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Association between Low Ambient Temperature and the Severity of Acute Ischemic Stroke

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Abstract: *Objective:* To explore the relationships among ambient temperature, ischemic stroke severity, and blood pressure. *Methods:* Meteorological data (2005–2015) were collected from the Guangzhou Meteorological Data Service. Ischemic stroke patients from the Department of Neurology of the First Affiliated Hospital, Sun Yat-sen University were retrospectively evaluated, each winter from 2005 to 2015. Patient demographics, baseline measurements, and National Institute of Health Stroke Scale (NIHSS) score were evaluated. *Results:* Three hundred sixty-two patients were included. The median latency from symptom onset to admission was 2 d (IQR: 1–3 d). During recruitment, the highest and lowest temperatures were 39℃ and 1.3℃, respectively. Hypertension was the most common comorbidity (75.1%). NIHSS scores at admission and discharge were higher in the cold-exposed group than in the controls regardless of the average temperature at admission. In addition, systolic and diastolic blood pressure values at admission were higher in the cold-exposed group than in the controls. When stratified by hypertensive status, the average and minimum temperatures at admission were negatively associated with systolic and diastolic blood pressure values in hypertensive patients. Reductions in the average and minimum temperatures at symptom onset were associated with more severe stroke. *Conclusion:* Ischemic stroke patients with symptom onset in winter had higher systolic blood pressure values and more serious neurologic deficits upon admission.

Keywords: Low ambient temperature; Stroke; Blood pressure; Severity

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1. Introduction

Previous population-based studies have focused on the associations among ambient temperature, stroke morbidity [1-3], hospitalization rate [4-6], and mortality [7-9]. Prospective studies in Germany and Japan have shown a higher risk of ischemic stroke at low temperatures [10,11]. With increasing morbidity, the admission rate of patients with ischemic stroke also increased as the temperature decreased [5,12]. In addition, a multicenter study in China showed that the stroke-associated mortality rates in the 10th and 1st percentiles of the annual temperature distribution are 1.11 and 1.39 times the mortality rate in the 25th percentile, respectively [13]. However, those studies were mainly epidemiological investigations and did not relate the temperature to the clinical data of stroke patients. Thus, a retrospective observational study was performed to explore the relationship between low ambient temperature, the severity of ischemic stroke, and blood pressure.

2. Materials and methods

2.1. Meteorological Data

Meteorological parameters were collected from the Guangzhou meteorological data sharing network service, including daily mean temperature, daily maximum temperature, daily minimum temperature, daily average relative humidity, and daily precipitation data from 2005 to 2015.

2.2. Study patients

This study involved 884 patients with ischemic stroke who were hospitalized in the Department of Neurology of the First Affiliated Hospital, Sun Yat-sen University between December 1st and March 1st of every year from 2005 to 2015 (i.e., 2005.12.01 – 2006.03.01). Eligible patients were selected according to the following inclusion and exclusion criteria.

The inclusion criteria were as follows: (1) patients with acute onset of a focal neurological deficit with infarction confirmed by computed tomography (CT) and/or magnetic resonance imaging (MRI); and (2) patients who were Guangzhou residents at the time of symptom onset.

The exclusion criteria were as follows: (1) patients younger than 18 years old; (2) patients with transient ischemic attacks (TIAs), hemorrhagic strokes, and mixed strokes; (3) patients with cancer or serious heart, liver, kidney, and other diseases that might affect the results; (4) patients with stroke onset to admission times > 14 days or unclear stroke onset time; and (5) patients with insufficient clinical information.

2.3. Data collection

Patient data were obtained from the medical record system, including age, gender, medical history, family history of cardiovascular disease, smoking habits, alcohol consumption, blood pressure at the time of admission, the Trial of Org 10172 in Acute Stroke Treatment (TOAST) classification, and National Institutes of Health Stroke Scale (NIHSS) score at admission and discharge. Moreover, patients' stroke onset times were investigated according to their medical records. The study was approved by the ethics committee of The First Affiliated Hospital, Sun Yat-sen University (No. 2017[052]).

