Heat Stress Non-Linear, *Exposure-Lag-Response* Case-Crossover Analysis

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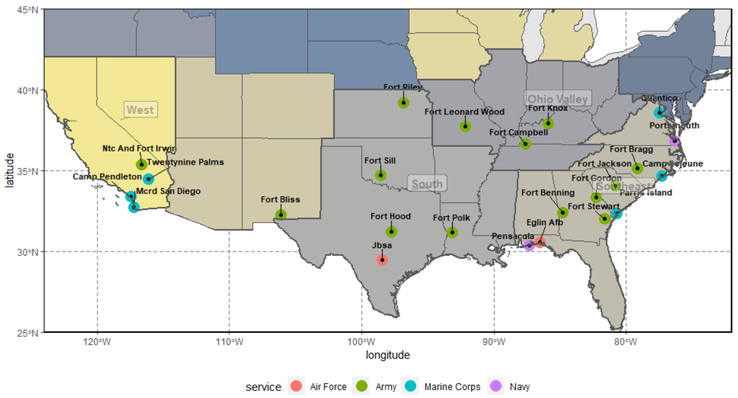
Introduction

Exertional heat stress illnesses (HSIs) pose a serious health threat to military servicemembers, which is magnified in the context of a changing climate with increasing heat and humidity extremes. This study aspires to serve as the most comprehensive, cross-country, multi-decade study of HSI morbidity and daily indices of heat on a working-age, physically-active population.



	Control (N=108233)	Case (N=31642)	Overall (N=139875)
HSI Diagnosis			
Heat Exhaustion	86290 (79.7%)	25213 (79.7%)	111503 (79.7%)
Heat Stroke	21943 (20.3%)	6429 (20.3%)	28372 (20.3%)
Encounter Type			
In-Patient	11212 (10.4%)	3274 (10.3%)	14486 (10.4%)
Out-Patient	61017 (56.4%)	17856 (56.4%)	78873 (56.4%)
Reportable Event	36004 (33.3%)	10512 (33.2%)	46516 (33.3%)
NOAA NCEI Climate Region			
Ohio Valley	9752 (9.0%)	2861 (9.0%)	12613 (9.0%)
South	18191 (16.8%)	5356 (16.9%)	23547 (16.8%)
Southeast	67779 (62.6%)	19782 (62.5%)	87561 (62.6%)
West	12511 (11.6%)	3643 (11.5%)	16154 (11.5%)

Figure 1. Map of 24 military installations included in the study and NOAA NCEI climate regions (L) and summary of HSI cases and case-crossover controls from 1998-2019 (R).

Methods

We applied a time-stratified case-crossover design with a distributed lag non-linear model (DLNM) to associate case-defined active-duty military heat stroke and heat exhaustion encounters from 1998-2019 with daily indices of mean and maximum temperature, heat index (HI), and wet-bulb globe temperature (WBGT)[1]. We derived our indices from hourly NLDAS-2 forcing data[2].

