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Supplemental Material

Geographic, Demographic, and Temporal Variations in the Association between Heat Exposure and Hospitalization in Brazil: A Nationwide Study between 2000 and 2015

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Figure S5. The fraction (A) and rate (B) of hospitalizations attributable to heat exposure over lag 0−7 days in the 1,814 Brazilian cities during 2000−2015 hot seasons. The best linear unbiased prediction of the cumulative association in each city was used to calculate the attributable burden.

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Table S1. Cause categories of hospitalizations and ICD-10 codes.

No.	Cause categories	ICD-10 codes
1	Certain infectious and parasitic diseases	A00-B99
2	Endocrine, nutritional and metabolic diseases	E00-E90
3	Diseases of the cardiovascular system	I00-I99
4	Diseases of the respiratory system	J00-J99
5	Diseases of the digestive system	K00-K93
6	Diseases of the skin and subcutaneous tissue	L00-L99
7	Diseases of the musculoskeletal system and connective tissue	M00-M99
8	Diseases of the genitourinary system	N00-N99
9	Maternal conditions	O00-O99
10	Certain conditions originating in the perinatal period	P00-P99
11	Injury, poisoning and certain other consequences of external causes	S00-T98

Table S2. Results of meta-regression: the differences in heat-hospitalization association across regions, population subgroups and cause categories for both sex.

	Coefficient (95%CI)	**Z value**	**P value**
Region			
North	0.012 (-0.015, 0.039)	0.9	0.375
Northeast	0.034 (0.025, 0.042)	7.6	< 0.001
Central West	0.017 (0.006, 0.028)	3.0	0.003
Southeast	0.009 (0.002, 0.015)	2.7	0.007
South (reference)	–	–	–
Sex			
Men	0.004 (-0.001, 0.009)	1.4	0.158
Women (reference)	–	–	–
Age (years)			
0−4	0.068 (0.058, 0.078)	13.6	< 0.001
5−9	0.059 (0.046, 0.072)	9.0	< 0.001
10−19	0.040 (0.030, 0.050)	8.0	< 0.001
20−29	0.032 (0.023, 0.041)	6.9	< 0.001
30−39	0.028 (0.018, 0.037)	5.7	< 0.001
40−49	0.014 (0.004, 0.024)	2.7	0.007
50−59	0.004 (-0.006, 0.014)	0.8	0.423
60−69 (reference)	–	–	–
70−79	0.003 (-0.008, 0.013)	0.5	0.597
≥ 80	0.037 (0.026, 0.049)	6.3	< 0.001
Cause category			
Infectious and parasitic diseases	0.141 (0.127, 0.154)	20.6	< 0.001
Endocrine, nutritional and metabolic diseases	0.131 (0.112, 0.150)	13.7	< 0.001
Perinatal conditions	0.090 (0.070, 0.110)	8.8	< 0.001
Injury and poisoning	0.091 (0.079, 0.103)	14.7	< 0.001
Genitourinary diseases	0.079 (0.065, 0.094)	10.4	< 0.001
Skin problems	0.062 (0.041, 0.084)	5.8	< 0.001
Respiratory diseases	0.045 (0.033, 0.057)	7.6	< 0.001
Maternal conditions	0.019 (0.004, 0.035)	2.4	0.016
Musculoskeletal disorders	0.053 (0.034, 0.072)	5.5	< 0.001
Digestive diseases	0.030 (0.017, 0.042)	4.7	< 0.001
Cardiovascular diseases (reference)	–	–	–

Note: The south, women, the elderly 60−69 years and cardiovascular diseases were set as the references for corresponding comparisons considering their lowest effect estimates. City-specific coefficients of the heat-hospitalization association over lag 0−7 days were estimated using quasi-Poisson regression with constrained lag model, with controlling for long-term trend and intra-seasonal variation, day of the week and holidays. CI, confidence interval.

Table S3. Results of meta-regression: the differences in heat-hospitalization association across 10 age-groups for men and for women, respectively; and the difference in heat-hospitalization association between men and women for each age-group.

