Estimating Occupational Heat Exposure from Personal Sampling of Public Works Employees in Birmingham, Alabama

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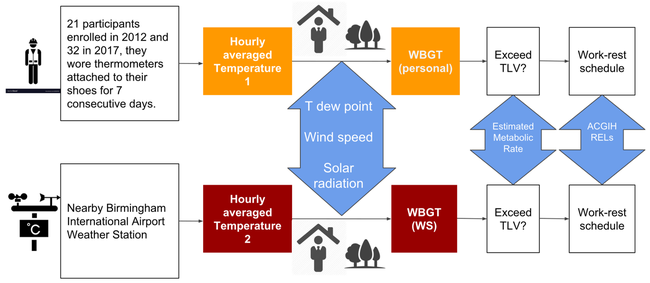
Introduction

- Occupational heat stress puts workers at risk for illnesses such as heat stroke, heat exhaustion, heat cramps, or heat rashes. According to the Bureau of Labor Statistics, overexposure to heat caused 783 deaths and 69,374 serious injuries among US workers between 1992 and 2016.
- Wet bulb globe temperature (WBGT), which considers environmental conditions, is combined with clothing and metabolic rates of workers to assess heat stress and recommend work-rest cycles, based on comparisons to the threshold limit value (TLV).
- Currently, estimates of WBGT using meteorological data from the nearest weather station (WS) are used, but likely do not reflect actual environmental conditions at a specific workplace.
- We hypothesized that **thermometers co-located with workers will result in different work-rest cycle for outdoor workers**.

Methods



Thermometers clipped to participant's shoes in 2012 and 2017, respectively

A demo of hourly activity log

Weight-adjusted metabolic rate and TLV calculation

$$\text{Weight adjusted metabolic rate} = \frac{\text{standard human metabolic rate (Watts)} \times \text{worker body weight}}{70\text{ kg (154 lbs)}}$$

Weight adjusted TLV
=56.7-11.5Log10(Weight adjusted metabolic rate)

Recommended heat stress exposure limits (RELs) for acclimatized workers

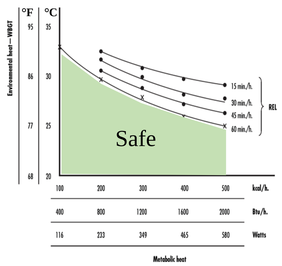


Table 1: Demographics and measurements for participants in 2012 and 2017

Parameter	2012	2017
N	19	32
Median age (range), years	44 (24-57)	39.5(21-60)
Sex-Male	16 (84%)	0(0%)
Sex-Female	3(16%)	32(100%)
% Black or African-American	17(89%)	30(94%)
Education		
Less than High School Diploma	4(21%)	2(6%)
High School Diploma (or GED or Equivalence)	8(42%)	16(50%)
Post-Secondary Certificate and above	7(37%)	14(44%)
Income		
Less than $20,000	4(21%)	10(31%)
$20,000 to $49,999	11(58%)	18(56%)
$50,000 and above	4(21%)	4(12%)
Body Mass Index (BMI)		
BMI in Male (Median, range)	29.2(18.3-38.4)	N/A
BMI in Female (Median, range)	36.1(25.7-36.6)	34.3(19.3-52.3)
Obese (BMI ≥30.0)	9 (47%)	22(69%)

Temperature measurements from personal thermometers had a wider range than those from WS

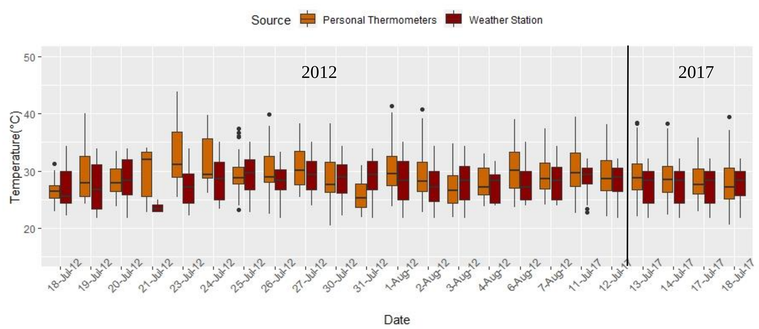


Figure 1. Comparison of hourly temperature measurements from personal thermometers and from weather station between 6am and 2pm on the days participants worked. Minimal and maximal, 25th and 75th percentiles, median (solid line in the box), and outliers (black circle) were shown.

