The Effect of Season and Temperature Variation on Hospital Admissions for Incident Stroke Events in Maputo, Mozambique

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Background: Identifying locale-specific patterns regarding the variation in stroke incidence throughout the year and with atmospheric temperature may be useful to the organization of stroke care, especially in low-resource settings. *Goal:* We aimed to describe the variation in the incidence of stroke hospitalizations across seasons and with short-term temperature variation, in Maputo, Mozambique. *Methods:* Between August 1, 2005, and July 31, 2006, we identified 651 stroke events in Maputo dwellers, according to the World Health Organization's STEPwise approach. The day of symptom onset was defined as the index date. We computed crude and adjusted (humidity, precipitation and temperature) incidence rate ratios (IRRs) and 95% confidence intervals (CIs) with Poisson regression. *Results:* Stroke incidence did not vary significantly with season (dry versus wet: crude IRR = .98, 95% CI: .84-1.15), atmospheric temperature at the index date, or average atmospheric temperature in the preceding 2 weeks. The incidence rates of stroke were approximately 30% higher when in the previous 10 days there was a decline in the minimum temperature greater than or equal to 3°C between any 2 consecutive days (variation in minimum temperature −5.1 to −3.0 versus −2.3 to −.4, adjusted IRR = 1.31, 95% CI: 1.09-1.57). No significant associations were observed according to the variation in maximum temperatures. *Conclusions:* Sudden declines in the minimum temperatures were associated with a higher incidence of stroke hospitalizations in Maputo. This provides important information for prediction of periods of higher hospital affluence because of stroke and to understand the mechanisms underlying the triggering of a stroke event. **Key Words:** Stroke—Mozambique—temperature—seasons.

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Introduction

There is a large consensus regarding the main stroke determinants but little information on its triggering factors.[1,2] The understanding of the transient exposures that contribute to the occurrence of a stroke event in a specific moment might lead to the timely implementation of preventive measures and a better allocation of resources for its management.[2]

Atmospheric temperature has been associated with stroke incidence.[3-6] Despite the evidence is conflicting, some studies showed a higher frequency of stroke in the colder months,[5,7-12] and sudden temperature changes in the days before the event, both downward and upward, were shown to influence the risk of stroke.[3,4,13] However, most of the previous investigations were conducted in temperate climate settings of the northern hemisphere and describing these patterns of variation in tropical and subtropical climates may contribute to understand if high temperatures, together with high humidity, result in different biological consequences.[14,15]

Mozambique is a sub-Saharan country with a subtropical, high humidity (70%-80%) climate, with a dry season between June and September and a rainy season between October and April. The daily minimum temperature varies mostly between 14°C and 22°C and the daily maximum temperature lies in the interval between 25°C and 30°C throughout the year.[16] Although temperatures are fairly high all year round, in Maputo, the clinicians have the perception that the number of patients with an incident stroke admitted to the hospitals is higher in the days after the occurrence of "cold fronts" (a meteorological phenomenon described as being associated with sudden drops in temperature after a record of high temperatures in the previous days[17]). Although Mozambique is in its early steps in the epidemiological transition, stroke is already a frequent condition, responsible for high morbidity and mortality.[18,19] The recognition of an association between atmospheric temperature and the incidence of stroke in Maputo may allow a more efficient allocation of the limited resources available in this setting for an appropriate management of the cases that seek medical attention.[1,20,21] Therefore, we aimed to describe the variation in the incidence of stroke hospitalizations across seasons and with short-term temperature variation, in Maputo, Mozambique.

