HEART RATE AND THERMAL RESPONSES IN PROLONGED JOB-RELATED FIRE-FIGHTING DRILLS

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INTRODUCTION

Good physical and mental health and a certain minimum level of maximal oxygen consumption and muscle performance are the primary requirements in several countries in selecting candidates for occupational fire-fighting training. Tolerance to either high ambient temperatures or exercise-induced heat strain are normally not tested even though exhausting heat strain and high risk for heat-related disorders in fire-fighting and rescue work are reported in numerous studies (1-5).

The purpose of the present study was to investigate the test subjects' safety in an existing job-related test drill for sustained exertion in heavy clothing under strenuous conditions causing considerable heat stress to the subjects. Passing this drill is obligatory for every fire-fighting student in the Finnish Emergency Services College before finishing their occupational training.

MATERIAL AND METHODS

The *subjects* were 83 healthy male fire-fighting students with an average age of 23.4 (range 19-34) years, height 177.5 (164-197) cm, weight 75.7 (57-92) kg, body area 1.92 (1.67-2.16) m^2, body fat 13.2 (6-22) %, body mass index 25.2 (20-29), and maximal oxygen consumption 55.4 (42.5-70.5) $ml \cdot kg^{-1} \cdot min^{-1}$.

The students wore a *fire-protective equipment system* (FPES) consisting of a two-piece multilayer water vapour permeable turnout suit meeting the European standard EN 469, pants, cotton underwear with long sleeves and legs, cotton sweat shirt and trousers, rubber safety boots, leather gloves, wool underhood, helmet, tool belt, and Dräger self-contained breathing apparatus with one air container and full face mask. The total mass of FPES averaged 26.4 kg (about 35 % of the average body mass of the students) and had a thermal insulation of 1.8 clo.

The *test drill,* conducted in the mornings outdoors and indoors at air temperature ranging from 5 to 45°C and performed at one's own speed, was divided into three consecutive work sessions with a 10-min rest period between each session for body cooling, drinking *ad libitum,* and changing the air container. The work sessions included typical individual fire-fighting tasks (e.g. hammering, carrying hoses, climbing stairs and ladders, pulling weights, manoeuvering through restricted areas) and a rescue task in pairs. This involved manoeuvering a 60 kg manikin in the dark through a two-storey simulated apartment (ca. 30 m). The maximum time allowed for passing the drill was 105 min.

Measurements. The performance time was recorded. HR was continuously measured (Polar Sport Tester PM 3000) and recorded once a minute. Rectal temperature (T_{re}) at a depth of 10 cm (YSI 401) was registered at the beginning and end of each session. Sweat production (Sauter E 1200) was estimated as the change in nude body weight, measured before and after the work sessions and corrected for fluid intake. Subjective evaluations of thermal comfort and thermal sensation modified from ISO 10552 as well as skin wettedness (scale 1 *dry* to 5 watery wet) and ratings of perceived exertion RPE using the Borg scale from 6 'extremely light' to 20 'extremely hard' were requested at the end of the work and rest periods. Means SD and ranges were used for description of the data.

The test protocol was approved by the Institutional Ethics Committee, and the procedures followed the principles of the Helsinki Declaration. The test drill was discontinued if one of the following criteria was met: 1) $T_{re} \geq 39.5°C$ with objective signs of severe discomfort or fatigue, 2) subjective feelings of chest pain, intense muscle pain or exhaustion, 3) exertional dyspnea or dizziness.

RESULTS

Seventy-five students completed the drill but only 63 of them passed it within the required time limit. Eight students were withdrawn because of heat syncope, exhaustion, or steep continuous rise in T_{re}. The average performance time for the completed drill was 94 ±12 min ranging from 79 to 155 min. The premature terminations occurred after 75 min on average (range 65 - 85 min) either during or at the end of the 2nd work session. Ten exhausted students with T_{re} 39.5°C were actively cooled at the end of the test.

HR increased rapidly during the first minutes of each work session up to or near the individual HR_{max} and fluctuated at that level during the work. After the work ceased, the HR dropped slowly and remained during the 10-min rest periods at levels of 110 to 150 b·min^{-1}. After the entire drill, the mean HR was still on a considerably.higher level after the half-hour recovery than during dressing on FPES. In some cases the recovery took more than one hour.