Years	Men			Women			Men VS Women (reference: Women)		
	Coefficient (95%CI)	**Z value**	**P value**	**Coefficient (95%CI)**	**Z value**	**P value**	**Coefficient (95%CI)**	**Z value**	**P value**
0−4	0.066 (0.053, 0.079)	9.9	< 0.001	0.069 (0.055, 0.082)	10.2	< 0.001	-0.011 (-0.025, 0.003)	-1.5	0.131
5−9	0.060 (0.043, 0.076)	7.0	< 0.001	0.059 (0.041, 0.077)	6.4	< 0.001	-0.005 (-0.026, 0.015)	-0.5	0.607
10−19	0.057 (0.042, 0.072)	7.5	< 0.001	0.030 (0.018, 0.042)	4.8	< 0.001	0.022 (0.009, 0.034)	3.4	0.001
20−29	0.059 (0.045, 0.074)	8.1	< 0.001	0.020 (0.009, 0.032)	3.6	< 0.001	0.033 (0.022, 0.044)	6.0	< 0.001
30−39	0.049 (0.035, 0.063)	6.7	< 0.001	0.014 (0.002, 0.026)	2.3	0.023	0.029 (0.017, 0.041)	4.7	< 0.001
40−49	0.023 (0.009, 0.037)	3.3	0.001	0.005 (-0.008, 0.018)	0.7	0.465	0.013 (0.000, 0.027)	1.9	0.054
50−59	0.005 (-0.009, 0.018)	0.7	0.509	0.003 (-0.011, 0.016)	0.4	0.701	-0.004 (-0.017, 0.009)	-0.6	0.569
60−69 (reference)	−	−	−	−	−	−	-0.006 (-0.020, 0.008)	-0.8	0.411
70−79	-0.002 (-0.016, 0.013)	-0.2	0.836	0.007 (-0.007, 0.022)	1.0	0.306	-0.014 (-0.029, 0.001)	-1.9	0.060
≥ 80	0.013 (-0.003, 0.030)	1.6	0.112	0.055 (0.040, 0.070)	7.1	< 0.001	-0.047 (-0.064, -0.03)	-5.3	< 0.001

Note: The age-group 60−69 years was set as the reference for testing the differences in heat-hospitalization association across 10 age-groups for men and for women. Women were set as the reference for testing the difference in heat-hospitalization association between men and women for each age-group. City-specific coefficients of the heat-hospitalization association over lag 0−7 days were estimated using quasi-Poisson regression with constrained lag model, with controlling for long-term trend and intra-seasonal variation, day of the week and holidays. CI, confidence interval.

Table S4. Hospitalizations (with 95% empirical confidence intervals) attributable to heat exposure over lag 0−7 days in the 1,814 Brazilian cities during 2000−2015 hot seasons for men and women.