2.4. Statistics

After normality was examined by the Shapiro-Wilk test, continuous variables were reported as the mean ± standard deviation (SD) when normally distributed and as the median (25th–75th percentile) when not normally distributed. Categorical variables were reported as proportions. Between-group comparisons for nonnormally distributed continuous variables were performed with the Mann-Whitney U test, while categorical variables were compared using the χ^2 test or Fisher's exact test. A multiple linear regression model and a simple linear regression model were used to analyze the relationship between systolic blood pressure (SBP), diastolic blood pressure (DBP), and temperature. A univariate logistic regression model and a multivariate logistic regression model were used to analyze factors that affected stroke severity at admission.

A two-sided *P* value < 0.05 was considered statistically significant. Microsoft Excel and Statistical Product and Service Solutions software version 21.0 for Windows (IBM SPSS 21.0) were used for the statistical analyses.

3. Results

3.1. Clinical characteristics of all patients

In total, 884 patients were admitted to the stroke center between December 1st and March 1st of every year from 2005 to 2015. Ultimately, 522 patients were excluded, and 362 patients were included in this study. The flow diagram (**Figure 1**) is shown below.

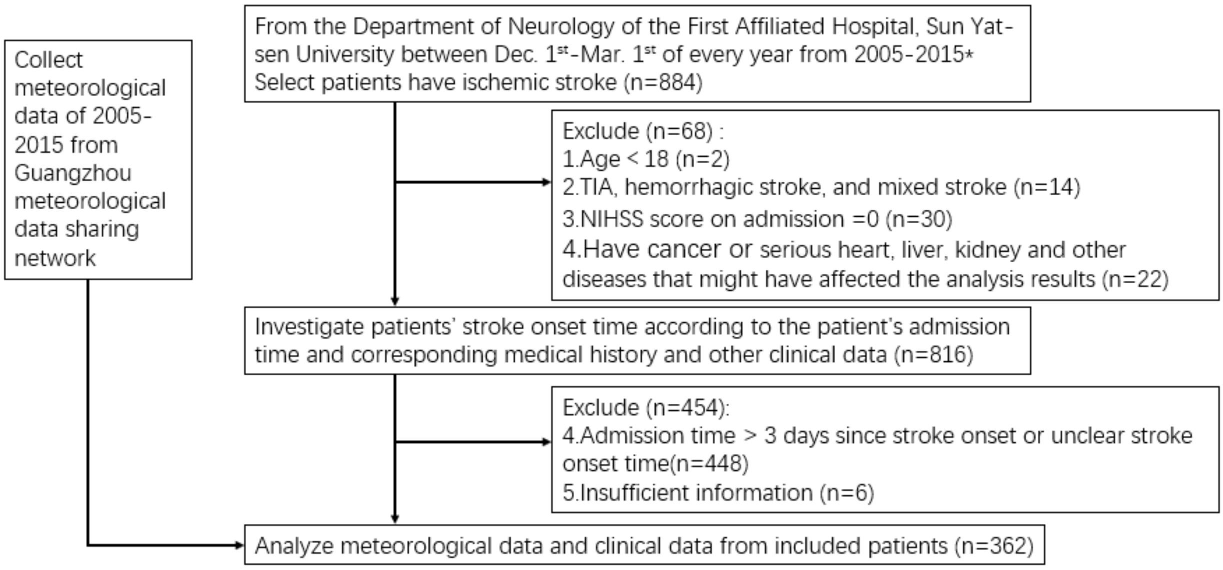

Figure 1. The flow diagram of this study

Table 1 summarizes the clinical characteristics of the included patients. The median age of the included patients was 68.0 years (IQR: 58.0–75.3 years). More than half of the patients were male (62.7%). In terms of comorbidities, hypertension was the most common (75.1%), followed by diabetes mellitus (29.0%), dyslipidemia (22.7%), atrial fibrillation (9.1%) and coronary heart disease (8.6%). Current smokers and alcohol consumers accounted for 33.1% and 18.8% of the included patients, respectively. Approximately 23.2% of the included patients had a history of stroke, while a history of TIA and a family history of cardio-cerebrovascular diseases were less common (3.9% and 10.8%, respectively).

