A MODIFIED DISCOMFORT INDEX (MDI) AS AN ALTERNATIVE TO THE WET BULB GLOBE TEMPERATURE (WBGT)

D.S. Moran[1,2], Y. Shapiro[2], Y. Epstein[2], W. Matthew[1] and K.B. Pandolf[1]

[1]U.S. Army Research Institute of Environmental Medicine, Natick, MA, USA, [2]Heller Institute of Medical Research, Sheba Medical Center, IDF Medical Corps—The Institute of Military Physiology, Israel 52621 1

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INTRODUCTION

In **1957,** Yaglou and Minard (1) developed the **WBGT** as a thermal index calculated as follows: $WBGT=0.7T_w+0.2T_g+0.1T_a$ where $T_w =$ wet bulb temperature, $T_g =$ black globe temperature and $T_a =$ ambient temperature. This index has been in extensive use for evaluating environmental heat stress in the U.S. Army, sport activities and as safety guidance for workers in different occupations **(2-4).** However, **WBGT** was found to be limited in evaluating heat stress mainly due to the inconvenience of measuring T_g, the corrections needed for different clothing (e.g., protective clothing) and for various metabolic rates **(5).** The purpose of this study was to determine whether the newly developed modified discomfort index **(MDI)** calculated as **(6)** $MDI = 0.30T_a+0.75T_w$ can be used as an alternative for **WBGT.**

MATERIALS AND METHODS

The data for this study were obtained at **3** separate locations: USA, Egypt, and Israel. Measurements of the meteorological parameters to calculate WBGT and MDI were done using the same thermometers. T_a was measured using a mercury-in-glass thermometer, T_w was measured using a naturally aspirated wet bulb and T_g was measured using the Vernon black globe thermometer. In addition, wind speed at **1.2**m above ground level and total hemispheric radiation levels were measured in Egypt and in Israel. Evaluations and comparisons of **WBGT** and MDI were done using the procedures and calculations described above in the introduction **(1,6).** The material and methods can be found in greater detail elsewhere **(7-9).**

USA Measurements. Hourly weather measurements were collected daily between **7:00** AM to **8:00** PM fiom April until October in **1990** at a vegetative environment in South Carolina.

Egypt Measurements. Hourly weather measurements were collected daily between 5:00 AM to 4:00 PM for a week in August **1985** in an arid environment west of Cairo.

Israel Measurements. Daily weather measurements were collected simultaneously in the shade and under open sky every **15** min between **11:00** AM to 3:00 PM in July through August during 2 years **(1987-1988)** at a tropical location.

RESULTS

The comparisons between MDI and WBGT are depicted in Table 1 and Figure 1. Generally, highly significant correlations were found between the indices.

DISCUSSION

The MDI was calculated fiom database sets obtained fiom three separate studies conducted in America, Africa and Eurasia and was favorably compared to the WBGT. These results strengthen the argument for use of MDI, which uses only T_a and T_w for evaluating heat stress.

The integrated T_g in the WBGT is an important parameter to evaluate thermal load by representing mainly the solar load (SL). Furthermore, T_g also considers the impact of the reflected radiation fiom any surface and object, including short- and long-wave radiation and is also affected by the wind velocity. However, measuring T_g by a black globe thermometer **is** cumbersome and inconvenient.

Analyzing the results from the three locations, using MDI without any correction factor, revealed a symmetrical distribution around the zero line only for the, **USA** database. In the Egyptian and Israeli databases, the observations were mainly under the zero line, representing underestimation of WBGT by MDI. **As** a 'consequence, when a correction factor of 2 was added to the calculated MDI for the Israeli database depicting a high **SL,** a very high correlation was found between MDI and WBGT.

The effect of SL on the environment depends on four factors: time of year and latitude; time of day; the environmental surface; and the atmosphere (10). Seasonal variation in the incoming solar radiation at the upper layers of the atmosphere is a function of the earth-sun orbital geometry, which changes the distance between the earth and the sun. Latitude and the hourly changes in solar plevation influence path length through the atmosphere and the attenuation of 'solar radiation arriving at the earth's surface. **As** the source of the solar beam ,moves fiom directly overhead ($-12{:}00$ noon) to the horizon (sunset), the cross {sectional area of almost any object **to** the solar rays goes fiom minimum to maximum. Thus, around $12{:}00$ noon when the sun is overhead, the ray path through the atmosphere will be the shortest, resulting in the highest SL. The amount of absorbed solar radiation, apart fiom depending on the zenith angle calculated fiom the time of the day, is affected by the site characteristics. In a vegetative surface, there is no reflection of radiation, whereas in the desert about 20% of the overhead radiation would be reflected. In addition, the other radiative components including diffuse solar, reflected solar, ground thermal, and sky thermal radiation must be taken into account when we quantify the solar load (e.g., clouds and haze markedly decrease SL).