Comparison between Temperature (WBGT) App Prototype and WBGT Monitor to Assess Heat Stress Risk in Groundskeeping in an Eastern North Carolina University Setting

Bridget Angol*, Sinan Sousan**, Stephanie Richards* and Jo Anne Balanay*

*Environmental Health Sciences Program, Department of Health Education and Promotion, College of Health and Human Performance, East Carolina University

**Department of Public Health, Brody School of Medicine, East Carolina University; North Carolina Agromedicine Institute

BACKGROUND

- The Wet Bulb Globe Temperature (WBGT) index is the preferred metric for preventing heat-related illness (HRI) in workplaces, typically measured with a heat stress monitor (OSHA, n.d.)
- Access to WBGT data for worksite heat stress evaluation can be challenging due to various factors.
- The OSHA-NIOSH Heat Safety Tool, a free mobile app offering current and forecasted heat index and corresponding risk levels (NIOSH, 2022), has been proposed as an alternative but was found to inaccurately assess heat stress risks for heavy and very heavy workload types (Dillane et al., 2020).
- There is a demand for well-designed, reliable, accessible and cost-effective WBGT-based tools (e.g., mobile apps) for HRI prevention among outdoor workers, especially in heavy workload scenarios.
- A prototype WBGT web app was developed by university professors to calculate current and forecasted WBGT but has not yet been tested for accuracy.

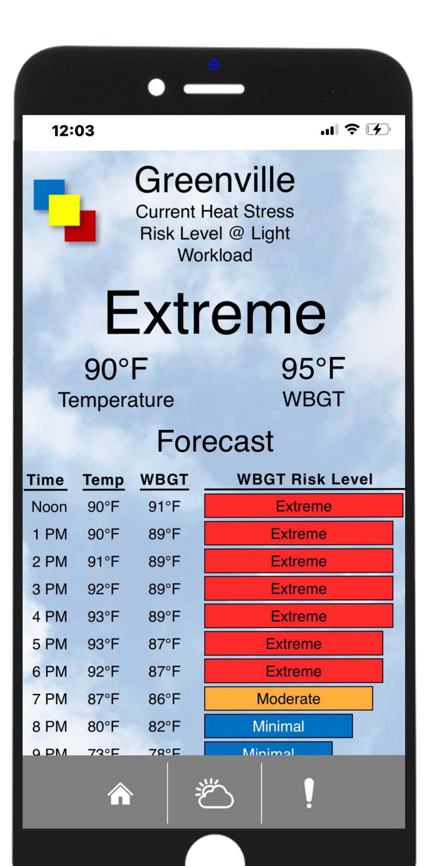
STUDY OBJECTIVES

- Assess the exposure of university groundskeepers to heat stress based on ACGIH Threshold Limit Values (TLVs) and action limits
- Determine the correlation between WBGT indices measured by a heat stress monitor ($WBGT_{ins}$) and those calculated by the app prototype ($WBGT_{app}$)
- Compare the heat stress risk levels indicated by the WBGT app prototype with those obtained from monitor measurements.

MATERIALS & METHODS

- A heat stress monitor (Figure 1) was used as the 'gold standard' instrument to measure WBGT index ($WBGT_{ins}$).
- A novel web-based app (Figure 2) was used to record the current hourly WBGT indices based on weather data from regional weather stations ($WBGT_{app}$), and the corresponding risk levels assuming 3 workload types.
- Independent sample t-test, Pearson correlation test and cross-tabulation were conducted for data analysis using Statistical Package for Social Sciences (SPSS v. 25, IBM, Armonk, NY)
- P<0.05 was considered statically significant.

