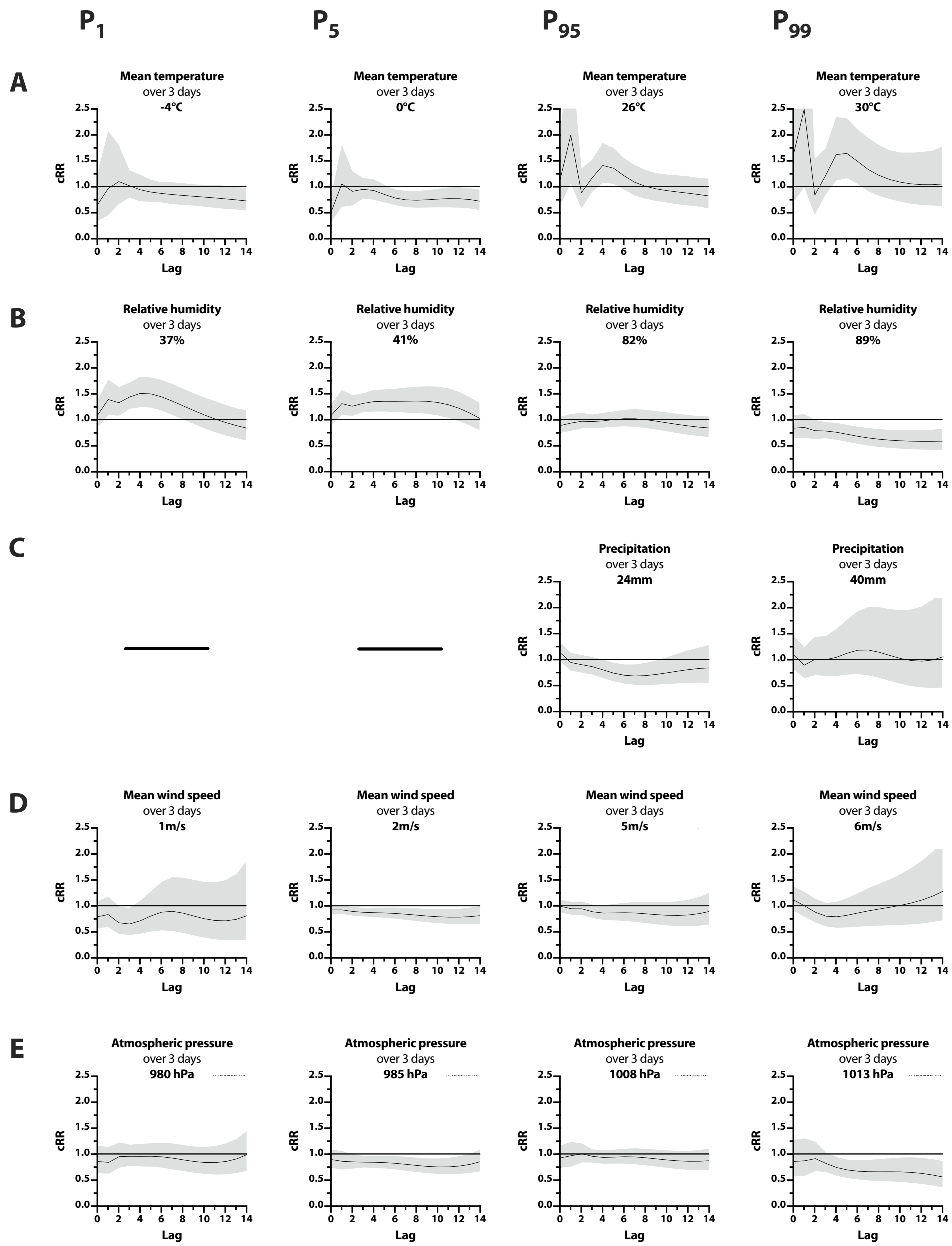
Cumulative relative risk (cRR) after prolonged extreme conditions (3 days)				
Mean temperature over 3 days (mean)	-4°C (P_1)	0°C (P_5)	26°C (P_{95})	30°C (P_{99})
lag0	0.65 [0.33-1.26; p=0.2]	**0.51 [0.31-0.82; p=0.006]**	1.13 [0.63-2.02; p=0.686]	1.61 [0.7-3.69; p=0.264]
lag1	0.96 [0.45-2.06; p=0.914]	1.05 [0.61-1.8; p=0.864]	**1.98 [1.06-3.7; p=0.032]**	2.48 [0.99-6.21; p=0.054]
lag3	1.01 [0.78-1.31; p=0.924]	0.94 [0.77-1.16; p=0.588]	1.16 [0.9-1.51; p=0.256]	1.2 [0.84-1.72; p=0.312]
lag7	0.84 [0.66-1.08; p=0.176]	**0.74 [0.6-0.92; p=0.006]**	1.08 [0.83-1.41; p=0.572]	1.33 [0.91-1.93; p=0.144]
lag14	**0.72 [0.54-0.97; p=0.032]**	**0.72 [0.55-0.94; p=0.014]**	0.82 [0.58-1.15; p=0.244]	1.05 [0.62-1.77; p=0.864]
Relative humidity over 3 days (mean)	37% (P_1)	41% (P_5)	82% (P_{95})	89% (P_{99})
lag0	1.08 [0.85-1.37; p=0.522]	1.07 [0.9-1.29; p=0.438]	0.88 [0.74-1.05; p=0.16]	0.83 [0.64-1.08; p=0.168]
lag1	**1.38 [1.09-1.76; p=0.008]**	**1.3 [1.08-1.56; p=0.004]**	0.93 [0.78-1.1; p=0.412]	0.85 [0.65-1.1; p=0.218]
lag3	**1.43 [1.2-1.7; p<0.001]**	**1.31 [1.14-1.5; p<0.001]**	0.96 [0.84-1.1; p=0.548]	0.78 [0.64-0.95; p=0.012]
lag7	**1.35 [1.09-1.68; p=0.006]**	**1.35 [1.13-1.61; p<0.001]**	1.01 [0.86-1.2; p=0.868]	**0.65 [0.5-0.84; p<0.001]**
lag14	0.83 [0.59-1.17; p=0.29]	1.01 [0.78-1.3; p=0.936]	0.84 [0.66-1.06; p=0.136]	**0.59 [0.42-0.82; p=0.002]**
Precipitation over 3 days (sum)	-	-	24mm (P_{95})	40mm (P_{99})
lag0	-	-	1.12 [0.96-1.32; p=0.15]	1.09 [0.81-1.46; p=0.586]
