THE EFFECT OF FITNESS ON PERFORMANCE IN A HOT ENVIRONMENT WEARING NORMAL CLOTHING AND WHEN WEARING PROTECTIVE CLOTHING

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INTRODUCTION

The physiological adaptions associated with increased levels of physical fitness are synonymous with the adaptions to a hot environment (acclimatisation) (1). These adaptions result in an increased capacity to work in the heat as indicated by a lower rate of rise in core temperature and a reduced heart rate for set work rates and environmental conditions. When protective clothing is worn, evaporation of sweat is impeded, reducing heat loss, this may compromise performance regardless of fitness status. When wearing chemical protective clothing, soldiers performing simulated military duties in the Singapore hot season, found that neither acclimatisation nor fitness prevented heat exhaustion (2). If individuals do not adequately rehydrate, fitter subjects may dehydrate at a faster rate than their less fit colleagues, putting their cardiovascular system under greater stress, possibly reducing performance and increasing their risk of developing heat illness. Even mild dehydration (2% loss of body weight), is reported to impair exercise **(3)** and mental performance (4).

This study was undertaken to examine any physiological performance differences between two groups of subjects, deemed "very fit" and of "average fitness" when exercising in the heat, wearing permeable and semi-permeable clothing.

METHOD

Ten male subjects participated in the study. Subjects had their maximal oxygen uptake (VO_2max) measured running on a treadmill, using an incremental protocol to volitional exhaustion. Five of the subjects were very fit (VF), the remaining five were of average fitness (AF).

For the trial the subjects undertook a stepping exercise (step rate: 12 steps/minute, on and off a 22.5cm high box), performed on two occasions, separated by 7 days. The thermal environment of the chamber in which the subjects stepped was: 40°C dry bulb, 30°C wet bulb (50% relative humidity), WBGT index of 33°C. On one occasion the subjects wore normal Royal Navy working rig (WRG), this consisted of shirt, trousers, underpants, socks and leather DMS boots. On the other occasion they wore nuclear, biological and chemical (NBC) protective clothing, which consisted of charcoal lined dungarees and smock, a respirator, rubber gloves with cotton liners and leather boots with rubber overboots, beneath this was worn WRG. **A** balanced cross-over experimental design was used.

The subjects stepped in the environmental chamber until either: aural temperature reached 38.5°C; heart rate reached the subjects measured maximum (from the VO, max test) minus 10 beats.min^{-1}; request of the subject, medical or project officer or 180 minutes had elapsed. Subjects then sat in the chamber for a thirty minute recovery period.

Aural temperature (T_{au}), skin temperature (T,) and electrocardiograph were monitored continuously and recorded. Expired air samples, collected in Douglas bags at 15 minute intervals during the first hour of stepping and thereafter at 30 minute intervals were analysed and oxygen consumption calculated. At thirty minute intervals, blood lactate was determined from 50µL samples of blood taken from a finger tip and subjects rated their thermal discomfort, tiredness and skin wettedness. Water was provided at room temperature to drink *ad libitum,* the weight of water consumed was recorded. Sweat production and evaporation rates were calculated from changes in nude and dressed body weight. Rates of rise and fall (recovery) of heart rate, T_{au} and T_{sk}, rates of sweat production and evaporation, oxygen consumption, lactate concentration and subjective measurements were analysed across garment and fitness conditions using ANOVA.

RESULTS

The average VO_2max per kilogram lean body mass of the VF subjects was 74.7 (range: 71.2 - 85.2) ml.kgLBM.min^{-1}, that of the AF subjects was 59.7 (55.1 - 62.5) ml.kgLBM.min^{-1}. Non-parametric statistics indicated that there were no differences between the two groups in terms of age, height, body weight and percentage body fat and that the only difference was in their fitness levels.

All five VF subjects stepped for 180 minutes when wearing WRG. Two subjects in the AF group also stepped for this length of time, one subject stopped prior to this time because his T_{au} rose to 38.5°C, the other two because of discomfort; mean stepping time was 144 minutes. In NBC clothing, average stepping times for the VF and AF groups were 54 and 45 minutes respectively, all subjects except one in the VF group (who stopped because of discomfort) stopped because their T_{au} had reached 38.5°C.

When wearing WRG, during stepping and recovery mean T_{au} and T_{sk} for the AF group were significantly ($P<0.05$) higher than those of the VF group. When wearing NBC clothing mean T_{au} and T_{sk} were the same for both groups. Mean T_{au} are presented on Figure 1. Mean heart rates of the AF group were approximately 30-35 beats per minute higher than those of the VF group during stepping and recovery in both clothing ensembles. There were no differences in mean oxygen consumption between the two groups during stepping and recovery. Mean lactate concentration of the AF group was significantly ($P<0.05$) higher than that of the VF group during stepping when wearing WRG, there were no differences between the two groups when wearing NBC clothing.