	Attributable cases		Attributable fraction (%)		Crude attributable rate (per 100,000 population)		Age-standardized attributable rate (per 100,000 population)	
	Men	Women	Men	Women	Men	Women	Men	Women
National	1,381,501 (725,616, 2,004,986)	1,682,369 (857,792, 2,468,353)	6.8 (3.6, 9.9)	5.8 (3.0, 8.5)	120 (63, 175)	143 (73, 209)	121 (35, 200)	141 (52, 225)
Region								
North	26,021 (-4,826, 54,635)	36,195 (- 4,051, 74,206)	5.7 (-1.1, 12.0)	4.4 (-0.5, 9.1)	81 (-15, 170)	116 (-13, 238)	111 (-141, 322)	141 (-156, 396)
Northeast	370,430 (133,241, 595,991)	520,157 (146,838, 875,118)	7.2 (2.6, 11.5)	6.0 (1.7, 10.1)	117 (42, 188)	159 (45, 267)	119 (23, 208)	162 (56, 261)
Central West	132,794 (60,175, 201,265)	187,444 (72,257, 295,342)	8.5 (3.8, 12.9)	8.2 (3.2, 12.9)	154 (70, 233)	216 (83, 340)	149 (-7, 288)	213 (39, 368)
Southeast	593,941 (378,864, 797,642)	703,264 (487,630, 909,685)	6.2 (4.0, 8.4)	5.6 (3.9, 7.2)	111 (71, 149)	127 (88, 164)	114 (52, 173)	123 (68, 176)
South	237,258 (175,440, 297,177)	235,869 (178,930, 291,942)	6.7 (5.0, 8.4)	5.1 (3.9, 6.3)	135 (100, 169)	131 (100, 163)	125 (47, 199)	124 (33, 211)
Age (years)								
0−4	351,358 (183,935, 503,148)	325,899 (167,728, 464,361)	11.6 (6.1, 16.6)	13.4 (6.9, 19.1)	394 (206, 564)	381 (196, 543)	−	−
5−9	103,546 (47,138, 155,542)	80,184 (26,571, 127,897)	10.4 (4.8, 15.7)	11.4 (3.8, 18.2)	110 (50, 165)	88 (29, 141)	−	−
10−19	159,859 (70,190, 242,985)	229,631 (91,568, 361,610)	10.7 (4.7, 16.2)	6.3 (2.5, 9.9)	75 (33, 114)	111 (44, 175)	−	−
20−29	230,422 (92,403, 357,689)	384,689 (151,324, 609,199)	10.9 (4.4, 16.8)	5.1 (2.0, 8.1)	109 (44, 169)	184 (72, 291)	−	−
30−39	229,888 (91,419, 357,884)	215,799 (93,172, 334,537)	9.6 (3.8, 14.9)	4.9 (2.1, 7.5)	126 (50, 197)	117 (51, 182)	−	−
40−49	156,278 (53,989, 252,694)	112,953 (21,995, 199,908)	6.0 (2.1, 9.7)	4.0 (0.8, 7.1)	106 (37, 171)	73 (14, 130)	−	−
50−59	84,116 (-11,741, 175,171)	74,254 (-738, 145,793)	3.3 (-0.5, 6.8)	3.2 (0.0, 6.2)	81 (-11, 168)	65 (-1, 128)	−	−
60−69	15,126 (-54,822, 82,044)	37,053 (-28,208, 99,168)	0.7 (-2.6, 3.9)	2.0 (-1.5, 5.3)				
70-79	-2,211 (-62,085, 54,757)	52,696 (-9,711, 111,112)	-0.1 (-3.8, 3.4)	3.2 (-0.6, 6.8)	27 (-135, 181)	146 (15, 269)	−	−
≥ 80	15,557 (-26,151, 54,658)	107,343 (57,987, 153,605)	1.7 (-2.8, 5.9)	8.8 (4.8, 12.7)				

Note: Heat exposure was defined as the increase in daily mean temperature during 2000−2015 hot seasons (the hottest four consecutive months for each city). The best linear unbiased prediction of the cumulative association in each city was used to calculate the attributable burden.

Table S5. Results of sensitivity analyses: percentage change in the risk of hospitalization every 5°C increase in daily mean temperature during the hot season (at the national level).

Group	Percentage change in the risk of hospitalization (%)	I^2 value
1,814 cities		
Primary model	4.0 (3.7, 4.3)	28.65
Lag = 0−8	3.7 (3.4, 4.0)	29.35
Lag = 0−9	3.5 (3.1, 3.8)	29.75
Df = 4	3.8 (3.6, 4.1)	28.40
Df = 5	4.1 (3.8, 4.4)	28.99
193 cities		
Primary model	4.5 (3.6, 5.4)	38.95
Station-based temperature	5.0 (4.1, 5.9)	41.38
Relative humidity	4.0 (3.2, 4.8)	39.30

Note: Lag 0−7 days and three degrees of freedom (df) were used for the primary model. Data from 1,814 cities during 2000−2015 were used for sensitivity analyses of changing lag from 0−7 to 0−9 days and df from three to five. Data from 193 cities during 2000−2012 were used for comparing the performance of gridded and station-based temperature data, and for assessing the potential confounding effect of relative humidity.