Table 1. Baseline characteristics of eligible patients with ischemic stroke

Variable	*n* [mean (Q1, Q3) or *n* (%)]
Total	362
Age (years)	68.0 (58.0, 75.3)
Male gender	227 (62.7)
Hypertension	272 (75.1)
Diabetes mellitus	105 (29.0)
Dyslipidemia	82 (22.7)
Atrial fibrillation	33 (9.1)
Coronary heart disease	31 (8.6)
Previous Stroke	84 (23.2)
Previous TIA	14 (3.9)
Current smoking	120 (33.1)
Alcohol consumption	68 (18.8)
Family history of cardiovascular disease	39 (10.8)
Time from admission to discharge (days)	13 (10, 18)
Time from symptom onset to admission (days)	2 (1, 3)
SBP at admission (mmHg)	148.5 (130.0, 161.0)
DBP at admission (mmHg)	85.0 (80.0, 92.0)
LAA	193 (53.3)
CE	35 (9.7)
SAO	115 (31.8)
SOE	4 (1.1)
SUE	15 (4.1)
NIHSS score at admission	6 (3, 9)
NIHSS score at discharge	2 (1, 5)

Abbreviation: TIA, transient ischemic attack; LAA, large-artery atherosclerosis; CE, cardioembolism; SAO, small-artery occlusion; SOE, acute stroke of other determined etiology; SUE, stroke of undetermined etiology; NIHSS, National Institutes of Health Stroke Scale.

All the included patients were admitted to our hospital within 3 days after symptom onset. The median latency from symptom onset to admission was 2 d (IQR: 1–3 d). Blood pressure was assessed on the day of admission for each patient. The median SBP at admission was 148.5 mmHg (IQR: 130.0–161.0 mmHg), and the median DBP at admission was 85.0 mmHg (IQR: 80.0–92.0 mmHg). In terms of the severity of stroke, the median NIHSS score at admission was 6 (IQR: 3–9). The median duration of hospital stay was 13 days (IQR: 10–18 days). Most of the included patients recovered, and the median NIHSS score at discharge was 2 (IQR: 1–5). On average, the NIHSS score decreased by 54.5% (IQR: 33.3%–80.0%).

3.2. Meteorological characteristics

Guangzhou is located in the southern part of China and has an oceanic subtropical monsoon climate. **Table 2** summarizes the meteorological data, including the daily average temperature, daily minimum temperature, daily maximum temperature, daily average relative humidity, daily precipitation, and daily average atmospheric pressure in Guangzhou from 2005 to 2015. During this period, the highest and lowest temperatures were 39℃ and 1.3℃, respectively. The means of the daily average temperature, daily minimum temperature, daily maximum temperature, average relative humidity, daily precipitation, and daily average atmospheric pressure were 22.36 ± 6.30℃ (ranging from 34.2℃ to 4.8℃), 19.26 ± 6.38℃ (ranging from 30.4℃ to 1.3℃), 26.94 ± 6.48℃ (ranging from 39.0℃ to 6.2℃), 74.57 ± 12.80% (ranging from 100% to 20%), 30.18 ± 93.72 cm (ranging from 327 cm to 0 cm), and 1.0 ± 0.01 hKPa (ranging from 1.03 hKPa to 0.99 hKPa), respectively. The daily average temperature, average relative humidity, daily precipitation, and daily average atmospheric pressure on the day of symptom onset for each patient are summarized in **Figure 2** as a scatter plot. The most common time of symptom onset was December, January, and February from 2005 to 2015, and the daily average temperature on the day of symptom onset was relatively low.