Methods

This study was based on the data collected following the STEPS stroke protocol, Step 1 (registration of hospitalized patients) as previously described in detail.[18,19] During a 12-month period, from August 1, 2005, to July 31, 2006, all patients admitted to any governmental or private hospital in Maputo (the Maputo Central Hospital, 3 general public hospitals, the military hospital, and 6 private clinics), living in town for more than 12 months, and suspected of having an incident stroke event were registered. Stroke was defined according to the World Health Organization clinical definition: "a focal (or at times global) neurological impairment of sudden onset, and lasting more than 24 hours (or leading to death), and of presumed vascular origin."[22] During this period, 651 stroke events were registered in a population of 1.2 million inhabitants.[23] A computed tomography scan or autopsy was performed in 92.3% of the clinically confirmed stroke events, which allowed categorization according to stroke subtype. Date of symptom onset, as stated by the patient or a next of kin, was used as the date of the event (index date) regardless of date of admission.

Data on the temperature in Maputo (maximum, minimum, and mean temperatures for each day) were obtained from the Meteorological Institute of Mozambique, for the period between July 1, 2005, and July 31, 2006, along with mean relative daily humidity (%) and total daily precipitation (mm^3) data.

The factors associated with stroke hospitalizations in Maputo were assessed through incidence rate ratios (IRRs), computed using Poisson regression. We computed crude IRR for the associations with the month of the year and the season (dry versus wet) in the index dates of the stroke events and temperature-, humidity- and precipitation-adjusted IRR for the association with different measures of the temperature in Maputo or its short-term variation; the latter are described in detail in the tables and respective footnotes.

All analyses were conducted using STATA, version 11.0 (Stata Corporation, College Station, TX).

The registry of the stroke events was approved by the National Mozambican Ethics Committee, and written informed consent was obtained from all participants or their relatives.

Results

The monthly mean temperatures were highest in February (maximum, 31.7°C; minimum, 22.7°C) and lowest

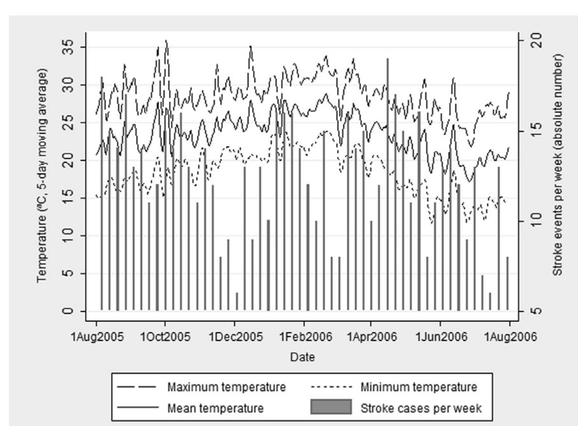

Figure 1. *Maximum, minimum, and mean temperature (5-day moving average) and stroke distribution (each bar represents a 1-week period), from August 1, 2005, to July 31, 2006, in Maputo, Mozambique.*

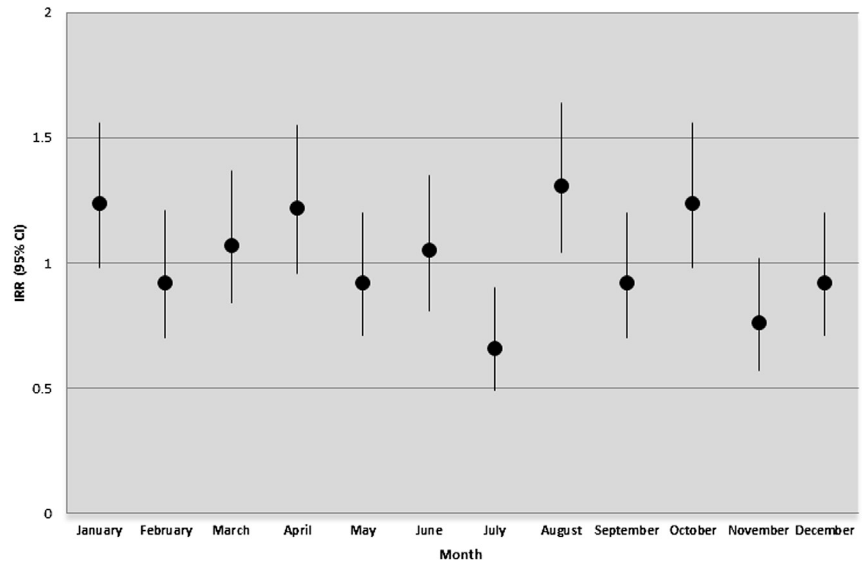

Figure 2. *Incidence rate ratios and 95% confidence intervals for stroke incidence in Maputo, Mozambique, according to the month of the year. Circles represent the point estimates of IRRs, computed using the mean annual stroke incidence as reference and vertical lines the 95% CIs. Abbreviations: CI, confidence interval; IRR, incidence rate ratio.*

