# Project HeatSafe: Effects of Seasonal Heat Stress on Shoe-Manufacturing Workers in Vietnam

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## Introduction

Manufacturing workers in non-climate-controlled environments can be at risk of heat stress, especially during summer [1]. This is further exacerbated by global warming where hotter and longer summers are expected [2]. Excessive heat exposure increases physiological strain and can reduce workers' health and productivity [3]. Vietnam is a country with a large proportion of the workforce in the manufacturing sector (~23.3% of total employment) that experiences seasonal variations in climatic conditions (± 8°C between seasons) [4,5]. Thus, we examined the effects of seasonal heat stress (summer vs. winter) on shoe manufacturing workers in Vietnam using both physiological and ethnographic methods.

## Methods

Twenty-five shoe-manufacturing workers [18 females; age (mean ± SD): 33 ± 9 years] in the summer and 33 workers (26 females; age: 32 ± 6 years) in the winter were profiled during a typical work shift (~8hrs). Environmental [wet-bulb globe temperature (WBGT)], thermal [body core ($T_c$) and skin ($T_{sk}$) temperatures], cardiovascular (heart rate) and activity (step count) measures were captured continuously while physical (grip strength) and perceptual (thermal perception and perceived exertion) measures were collected at pre-shift, during lunch break and post-shift. Overall physiological strain of workers was reflected using a calculated Adaptive Physiological Strain Index (aPSI). Semi-structured interviews were conducted with ten workers and five managers to understand their experiences and management of workplace heat stress.

## Results and discussion

Mean WBGT over the work shift was higher during summer than winter [29.2 ± 1.3°C vs. 19.2 ± 1.5°C; $P$<0.001] (Fig 1.). Workers' mean $T_c$ was similar between seasons [37.4 ± 0.2°C vs. 37.5 ± 0.2°C; $P$>0.05); however, mean $T_{sk}$ was higher (34.5 ± 0.5°C vs. 32.6 ± 0.7°C; $P$<0.001) while mean heart rate was lower (87 ± 9 bpm vs. 94 ± 9 bpm; $P$<0.05) during summer. Mean aPSI was similar between seasons as well (1.7 ± 0.4 vs. 1.9 ± 0.4; P>0.05) (Fig 2.). Step count and grip strength were similar between seasons ($P$>0.05) while thermal satisfaction was lower in summer ($P$<0.05). Interviews revealed common consensus among managers (4 out of 5) that there is a higher incidence of heat injury and absenteeism in summer than winter. Workers also revealed that they received limited heat-health advisories from management.

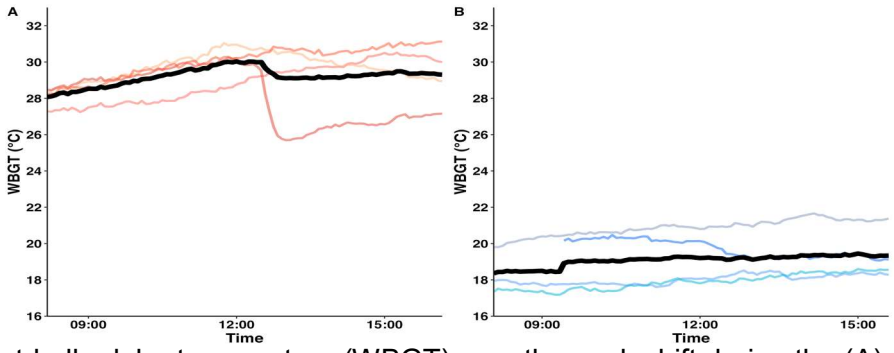


***Figure 1***. Wet-bulb globe temperature (WBGT) over the work shift during the (A) summer and winter (B). The black line represents the average across all study days while coloured lines represent each profiling day.

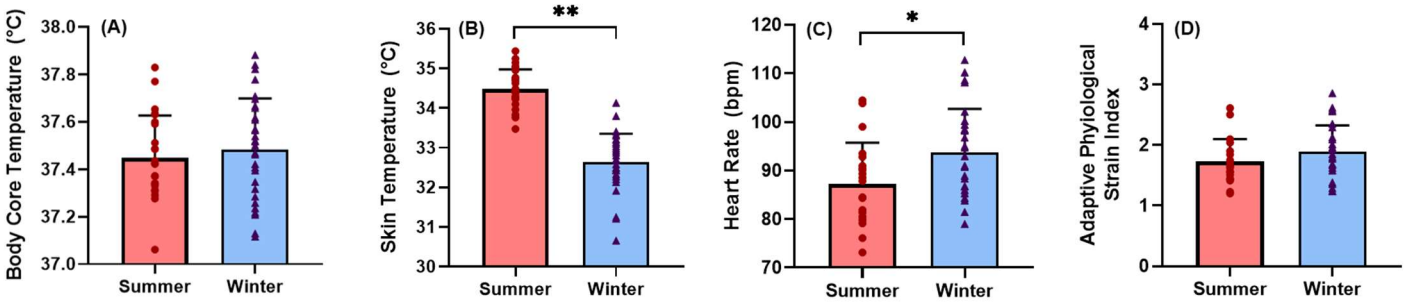


**Figure 2.** (A) Mean body core temperature (summer: n=24, winter: n=31), (B) mean skin temperature (summer: n=25, winter: n=33), (C) mean heart rate (summer: n=21, winter: n=30) and (D) mean adaptive physiological strain index of workers over the work shift. Data are means ± SD. Dots represent individual data. *Significantly different between seasons (*$P$<0.05 and **$P$<0.001).

## Conclusions

Lower heart rates during summer suggest workers were likely self-pacing, which may explain the similarity in thermal strain between seasons despite higher WBGT in summer (+10°C) [6]. Nonetheless, the higher reported incidence of heat injury during summer and limited provision of heat-health advisories suggests the need for increased awareness of the risks of heat stress and effective heat adaptation measures for manufacturing workers, especially during summer.

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