Table 2. The meteorological data from 2005 to 2015 in Guangzhou

Variable	Maximum	Minimum	Mean ± SD
Daily average temperature (°C)	34.2	4.8	22.36 ± 6.30
Daily minimum temperature (°C)	30.4	1.3	19.26 ± 6.38
Daily maximum temperature (°C)	39	6.2	26.94 ± 6.48
Daily average relative humidity (%)	100	20	74.57 ± 12.80
Daily precipitation (cm)	32.7	0	30.18 ± 93.72
Daily average atmospheric pressure (kPa)	1.03	0.99	1.0 ± 0.01

3.3. Clinical characteristics between cold-exposed group and control group

The 10th percentile (P10) and the 25th percentile (P25) of the annual daily average temperature and daily minimum temperature were defined as the cut-off points [13]. If the temperature of onset day was under the 10th percentile (< P10) of the annual daily average temperature or daily minimum temperature, patients would be classified as the cold-exposed group. If the temperature of onset day was between the 10th percentile and the 25th percentile (P10–P25) of the annual daily average temperature or daily minimum temperature, patients would be classified as the control group. Otherwise, patients were excluded.

When grouped according to the daily average temperature on the day of symptom onset, NIHSS score at admission (7 [IQR: 4–11] vs. 5 [IQR: 3–8.5], $P = 0.01$) and discharge (3 [IQR: 1–6] vs. 2 [IQR: 1–4], $P = 0.01$) were higher in the patients in the cold-exposed group than in the control group. There were no significant differences between the cold-exposed group and the control group with regard to age; sex; the prevalence of hypertension, diabetes mellitus, dyslipidemia, atrial fibrillation, coronary heart disease, previous stroke, or previous TIA; current smoking; alcohol consumption; the presence of a family history of cardio-cerebrovascular diseases; the duration of hospitalization; the latency from symptom onset to admission; SBP at admission; DBP at discharge; or TOAST classification.

When grouped by the daily minimum temperature on the day of symptom onset, NIHSS score at admission (7 [IQR: 4–10] vs. 5 [IQR: 3–8], $P = 0.02$) and discharge (3 [IQR: 1–6] vs. 2 [IQR: 1–4], $P = 0.01$) were higher in the patients in the cold-exposed group than in the control group. In addition, the SBP (156 mmHg [IQR: 136.25–169 mmHg] vs. 147 mmHg [IQR: 130–160 mmHg], $P = 0.01$) and DBP (90 mmHg [IQR: 80–98 mmHg] vs. 85 mmHg [IQR: 80–91 mmHg], $P = 0.03$) at admission were higher in the patients in the cold-exposed group than in those in the control group. There were no differences between the cold-exposed group and the control group with regard to age; sex; the prevalence of hypertension, diabetes mellitus, dyslipidemia, atrial fibrillation, coronary heart disease, previous stroke, and previous TIA; current smoking; alcohol consumption; the presence of a family history of cardio-cerebrovascular diseases; the duration of hospitalization; the latency from symptom onset to admission; or TOAST classification (**Table 3**).

Table 3. Characteristics of the cold-exposed group and the control group stratified by the daily average temperature and the daily minimum temperature on the day of symptom onset