in June (maximum, 25.0°C) and July (minimum, 14.1°C). The daily temperature range was similar throughout the year, with both maximum and minimum temperatures increasing from July to February and decreasing thereafter. Day-to-day temperature variation was high (ranging from −15.0°C to 16.3°C for maximum temperature and from −5.1°C to 5.1°C for minimum temperature) throughout the year. Stroke hospitalizations were more frequent in August, October, January, and May, which encompass both summer and winter months and suggest no seasonal pattern of stroke incidence in Maputo (Fig 1).

When compared with the average incidence throughout the year, the rate was significantly lower only in July (IRR = .66; 95% confidence interval [CI]: .49-.90; Fig 2). This in accordance with the observation of no seasonality in the graphical presentation of these data and is further confirmed by the absence of significant differences in IRRs according to season (dry season versus wet season, crude IRR = .98; 95% CI: .84-1.15).

We computed IRR according to quarters of the minimum and maximum temperature distribution throughout the year, using the first quarter as reference. No significant differences were found either for the index date or for the average temperatures in the 3 or 15 days before the event (Table 1). This analysis was also conducted for the 5, 7, and 10 days preceding the event yielding similar results (data not shown).

No significant differences were found in the incidence of stroke hospitalizations according to the variation in the minimum temperature between the day preceding

Table 1. *Incidence rate ratios for stroke incidence in Maputo, Mozambique, according to quarters of minimum and maximum temperature on the index date, and average temperatures in the 3 and 15 days before the event (August 1, 2005, to July 31, 2006)*

	Index date		3 d before the event (mean)		15 d before the event (mean)	
	Crude IRR	Adjusted IRR*	Crude IRR	Adjusted IRR*	Crude IRR	Adjusted IRR*
Minimum temperature (°C)†						
10.2-16.0	1 (reference)	1 (reference)	1 (reference)	1 (reference)	1 (reference)	1 (reference)
16.1-18.6	1.20 (.97-1.48)	1.17 (.92-1.50)	1.06 (.85-1.33)	1.06 (.84-1.34)	1.06 (.86-1.33)	1.06 (.84-1.34)
18.7-21.0	1.01 (.80-1.26)	.97 (.72-1.32)	1.02 (.82-1.27)	1.01 (.78-1.31)	1.02 (.82-1.27)	1.01 (.76-1.31)
21.1-24.8	1.09 (.87-1.35)	1.04 (.71-1.52)	1.06 (.84-1.34)	1.07 (.79-1.45)	1.06 (.84-1.34)	1.07 (.79-1.45)
Maximum temperature (°C)‡						
19.7-25.7	1 (reference)	1 (reference)	1 (reference)	1 (reference)	1 (reference)	1 (reference)
25.8-28.2	1.00 (.81-1.24)	.95 (.74-1.22)	1.09 (.80-1.50)	1.09 (.79-1.52)	1.09 (.80-1.50)	1.09 (.79-1.52)
28.3-30.9	.92 (.74-1.14)	.84 (.60-1.16)	1.18 (.86-1.61)	1.19 (.84-1.68)	1.18 (.86-1.61)	1.19 (.84-1.68)
31.0-43.0	1.03 (.83-1.27)	.89 (.57-1.38)	1.11 (.78-1.57)	1.13 (.76-1.68)	1.11 (.78-1.57)	1.13 (.76-1.68)

Abbreviation: IRR, incidence rate ratio.

