CARDIAC STRAIN IN TWO CONSECUTIVE EXPOSURES TO HEAVY WORK WITH FIRE-PROTECTIVE EQUIPMENT IN THE HEAT

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INTRODUCTION

Fire-fighting and rescue operations such as smoke-diving are often strenuous and carried out in a hostile environment which requires the use of protective clothing and equipment. A multilayer turnout suit designated to fulfil the European standard, EN 469 (1) provides a good protection against fire, thermal radiation and chemicals. On the other hand, the suit is heavy when used over standardised (Nordic) clothing and with a self-contained breathing apparatus (SCBA). The recent study of Louhevaara et al. (2) indicated that this type of fire-protective clothing system and SCBA (total weight: 26 kg) increased submaximal cardiorespiratory responses as well as decreased the maximal power output, on average, 25 % in a thermoneutral environment. Few reports are available about the effects of this fire-protective clothing system and SCBA on physical work performance in the heat (3, 4), and no information can be found on the effects in repeated combined exposures to heavy dynamic work and heat.

The aim of this study was to investigate cardiac responses in two consecutive exposures simulating physically and thermally demanding smoke-diving tasks with the European standard based turnout suit used over standardised (Nordic) clothing and with SCBA.

MATERIAL and METHODS

The subjects were 12 male experienced fire fighters with the mean age of 32 years (range: 26-46 years). The mean (range) of their weight, height, body fat, maximal oxygen consumption (VO_2max) and maximal heart rate (HRmax) was 86 (69-101) kg, 180 (174-187) cm, 14 (10-20) %, 46.9 (33.4-73.3) ml/min/kg, and 186 (168-194) beats/min, respectively.

After the medical examination and maximal exercise test on a treadmill the subjects performed two consecutive tests (15 min + 15 min) simulating demanding smoke-diving. Both tests included the same exposure to heavy dynamic work (treadmill

walk, speed: 4.5 km/h, angle: 2°, estimated V02 with fire-protective equipment: 25 ml/min/kg), to hot dry environment and to the use of fire-protective clothing (Nordic) system and SCBA having a total weight of 25.9 kg with thermal insulation of 1.85 clo (2). In the tests the environmental characteristics were the following: ambient temperature (T_a): 50 "C, radiant heat: 1000 W/m^2, relative humidity: 20 %, and air velocity: <0.3 m/s. The consecutive tests were repeated with four combinations of the length of recovery and T_a during recovery between the tests (15/0, 30/0, 15/20, and 30 min/20 "C). Cardiac (HR, systolic blood pressure, **SBP,** and the rating of perceived exertion, RPE) and thermal responses were registered in the tests. **SBP** was measured before the tests and 3-4 minutes after the tests in a sitting position. The criteria for the interruption of the tests were exceeding the level of 90 % of the individual HRmax or 39 "*C* in rectal temperature.

The statistical significance of the differences in the cardiac responses and work performance in the four test combinations was tested by two-way analysis of variance with repeated measures.

RESULTS

Three subjects passed all tests without interruptions. Seven second tests were interrupted when the preceding recovery time was short (15 min) and warm (20 "C). The mean incomplete performance time was 1300 s. The length and T_a during the rest pauses between the tests did not affect significantly the number of interruptions in the second test but they affected endurance times significantly ($p<0.001$)(Table 2).

Table 2. Number of the interruptions and the mean incomplete performance time in the second tests after the different combinations of the length of recovery and ambient temperature (T_a) during the rest pauses between the tests.

	Number of interruptions[a] (n)		Mean incomplete performance time[b] (s)	
Length (min)	15	30	15	30
T_a 20	7	5	1300	648
(°C) 0	5	4	948	367

[a] $p=0.899$, [b] $p<0.001$

At the end of the second test following the 15 min/20 "C rest pause HR was 172±12 beats/min associated with RPE of 16±1. **SBP** was 134±17 mmHg. For the tests combinations of 15/0, 30/0, and 30 min/20 "C the corresponding values were 171±9

beatslmin, 17±1 and 128±14 mmHg, 162±15 beatslmin, 16±1 and 137±18 mmHg, and 170±13 beats/min, 16±1 and 135±19 mmHg, respectively. The length and T_a of the rest pauss between the tests affected significantly ($p<0.05$) *HR* (Fig. 1).