Variable	The daily average temperature			The daily minimum temperature		
	Cold-exposed group (*n* = 111)	Control group (*n* = 173)	*P* value	Cold-exposed group (*n* = 136)	Control group (*n* = 131)	*P* value
Age (years)	68 (58,75)	69 (58,76)	0.96	69.5 (59.25,76)	67 (56,76)	0.25
Male gender	70 (63.06)	107 (61.85)	0.84	85 (62.5)	84 (64.12)	0.78
Hypertension	89 (80.18)	125 (72.25)	0.13	108 (79.41)	94 (71.76)	0.15
Diabetes mellitus	36 (32.43)	46 (26.59)	0.29	42 (30.88)	36 (27.48)	0.54
Dyslipidemia	26 (23.42)	42 (24.28)	0.87	33 (24.26)	33 (25.19)	0.86
Atrial fibrillation	12 (10.81)	16 (9.25)	0.67	15 (11.03)	11 (8.40)	0.47
Coronary heart disease	13 (11.71)	13 (7.51)	0.23	14 (10.29)	10 (7.63)	0.45
Previous stroke	19 (17.12)	45 (26.01)	0.08	24 (17.65)	33 (25.19)	0.13
Previous TIA	4 (3.60)	8 (4.62)	0.91†	2 (1.47)	8 (6.11)	0.09†
Current smoking	33 (29.73)	62 (35.84)	0.29	46 (33.82)	47 (35.88)	0.73
Alcohol consumption	22 (19.82)	32 (18.50)	0.78	29 (21.32)	22 (16.79)	0.35
Family history of cardiovascular disease	16 (14.41)	18 (10.40)	0.31	15 (11.03)	17 (12.98)	0.62
Time from admission to discharge (days)	13 (10,18)	13 (10,17)	0.32	13 (10,18)	13 (9,18)	0.39
Time from symptom onset to admission (days)	2 (1,3)	2 (1,3)	0.24	2 (1,3)	2 (1,3)	0.76
SBP at admission (mmHg)	151 (134,164)	148 (130,163)	0.26	156 (136.25,169)	147 (130,160)	0.01
DBP at admission (mmHg)	90 (80,96)	85 (80,93)	0.1	90 (80,98)	85 (80,91)	0.03
LAA	58 (52.3)	94 (54.3)		70 (51.47)	75 (57.25)	
CE	12 (10.8)	17(9.8)		15 (11.03)	12 (9.16)	
SAO	35 (31.5)	54 (31.2)	0.99‡	43 (31.62)	41 (31.30)	0.42‡
SOE	2 (1.8)	2 (1.2)		2 (1.47)	2 (1.53)	
SUE	4 (3.6)	6 (3.5)		6 (4.41)	1 (0.76)	
NIHSS score at admission	7 (4,11)	5 (3,8.5)	0.01*	7 (4,10)	5 (3,8)	0.02
NIHSS score at discharge	3 (1,6)	2 (1,4)	0.01*	3 (1,6)	2 (1,4)	0.01

Note: Continuous variables were reported as the median (Q1, Q3); categorical variables were reported as the number (%). †Continuity correction; ‡Fisher's exact test. Abbreviation: TIA, transient ischemic attack; LAA, large-artery atherosclerosis; CE, cardioembolism; SAO, small-artery occlusion; SOE, acute stroke of other determined etiology; SUE, stroke of undetermined etiology; SBP, systolic blood pressure; DBP, diastolic blood pressure.

3.4. Correlations between the SBP, DBP, and the temperature on the day of symptom onset

The aforementioned results showed that when grouped according to the minimum temperature on the day of symptom onset, the SBP and DBP at admission were significantly higher in the cold-exposed group than in the control group. To further analyze the relationship between the temperature on the day of symptom onset and the patient's blood pressure at admission, the SBP and DBP of the patients were analyzed by multiple linear regression analysis with the daily average temperature and the daily minimum temperature. Considering the individual differences among the included patients, this model used a stepwise approach to include age and hypertension as adjustment factors. The results are shown in **Table 4**. There was a negative correlation between blood pressure and temperature on the day of symptom onset. When the daily average temperature decreased by 1°C on the day of symptom onset, the SBP at admission increased by 0.695 mmHg, and the DBP at admission increased by 0.619 mmHg. When the daily minimum temperature decreased by 1°C on the day of symptom onset, the SBP at admission increased by 0.756 mmHg, and the DBP at admission increased by 0.558 mmHg.