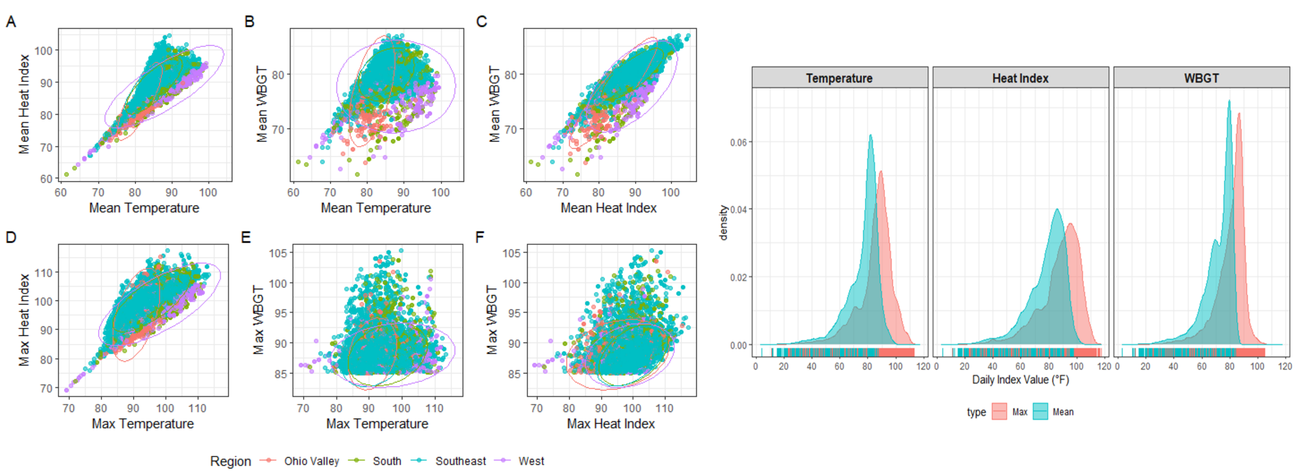


Figure 2. Pairwise mean (L-Upper) and maximum (L-Lower) daily indices on HSI case days with $WBGT_{max}$ > 85ºF cutoff. Density plot of HSI case counts on all HSI case days (R).

Results

For each index of heat, the association with HSI cases is non-linear. In all indices, except maximum daily WBGT, the odds ratio (OR) increases throughout the range of observed index temperatures. The max WBGT OR curve drops beyond 90°F in correspondence to Heat Category 5 ("Black") designation, used as a basis for military training prevention measures. Lag effects (heat on the day(s) preceding the HSI event) measurably contribute to risk, particularly the first day of lag.

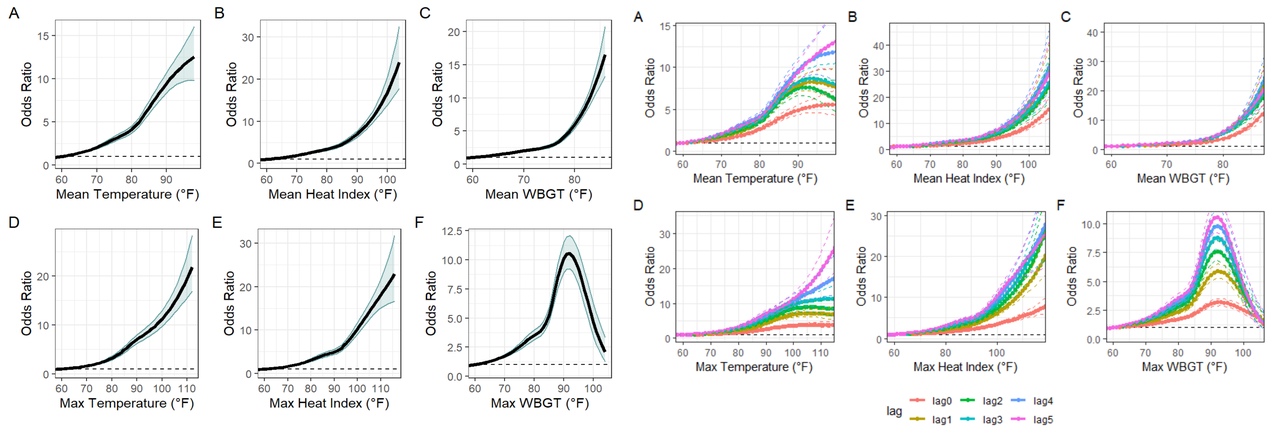
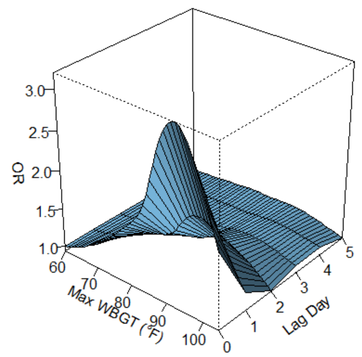


Figure 3. Overall HSI odds ratios, cumulative over 0-5 days lag, relative to 60°F for each index, natural spline df = 5 for dose-response, 4 for lag (L). Cumulative OR by lag day (R). Below: 3-D surface plot of OR by $WBGT_{max}$ and lag day.

Recommendations

- Evidence suggests including temperature and/or HI in addition to WBGT for HSI mitigation measures
- Include heat level of prior day in risk assessments
- Although OR increases with heat level, many HSIs still occur in lower Heat Categories – prevention awareness is important throughout temperature range



Disclaimer

The opinions and assertions expressed herein are those of the author(s) and do not necessarily reflect the official policy or position of the Uniformed Services University or the Department of Defense.

References

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2. Xia Y, Mitchell K, Ek M, et al. Continental-scale water and energy flux analysis and validation for the North American Land Data Assimilation System project phase 2 (NLDAS-2): Intercomparison and application of model products. Journal of Geophysical Research: Atmospheres. 2012;117(D3). doi:10.1029/2011JD016048