Project HeatSafe: Validity of Weather Station for Understanding in-situ Workplace Heat Stress Levels in Singapore

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Introduction

Climatic projections suggests that the mean daily maximum air temperature in Singapore is expected to hit 34°C by 2100 [1]. Workers working in hot outdoor environments are at a high risk of reduced productivity, workplace accidents, heat injuries, and knock-on chronic health effects [2].Monitoring of environmental heat stress levels is necessary to guide timely implementation of heat protection strategies. This study therefore investigated the validity of using hourly WBGT measured at weather stations as a proxy for WBGT at outdoor workplaces in Singapore.

Methods

Environmental monitors at 20 outdoor workplaces across Singapore recorded wet-bulb globe temperature (WBGT) during four two-week periods of a full year. Hourly workplace WBGT during working hours at each workplace was compared with WBGT from the nearest weather station during the same hour. Pearson correlation coefficient was used to analyse the correlation between (i) mean difference in WBGT between workplace and weather station, and distance of each workplace from its nearest weather station, and (ii) WBGT at workplace and weather station. Bland-Altman plot was used to analyse the agreement between WBGT at workplaces and weather station. A priori validity criterion of 95% percentage target attainment (PTA) within ±1.0°C was used.

Results and discussion

Mean and range of WBGT at workplaces and weather stations were 28.2°C (23.1 – 33.4) and 28.3°C (22.0 – 34.2) respectively. Distance of each site from its nearest weather station was not correlated with the mean difference in WBGT observed ($r = 0.36$, $p > 0.05$). Collectively, workplace WBGT exhibited a strong positive correlation with WBGT at weather station ($r = 0.88$, $p < 0.01$), with a mean bias of -0.03°C and 72% of data points within ± 1°C (9142 out of 12953 data points) (Figure 1). The level of agreement observed did not meet our validation criterion of 95% PTA within ±1.0°C. This was an expected observation due to varying weather conditions experienced at two geographically different locations. Some possible causes include differences in local cloud cover, rain, wind conditions or solar radiation at workplaces as compared to its nearest weather station [3]. Additionally, hourly WBGT comparisons between workplaces and weather stations show differences up to 5.7°C, further highlighting the need for local workplace measurement of heat stress levels.

When categorised into official Singapore heat stress risk levels, agreements between WBGT at the workplace and the nearest weather station were 92%, 33%, and 17% for low (WBGT < 31°C), moderate (31°C ≤ WBGT < 32°C), and high (WBGT ≥ 32°C) risk level categories respectively (Table 1). When WBGT crosses each heat stress threshold, activity modification can be implemented in order to reduce the risk of heat injury among workers. Some activity modification strategies include increasing the frequency and/or duration of rest and water breaks. The

decreasing agreement between heat stress risk levels reported at workplaces and at the nearest weather station with increasing heat stress levels highlight that local WBGT measurements are recommended in order to get accurate real-time data on local workplace heat. WBGT from weather stations should be used with caution.

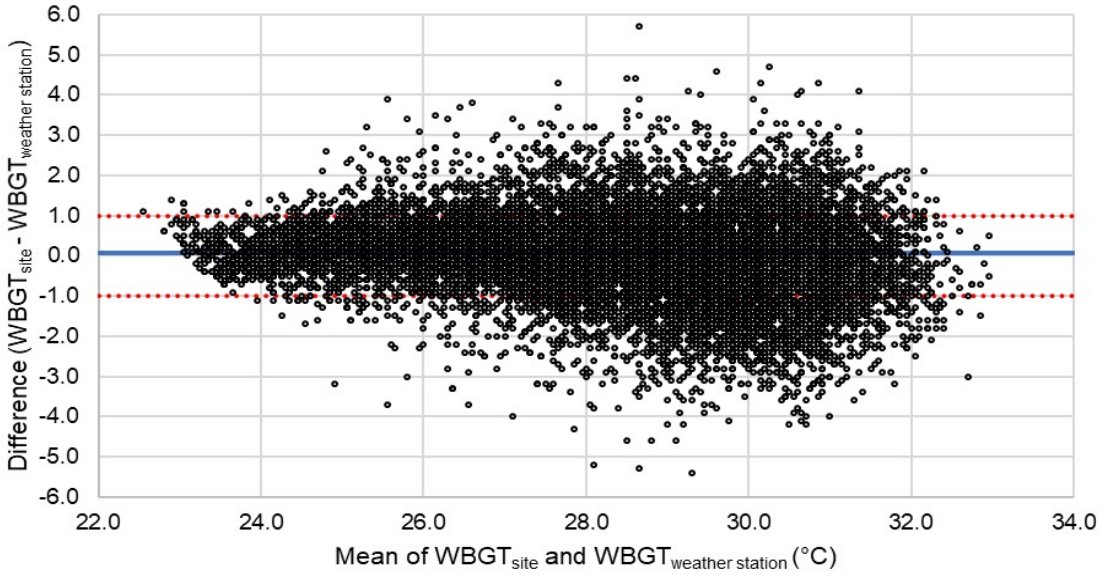

Figure 1. Agreement between hourly wet-bulb globe temperature (WBGT) collected across 20 outdoor sites and their nearest weather station (12953 paired data points). The blue line represents the mean bias and the red dotted lines represent the fixed upper and lower limits of ±1.0°C.

Table 1. Number of hourly readings recorded at workplaces against weather station at each heat stress risk levels (n = 12953). Low heat stress risk: WBGT < 31°C; Moderate heat stress risk: 31°C ≤ WBGT < 32°C; High heat stress risk: WBGT ≥ 32°C. Green boxes refer to instances where WBGT at weather station and workplace are classified under the same heat stress risk level.

		Workplace heat stress risk level		
		Low	**Moderate**	**High**
Weather station heat stress risk level	**Low**	10,774 (92%)	522 (52%)	110 (46%)
	Moderate	755 (6%)	336 (33%)	88 (37%)
	High	175 (2%)	153 (15%)	40 (17%)
	Total	11,704 (100%)	1,011 (100%)	238 (100%)

Conclusions

These findings suggest that localised WBGT monitoring should be recommended for real-time measurements, due to differences in WBGT and its associated heat stress risk levels between workplaces and weather stations. If heat stress levels reported at weather stations are used as a guide, caution should be taken especially at higher heat stress risk levels where discrepancies are greater.

References

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