Table 4. Results of a multiple linear regression analysis of the temperature on the day of symptom onset and the ischemic stroke patients' blood pressure at admission

Dependent variable	Independent variable	Regression coefficient	Std. error	*β*	*t*	*P*
SBP	Daily average temperature†	-0.695	0.265	-0.121	-2.624	0.009
	Daily minimum temperature†	-0.756	0.244	-0.143	-3.098	0.002
DBP	Daily average temperature‡	-0.619	0.159	-0.187	-3.895	< 0.001
	Daily minimum temperature‡	-0.558	0.147	-0.182	-3.791	< 0.001

Note: †Adjusted for hypertension; ‡Adjusted for hypertension and age. Abbreviation: SBP, systolic blood pressure; DBP, diastolic blood pressure.

Furthermore, the patients were stratified by the presence of hypertension, and a simple linear regression analysis of temperature and the patient's blood pressure at admission was performed. The results are shown in **Table 5**. There were negative correlations between the daily average temperature and the daily minimum temperature on the day of symptom onset and hypertension. When the daily average temperature decreased by 1°C on the day of symptom onset, SBP at admission increased by 0.685 mmHg, and DBP at admission increased by 0.611 mmHg in patients with a history of hypertension. When the daily minimum temperature on the day of symptom onset decreased by 1°C, the SBP at admission increased by 0.787 mmHg, and the DBP at admission increased by 0.601 mmHg in hypertensive patients. There were negative correlations between the daily average temperature and the daily minimum temperature on the day of symptom onset and the absence of hypertension. However, the regression coefficient was not statistically significant.

Table 5. Simple linear regression analysis of the blood pressure at admission in ischemic stroke patients with and without hypertension according to the temperature on the day of symptom onset

Group	Dependent variable	Independent variable	Regression coefficient	Std. error	*β*	*t*	*P*
With hypertension	SBP	Daily average temperature	-0.685	0.318	-0.130	-2.156	0.032
		Daily minimum temperature	-0.787	0.295	-0.161	-2.673	0.008
	DBP	Daily average temperature	-0.611	0.188	-0.194	-3.243	0.001
		Daily minimum temperature	-0.601	0.175	-0.205	-3.436	0.001
Without hypertension	SBP	Daily average temperature	-0.729	0.455	-0.168	-1.602	0.113
		Daily minimum temperature	-0.657	0.411	-0.168	-1.600	0.113
	DBP	Daily average temperature	-0.588	0.309	-0.199	-1.903	0.060
		Daily minimum temperature	-0.368	0.282	-0.138	-1.307	0.195

Abbreviation: SBP, systolic blood pressure; DBP, diastolic blood pressure.

3.5. Factors affecting stroke severity at admission

The patient's stroke severity at admission was considered the dependent variable, and the daily average temperature; daily minimum temperature; age; sex; the presence of hypertension, diabetes mellitus, dyslipidemia, atrial fibrillation, coronary heart disease, previous stroke, and previous TIA; current smoking; alcohol consumption; a family history of cardio-cerebrovascular diseases; SBP at admission; DBP at admission; and TOAST classification were used as independent variables for univariate logistic regression analysis. The results are shown in **Table 6**. Lower daily average temperature (OR = 0.941, 95% CI: 0.889–0.996, *P* = 0.036) and the daily minimum temperature on the day of symptom onset (OR = 0.948, 95% CI: 0.901–0.999, *P* = 0.045) and elevated SBP at admission (OR = 1.016, 95% CI: 1.005–1.026, *P* = 0.003) and DBP at admission (OR = 1.022, 95% CI: 1.004–1.04, *P* = 0.017) were associated with more severe stroke at admission.

Table 6. Univariate logistic regression analysis of factors affecting stroke severity at admission