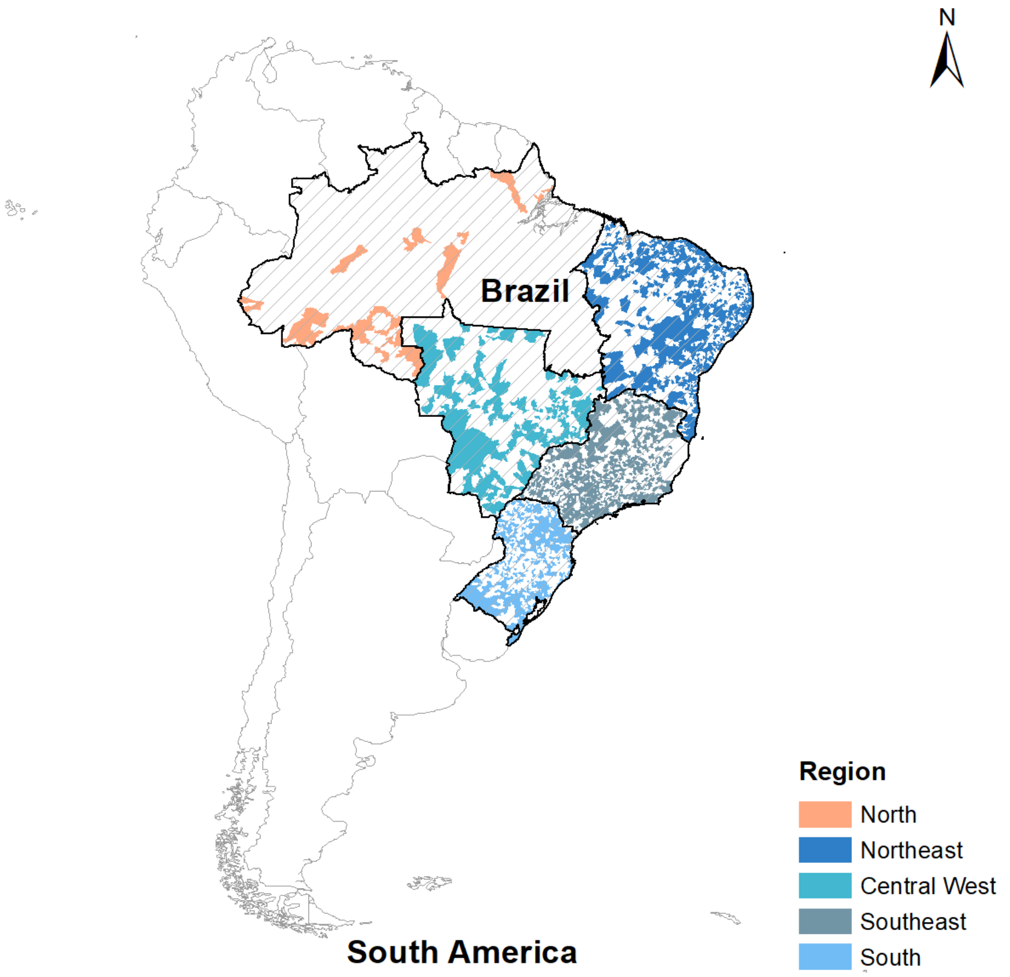

Figure S1. Distribution of the enrolled 1,814 cities across the five Brazilian regions, and the location of Brazil in South America.

