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Letter to the Editor

Comparison of Different Heat Stress Indices for Assessing Farmers' Exposure to Heat Stress

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Dear Editor-in-Chief

Exposure to extreme heat has been found to be hazardous agent to health, and it has been linked to a range of illnesses and premature death. This is especially true about the outdoor workers like farmers whose involves performing physical task and those experience high heat stress condition (1, 2).

Hence, the present research aimed to evaluate heat stress exposure among the farmers and also to compare the different heat stress and strain indices for assessing heat exposure of the farmers.

The present cross-sectional descriptive-analytical study was performed on 87 male farmers in Bukan, Azerbaijan Province, Iran, in 23 Jul to 16 Aug 2016. For selecting the subjects, first, the field inspections are done to identify the farmers. Then, people who had permanent farmer job in that season and also had no history of diseases such as blood pressure, cardiovascular disease, diabetes, skin disease and no drug consumption are included in the study. The mean age of participants was 37.10 ± 14.22 yr and their mean duration of employment was 16.8 ± 12.2 years. Their mean BMI was 24.3 ± 7.4 kg/m^2.

"Environmental parameters including air temperature(T_a), black globe temperature (T_g), natural wet temperature (T_{nw}) and wet-bulb globe temperature (WBGT) index were measured by a calibrated WBGT meter based on standards ISO 7243" (3). Relative humidity (RH) was measured by humidity meter and air velocity (V_a) was assessed using the hot wire anemometer. All environmental parameters were evaluated at four time periods (7-9 a.m., 9-12 a.m., 12-15 p.m., and 3-4 p.m.) on workdays.

The farmers' physiological parameters were measured based on standard ISO 9886 (4) as follows: systolic-diastolic blood pressure and heart rate using a digital sphygmomanometer, oral temperature by a digital thermometer, and skin temperature by the help of a digital thermometer. The calculation approach of the studied heat strain and stress indices were presented in Table 1.

Our results indicated that the mean ±SD of systolic blood pressure, diastolic blood pressure, heart rate, oral temperature and skin temperature was 127.24 ±14.12 (mmHg), 76.20±10.37 (mmHg), 75.71±12.15 (beats/min), 36.01±0.64 (°C), and 34.43±1.67 (°C). The measured climate data have been indicated in Table 2. The maximum values for Ta, Tnw, Tg and MRT were related to 12-3 p.m. and it was quite expected concerning the geographical position of the area that has the highest sun radiation at 12-3 p.m. and the highest humidity and wind speed at 7-9 a.m.

Table 1: Calculation of some studied variables and indices

Indicator	*Formula*	*Unit*
Metabolic rate	*Calculated based on standard ISO 8996*	*W/m²*
Basal Metabolic Rate (BMR)	$BMR = 66.4730 + (13.7516 \times Wb) + (5.0033 \times Hb) - (6.7550 \times A)$	Kcal/day
Mean Radiant Temperature (MRT)	$MRT = 1.8\sqrt{Va}(T_a - T_g)$	℃
Dew point (dp)	$dp = \left(\frac{f}{100}\right)^{1/8}(112 + 0.9\,T_a) + 0.1\,T_a - 112$	℃
Universal Thermal Climate Index (UTCI)	$UTCI = f(T_a;\ MRT;\ V_a;\ RH)$	℃
Heat Stress Index (HSI)	$HSI = \frac{Ereq}{Emax} \times 100$	%
Required rate of evaporation for heat balance (Ereq)	$E_{req} = M - R - C$	W/m²
Rate of radiant heat exchange (R)	$R = 4.4(35 - MRT)$	W/m²
Rate of convective heat exchange (C)	$C = V_a^{0.6}(35 - t_a)$	W/m²
Maximum evaporation achieved under hypothetical conditions (Emax)	$E_{max} = 7 \times V_a^{0.6}(56 - Pa)$	W/m²
Predicted heat strain (PHS)	Calculated based on standard ISO7933	W/m²
Humidex (HD)	$HD = T_a + 0.5555\left[6.11e^{5417.7530\left(\frac{1}{273.16} - \frac{1}{273.15+T_{dew}}\right)} - 10\right]$	℃
Subjective Temperature Index (STI)	$STI = Mrt + \left\{\left[\frlac{\lvert S\rvert^{0.75}}{(Sh.\sigma) + 273^4}\right]^{0.25} - 273\right\}$	℃
Thermal insulation of clothing	Calculated based on standard ISO-9920 (2007).	Clo

The indices such as Universal Thermal Climate Index (UTCI) (35±1.59 °C), Predicted Heat Stress (PHS) (157.2±11.64 w/m2), and Subjective Temperature Index (STI) (35.94±4.66 °C) had the highest level at 12-3 p.m., and the indices such as Wet-Bulb Globe Temperature (WBGT) (29.03±2.72 °C), Humidex (HD) (43.67±26.88 %), and Heat Stress Index (HSI) (35.76±4.22 °C), the highest level was obtained at 9-12 a.m.. The desired heat indices were significantly correlated to each other (P<0.001) and some heat stress indices showed stronger relationships with others. WBGT index showed the highest correlation with HD index (r=0.999, P<0.001) and the lowest correlation with STI (r=0.726, P<0.001).

Table 2: Environmental measurements at four-time periods (Mean±SD)

Time	*Ta (°C)*	*Tg (°C)*	*Tnw (°C)*	*MRT (°C)*	*RH (%)*	*Va (m/s)*	*dp (°C)*
7-9 (a.m.)	25.35 ± 1.43	27.25 ± 2.22	22.90 ± 3.38	32.49 ± 5.55	54.1 ± 10.8	2.48 ± 0.65	15.1 ± 2.95
9-12 (a.m.)	29.44 ± 2.04	35.68 ± 4.41	22.29 ± 0.91	50.49 ± 7.13	51.52 ± 6.10	2.18 ± 0.98	18.30 ± 3.42
12-3 (p.m.)	32.42 ± 0.90	38.6 ± 1.73	22.98 ± 0.30	53.35 ± 3.27	30.14 ± 2.10	1.93 ± 0.58	12.73 ± 0.99
3-4 (p.m.)	32.17 ± 0.46	35.94 ± 0.99	22.31 ± 1.23	44.47 ± 3.81	27.39 ± 4.69	1.60 ± 0.54	10.90 ± 2.40
Time Weighted Average (TWA)	29.85 ± 0.24	34.37 ± 0.56	22.62 ± 0.62	45.2 ± 1.54	40.78 ± 0.46	2.05 ± 0.16	14.28 ± 2.33

The majority of the calculated indices were higher than the permissible and recommended limits; thus, the farmers were at risk of heat stress and heat-related illnesses. The study results indicated significant correlations among all the heat stress indices. Overall, all studied indices may be efficient in evaluation of heat stress effects among the farmers engaged in this region.

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Conflict of interest

The authors declare that there is no conflict of interests.

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