Independent variable	Regression coefficient	Std. error	Wald	*P*	OR value	95% CI
Daily average temperature	-0.061	0.029	4.416	0.036*	0.941	0.889–0.996
Daily minimum temperature	-0.053	0.026	4.019	0.045*	0.948	0.901–0.999
Age (years)	0.005	0.009	0.282	0.595	1.005	0.988–1.022
Male gender	0.093	0.238	0.153	0.696	1.098	0.688–1.750
Hypertension	0.268	0.259	1.066	0.302	1.307	0.786–2.172
Diabetes mellitus	-0.335	0.247	1.840	0.175	0.715	0.441–1.161
Dyslipidemia	0.052	0.275	0.036	0.850	1.053	0.614–1.807
Atrial fibrillation	0.152	0.409	0.139	0.710	1.164	0.523–2.595
Coronary heart disease	-0.110	0.403	0.074	0.785	0.896	0.407–1.972
Previous stroke	0.022	0.272	0.006	0.937	1.022	0.600–1.742
Previous TIA	-0.265	0.570	0.216	0.642	0.767	0.251–2.344
Smoking	-0.110	0.242	0.206	0.65	0.896	0.558–1.439
Alcohol consumption	-0.045	0.292	0.024	0.878	0.956	0.540–1.694
Family history of cardiovascular disease	-0.167	0.361	0.215	0.643	0.846	0.417–1.716
Time from symptom onset to admission (days)	0.114	0.111	1.043	0.307	1.12	0.901–1.393
SBP at admission (mmHg)	0.016	0.005	8.793	0.003	1.016	1.005–1.026
DBP at admission (mmHg)	0.022	0.009	5.730	0.017	1.022	1.004–1.04
LAA	-	-	2.716	0.606	1	–
CE	0.115	0.419	0.076	0.783	1.122	0.494–2.550
SAO	-0.317	0.253	1.568	0.211	0.728	0.444–1.196
SOE	-0.945	1.013	0.872	0.551	0.388	0.053–2.828
SUE	0.066	0.605	0.012	0.913	1.068	0.326–3.500

Abbreviation: TIA, transient ischemic attack; LAA, large-artery atherosclerosis; CE, cardioembolism; SAO, small-artery occlusion; SOE, acute stroke of other determined etiology; SUE, stroke of undetermined etiology; SBP, systolic blood pressure; DBP, diastolic blood pressure; 95% CI, 95% confidence interval.

The factors that were significant in the univariate analysis were included in the multivariate logistic regression for further analysis. Taking into account linear relationships, daily average temperature, daily minimum temperature, SBP at admission, and DBP at admission, the daily average temperature, daily minimum temperature, SBP at admission, DBP at admission, SBP at admission × DBP at admission, daily average temperature × daily minimum temperature, daily average temperature × SBP at admission, daily average temperature × DBP at admission, daily minimum temperature × SBP at admission, and daily minimum temperature × DBP at admission were included in multivariate logistic regression. The results are shown in **Table 7**. The daily minimum temperature on the day of symptom onset (OR = 0.789, 95% CI: 0.991–0.900, $P < 0.001$) and the daily minimum temperature × SBP at admission (OR = 1.001, 95% CI: 1.000–1.002, $P = 0.003$) were related to stroke severity at admission.

Table 7. Multivariable logistic regression analysis of factors affecting stroke severity at admission

Independent variable	Regression coefficient	Std. error	Wald	*P*	OR value	95% CI
Daily minimum temperature	-0.238	0.067	12.465	< 0.001	0.789	0.691–0.900
Daily minimum temperature × SBP at admission (mmHg)	0.001	0	8.829	0.003	1.001	1.000–1.002

Abbreviation: SBP, systolic blood pressure; 95% CI, 95% confidence interval.

4. Discussion

Many epidemiological studies have focused on the effect of ambient temperature on the incidence of stroke, hospitalization, and mortality, but few studies have focused on the severity and possible mechanisms of stroke in patients exposed to low ambient temperature. This present study focused on the incidence of ischemic stroke during winter. When grouped by the temperature on the day of symptom onset, SBP at admission, DBP at admission, NIHSS score at admission, and NIHSS score at discharge were higher in the cold-exposed group than in the control group.