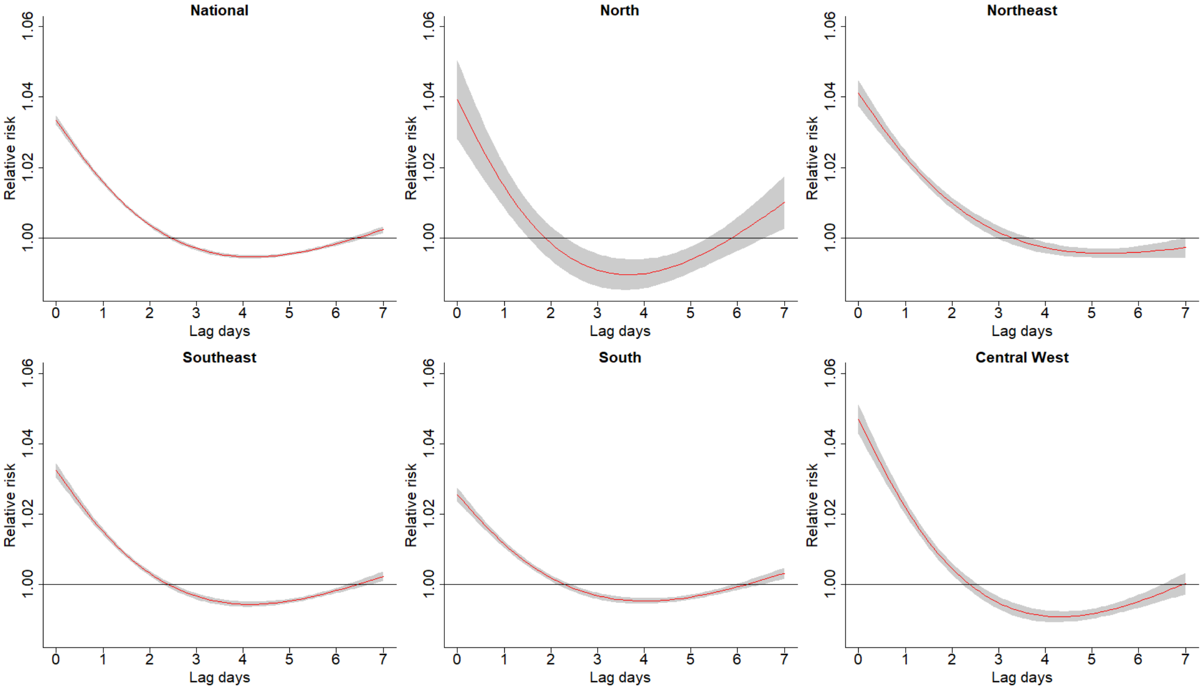

Figure S2. The effect of heat exposure (5°C increase in daily mean temperature) on hospitalizations across lag 0−7 days by region during 2000−2015 hot seasons. City-specific heat-hospitalization associations were estimated using quasi-Poisson regression with constrained lag model, which were then pooled at the regional and national levels using random-effect meta-analyses. Long-term trend and intra-seasonal variation, day of the week and holidays were controlled for.

