# Supplemental Materials

# Extreme environmental temperatures and motorcycle crashes: A time-series analysis

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**Table S1.** Definitions of the temperature and indices which are used in the study.

| Parameter | Definition | Calculation |
|---|---|---|
| Maximum Temperature (°C) | The maximum recorded temperature during 24 hrs. | -- |
| Minimum Temperature (°C) | The minimum recorded temperature during 24 hrs. | -- |
| Mean Temperature (°C) | The average of recorded temperature during 24 hrs. | Average of all hourly recorded temperature during 24 hrs. |
| Apparent temperature (°C) | The equivalent temperature is perceived by humans, by the combined effects of air temperature, relative humidity, and wind speed (Nguyen et al. 2014). | $AT = T + 0.33\ vp - 0.7\ v - 4$ |
| Effective temperature (°C) | The temperature in an environment with 50% relative humidity in which a hypothetical person experiences the same amount of heat losses as in the situation under analysis (Sala-Lizarraga et al. 2019). | $T - 0.4 \times (T - 10) \times (1 - (RH\ /100))$ |
| Net effective temperature (°C) | Net effective temperature (NET) integrates temperature, relative humidity, and wind speed as a cooling indicator (Hentschel 1986). | $37 - \frac{37 - T}{0.68 - 0.0014RH + \frac{1}{1.76 + 1.4V^{0.75}}} - 0.9T \times (1 - \frac{RH}{100})$ |
| Humidex temperature (°C)* | perceived thermal feeling of a person, by combining the effect of heat and humidity (Rana et al. 2013). | $T + 0.5555 \times (vp - 10)$ |
| Wet bulb globe temperature (°C) | The measure of the heat stress in direct sunlight, takes into account: temperature, humidity, and wind speed (Budd 2008, Zhao et al. 2015). | $0.567\ T \times 0.393\ vp \times 3.94$ |

T: dry globe temperature (°C); vp: vapor pressure (Pa; for Humidex mbar; for WBGT as hPa); RH: relative humidity (%); v: wind velocity (m/s)
*: Humidex can also be regarded as a unitless index.

**References:**


Budd, G. M. (2008). Wet-bulb globe temperature (WBGT)—its history and its limitations. *Journal of Science and Medicine in Sport*, *11*(1), 20-32.

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Sala-Lizarraga, J. M., & Perez, A. P. (2019). *Exergy Analysis and Thermoeconomics of Buildings: Design and Analysis for Sustainable Energy Systems*. Butterworth-Heinemann.

Zhao, Y., Ducharne, A., Sultan, B., Braconnot, P., & Vautard, R. (2015). Estimating heat stress from climate-based indicators: present-day biases and future spreads in the CMIP5 global climate model ensemble. *Environmental Research Letters*, *10*(8), 084013.

**Table S2.** The number of "heat wave" days during 2011-2017 (based on different heat wave definitions borrowed from Kent et.al.; 2014), and the corresponding number of daily medical attendance for motorcycle accidents (mean ± SD) at each heat wave definition.