lag1	-	-	0.94 [0.78-1.12; p=0.478]	0.89 [0.64-1.23; p=0.48]
lag3	-	-	0.86 [0.71-1.04; p=0.124]	0.99 [0.68-1.44; p=0.976]
lag7	-	-	**0.68 [0.51-0.9; p=0.008]**	1.18 [0.69-2; p=0.544]
lag14	-	-	0.83 [0.55-1.27; p=0.402]	1.05 [0.46-2.39; p=0.908]
Mean wind speed over 3 days (mean)	1m/s (P_1)	2m/s (P_5)	5m/s (P_{95})	6m/s (P_{99})
lag0	0.79 [0.57-1.08; p=0.138]	**0.91 [0.84-1; p=0.04]**	0.98 [0.87-1.11; p=0.784]	1.1 [0.89-1.35; p=0.374]
lag1	0.83 [0.58-1.17; p=0.284]	**0.91 [0.84-1; p=0.048]**	0.94 [0.82-1.07; p=0.322]	0.99 [0.78-1.26; p=0.934]
lag3	**0.65 [0.44-0.96; p=0.028]**	**0.87 [0.79-0.95; p=0.002]**	0.88 [0.76-1.01; p=0.074]	0.79 [0.6-1.05; p=0.102]
lag7	0.89 [0.51-1.54; p=0.676]	**0.83 [0.72-0.95; p=0.008]**	0.85 [0.69-1.06; p=0.158]	0.9 [0.6-1.33; p=0.588]
lag14	0.81 [0.35-1.85; p=0.612]	0.81 [0.65-0.99; p=0.042]	0.89 [0.63-1.24; p=0.49]	1.27 [0.72-2.27; p=0.408]
Atmospheric pressure over 3 days (mean)	980 hPa	985 hPa	1008 hPa	1013 hPa
lag0	0.85 [0.63-1.15; p=0.29]	0.89 [0.73-1.08; p=0.23]	0.92 [0.73-1.16; p=0.47]	0.85 [0.57-1.27; p=0.424]
lag1	0.83 [0.62-1.13; p=0.236]	0.85 [0.7-1.05; p=0.126]	0.96 [0.75-1.23; p=0.75]	0.86 [0.58-1.29; p=0.474]
lag3	0.95 [0.77-1.17; p=0.622]	**0.84 [0.73-0.95; p=0.008]**	0.95 [0.83-1.08; p=0.42]	0.81 [0.65-1.02; p=0.072]
lag7	0.91 [0.7-1.19; p=0.508]	**0.79 [0.67-0.94; p=0.008]**	0.94 [0.8-1.1; p=0.428]	**0.65 [0.49-0.88; p=0.006]**
lag14	0.99 [0.67-1.45; p=0.946]	0.85 [0.67-1.09; p=0.196]	0.87 [0.68-1.1; p=0.238]	**0.55 [0.35-0.86; p=0.008]**