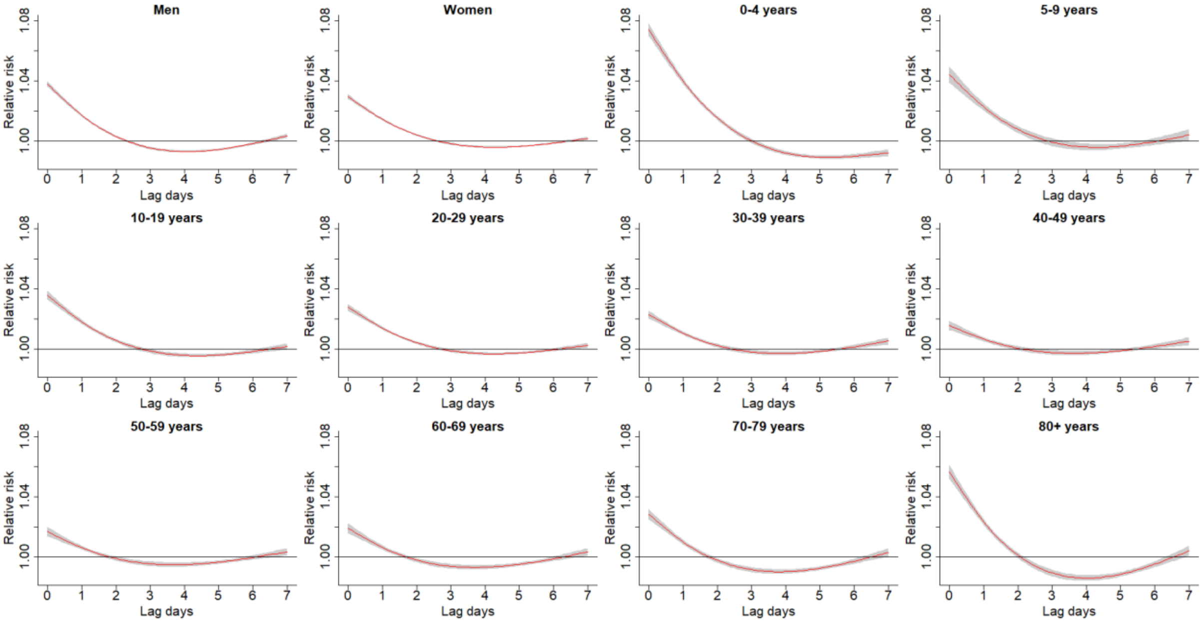

Figure S3. The effect of heat exposure (5°C increase in daily mean temperature) on hospitalizations across lag 0−7 days by sex and age-group during 2000−2015 hot seasons. City-specific heat-hospitalization associations were estimated using quasi-Poisson regression with constrained lag model, which were then pooled at the national level using random-effect meta-analyses. Long-term trend and intra-seasonal variation, day of the week and holidays were controlled for.

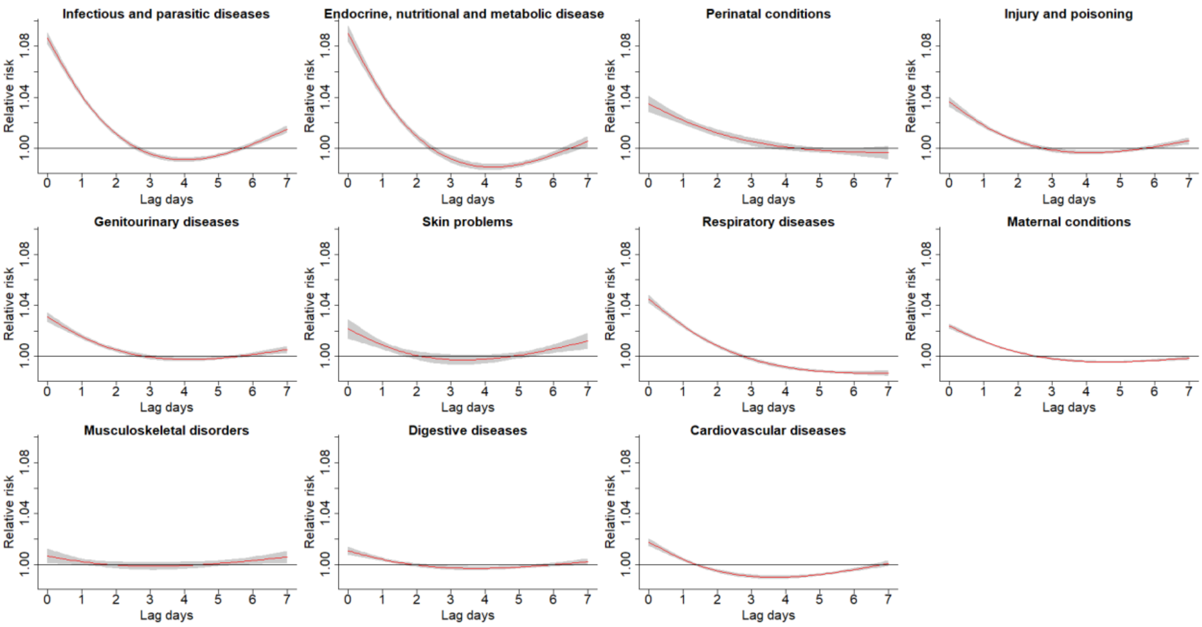

Figure S4. The effect of heat exposure (5°C increase in daily mean temperature) on hospitalizations across lag 0−7 days by cause category during 2000−2015 hot seasons. City-specific heat-hospitalization associations were estimated using quasi-Poisson regression with constrained lag model, which were then pooled at the national level using random-effect meta-analyses. Long-term trend and intra-seasonal variation, day of the week and holidays were controlled for.