| Code | Heat wave definition | Number of days in the definition | Number of daily medical attendance for motorcycle accidents in definition (Mean ± SD) |
|---|---|---|---|
| H01 | Mean daily temperature > 95th percentile for ≥ 2 consecutive days | 19 | 19.21 ± 4.26 |
| H02 | Mean daily temperature > 90th percentile for ≥ 2 consecutive days | 74 | 19.79 ± 5.30 |
| H03 | Mean daily temperature > 98th percentile for ≥ 2 consecutive days | 4 | 15.25 ± 2.87 |
| H04 | Mean daily temperature > 99th percentile for ≥ 2 consecutive days | 0 | - |
| H05 | Minimum daily temperature > 95th percentile for ≥ 2 consecutive days | 12 | 19.83 ± 4.87 |
| H06 | Maximum daily temperature > 95th percentile for ≥ 2 consecutive days | 4 | 21.75 ± 5.85 |
| H07 | Maximum daily temperature ≥ 81st percentile every day, ≥ 97.5$^{th}$ percentile for ≥ 3 nonconsecutive days, and consecutive day average ≥ 97.5th percentile | 4 | 15.25 ± 2.87 |
| H08 | Maximum daily apparent temperature > 85th percentile for ≥ 1 day | 16 | 19.75 ± 4.41 |
| H09 | Maximum daily apparent temperature > 90th percentile for ≥ 1 day | 11 | 18.90 ± 5.10 |
| H10 | Maximum daily apparent temperature > 95th percentile for ≥ 1 day | 4 | 15.25 ± 2.87 |
| H11 | Maximum daily temperature > 35°C (95°F) for ≥ 1 day | 625 | 17.90 ± 5.57 |
| H12 | Minimum daily temperature > 26.7°C (80.1°F) or maximum daily temperature > 40.6°C (105.1°F) for ≥ 2 consecutive days | 37 | 20.83 ± 5.59 |
| H13 | Maximum daily heat index* > 80°F for ≥ 1 day | 84 | 19.92 ± 5.32 |
| H14 | Maximum daily heat index > 90°F for ≥ 1 day | 60 | 20.90 ± 5.08 |
| H15 | Maximum daily heat index > 105°F for ≥ 1 day | 19 | 19.73 ± 5.76 |
| H16 | Maximum daily heat index > 130°F for ≥ 1 day | 12 | 19.91 ± 5.17 |

* Heat index is a function of air temperature and humidity, parameterized to take account of other environmental factors.

Reference: Kent, Shia T., et al. "Heat waves and health outcomes in Alabama (USA): the importance of heat wave definition." Environmental health perspectives 122.2 (2014): 151.

**Table S3.** The relative risk of medical attendance for motorcycle crashes due to exposure to the daily minimum temperature at 1st, 25th, 75th, and 99th percentile of minimum temperature compared to the temperature with minimum effect with models additionally adjusted for dust visibility.

| Lag effect | Extremely cold | Cold | Hot | Extremely hot |
|---|---|---|---|---|
| Minimum temperature | | | | |
| Lag0 | 1.05 (1.00: 1.11) | 1.01 (0.99: 1.02) | 1.05 (0.99: 1.10) | **1.08 (1.01: 1.16)** |
| Lag1 | 1.01 (0.97: 1.05) | **1.02 (1.01: 1.03)** | 1.01 (0.98: 1.05) | 1.05 (1.00: 1.10) |
| Lag2 | 1.01 (0.97: 1.06) | **1.02 (1.01: 1.03)** | 1.02 (0.98: 1.05) | 1.04 (0.99: 1.09) |
| Lag3 | **1.07 (1.01: 1.13)** | 1.01 (0.99: 1.02) | 1.06 (1.00: 1.11) | 1.05 (0.98: 1.12) |
| Mean temperature | | | | |
| Lag0 | 1.05 (0.99: 1.12) | 1.01 (0.99: 1.03) | 1.06 (1.00: 1.13) | **1.10 (1.01: 1.19)** |
| Lag1 | 1.03 (0.98: 1.08) | **1.02 (1.01: 1.04)** | 1.02 (0.97: 1.06) | 1.05 (0.99: 1.11) |
| Lag2 | 1.03 (0.98: 1.08) | **1.02 (1.01: 1.04)** | 1.01 (0.97: 1.06) | 1.03 (0.97: 1.09) |
| Lag3 | 1.04 (0.98: 1.11) | 1.01 (0.99: 1.04) | 1.05 (0.99: 1.11) | 1.04 (0.96: 1.12) |
| Maximum temperature | | | | |
| Lag0 | 1.04 (0.98: 1.09) | 1.01 (0.99: 1.03) | 1.05 (0.99: 1.11) | 1.07 (0.99: 1.15) |
| Lag1 | **1.04 (1.01: 1.08)** | 1.01 (1.00: 1.03) | 1.03 (0.99: 1.08) | 1.06 (1.00: 1.12) |
| Lag2 | 1.04 (1.00: 1.08) | **1.02 (1.01: 1.03)** | 1.02 (0.98: 1.06) | 1.04 (0.98: 1.09) |
| Lag3 | 1.01 (0.96: 1.07) | **1.03 (1.01: 1.05)** | 1.01 (0.96: 1.07) | 1.00 (0.93: 1.08) |

RR: Relative risk, CI: Confidence interval.