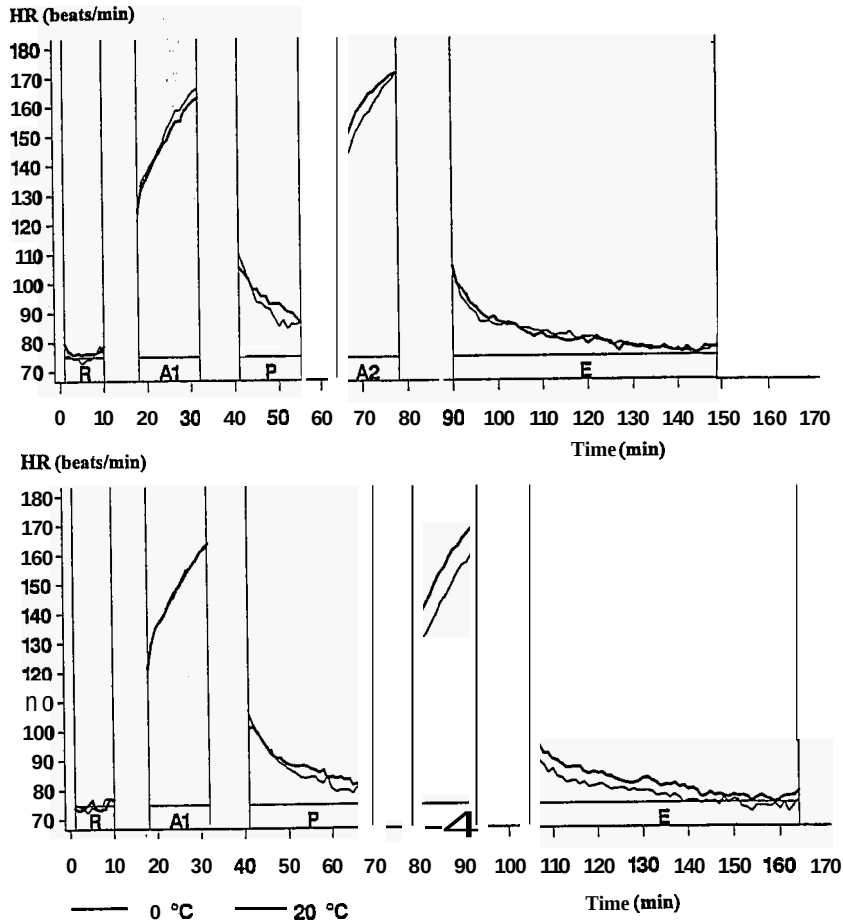

Figure 1. Mean heart rate (HR) of the 12 subjects in the experiments. R=Rest, A1=First test (15 min), P=Rest pause (15 or 30 min), A2=Second test (15 min), and E=Recovery period (30 min). The measurements were interrupted when the subjects walked from the thermal chamber to the recovery chamber and vice versa.

The interruptions of the tests were always due to HR over 90 % of the individual maximum. The length of the preceding rest pause or its T_a had no significant effects on **SBP** and RPE of the second test.

CONCLUSIONS

The cardiac strain in the present consecutive multi-exposures was too heavy for about the half of the subjects who were experienced fire fighters with an average or good VO_2max. In actual fire-fighting and rescue situations, repeated exposures consisting of heavy dynamic work, hot environment and the use of the Nordic type of fire-protective clothing system and SCBA should be avoided or sufficient time for recovery should be given. All possible means should be considered to reduce the weight of protective clothing and SCBA so that the balance between a fire fighter's physiological strain and safety could be optimised.

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