When exposed to cold ambient temperatures in winter, the general population [14], hypertensive patients [15], and patients with their first stroke [10] all experience significant elevation of their SBP and DBP. The increase in blood pressure is more pronounced in the general population over 65 years of age [14]. In addition, Lin *et al*. [16] exposed normotensive rats and stroke-prone renovascular hypertensive rats to artificial cold waves. The results suggested that the fluctuations in blood pressure before and after the artificial cold wave did not differ significantly between normotensive rats and hypertensive rats, with blood pressure values between 160 mmHg and 199 mmHg. In addition, hypertensive rats with blood pressure values over 200 mmHg experienced significant increases in blood pressure after an artificial cold wave. The results of our study were consistent with the above findings. Compared with patients in the control group, the patients in the cold-exposed group (daily minimum temperature on the day of symptom onset lower than the P10 temperature of the whole year) had higher SBP and DBP values at admission. After adjusting for age and hypertension, the daily average temperature and the daily minimum temperature on the day of symptom onset were negatively correlated with SBP and DBP at admission according to the multivariate linear regression. Hypertension was one of the factors affecting blood pressure in the multivariate linear regression. Therefore, the patients were stratified according to their hypertensive status for further analysis. The results showed that SBP and DBP at admission in patients with ischemic stroke and comorbid hypertension were affected by the daily average temperature and the daily minimum temperature on the day of symptom onset. However, for patients without hypertension, SBP and DBP at admission were not significantly correlated with the daily average temperature or the daily minimum temperature on the day of symptom onset. This suggested that a decrease in outdoor temperature had a pronounced effect on blood pressure fluctuations in hypertensive patients.

However, previous studies investigating blood pressure at admission and the severity of stroke have obtained inconsistent results. A prospective registration study showed that higher SBP at admission in patients with ischemic stroke correlated with more severe stroke [17]. In contrast, another stroke registration study showed that increased blood pressure at admission (SBP ≥ 140 mmHg or DBP ≥ 90 mmHg) in patients with ischemic stroke was associated with more mild stroke (NIHSS score < 8) [18]. In addition, studies have shown that high blood pressure (SBP ≥ 211 mmHg or DBP ≥ 111 mmHg) or low blood pressure (SBP ≤ 110 mmHg or DBP ≤ 70 mmHg) can exacerbate the severity of both ischemic and hemorrhagic strokes [19]. The results of this study showed that the patients with ischemic stroke who had higher blood pressure levels had more severe strokes. However, the SBP at admission is not an independent risk factor affecting stroke severity. The stroke severity is also affected by the ambient temperature. The inconsistency of the results of previous studies investigating blood pressure and stroke severity may be explained by the diversity of blood pressure control measures, sample sizes, and other factors, as well as the ambient temperature on the day of symptom onset.

In this study, NIHSS scores at admission and discharge were higher in the cold-exposed group than in the control group. After applying the regression model to explore the factors affecting the severity of ischemic stroke in winter, it was found that decreases in the daily average temperature and the daily minimum temperature on the day of symptom onset and increases in the SBP and DBP at admission were related to more severe strokes. Furthermore, multivariate regression analysis revealed that the daily minimum temperature on the day of symptom onset had a direct impact on stroke severity but also indirectly affected stroke severity via the change in SBP at admission. Similarly, in animal experiments, the researchers examined the pathological cerebral changes in stroke-prone renovascular hypertensive rats and found an increase in the number of infarct lesions in the brain induced by artificial cold waves [20]. This finding also suggests that cold weather may increase stroke severity. However, there have been few studies on the correlation between ambient temperature and stroke severity. Further research in a prospective multicenter study with a large sample size and follow-up investigation is needed.

One limitation of this study was its retrospective nature. Some patients were excluded because of missing data, which may lead to bias. The patients admitted during winter were included and hence the patients admitted in other seasons were unable to be analyzed. All patients came from Guangzhou, and regional bias was not excluded. A prospective multicenter study with a large sample size is needed.

5. Conclusion

Among ischemic stroke patients with the onset of symptoms in winter, compared with those admitted when the ambient temperature was relatively high, those admitted when the ambient temperature was relatively low had higher admission SBP values and more serious neurologic deficits at admission.

Disclosure statement

The authors declare no conflict of interest.

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