The range of the individual mean work HR during the drill, was 150 to 185 b/min corresponding to near-maximal circulatory strain of 75-96 % HR_{max}. The individual peak HR for the 1st work session varied from 171 to 196 b·min^{-1}, and respectively, for the 2nd from 169 to 199 b·min^{-1}, and for the 3rd from 175 to 206 b·min^{-1}. In nine students HR ≥200 b/min was registered.

Mean T_{re} and the T_{re} ranges for the start of the drill and at the end of each work session are given in Table 1. The average T_{re} increase in the completed drills was 1.5 0.4C. However, the individual variation in T_{re} responses was considerable: the T_{re} increase ranged from 0.7 to 2.2°C. The students who interrupted the drill had T_{re} of 39.1 ±0.6 (38.3 - 39.9)°C on average at the time of termination and they reported the work as 'extremely hard' or 'impossible to continue' and their conditions as 'very hot', 'watery wet' and 'very uncomfortable' on average.

The average sweat rate in the completed drills was 0.8 ±0.2 (0.3-1.2) kg·m^{2}·h^{-1} and respectively, water intake 0.8 ±0.4 l (0.2-1.9) kg, and water deficit

Table 1. Rectal temperature and ratings of perceived exertion (RPE) measured at the start of the drill and at the end of the work sessions*.

	Rectal Temperature, °C		RPE	
	Mean ± SD	*Range*	*Mean ± SD*	*Range*
Start	37.6 ± 0.23	37.1 - 38.1	10.2 ± 1.9	6 - 13
1. WS	38.2 ± 0.38	37.5 - 39.4	13.9 ± 1.8	7 - 17
2. WS	38.8 k0.36	38.1 - 39.9	16.4 ± 1.6	13-20
3. WS	39.0 ± 0.35	38.0 - 39.8	16.2 ± 1.5	13-20

* Values are for completed drills (n = 75).

1.6 ±0.7 (0.4 - 4.0) %. The respective values for prematurely terminated drills were 1.0 ±0.3 (0.6-1.5) kg·m^{2}·h^{-1}, 1.3 ±0.7 (0.2 - 2.1) kg, and 1.0 ±0.7 (0.5 - 2.4) %.

The physical work in the completed drills was perceived as being 'hard' on average, but the ratings varied from 'somewhathard' to 'extremely hard' (Table 1). At the start of the drill the students reported their conditions as 'neutral' or 'slightly cool', 'comfortable' or 'slightly uncomfortable' and the skin was felt to be 'dry' or 'clammy'. Correspondingly, at the end of the drill, they reported 'hot', 'uncomfortable' and 'wet' on average, but the individual variation in thermal votes was considerable. For example, at the end of the drill the ratings for thermal sensation varied from 'slightly cool' (a shivering student with T_{re} of 39.4°C) to 'exhaustivehot'.

DISCUSSION AND CONCLUSIONS

The studied fire-fighting students were young and healthy and their physical work capacity fulfilled the criteria for occupational fire-fighting training in the Finnish Emergency Services College. However, the individual variation within this selected group in thermal and circulatory responses to exercise-induced heat strain was significant.

Aerobic fitness did not explain the variation. The results are rather in accordance with some earlier studies (1, 5), namely that good maximal oxygen consumption alone does not predict very well individual performance in the heat or tolerance to exercise-induced heat stress. Therefore the testing of individual heat tolerance is recommended in selecting candidates for occupational fire-fighting training.

The risk of heat-related physical exhaustion and even fatal heat stroke grows when T_{re} rises above 38.9 to 39.2°C (1). T_{re} 39.0°C was measured in 55 students, and the highest T_{re} value was 39.9°C. Questions about safety of occupational training came up. Should physiological monitoring of fire-fighting students undergoing occupational training be obligatory in job-related drills, as recommended in international draft standard ISO/DIS 12894, which provides guidance about medical fitness assessment and heath monitoring which may be appropriate prior to and during extreme hot exposures. Our results support this recommendation.

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