*IRR adjusted for mean relative daily humidity (%), total daily precipitation (mm^3), and mean temperature (continuous variables) on the index date and 3 and 15 days before the event, respectively.

†The cutoffs used to define the categories correspond to the quartiles of the minimum temperature distribution throughout the year.

‡The cutoffs used to define the categories correspond to the quartiles of the maximum temperature distribution throughout the year.

Table 2. *Incidence rate ratios for stroke incidence in Maputo, Mozambique, according to the variation in the minimum temperature observed in different periods before the index date*,† (August 1, 2005, to July 31, 2006)*

	Crude IRR	Adjusted IRR‡
Variation in the minimum temperature observed between the day before the index date and the index date§:		
−5.1 to −.7(highest decrease)	.98 (.81-1.18)	.98 (.81-1.18)
−.8 to .7	.98 (.81-1.18)	.97 (.81-1.18)
.8 to 5.1	1 (reference)	1 (reference)
Maximum decrease in the minimum temperature observed in any of 2 consecutive days among:		
3 d preceding the index dates§		
−5.1 to −2.0 (highest decrease)	1.11 (.92-1.34)	1.14 (.94-1.39)
−2.1 to −.8	.97 (.80-1.17)	.93 (.76-1.18)
−.9 to 1.2	1 (reference)	1 (reference)
5 d preceding the index dates§		
−5.1 to −2.5 (highest decrease)	1.22 (1.01-1.45)	1.22 (1.01-1.46)
−2.6 to −1.4	.93 (.76-1.14)	.93 (.76-1.14)
−1.5 to .5	1 (reference)	1 (reference)
10 d preceding the index dates§		
−5.1 to −3.0 (highest decrease)	1.30 (1.09-1.56)	1.31 (1.09-1.57)
−3.1 to −2.2	1.06 (.86-1.30)	1.06 (.86-1.30)
−2.3 to −.4	1 (reference)	1 (reference)
15 d preceding the index dates§		
−5.1 to −3.3 (highest decrease)	1.07 (.88-1.31)	1.08 (.88-1.32)
−3.4 to −2.5	1.25 (1.04-1.51)	1.26 (1.04-1.53)
−2.6 to −.9	1 (reference)	1 (reference)

Abbreviation: IRR, incidence rate ratio.

*To define the maximum daily variation in the minimum temperature in a given period preceding the index date (3, 5, 10, or 15 days), we computed the difference between the minimum temperature in each day and the day before and selected the figure corresponding to the highest decrease in any consecutive days. For example, for a 3-day period (day 1, the day before index date; day 2, the day before day 1; day 3, the day before day 2), we selected the lowest value from that obtained in each of the following calculations: index date − day 1; day 1 − day 2; day 2 − day 3.

†Positive figures correspond to a temperature increase and negative figures correspond to decreases in the temperature.

‡IRR adjusted for mean relative daily humidity (%), total daily precipitation (mm^3), and mean temperature (continuous variables) for the day previous to the event and 3, 5, 10, and 15 days preceding the event, respectively, for each period.

§The cutoffs used to define the categories correspond to the tertiles of the maximum decrease in minimum temperature for each period.

the event and the index date (Table 2). When analyzing IRR for the maximum decline in the minimum temperature observed in any 2 consecutive days among the 3, 5, 10, and 15 days preceding the event, the incidence rates were significantly higher when the decreases in the temperatures were more pronounced, in comparison with the days with the lowest temperature variation, for the 5-day (adjusted IRR = 1.22; 95% CI: 1.01-1.46) and 10-day periods (adjusted IRR = 1.31; 95% CI: 1.09-1.57). The association was not significant for the 3 or 15 days preceding the index date (Table 2).