Fig. 1. Heat stress monitor at the monitoring site



Fig, 2. Web-based heat stress app

RESULTS

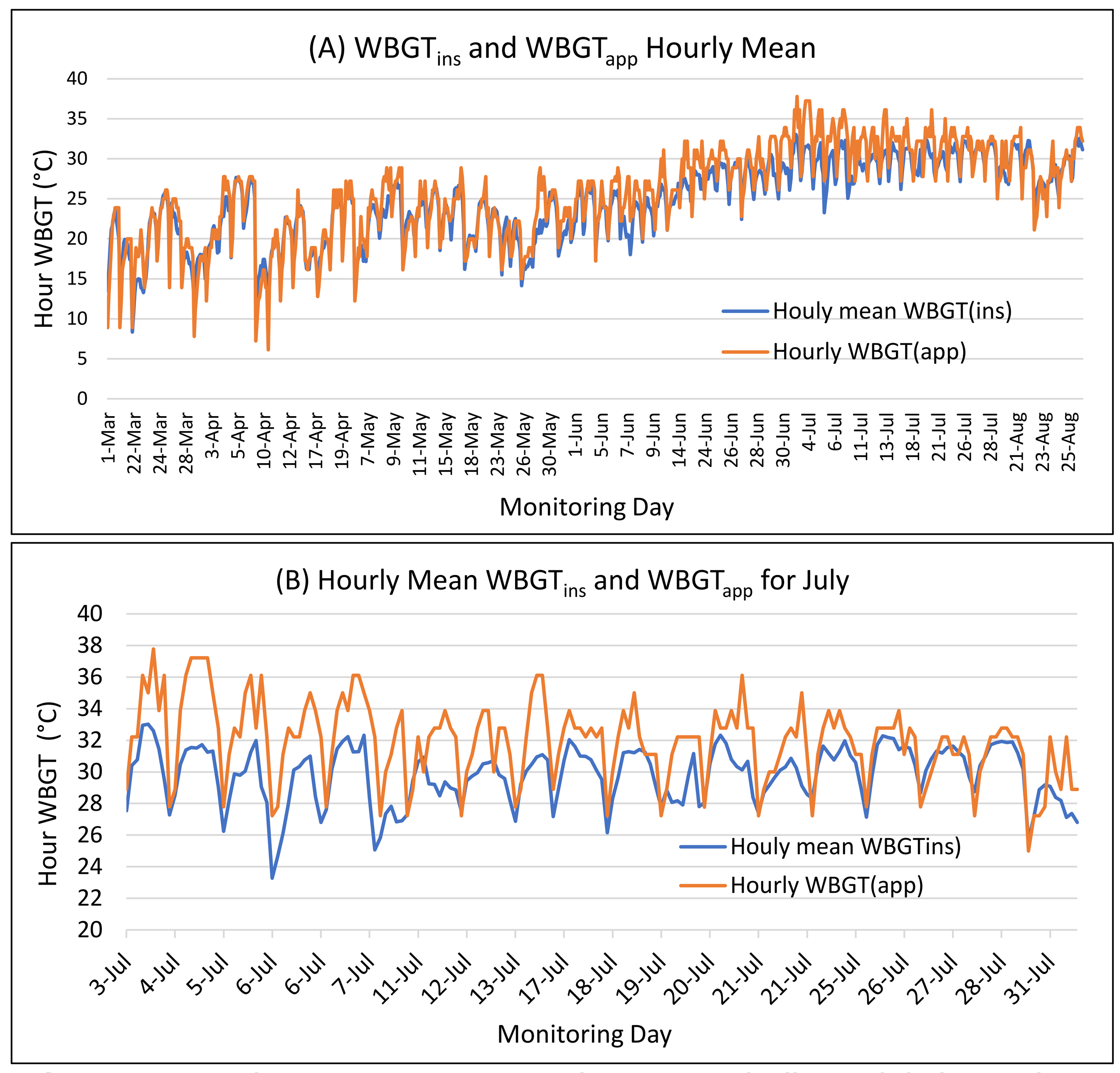


Figure 3. *Hourly mean $WBGT_{ins}$ and $WBGT_{app}$ indices: (A) the entire study period (March-August 2023), and (B) the month of July.*

