THE ESTIMATION OF HEAT TOLERANCE BY A NEW CUMULATIVE HEAT STRAIN INDEX

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INTRODUCTION

Heat tolerance is evaluated during exposure to heat by the usage of various physiological parameters and indices (1). Previously, the Cumulative Heat Strain Index (CHSI), which is based on principles of physiological cost (3,4), was proved to be a sensitive criterion for comparing the physiological strain under various climatic conditions and exercise intensities **(2).** The aim of the present study was to test the hypothesis that this index is effective also in characterizing individual heat tolerance of subjects preselected for their medical history of heat disorders.

MATERIALS and METHODS

Subjects: Fifty-one male subjects with medical history of heat related disorders were tested. The anthropometric data of the subjects (mean ±SD) were: age **19.6±2.3** years, height 177±7 cm, mass 73.6±9.5 kg, body surface area **1.90M.13** m^2, and body mass to body surface area ratio (BM/BSA) **38.4±2.5** kg/m^2. None of the subjects was under any medication treatment. All subjects were carefully instructed about the procedures, and gave their written consent to be tested in this study.

Experimental condifions; The subjects, dressed in shorts, socks, and sneakers, exercised for two hours on a treadmill (walking 5 km/h, 2% grade, $VO_2 \approx 1L$ O_2/min) in a climatic chamber (40 °C, 40 % rh, air velocity 1 m/s). The exercise was preceded by 5 minutes of rest while the initial values of T_r and HR were measured. During the test the subjects were allowed to drink tap water *ad libitum.*

Measurements: T_r was measured by YSI (series 400) thermistor probe inserted ten cm beyond the anal sphincter. Heart beats were accumulated through bipolar chest leads using Polar belt electrodes (Polar CIC, Inc., USA). T_r and HR were on-line accumulated and processed every minute by the Alina 1000 System (Alina, Israel). Evaporative sweat loss was estimated from changes in nude weight, adjusted for water intake and urine (not corrected for respiratory weight loss).

Calculations and statistical analysis: The **CHSI** was calculated as the product of cardiac strain and the area under the hyperthermic curve as follows:

$$CHSI = \left[\sum_{0}^{t} hb - HR_0 \cdot t\right] \cdot 10^{-3} \cdot \left[\int_{0}^{t} Tr \cdot dt - Tr_0 \cdot t\right] \quad ; \text{(units)}$$

where: hb - heart beats; HR_0 - initial heart rate (bpm); T, - rectal temperature, $T_{r\,0}$ - initial rectal temperature ("C) and t - time in minutes elapsed from the first measurement. The CHSI was calculated for the first 60 minutes (CHSI,,) of the test and for the entire exposure **(CHSI,,,).**

The results are presented as mean ± SD. The cluster analysis mas performed for subdivision of the subjects according to their tolerance to heat.

RESULTS

All the subjects tolerated the exercise-heat test. The mean values of the measured parameters are presented in table 1 and the dynamics of changes in T, and HR are shown in fig. 1.

	T_r (°C)	*HR* (bpm)	Sweating (L)
before the exercise	37.16B.27	85.91±15.59	
after 60 min	37.85±0.30	121.87±16.55	
after 120 min	37.98±0.30	124.98±17.89	1.62±0.48

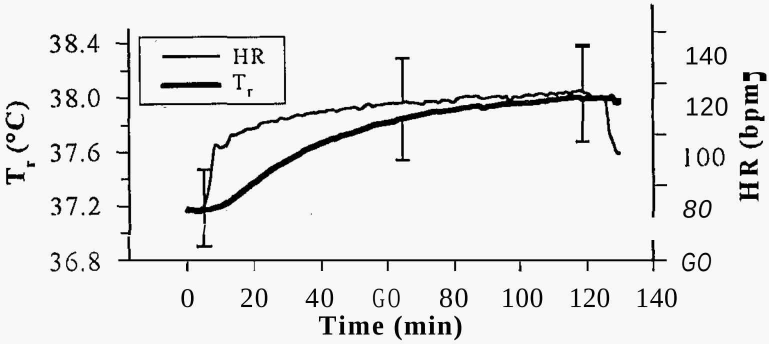


Fig. 1. The dynamics of changes in T, and HR

The changes in T, **(AT,)** after an hour and two hours were 0.73±0.25 °C and 0.94±0.35 °C, respectively.. The changes in the mean HR **(AHR)** after 60 and 120 min were 53.52M.40 **bpm,** and 61.22±16.66 bpm, respectively. The main increase in HR took place at onset of exercise. High variability in T_r and HR was observed.

The individual changes in T_r and HR after the first hour highly correlated with those after two hours of exercise (Fig. 2).