When analyzing the increase in the maximum temperatures in consecutive days, no significant differences were observed, regardless of the period of analysis considered (Table 3). During the study period, there were no heat waves, as defined by the World Meteorology Organization (5 consecutive days on which maximum temperature exceeded by 5°C the average maximum temperatures from the 1961 to 1990 period).[24-26] Therefore, we assessed the potential effect of consecutive days of high temperatures using the alternative criterion[27] of 2 days of maximum temperatures exceeding the 90th percentile of the annual maximum temperature distribution (in our case, exceeding 33.8°C) to define a "heat wave." There were 7 periods meeting this criterion during the study period, but these were not significantly associated with a higher incidence of stroke (crude IRR = 1.04; 95% CI: .60-1.80; humidity- and precipitation-adjusted IRR = 1.07; 95% CI: .61-1.87).

All the analyses were conducted stratified by sex, age (<60 and ≥60 years of age), and stroke subtype (ischemic and hemorrhagic), with strata yielding similar results (data not shown).

Discussion

In Maputo, there was no consistent pattern of variation in the incidence of stroke hospitalizations according to the season or mean temperatures. However, sudden decreases in the minimum temperature over the 5-10 days previous to the event were consistently associated with a 20%-30% increase in the incidence of stroke.

Previous studies conducted in Japan,[8] United Kingdom[11] and United States[7,28] found no seasonality in

Table 3. *Incidence rate ratios for stroke incidence in Maputo, Mozambique, according to the variation in the maximum temperature observed in different periods before the index date**,† *(August 1, 2005, to July 31, 2006)*

	Crude IRR	Adjusted IRR‡
Variation in the maximum temperature observed between the day previous to the index date and the index date§:		
−16.3 to −.8	1 (reference)	1 (reference)
−.9 to 1.2	1.01 (.83-1.22)	1.00 (.83-1.22)
1.3 to 15.0 (highest increase)	1.08 (.90-1.31)	1.08 (.90-1.30)
Maximum increase in the maximum temperature observed in any of 2 consecutive days among:		
3 d preceding the index dates§		
−1.3 to 2.2	1 (reference)	1 (reference)
2.3 to 4.2	.96 (.79-1.17)	.96 (.79-1.16)
4.3 to 15.0 (highest increase)	1.15 (.95-1.38)	1.16 (.96-1.40)
5 d preceding the index dates§		
1.3 to 3.0	1 (reference)	1 (reference)
3.1 to 5.6	1.00 (.82-1.21)	.98 (.80-1.19)
5.7 to 15.0 (highest increase)	1.14 (.95-1.37)	1.16 (.96-1.40)
10 d preceding the index dates§		
.3 to 5.2	1 (reference)	1 (reference)
5.3 to 7.9	1.20 (.99-1.45)	1.20 (.99-1.46)
8.0 to 16.3 (highest increase)	1.16 (.98-1.40)	1.16 (.95-1.42)
15 d preceding the index dates§		
2.3 to 6.1	1 (reference)	1 (reference)
6.2 to 9.6	1.05 (.87-1.26)	1.04 (.84-1.30)
9.7 to 16.3 (highest increase)	1.01 (.83-1.22)	.94 (.75-1.19)

Abbreviation: IRR, incidence rate ratio.

*To define the maximum daily variation in the maximum temperature in a given period preceding the index date (3, 5, 10, or 15 days), we computed the difference between the maximum temperature in each day and the day before and selected the figure corresponding to the highest increase in any consecutive days. For example, for a 3-day period (day 1, the day before index date; day 2, the day before day 1; day 3, the day before day 2), we selected the highest value from the obtained in each of the following calculations: index date − day 1; day 1 − day 2; day 2 − day 3.

†Positive figures correspond to a temperature increase and negative figures correspond to decreases in the temperature.

‡IRR adjusted for mean relative daily humidity (%), total daily precipitation (mm^3), and mean temperature (continuous variables) for the day previous to the event and 3, 5, 10, and 15 days preceding the event, respectively, for each period.