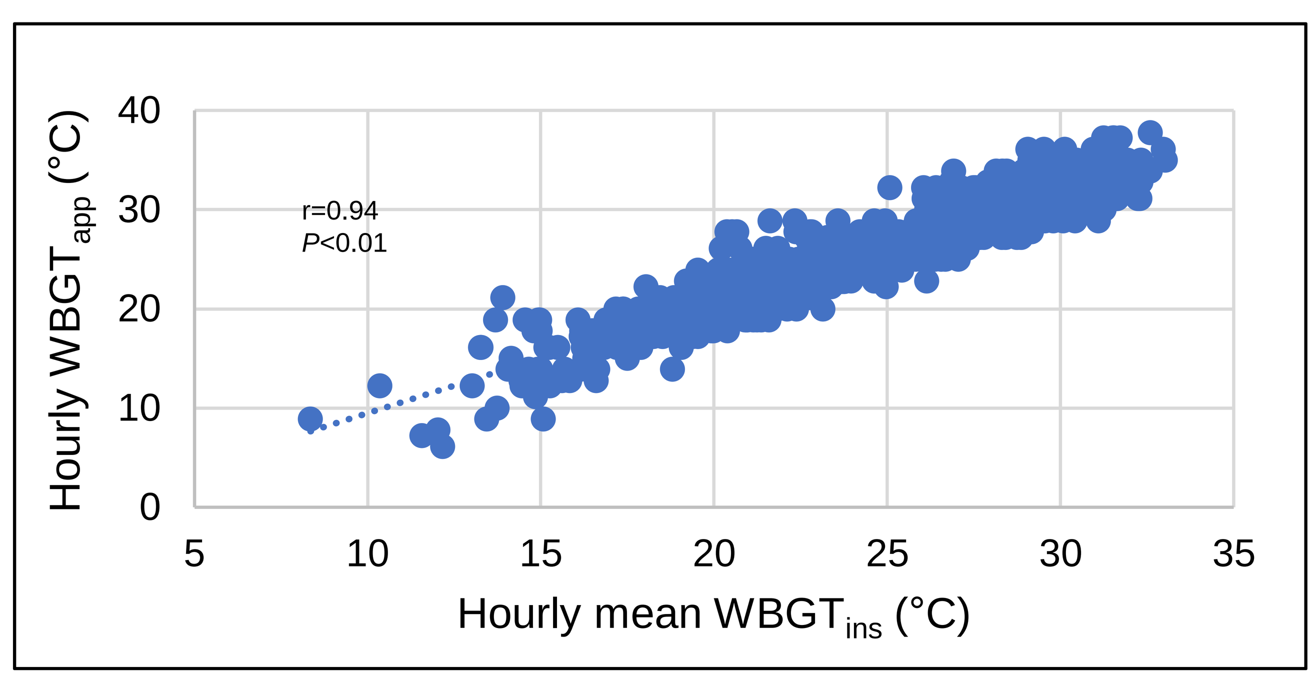


Fig. 4. *Correlation between hourly mean $WBGT_{ins}$ (°C) and $WBGT_{app}$ (°C)*

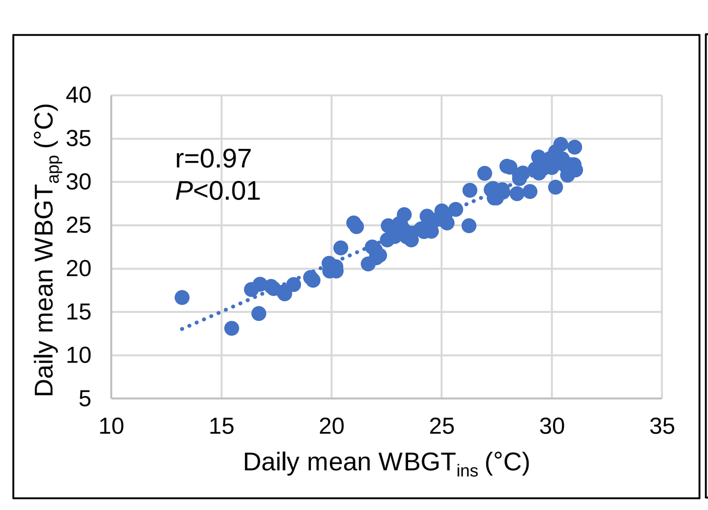


Fig. 5. *Correlation between daily mean $WBGT_{ins}$ (C°) and $WBGT_{app}$ (°C)*

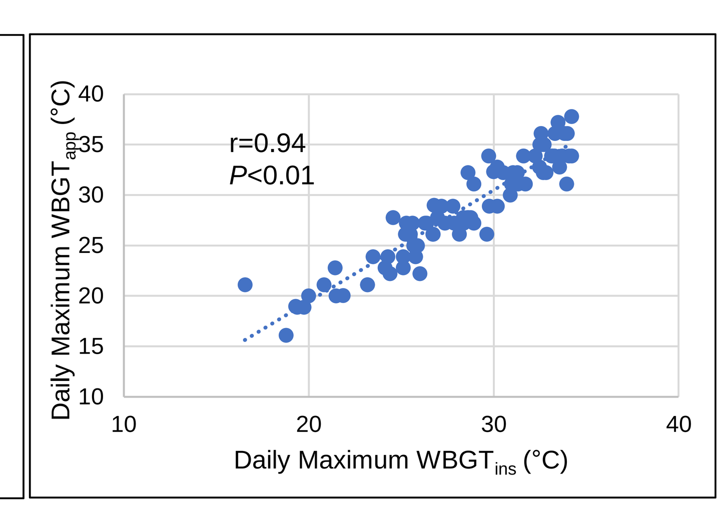


Fig. 6. *Correlation between daily maximum $WBGT_{ins}$ (C°) and $WBGT_{app}$ (°C)*

Table 1. *Overall Comparison between $WBGT_{ins}$ and $WBGT_{app}$ indices*

	$WBGT_{ins}$	$WBGT_{app}$	t	P-value
Hourly mean	24.6 ± 4.9 °C	25.7 ± 5.8 °C	4.04	<0.01
Daily mean	24.6 ± 4.6 °C	25.7 ± 5.3 °C	1.44	0.15
Daily maximum	28.1 ± 4.4 °C	28.4 ± 5.2 °C	0.39	0.69

Table 2*. Comparison of hourly mean, daily mean and daily maximum between $WBGT_{ins}$ and $WBGT_{app}$ indices by month*

