Heat Intolerance, Body Size, and Return to Duty

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BACKGROUND: Exertional heatstroke affects athletes and soldiers and can lead to temporary heat intolerance. The heat tolerance test (HTT) was developed to assist in the return-to-duty decisions of military personnel. Although there are several possible causes for heat intolerance, a soldier who fails the test is prevented from returning to serve in a front-line combat unit, regardless of the underlying reason.

CASE REPORT: A 19-yr-old special infantry male soldier with unremarkable medical history collapsed during an afternoon hand-to-hand combat training session in the gym. The medic on site promptly initiated inefficient tap water cooling and measured a rectal temperature of 38.7 °C; he returned to duty the same evening. A few weeks later, after intensive physical training, he experienced exhaustion during a stretcher-carrying foot march. He was referred by the unit's physician, who suspected a condition of heat intolerance, to an HTT. The soldier underwent two HTTs, which were found to be positive. Consequently, he was discharged from serving in his infantry unit. No congenital or functional underlying causes could explain the diagnosis of heat intolerance.

DISCUSSION: We discuss the possibility that the only explaining cause for the two positive HTTs was the soldier's anthropometric measures, particularly the low body surface area to body weight ratio. We raise the question of whether this soldier could have been returned safely to duty.

KEYWORDS: heat stress, heat tolerance test, body surface area, soldier.

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Exertional heatstroke (EHS) is a sporadic event affecting mainly athletes and soldiers who were previously considered healthy.[6] Hence, EHS is a consequence of an underlying inherent or acquired cause that compromises the ability to sustain exercise-heat stress.[11] While the ability to tolerate exercise-heat stress is within a wide range of interindividual variability, those individuals who experience an earlier and greater rise in core body temperature (T_c) are defined as "heat intolerant" and are possibly prone to EHS.[8] A temporarily acquired heat intolerance (HI) underlies most EHS cases. However, some inherent conditions may endanger an individual's tolerance to heat and expose him/her to a recurrent EHS episode.

A heat tolerance test (HTT) was developed over 40 yr ago by the Israel Defense Forces (IDF) Medical Corps with the aim to serve as a decision support tool for the return to duty (RTD) of combat soldiers who suffered (or were suspected to suffer) from EHS.[10] That is, the HTT is considered a functional measure for return to activity.

This case report describes a special forces infantry soldier found to be heat intolerant on two HTTs; a priori this prevented his RTD as a combatant. However, a deeper evaluation of the case proposes a possible explanation for the two positive results of the HTT and questions whether RTD of this soldier would have endangered him. The soldier gave his written consent to use his data in the following case report.

CASE REPORT

A 19-yr-old highly motivated man with an unremarkable medical history (weight 92 kg, height 184 cm) was drafted in November. After completing basic training with honors and

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without any notable medical events, he began advanced special forces infantry training in May. He was rated by his commanders as a good combatant with the potential to become a platoon commander.

During an afternoon hand-to-hand combat training session in an unairconditioned gym, including bouts of high-intensity exercise, 2 mo through advanced training (July), he began running aimlessly across the hall, eventually collapsing. His peers described him as tachypneic and obtunded but responsive to voice. With a vague suspicion of exertional heatstroke, inefficient (small volume) tap water cooling was attempted promptly by the medic on site and within minutes a rectal temperature of 38.7 °C was measured. Upon evaluation in the base clinic, the soldier's vital signs (pulse, blood pressure, and temperature) were within normal limits and he was instructed to rest. A physician conducted a physical examination a few hours later that he described as normal and documented a diagnosis of "hyperventilation". The soldier also complained of subjective heat sensation and one episode of vomiting during this training session. Heat load during the day of the event (between 08:00 and 17:00) was moderate (discomfort index was 24–27 units) and comfortable during the night (discomfort index < 22 units). Similar heat loads were also measured on the day prior to the event. The soldier was cleared to continue training.

A few weeks later, during a 25-km navigation trek, the soldier felt ill toward the end and was assisted by a team member to complete the mission. During a stretcher-carrying foot march that began right afterwards, he experienced exhaustion and finished with the support of his comrades. He was not referred to the base clinic for further evaluation and was not treated by a medic on site.

Although those two episodes were not diagnosed as EHS or suspected EHS, the unit physician, who suspected a condition of HI, referred the soldier to the IDF Institute of Military Physiology for further evaluation and an HTT. As part of the test protocol, the Institute's physician performed a preliminary investigation of the soldier's past medical history, including his family history, medication/supplement use, and history regarding smoking, alcohol, and illicit drug use. On the morning of the HTT, the soldier was briefed by the physician to assess medical eligibility to perform the test (excluding any signs of acute illness and inadequate adherence to the preliminary instructions, e.g., a minimum of 6 h of sleep in the night before the test).[10]

By the end of September, 4 wk after the second episode, he underwent an HTT. The test was considered positive (**Fig. 1**). In December, the soldier underwent a second HTT that was found to be positive as well (**Fig. 2**). Sweat rate in both tests was within the expected values (570 g · h^{-1} and 890 g · h^{-1} on the first and second HTT, respectively).