Extreme hot and hot conditions were calculated by comparing the 75th and 99th percentile of the distribution. Extreme cold and cold conditions were also calculated using the 1st and 25th percentile of the distribution.

For minimum temperature: 1st percentile: -5.9 °C; 25th percentile: 4.2 °C; 50th percentile (median):12.9 °C; 75th percentile: 20.8 °C; 99th percentile: 28.3 °C.

For maximum temperature: 1st percentile: 3.1 °C; 25th percentile: 15.7 °C; 50th percentile (median):26.9 °C; 75th percentile: 35.5 °C; 99th percentile: 42.4 °C.

For mean temperature: 1st percentile: -0.7 °C; 25th percentile: 9.9 °C; 50th percentile (median):19.9 °C; 75th percentile: 28.2 °C; 99th percentile: 35.1 °C.

The model included the following variables: minimum temperature, the long-time trend, day of the week, holidays, raining, wind velocity, visibility

**Table S4.** The relative risk of daily medical attendance for motorcycle accidents according to different heat wave definitions.

| Heat wave definition* | Heat wave day (yes/no) | Accident frequency | | Lag specific relative risk** | |
|---|---|---|---|---|---|
| | | Mean | Standard Deviation | Lag 0 | Lag 03 |
| H01 | No | 15.76 | 5.92 | Reference | Reference |
| | Yes | 19.21 | 4.26 | **1.08 (1.01: 1.16)** | 1.13 (1.00: 1.28) |
| H02 | No | 15.66 | 5.89 | Reference | Reference |
| | Yes | 19.80 | 5.30 | **1.07(1.03: 1.11)** | **1.16(1.09: 1.23)** |
| H03 | No | 15.79 | 5.92 | Reference | Reference |
| | Yes | 15.25 | 2.87 | 0.99(0.84: 1.16) | 1.10(0.82: 1.48) |
| H04 | No | 15.78 | 5.91 | NA | NA |
| | Yes | -- | -- | NA | NA |
| H05 | No | 15.77 | 5.91 | Reference | Reference |
| | Yes | 19.83 | 4.87 | **1.12(1.03: 1.23)** | **1.24(1.07: 1.44)** |
| H06 | No | 15.78 | 5.91 | Reference | Reference |
| | Yes | 21.75 | 5.85 | 1.09 (0.95: 1.26) | **1.41(1.04: 1.90)** |
| H07 | No | 15.79 | 5.92 | Reference | Reference |
| | Yes | 15.25 | 2.87 | 0.99(0.84: 1.16) | 1.10(0.82: 1.48) |
| H08 | No | 15.76 | 5.92 | Reference | Reference |
| | Yes | 19.75 | 4.41 | 1.08(1.00: 1.16) | 1.12 (0.98: 1.28) |
| H09 | No | 15.78 | 5.91 | Reference | Reference |
| | Yes | 18.91 | 5.10 | **1.12 (1.03: 1.23)** | 1.18 (1.00: 1.40) |
| H10 | No | 15.79 | 5.92 | Reference | Reference |
| | Yes | 15.25 | 2.87 | 0.99(0.84: 1.16) | 1.10(0.82: 1.48) |
| H11 | No | 15.00 | 5.85 | Reference | Reference |
| | Yes | 17.91 | 5.57 | **1.05(1.02: 1.08)** | **1.15(1.10: 1.20)** |
| H12 | No | 15.71 | 5.88 | Reference | Reference |
| | Yes | 20.84 | 5.59 | **1.09(1.03: 1.14)** | **1.12(1.03: 1.21)** |
| H13 | No | 15.63 | 5.88 | Reference | Reference |
| | Yes | 19.93 | 5.32 | **1.06(1.02: 1.10)** | **1.18(1.11: 1.26)** |
| H14 | No | 15.65 | 5.87 | Reference | Reference |
| | Yes | 20.90 | 5.08 | **1.08(1.03: 1.12)** | **1.18(1.10: 1.27)** |
| H15 | No | 15.76 | 5.92 | Reference | Reference |
| | Yes | 19.74 | 5.76 | 1.07 (1.00: 1.15) | **1.23 (1.06: 1.42)** |
| H16 | No | 15.77 | 5.91 | Reference | Reference |
| | Yes | 19.92 | 5.17 | **1.11(1.01: 1.21)** | **1.34 (1.11: 1.63)** |