WBGT(personal) estimates more person-work hours above TLV than WBGT(WS) 47.8% vs. 42.1%

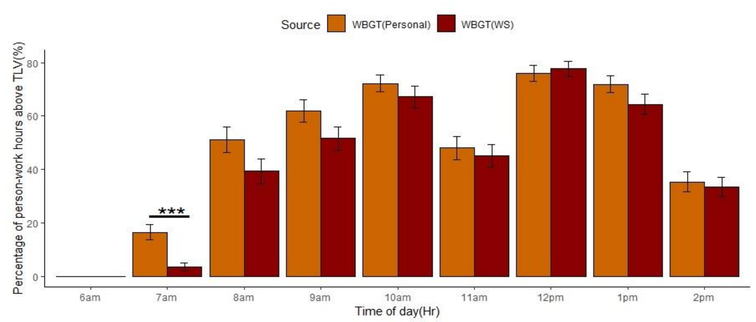


Figure 2. Average percentage of person-work hours of WBGT index that exceeds weight adjusted TLV across all participants(Mean±Standard Error). Statistical significance symbols: '***' denotes P-value of 0 - 0.001.

WBGT(personal) recommends similar amount of rest compared to WBGT(WS)

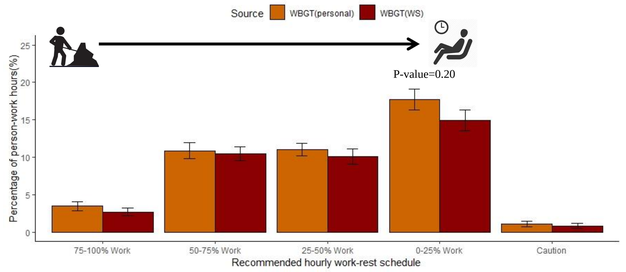


Figure 3. Average percentage of person-work hours in recommended work-rest schedule based on WBGT index across all participants(Mean±Standard Error). 75-100% Work is 45-60 min work/0-15 min rest per hour, 50-75% Work is 30-45 min work/15-30 min rest per hour, 25-50% Work is 15-30 min work/30-45 min rest per hour, 0-25% Work is 0-15 min work/45-60 min rest per hour. Caution category represents WBGT index that exceeds weight adjusted TLV when participants were at rest (estimated hourly metabolic rate around 115 Watts) in that person-work hour. Unshown percentage of hours fell into continuous work category. The percentage of person-work hours in Continuous Work is 55.8%±2.3% for WBGT(personal) and 60.9%±2.4% for WBGT(WS), no significant difference.

Conclusions

- Temperature measurements from the thermometers co-located with participants had a wider range than those collected from the nearest weather station.
- More person-work hours of WBGT(personal) exceeded ACGIH TLV than when using WBGT(WS) to calculate exceedances(47.8% vs. 42.1%). By using WBGT(personal), more person-work hours fell into the 0~15 min work/45~60 min rest hourly schedules(17.4% vs. 14.4%), indicating conditions with the highest risk of heat related illness.
- Our findings suggested that using temperature measured by small thermometers clipped to outdoor workers' shoes, together with meteorological data, can serve as a method to identify occupational heat exposure and recommend work/rest schedule during work hours.

Limitations and future directions

- The study had a relatively small sample size of 51 participants and work tasks were based only on 2012 participants.
- The estimated hourly metabolic rate considered individual weight; however future studies could consider additional physiological parameters such as heart rate.
- The impact of solar radiation on iButton measurements was not able to be fully quantified. WBGT meter, block globe temperature, or solar shield on thermometers will be considered in future studies.

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