§The cutoffs used to define the categories correspond to the tertiles of the maximum increase in maximum temperature for each period.

stroke occurrence, whereas others, from Argentina,[5] Australia,[12] Finland[9] and Sweden,[10] found stroke to occur more often during the winter. This investigation adds to previous reports a comprehensive characterization of the influence of temperature and temperature variation on the occurrence of stroke in a tropical setting. The absence of a seasonal pattern of variation may be because Mozambique has high temperatures throughout the year. Also, seasonal variation of stroke may be confounded by factors like physical activity and alcohol consumption that may also vary with atmospheric temperature.[7] However, we found no significant association between the day of the week and the incidence of stroke occurrence (data not shown), despite the weekends' known association with binge drinking episodes in this setting.[29] Relative daily humidity was also used as an independent variable to assess its relationship with stroke occurrence; there was no association between the occurrence of stroke and mean relative humidity in the day previous to the event and average relative humidity in the 3, 5, 10 and 15 days preceding the event (data not shown). This is in accordance with the fact that the crude and humidity-adjusted IRR for the relation between temperature and stroke were similar.

The multiple biological mechanisms potentially associated with a higher risk of stroke support that both high and low temperature may have a relation with increased incidence rates.[30] On the one hand, high temperatures have been associated with increased plasmatic viscosity, higher platelet and red cell concentration, increased cholesterol levels, and higher cardiac output. Low temperatures, on the other hand, were shown to induce vasoconstriction, increased blood pressure, enhanced platelet aggregation, sympathetic nervous system activation, and increased levels of C-reactive protein, fibrinogen, and activated VII factor.[31,32] Our results also showed that temperature variations are more likely to affect stroke incidence than absolute temperature which is in accordance with previous evidence from Brazil,[3] Germany,[13] Japan,[33] Korea[4] and Portugal.[34] The clinicians' perception of increased incidence of stroke after sudden drops in temperature is in accordance with our results, and this effect was shown to be more pronounced with minimum temperature variations than with maximum temperature changes, despite the latter are more pronounced. In the Mozambican context, this is possibly because temperature is fairly high throughout the year and cold may have a greater impact on the biological mechanisms involved.[35,36] This is in accordance with previous evidence stating that in warmer climates cold exposure is associated with higher morbidity.[14]

Our results are limited by the fact that the definition of the day of the symptom onset may not be accurate as many patients arrived in the hospital several days after the index date.[18] We do not expect the misclassification to be associated with the temperature variation, and therefore it may have contributed to an underestimation of the association, along with lack of accuracy in the definition of the most relevant lags. Also, this investigation was based on a hospital register, and therefore, the cases considered for our analyses do not represent all the events that occurred in Maputo during the study period; however, there are no population-based estimates of the incidence of stroke in Mozambique, and such data have seldom been obtained in other developing countries. The proportion of nonhospitalized patients was 6.5% in Martinique in 1998-1999[37] and 19.1% in 2005 in India.[38] In Maputo, a high proportion of patients not reaching the hospital may be expected because of the difficult access to transportation and cultural beliefs.[18] This limits the generalization of our results to stroke patients who did not reach a medical facility and our ability to understand the mechanisms underlying the associations observed. Nevertheless, the hospital-based nature of the study is not expected to compromise the validity of the results, which are potentially useful to predict periods of higher affluence to the hospitals because of stroke.

Older individuals are more susceptible to temperature changes, and the relationship between temperature and different stroke subtypes implies distinct pathophysiological mechanisms.[4,6,11,12] Nevertheless, we found no meaningful differences in the relationship between temperature and stroke risk throughout the different age strata, possibly because stroke events in Maputo occur in fairly young individuals, in general less susceptible to temperature changes.[18] Regarding the lack of differences according to stroke subtype, although more than 90% of the events were classified as ischemic or hemorrhagic through computed tomography scan or autopsy, many were not performed during the acute phase of stroke which could have led to misclassification of some ischemic strokes with hemorrhagic transformation as primary hemorrhagic stroke.[18]

The evidence generated by this investigation may help clinicians to predict periods of higher affluence to the hospital because of stroke, according to the day-to-day variations in the minimum atmospheric temperature. Understanding the mechanisms underlying this association may allow the adoption of general measures to ensure an efficient use of the health care resources for the management of acute stroke.

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