*: for detailed information on heat waves refer to table S2.

** Models are adjusted for relative humidity, rain, wind velocity, day of the week, long-term trend, and holidays.

**Table S5.** The relative risk of medical attendance for motorcycle collision due to exposure to daily Humidex, and Wet Bulb Globe Temperature (WBGT) at 1st, 25th, 75th, and 99th percentile of indices compared to the value with lowest effect size (12.1, and 14.5 °C for Humidex and WBGT respectively).

| Lag effect | Extremely cold | Cold | Hot | Extremely hot |
|---|---|---|---|---|
| Humidex | | | | |
| Lag0 | **1.23 (1.14: 1.33)** | 1.02 (1.00: 1.04) | **1.12 (1.04: 1.20)** | **1.26 (1.16: 1.38)** |
| Lag1 | 1.02 (0.96: 1.08) | **1.03 (1.01: 1.05)** | 1.03 (0.98: 1.09) | **1.08 (1.01: 1.15)** |
| Lag2 | 1.01 (0.95: 1.07) | **1.03 (1.01: 1.05)** | 1.02 (0.97: 1.07) | 1.02 (0.95: 1.08) |
| Lag3 | **1.20 (1.11: 1.29)** | **1.03 (1.01: 1.05)** | 1.06 (0.99: 1.14) | 1.05 (0.96: 1.15) |
| WBGT (Wet Bulb Globe Temperature) | | | | |
| Lag0 | **1.24 (1.14: 1.34)** | 1.02 (1.00: 1.05) | **1.12 (1.04: 1.20)** | **1.25 (1.15: 1.37)** |
| Lag1 | 1.02 (0.96: 1.08) | **1.03 (1.01: 1.05)** | 1.03 (0.98: 1.08) | 1.07 (1.00: 1.13) |
| Lag2 | 1.01 (0.95: 1.07) | **1.03 (1.01: 1.05)** | 1.01 (0.96: 1.06) | 1.01 (0.95: 1.07) |
| Lag3 | **1.20 (1.11: 1.29)** | 1.03 (1.00: 1.05) | 1.07 (1.00: 1.14) | 1.06 (0.97: 1.15) |

RR: Relative risk, CI: Confidence interval.

Extreme hot and hot conditions were calculated by comparing the 75th and 99th percentile of the distribution. Extreme cold and cold conditions were also calculated using the 1st and 25th percentile of the distribution.

For Humidex: 1st percentile: -4.6 °C; 25th percentile: 8 °C; 50th percentile (median):18.6 °C; 75th percentile: 27 °C; 99th percentile: 35.6 °C.

For WBGT: 1st percentile: -16.1 °C; 25th percentile: -1.5 °C; 50th percentile (median):10.2 °C; 75th percentile: 18.8 °C; 99th percentile: 26.1 °C.