When wearing NBC clothing, the mean sweat production rate of the VF subjects was 31.6 ml.min^{-1}, this was significantly higher ($P<0.05$) than the 17.2 ml.min^{-1} of the AF subjects;

when wearing WRG the sweat rates of the two groups were similar (mean rate of 14.7 $ml.min^{-1}$). There was a strong positive relationship between fitness and sweat rate when wearing NBC clotling, there was no relationship when wearing WRG, tlis is demonstrated on Figure 2.

The average rate of sweat evaporation for the 10 subjects was 11.6 $ml.min^{-1}$ when wearing WRG and 6.2 $ml.min^{-1}$ in NBC clothing, this difference was significant ($P<0.05$). When wearing WRG, an average of 81% of the sweat produced by the 10 subjects was evaporated, in NBC clothing, 22% was evaporated by tlie VF group and 34% by the AF group. The average fluid deficit for the VF group when wearing NBC clothing was significantly ($P<0.05$) greater than that of the AJ? group (22.5 $ml.min^{-1}$ compared to 13.4 $ml.min^{-1}$), this was despite the greater drinking rate of tlie VF group (mean value of 9.1 $ml.min^{-1}$ compared to 3.8 $ml.min^{-1}$ for the AF group). When wearing WRG, Uie VF and AF groups had average fluid deficits of 0.8 and 3.4 $ml.min^{-1}$ respectively, their corresponding drinking rates were 15.1 and 10.0 $ml.min^{-1}$.

Tlie thermal discomfort and tiredness scores for the two groups when wearing WRG were significantly different ($P<0.05$); there were increases in tlie average values for both variables with time for tlie AF group, whereas the average values for the VF group remained relatively constant. No differences were found between the two groups when wearing WRG for wettedness, with wettedness increasing with time for both groups. When wearing NBC clothing, there were no differences between the two groups, with scores of both groups increasing with time on all three variables.

CONCLUSIONS

Fitness increases work capacity, and is physiologically and subjectively beneficial when working in a hot environment and wearing permeable clothing. When working, wearing NBC semi-permeable protective clothing in a hot environment, the thermal load is so high, and the ability to dissipate heat so poor, that even very fit subjects are unable to thermoregulate.

dehydrated more quickly in these conditions than subjects of average fitness because of their greater sweat production rate. Although in this experiment the physiological performance of the two groups of subjects did not differ, it is conceivable that in a situation requiring work of longer duration, greater intensity or repeated bouts, that tlie performance

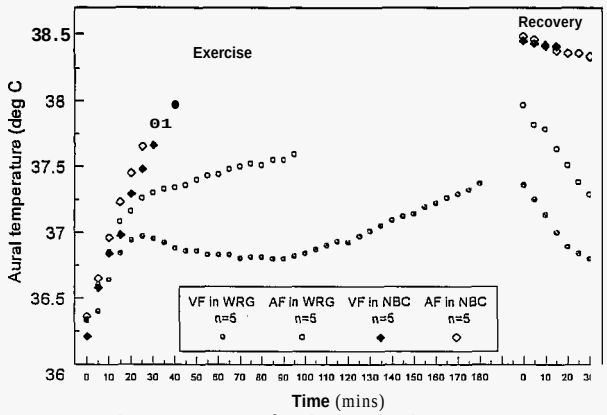

Figure 1. Mean aural temperatures for the VF and AF wearing WRG and NBC clothing

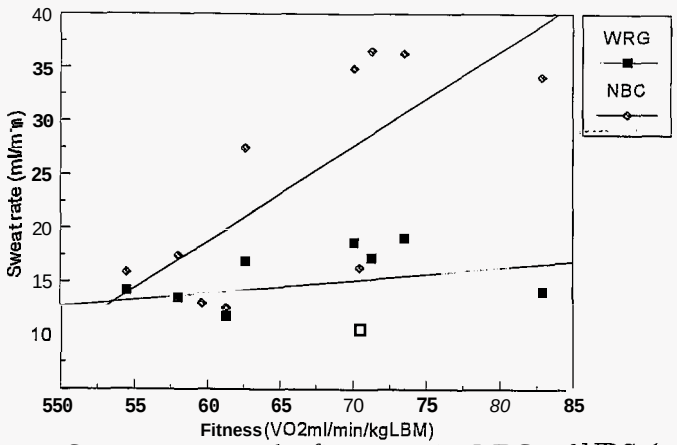

Figure 2. Sweat rate compared to fitness wearing WRG and NBC clothing

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