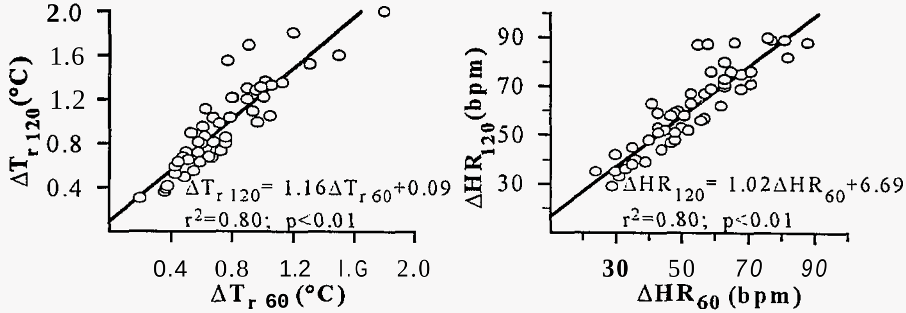
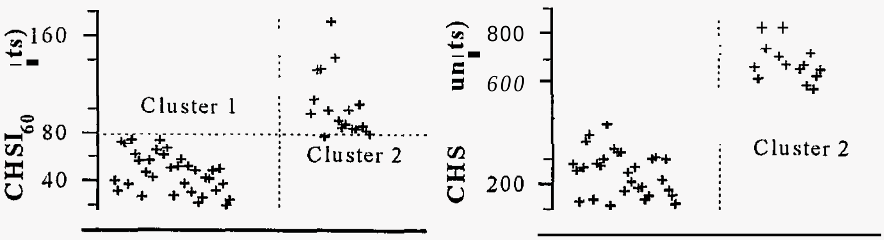


Fig. 2. The relation between the changes in T_r and HR after 60 and 120 min of exercise.

The average sweat loss was 1.62±0.47 L (0.84±0.25 L/m^2 of BSA), and the mean sweat rate (SR) was 14±4 mL/min.

Mean CHSI values for 60 and 120 min were 65.7±32.2 and 403.0±224.7 units, respectively. The analysis of $CHSI_{60}$ and $CHSI_{120}$ proved high correlation between these values ($r^2=0.78$; $p<0.001$).

Cluster analysis according to $CHSI_{60}$ revealed a statistically proved subdivision of the tested subjects into two groups, indicating a lower and higher tolerance to the exercise-heat stress (Fig. 3,4). The average value of CHSI for the more tolerant group was $CHSI_{60}=46$ vs. $CHSI_{60}=102$ for the less tolerant group. The categorization of a subject into one of the 2 subdivision after the 1st hour remained valid also after 120 min ($CHSI_{120}=251$ vs. $CHSI_{120}=627.2$). The differences between the groups were significant already after the first hour ($p<0.01$) which makes it possible to evaluate the subject's heat tolerance by exposing them to heat only for 1hour. Cluster analysis, applied for T_r and *HR* could not categorize the subjects systematically into the two distinctive groups.



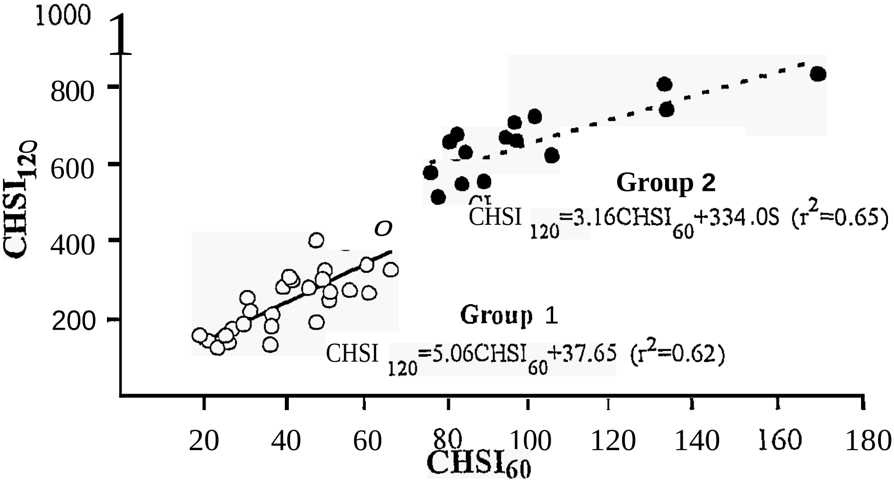


Fig. **4.** The relation between $CHSI_{60}$ and CHSI„„.

CONCLUSIONS

The CHSI might be a better predictor for heat tolerance than the reliance on changes in T_r and HR. It is suggested that the **CHSI** can allow the estimation of heat tolerance during early stages of the heat tolerance test. Therefore, it could serve as a useful tool for the quantitative estimation of lieat tolerance in subjects at risk for heat related disturbances.

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