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Original research

The validity of the heat tolerance test in prediction of recurrent exertional heat illness events

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ABSTRACT

Objectives: Heat-tolerance-testing (HTT) protocol is used as a screening test for secondary prevention of exertional heat illness (EHI) in the military. Subjects whose test results are positive (heat-intolerant, HI) are presumed to be at higher risk of repeated EHI events than heat-tolerant subjects (HT) and are therefore prevented from return to combat duty, but may return to unsupervised recreational activity. Our aim was to determine, whether HTT results predict the risk of repeated episodes of exertional heat illness (EHI).

Design: Retrospective cohort.

Methods: One-hundred-forty-five subjects (110 HT, 35 HI) who were diagnosed with an EHI event by a physician and underwent HTT during 2008–2015 were contacted and asked about recurrence of EHI. Incidence of recurrent events was reported as number of cases per 1000 person-years. Ratio of events among HI and HT individuals was presented as rate ratio (RR) and its 95% confidence interval.

Results: Of the 145 patients, six (4.1%) had experienced recurrent EHI events (10.63 per 1000 PY): four HI subjects (11.4%, 26.6 per 1000 PY) and two HT (1.8%, 4.8 per 1000 PY) (RR=5.504, CI 95%= 1.01–30, p=0.027). Only one of the six recurrent events was a heat stroke (HT individual), other five were heat exhaustions. Sensitivity, specificity and diagnostic accuracy of HTT were 66.7%, 77.7% and 77.2%, respectively.

Conclusions: The risk of EHI recurrence is measurable and can be discussed with patients before they return to sports. A referral to HTT can be considered, as negative HTT result is associated with substantial and significant EHI risk reduction.

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1. Introduction

On the spectrum of the exertional heat illness (EHI), exertional heat stroke (EHS) is a potentially fatal condition, resulting from excess heat accumulated in the body during physical exertion. It is an occupational hazard for young and healthy individuals: soldiers, manual laborers, and athletes.^{1,2} Residual neurologic damage, reduced exercise capacity, heat intolerance, and excess mortality have been reported among EHS survivors.^{3,4} Therefore, the prevention and treatment of EHS, as well as the decision to return an individual to active duty after an episode of EHS, receive high prior-

ity among other questions dealt with by sports and military training professionals.

Heat intolerance is characterized by a reduced ability to sustain exercise-induced heat stress.⁵ The symptoms have been linked to physiological defect in the ability to effectively dissipate metabolic heat. This concept is often used to distinguish between individuals who will endure standardized exercise heat stress and those who will not.⁶

Various protocols have been suggested to assist informed return-to-duty (RTD) decisions after EHS. Some protocols focus on clinical recovery⁶ and some rely on physiological responses to an exercise heat test.⁷ For the last 40 years, RTD decisions of soldiers who had experienced an episode of EHS in the Israeli Defense Force (IDF) have been based on the results of a heat tolerance test (HTT).⁷ In short, the results of the test are based on core body temperature and heart rate responses to a 2-h exercise-heat stress consisting

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of a treadmill walk (5 km/h) in a climate chamber under controlled conditions of 40 °C and 40% relative humidity. Testing is performed a few weeks after clinical recovery from the episode of EHS.⁷ The test is repeated, 2–3 months later, for those individuals who are considered heat intolerant (HI) during the 1st test. A positive result on the second test is a definitive indication for revision of the subjects' medical profile grade and discontinuation of their combat service.⁷

Nevertheless, the sensitivity and specificity of the test have never been analyzed, mostly due to the fact that those who are diagnosed as HI do not return to regular physical activity. In this paper, using retrospective data, we attempted to quantitatively evaluate the HTT-based decision to return to duty, by its ability to predict a repeated episode of EHI, either heat stroke or heat injury. We have also assessed for any residual post-EHS exertional symptoms among subjects who underwent HTT.

2. Materials and methods

The study was based on a cohort of 147 individuals who were referred to an HTT in our lab between 2008 and 2015 after sustaining an episode of EHS or suspected EHS (presentation with significant neurologic dysfunction, but with delayed measurement of core temperature, performed only after cooling and not reflective of core temperature at the time of collapse) and who were otherwise healthy. The diagnosis of EHS was made by a unit physician, based on the initial clinical presentation, rectal temperature value and emergency room laboratory results. Only individuals who performed the test at least 6 months prior to the survey where included in the cohort. This follow-up survey was approved by the IDF Medical Corps' institutional review board.