The model included the following variables: apparent temperature, the long-time trend, day of the week, holidays, rain,

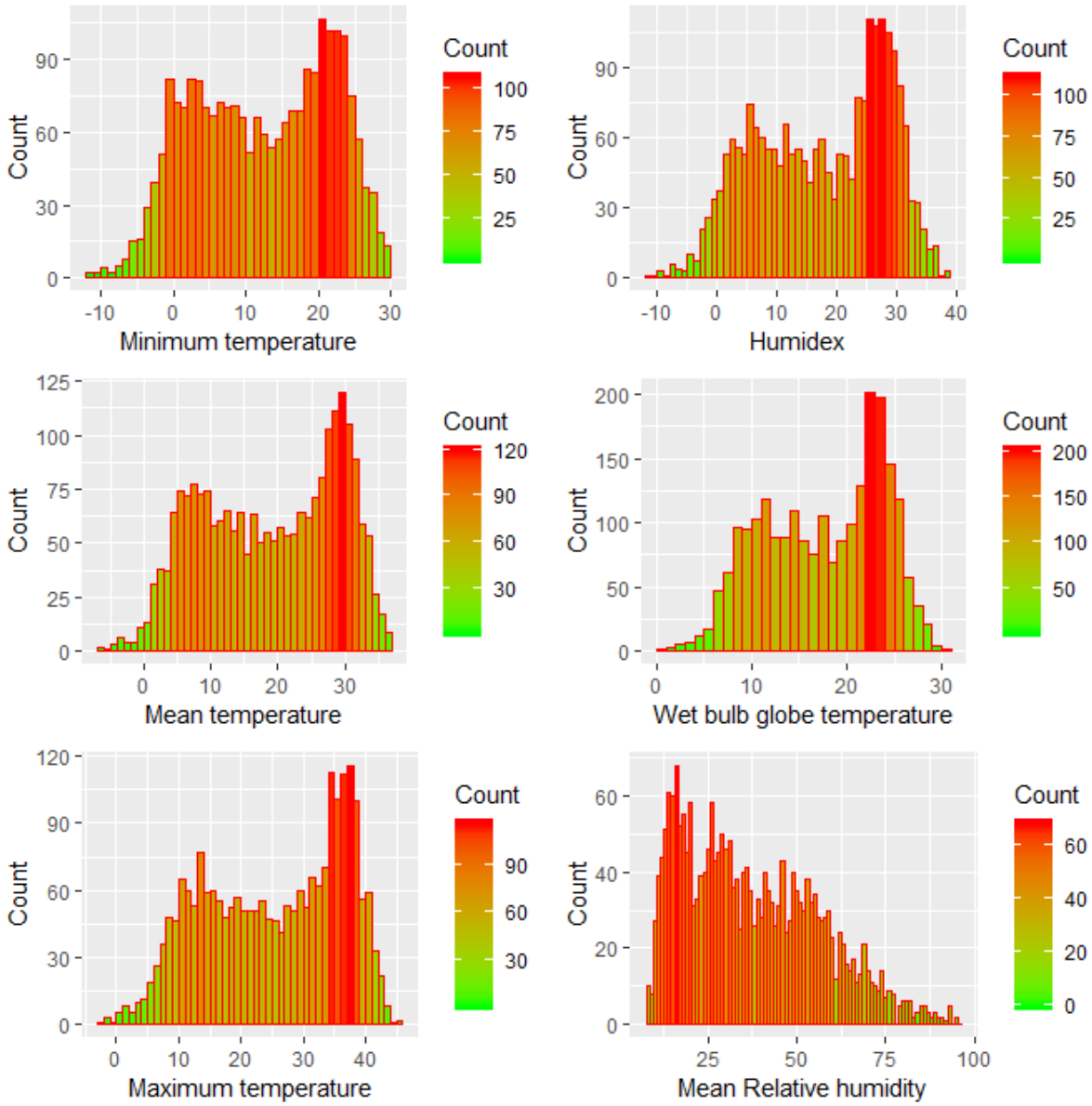


**Figure S1.** Distribution of thermal and meteorological parameters in the study period (March 2011 to June 2017) based on the readings from the nearest station to Sabzevar city.