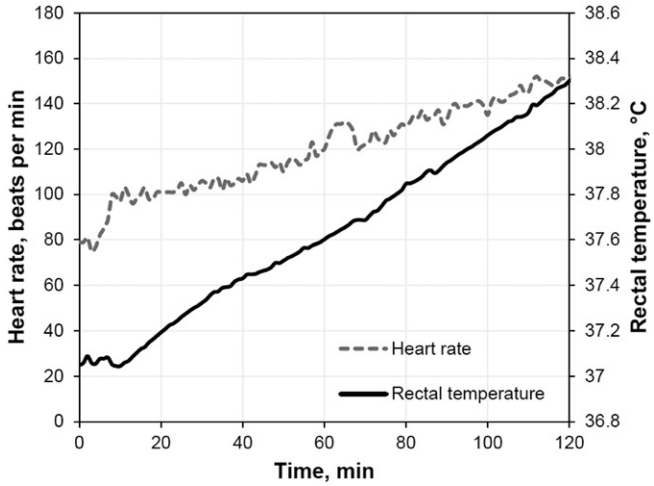

Fig. 1. Results of the first heat tolerance test.

DISCUSSION

This case exhibits the consequence of a skilled special infantry soldier who underwent two HTTs that were considered to be positive, based on the IDF criteria.[10] Accordingly, the soldier was diagnosed as heat intolerant; his medical profile was adjusted and he was disqualified from serving as an infantry soldier.

In view of the soldier's medical history and his proven ability to sustain intensive and highly demanding physical tasks allegedly under different harsh environmental conditions, two questions were raised. First, was there any evidence for EHS in either of the two events, although they were not reported as such, that justified an HTT? Second, what was the underlying cause for failing the two HTTs?

Exertional heatstroke is the most severe form of a spectrum of heat-related injuries.[9] It is a syndrome that involves, in the acute phase, elevated body temperature (usually > 40 °C) and noticeable neurological deficits (reduced consciousness level, cerebellar signs, and behavioral changes). Later it may involve multiorgan failure and, in severe cases, may potentially be fatal.[6] Heat exhaustion, a moderate form of heat-related injury, is described as a mild elevation of body temperature and reduced organ perfusion that result in fatigue. Organ damage and central

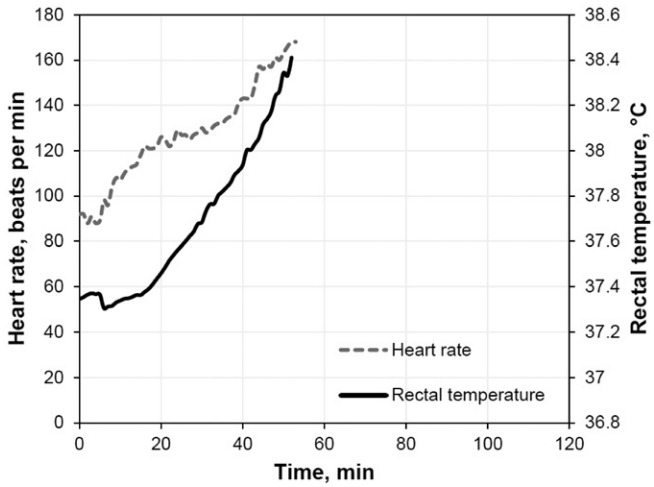

Fig. 2. Results of the second heat tolerance test.

nervous system dysfunction are absent or extremely mild and recovery occurs rapidly with the cessation of heat stress.[9]

The first event was characterized by a mild elevation in rectal temperature (38.7 °C) that was measured upon collapse, with no noticeable clinical signs to support heatstroke besides slight irrational behavior. Although mildly elevated, the temperature following the training session is not unusual for the type of physical exertion the soldier was participating in and certainly not life-threatening. This enabled him, after a few hours of resting, to continue with his training on the same evening. Additionally, a core body temperature of 38.7 °C, even if measured after cooling, is unlikely to suggest a heatstroke. With a cooling rate of 0.1–0.15 °C · min^{-1}, lowering a temperature above 40 °C would require about 15 min of splashing copious amounts of tap water.[2] There is no evidence of such cooling in the findings or the soldier's anamnesis. It is suspected, therefore, that this event could be addressed as physical exhaustion or heat exhaustion.

There is no clear underlying cause for the soldier being the 'weak link' among his teammates that can explain why he, and not others, experienced exhaustion in the hand-to-hand training session (the first episode). Allegedly, the soldiers in the platoon, who participated in the same activities and went through the same basic and advanced training course, were all healthy; they were all equally fit, heat acclimated, sleep-deprived, tired, and highly motivated. There are no laboratory measures of maximal oxygen consumption to support the soldier's physical fitness. However, the soldier graduated basic training with excellence, which also required a high level of physical fitness. Furthermore, being a special forces infantry soldier requires a sustained high level of physical fitness that is tested periodically during the training program; the soldier passed with scores that were acceptable by the unit. It seems that the only difference between this soldier and his peers was his physique. At the time of the event, he weighed 90 kg, which put him in a disadvantaged condition, probably leading him to accumulate excessive amounts of heat during the activity.