Demographic and contact information, details of the EHI event, and the HTT data of these individuals, were available from the clinical database of the Warrior Health Research Institute. Data collected included age at the time of the event, height, weight, type of activity preceding the event, first measured core temperature, time from collapse to temperature measurement (coinciding with the time when the subject was first examined by a medic and then cooling treatment with water was started), and time between the event and the HTT. Some subjects' initial HTT was positive, but second or third HTT was negative. We used the latest HTT result to classify individuals as heat tolerant or heat intolerant, and reported the time between the event and the latest HTT.

Of the 147 subjects, one refused to participate and one was excluded due to a history of recurrent syncope, unrelated to exertion. Remaining subjects reported no background medical conditions or chronic medications use. A physician who is familiar with EHI and the HTT completed the telephone interviews, which included questions about return to previous level of activity, recurrent episodes or symptoms of EHI, presence of any difficulties in performing exercise in the heat (i.e. heat intolerance symptoms), and any background medical conditions (Table 1). Each subject was classified as HI or HT, according to the HTT result.

A recurrent episode of EHI was established based on subjective reports of any impairment of consciousness that occurred during exercise or work, and a participant's description of an episode as

Table 1
 The survey questionnaire.

1	Have you returned to the level of activity that you were capable of before the initial exertional heat illness event?
2	Ever since the first event of exertional heat illness, have you experienced any recurrent event similar to the first one?
3	Have you been experiencing any symptoms on exertion? (headache, dizziness, nausea, any other symptom)
4	Do you have any background medical condition?

similar to the EHI event encountered in the past. The subjects were asked "Ever since the first event of exertional heat illness, have you experienced any recurrent event similar to the first one?" We further inquired about any medical documentation of the event, in order to obtain more clinical details.

Residual post-EHI symptoms were defined by reports of any headache or dizziness on exertion, disturbed thermoregulatory function (e.g. change in sweating pattern or perception of ambient heat different from other people), and any new neurologic impairment that was not present prior to the first EHI event.

Duration of follow-up was calculated as the time elapsed from the first EHI event to the telephone survey. Rate of the recurrent events was calculated as the number of events per 1000 person-years. Comparison of the event rates between the HT and HI individuals was done by using exact estimates of the rate ratio and their 95% confidence intervals.⁸

Screening utility of HTT was evaluated using standard contingency tables and by calculating sensitivity, specificity, and diagnostic accuracy of each classification, using recurrent EHI events as reference. Odds ratios of EHI events and their 95% confidence intervals were calculated from contingency tables using Wilson score.⁹ Statistical analysis was performed on R 3.3.0 open-source software.

3. Results

Based on the HTT results, 35 subjects were identified as HI and 110 subjects as HT. Mean time of follow-up was 48 months, ranging from 8 to 108 months. Six recurrent EHI episodes were reported (4.1%, 95% CI: 1.7–8.4). Four events occurred in 4 heat-intolerant (11.4%) and 2 (1.8%) heat-tolerant subjects. (odds ratio = 6.85, 95% CI (1.2–39.8), p = 0.03,). The recurrent event incidence rates, the rate ratios of HI to HT subjects, and the screening utility measures of HTT are presented in Table 2.

Only one event was registered in medical records as a heat stroke. It had occurred in an individual who was previously diagnosed as heat-tolerant, during reservist military training, while marching in full gear. Obvious risk factors for the event included high environmental heat load and inadequate hydration. Other five subjects described episodes of collapse due to fatigue, syncope or pre-syncope that were treated by cessation of activity, cooling with water and rest, and complete recovery occurring within minutes to hours. Only one of these events occurred during military training in an active service officer, who was diagnosed as heat-intolerant and was assigned an administrative role in a combat unit. He had violated the recommendations and participated in a training march

Table 2
 Recurrent heat illness events.

	HTT– (Heat-tolerant)	HTT+ (Heat intolerant)	Total/significance
No. of subjects tested (total n = 145)	110	35	145
No. of recurrent cases (total n = 6)	2	4	6
Duration of follow-up (total person-years for the group)	416.96	147.38	564.34
Ratio (recurrent events ratio (cases per 1000 person-years)	4.832	26.59	0.0267

HTT – heat tolerance test.

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