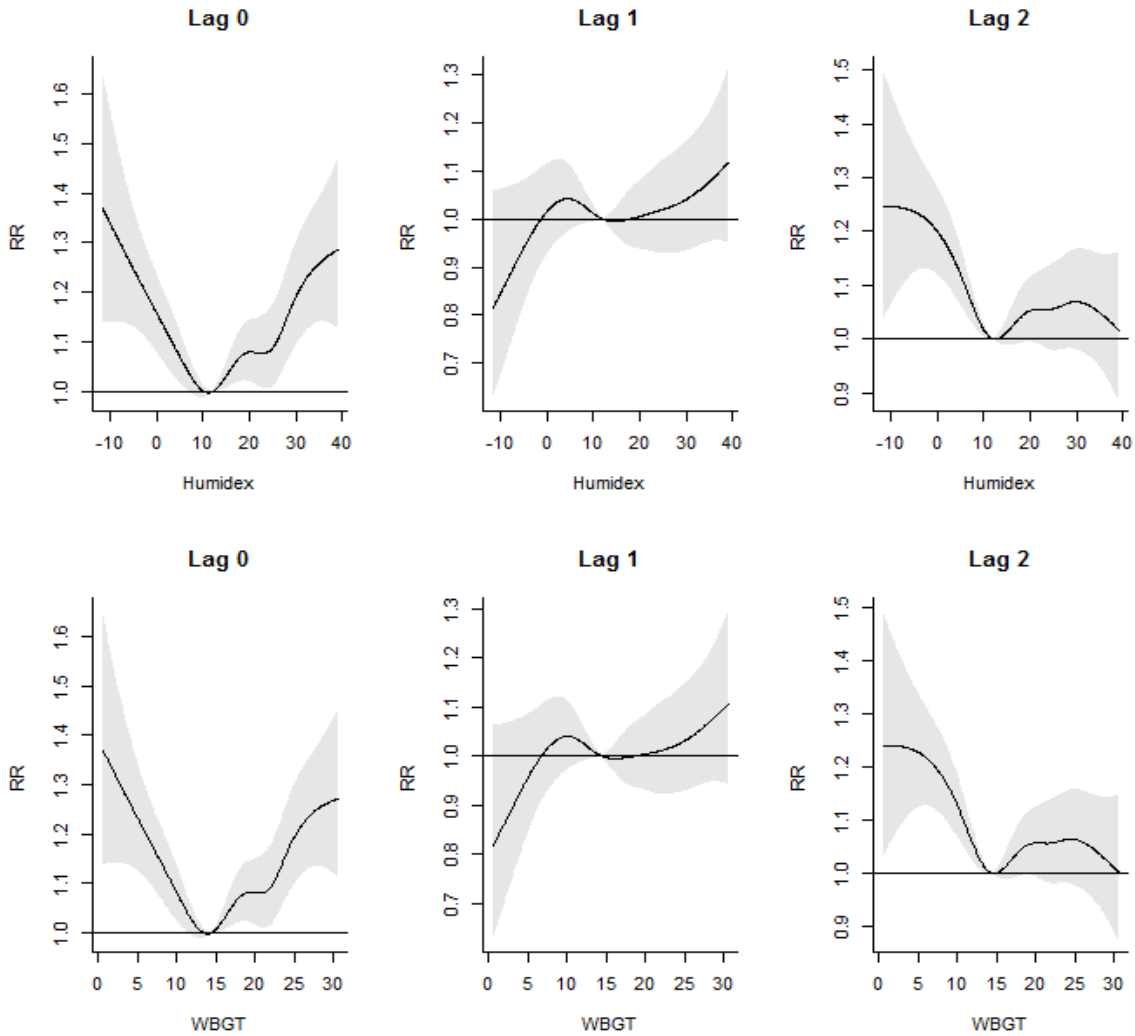


**Figure S2.** Dose-response relationship between Humidex (°C) and wet bulb globe temperature (WBGT; °C) and relative risk of medical attendance for motorcycle accidents at lag 0, 1, 2 days. Results are based on a model adjusted for long-term trends, holidays, rain, and day of the week.