The second event, addressed as physical exhaustion, was experienced also by several other soldiers of the platoon. It occurred after hours of physical exertion, which included a 25-km navigation trek that was followed by a stretcher-carrying foot march. In this event, core body temperature was not recorded and there were no symptoms of EHS (and even not of heat exhaustion). The soldier did not receive any treatment and was cleared to continue his training. This event differs considerably from the first event and cannot be considered a recurrent case of EHS. To the best of our judgment, this soldier did not suffer from EHS either on the first or the second episode.

A reduced ability to sustain exercise-heat stress, considered HI, is a consequence of inherent causes (e.g., impairment of thermoregulatory mechanisms) and acquired factors (e.g., drugs, acute illness) that can result in a positive HTT.[3] Heatstroke is also considered a temporary or (rarely) permanent cause of HI.[3,8] Therefore, with the notion that the HTT is a functional test that reflects the ability to thermoregulate properly at the time of testing, a common practice in the IDF is to perform a second HTT 3 mo after a test that is considered positive. A previous survey reported that only 10% of IDF individuals who performed the HTT failed on the first attempt, and less than 2% failed the second test.[4] Thus, the decision on RTD should be reviewed on an individualized basis, also looking at the underlying reason for the positive HTT.

In view of the soldier's medical history, his current activity, and physical fitness, the question that arises is what might be the underlying cause of the two positive HTTs. The possible underlying factors for HI are grouped under three categories: congenital, functional, and acquired.[3] Acquired and congenital conditions may cause reduced sweat production that can lead to hyperthermia during the HTT. On anamnesis prior to the HTT, the soldier complained of excessive rather than reduced sweating, which is inconsistent with a congenital sweating disorder. Furthermore, sweat rate measurements taken during the HTT were within the test norms, so any condition of temporary anhidrosis can also be eliminated. Moreover, any other congenital state can be eliminated, with high probability, as the soldier successfully completed his basic training and part of the advanced training in a special infantry unit without any major adverse event. Likewise, any other acquired factor underlying HI, such as acute infection, low physical fitness, and low level of heat acclimation, could also be ruled out. There were no signs of him suffering from acute illness. He was equally heat acclimated as his peers and, as stated above, he met the physical fitness standards of an elite infantry unit.

By eliminating all potential factors underlying HI which have been reviewed in the literature,[3] a possible explanation of this soldier's two positive HTT results may be the anthropometric factor and specifically a low body surface area (BSA) to bodyweight (M) ratio (BSA/M ratio).[1,5,7] Although this anthropometric variable is frequently listed, it received low attention. The soldier's anthropometric measurements at the time of the HTT were a body mass index (BMI) of 27.2 kg · m^{-2} (fat percentage 20.6%) and a BSA/M ratio of 234 $cm^2 \cdot kg^{-1}$ (weight 92 kg, height 184 cm), which significantly outranges the average combat infantry soldier in the IDF (BMI ~23.0 kg · m^{-2}, corresponding to BSA/M of ~258 $cm^2 \cdot kg^{-1}$).[12] Furthermore, in a random cohort of 50 HTTs performed in our Institute, preliminary results showed a mean BSA/M of 254 ± 21 $cm^2 \cdot kg^{-1}$, which was statistically significantly different between heat tolerant (N = 28, 263 ± 15 $cm^2 \cdot kg^{-1}$) and heat intolerant (N = 22, 244 ± 22 $cm^2 \cdot kg^{-1}$) examinees (P = 0.002, Cohen's d = 1.01). Interestingly, all subjects (N = 9) with BSA/M <235 $cm^2 \cdot kg^{-1}$ were heat intolerant. These results are in accord with previous studies that showed a significant correlation between BSA/M ratio and HI.[1,5]

The importance of BSA/M ratio in heat dissipation is evident from the fact that, under the conditions of the HTT, heat accumulated exceeded heat dissipation, resulting in an increase of both heart rate and body core temperature. Under field conditions where heat dissipation is usually not limited, this soldier

is not disadvantaged. However, during the first episode, when training took place in a crowded and less-ventilated gym, the ability to dissipate heat was limited and, ultimately, he accumulated more heat than his peers. In this regard, although the soldier was identified as heat intolerant based on two positive HTTs, was it justified, from a physiological perspective, to amend his military medical profile and discharge him from serving in a combat infantry position, or could he have been allowed to continue to serve safely in the capacity as a combat infantry soldier?

The lesson learned from this case is that positive HTT results should be assessed carefully—not only by simply identifying an individual as heat intolerant, but also by understanding the reason for the diagnosis. A question yet to be resolved is the anthropometric background for heat intolerance and its importance in the decision on RTD of soldiers taking the HTT.

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