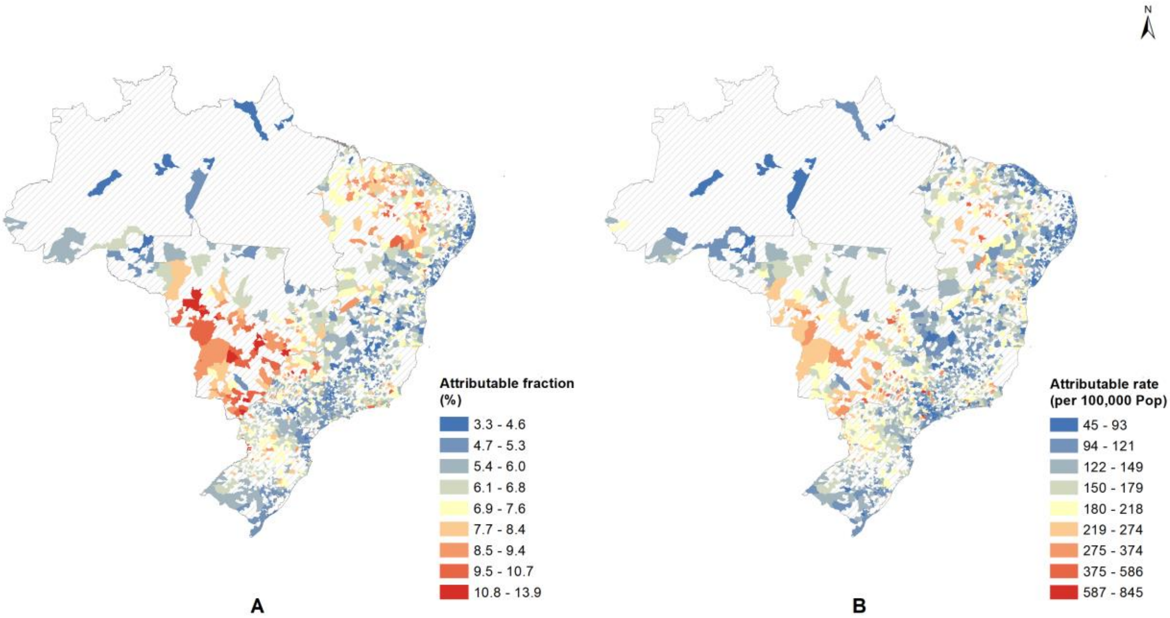

Figure S5. The fraction (A) and rate (B) of hospitalizations attributable to heat exposure over lag 0−7 days in the 1,814 Brazilian cities during 2000−2015 hot seasons. The best linear unbiased prediction of the cumulative association in each city was used to calculate the attributable burden.