Supplementary Table 6. Risk factors for epistaxis in the study population.

Risk factors for epistaxis in the study population (n=2179)	n
Vascular	
Hypertension	244
Diabetes	61
Morbus Osler	17
Congestive heart failure	11
Iatrogenic	
Comorbidities requiring anticoagulant or antiplatelet agent use	
Atrial fibrillation	87
Coronary artery disease	39
History of myocardial infarction	19
History of stroke	20
History of pulmonary embolism or deep vein thrombosis	10
Peripheral artery disease	9
History of heart valve surgery	7
Ventricular assist device	4
Cerebrovascular occlusive disease	3
Carotid artery disease	2
Cerebral aneurysm	2
Post-surgical	
Septo(rhino)plasty	16
Functional endoscopic sinus surgery	3
Transsphenoidal hypophysectomy	2
Metabolic	
Chronic kidney disease	22
Hepatic dysfunction (viral or alcohol-related)	12
Inflammatory	
Rhinosinusitis	10
Coagulopathies	
von Willebrand disease	14
Thrombocytopenia (not specified)	9
Hemophilia	8
Polycythaemia vera	6
Anemia	4
Thrombotic thrombocytopenic purpura	2
Factor V deficiency	1
Factor VII deficiency	1
Hematopoietic neoplasms	
Leukemia (ALL/AML)	5
Primary myelofibrosis	4
MDS	3
Essential thrombocytosis	1
Neoplasms of the head and neck	
Nasal lymphoma	2
Squamous cell carcinoma of the epipharynx	2
Squamous cell carcinoma of the hard palate	1

Supplementary Table 6 continued. Risk factors for epistaxis in the study population.

Risk factors for epistaxis in the study population (n=2179)	n
Traumatic	
Recent orbital fracture	4
Recent nasal fracture	3
Recent maxillary fracture	1
Septal perforation	1
Substance abuse	
Cocaine	1
Non reported	1707



Supplementary Figure 1. Line-plots (confidence interval 95%) of cumulative relative risk (cRR) from lag0 to lag14 for extreme weather events over three days defined as the 1th, 5th, 95th, and 99th percentile of mean temperature in °C (A), relative humidity in % (B), precipitation in mm (C) [P_{95} and P_{99} only], mean wind speed m/s (D), and atmospheric pressure in hPa (E). The percentiles for extreme conditions were calculated using the three-day average for mean temperature, relative humidity, mean wind speed, and atmospheric pressure or the three-day sum for precipitation.