Month	n	$WBGT_{ins}$ (°C)	$WBGT_{app}$ (°C)	T	df	*P*-value
Hourly Mean						
March	80	18.8 ± 3.9	19.1 ± 4.4	0.53	158	0.60
April	120	21.0 ± 3.9	20.9 ± 4.9	-0.13	238	0.90
May	175	21.8 ± 3.0	22.6 ± 3.4	2.34	348	0.02*
June	178	25.6 ± 2.8	27.4 ± 3.3	5.36	354	<0.01*
July	352	29.8 ± 1.8	31.9 ± 2.5	9.22	352	<0.01*
August	60	29.1 ± 2.3	29.2 ± 3.2	0.23	118	0.82
Daily Mean						
March	8	18.8 ± 3.3	19.1 ± 2.9	0.18	14	0.86
April	12	21.0 ± 3.3	20.9 ± 4.1	-0.05	22	0.96
May	18	21.8 ± 2.6	22.6 ± 2.8	0.89	34	0.38
June	18	25.6 ± 2.4	27.4 ± 2.5	2.14	34	0.04*
July	19	29.7 ± 1.2	31.9 ± 1.3	5.60	36	<0.01*
August	6	29.1 ± 1.9	29.2 ± 2.6	0.09	10	0.93
Daily Maximum						
March	8	22.4 ± 3.6	22.4 ± 2.7	-0.04	14	0.97
April	12	24.6 ± 3.6	23.7 ± 4.0	-0.62	22	0.54
May	18	25.6 ± 2.8	25.1 ± 3.2	-0.48	34	0.64
June	18	29.1 ± 2.3	29.9 ± 2.5	1.03	34	0.31
July	19	32.8 ± 1.1	34.6 ± 1.7	3.81	36	<0.01*
August	6	32.3 ± 2.2	31.7 ± 2.3	-0.46	10	0.65

RESULTS (cont'd)

Table 3. *Comparison of hourly mean, daily mean, and daily maximum between $WBGT_{ins}$ and $WBGT_{app}$ indices by WBGT range for all the months*

$WBGT_{ins}$ range (°C)	n	$WBGT_{ins}$ (°C)	$WBGT_{app}$ (°C)	t	df	*P*-value
Hourly Mean						
<15.00	26	13.6 ± 1.6	13.9 ± 4.2	-0.35	50	0.73
15.00-19.99	129	17.9 ± 1.4	18.0 ± 2.5	-0.29	256	0.78
20.0-24.99	244	22.7 ± 1.4	23.7 ± 2.3	-5.50	486	<0.01*
25.00-29.99	265	27.5 ± 1.4	29.0 ± 2.5	-8.54	528	<0.01*
≥30.00	126	31.1 ± 0.7	32.8 ± 1.9	-9.06	250	0.01*
Daily Mean						
<15.00	1	13.2	16.7	N/A	N/A	N/A
15.00-19.99	13	17.8 ± 1.4	17.7 ± 2.0	0.21	24	0.83
20.0-24.99	28	22.6 ± 1.4	23.5 ± 1.9	-1.99	54	0.05
25.00-29.99	26	27.6 ± 1.5	29.3 ± 2.3	-3.13	50	<0.01*
≥30.00	13	30.6 ± 0.4	32.1 ± 1.3	-4.05	24	<0.01*
Daily Maximum						
<15.00	0	-	-	-	-	-
15.00-19.99	6	19.0 ± 1.2	19.0 ± 1.7	-0.05	10	0.96
20.0-24.99	11	23.0 ± 1.4	22.4 ± 2.2	0.70	20	0.50
25.00-29.99	33	27.3 ± 1.5	27.3 ± 2.5	0.01	64	0.99
≥30.00	26	32.5 ± 1.2	33.5 ± 2.1	-2.22	60	0.03*

DISCUSSION

- The app demonstrated reliability and accuracy in assessing heat stress during March and April 2023.
- The current version of the app prototype tends to overestimate the WBGT values.
- The WBGT index indicated by the app ($WBGT_{app}$) is consistently higher than the index measured by the heat stress monitor ($WBGT_{ins}$).
- There is a strong positive correlation between the indices provided by the $WBGT_{app}$ and the $WBGT_{ins}$.
- The $WBGT_{app}$ prototype shows potential as a useful tool for monitoring heat stress effectively.

CONCLUSIONS

- The WBGT app prototype offers a promising approach for assessing heat stress risk, especially in extreme conditions.
- Provides early warnings, affordability, and convenience for preventing occupational heat stress.
- Adjusting the app's algorithm could enhance its accuracy and reliability.
- Beneficial for public health officials, small-scale industry employers, and outdoor workers.
- Future research could extend the study's geographical scope to various climates and regions.

ACKNOWLEDGEMENTS

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