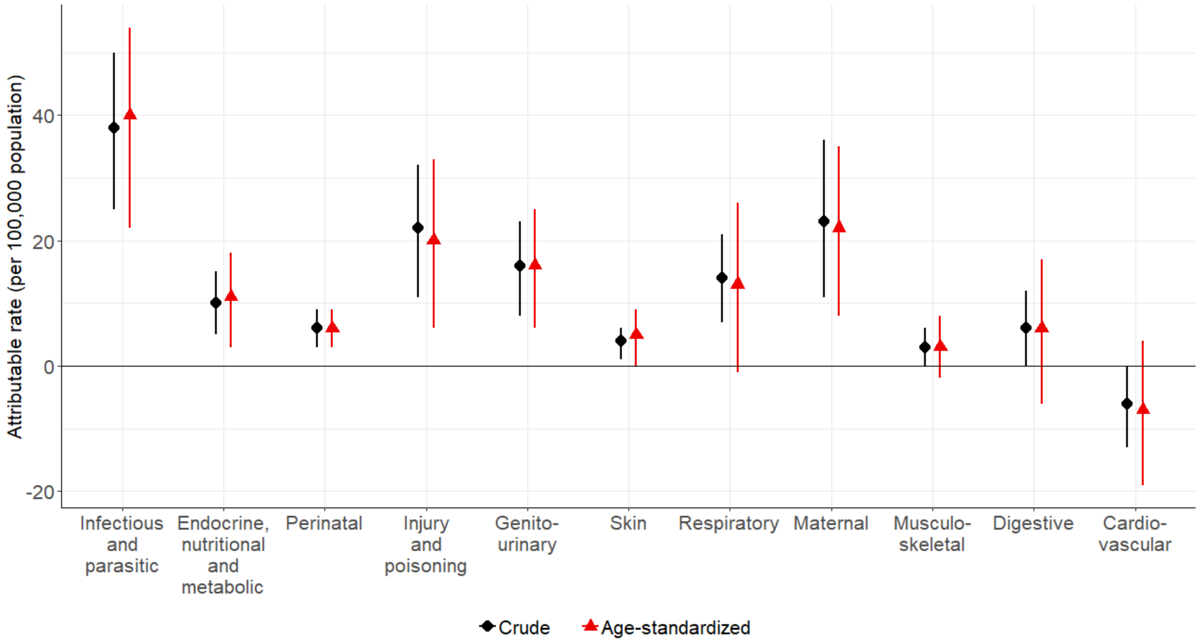

Figure S6. The attributable rates (crude and age-standardized) of hospitalization for 11 cause categories during 2000−2015 hot seasons. The best linear unbiased prediction of the cumulative association in each city was used to calculate the attributable burden.

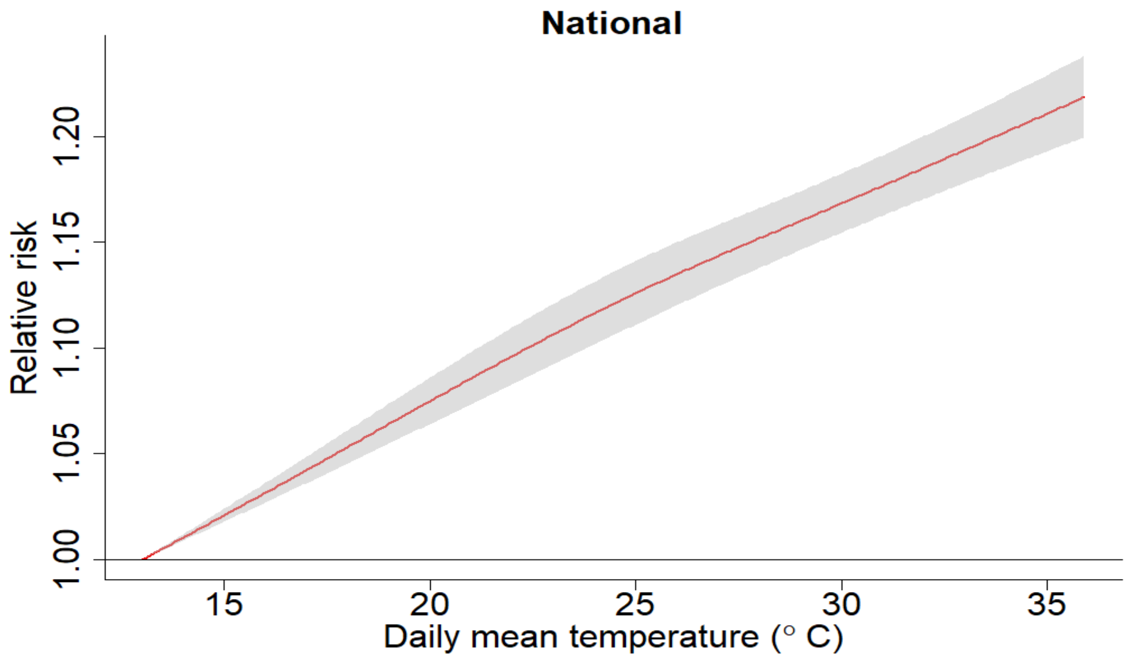

Figure S7. Association between daily mean temperature and hospitalization during 2000−2015 hot seasons (at the national level) modelled using a distributed lag non-linear model. A natural cubic spline with two degrees of freedom was applied for daily temperature. Long-term trend and intra-seasonal variation, day of the week and holidays were controlled for.