

OXYGEN UPTAKE AND HEART RATE DURING MARCHING IN WORK UNIFORMS (U) AND CHEMICAL DEFENSE ENSEMBLES (CDE) WHILE CARRYING LIGHT TO HEAVY LOADS IN A THERMAL NEUTRAL ENVIRONMENT

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INTRODUCTION

Cardiovascular endurance (as measured directly by VO_{2max} or indirectly by running or cycling performance) is a critical function of the human body in times of exercise and work when demands are made over periods of five minutes or longer. The onset of fatigue, the converse of endurance, is directly related to an individual's stamina and ability to complete physically demanding tasks. Most often, however, the measurement of endurance is carried out under good or ideal conditions. Consequently, these results have become yardsticks or standards to measure an individual's fitness against. While these standards are effective under most conditions, they may not apply to unusual situations. Such a situation is exercise while wearing CDE while carrying various loads, from light loads to heavy loads, which are often required during military operations.

Therefore, the purpose of this study is to determine the effect of prolonged, steady-state exercise in CDE and various packloads against the same loads while in standard work uniforms (U).

MATERIALS AND METHODS

After granting informed consent, 16 fit males (means: age = **22.8** years; weight = 74.1 kg and height = 179.4 cm) served as subjects for this study. Their relative body fat averaged 10.3%, while their aerobic capacity was 61.5 ml·kg⁻¹·min⁻¹, **STPD**. All of the subjects had been doing aerobic training for at least 6 months prior to the initial lab test.

The packload was determined after weighing the subjects in shorts. The ALICE pack, which housed weights (lead shot in bags), and uniforms were considered as part of the load. The load conditions were as follows: 0% (no load), 25%, **50%** and 75% of body weight. The subjects completed each load twice, once in U and once in CDE. The loads and clothing conditions were randomly assigned. The subjects marched at **4.8** kph (3.0 mph) on a level treadmill. No more than 3 loads were completed in one day with a minimum of 1 h of recovery. Only 1 session was completed on days in which a 75% body weight load was assigned.

Running shoes were utilized rather than boots to avoid blisters and other foot problems. During CDE conditions, a breathing mask was worn (model M17A1), as called for during military operational preparedness posture, stage 4 (MOPP4) conditions.

Oxygen uptake was determined by a computerized spirometry system employing a Rudolph breathing valve to shunt expired air through a corrugated tube (2.8 cm, id) into a 5-L mixing chamber. V_E (measured by a Rayfield dry gas meter) was then sampled to determine F_{EO_2} and F_{ECO_2} by Applied-Electrochemistry Oxygen and CO₂ analyzers. Heart rate was measured continuously using a single channel ECG with electrodes in the V5 position. The gas meter and gas analyzers were calibrated before and after each test session.

All VO_2 and associated measures along with HR were recorded and stored in the microcomputer for later analysis. Descriptive and inferential data analysis was accomplished with STATA (1), a statistical package written for microcomputers, with the alpha error level set at ($P < 0.05$).

RESULTS

As seen in Table 1, the steady-state VO_2 was $0.87 L \cdot \text{min}^{-1}$, STPD for 0% load when the exercise was done in standard work uniforms, which was significantly lower than when carried in CDE conditions ($1.01 L \cdot \text{min}^{-1}$). All other VO_2 scores were similar ($P > 0.05$) for the 2 clothing conditions for all the remaining loads.

Table 1. Oxygen uptake and heart rate for two clothing conditions and four exercise loads*..

Load %bw	Work Uniforms			Chemical Defense Ensembles		
	VO_2 $l \cdot \text{min}^{-1}$	VO_2 $ml \cdot \text{kg} \cdot \text{min}^{-1}$	HR $\text{beats} \cdot \text{min}^{-1}$	VO_2 $l \cdot \text{min}^{-1}$	VO_2 $ml \cdot \text{kg} \cdot \text{min}^{-1}$	HR $\text{beats} \cdot \text{min}^{-1}$
0	0.87f0.13	11.7 ± 1.8	87 ± 12	1.01 ± 0.15	13.622.0	96 ± 19
25	1.07f0.10	14.4 ± 1.3	103 ± 19	1.09f0.15	14.7f2.0	107 ± 29
50	1.30f0.17	17.552.3	108 ± 19	1.32 ± 0.23	17.7f3.1	115 ± 19
75	1.53 ± 0.19	20.6f2.6	128 ± 25	1.57 ± 0.24	21.2C3.2	135 ± 24

*Values shown are means ± SD. Subjects marched at $4.8 \text{ km} \cdot \text{h}^{-1}$ on a level treadmill at ambient temperature of 22°C and an RH of 40%

Heart rate values, as seen in Table 1, are similar for both clothing conditions, again with the exception of the no-load condition ($P < 0.05$). However, the pattern of change is somewhat curvilinear (see Figure 1), as opposed to the linear trend of VO_2 with increasing packloads. Figure 1 illustrates the curvilinear trend of the average HR response to increasing loads.

DISCUSSION

An important finding of this report was that marching in CDE requires a greater VO_2 and HR for the no-load condition when compared to the U condition. Further, the oxygen uptake for the greater loads was similar for both clothing conditions ($P > 0.05$) and reflects a linear increase with increasing loads. These findings extend the work of Wallcott and associates (2) who measured VO_2 on 17 middle-aged males for loads up to 40% of body weight on a level treadmill at 5.6 kph (3.5 mph). Furthermore, when adjustments were made for differences in walking speed between the 2 studies, the subjects from the

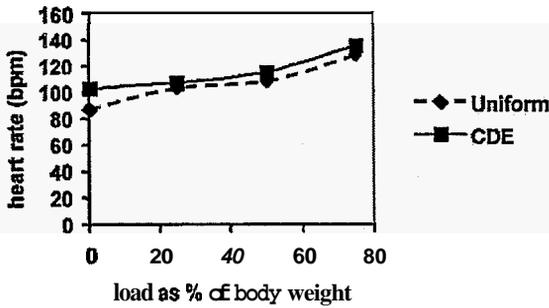


Figure 1. Mean heart rate responses to carrying packloads from no load to 75% of body weight for the two clothing conditions for 16 male subjects.

VO_2 required for a given speed was lower. Unexpectedly, the VO_2 , though usually higher for each respective packload when the subjects were wearing CDE, was not different compared to U ($P > 0.05$) with the lone exception of the 0% bw load, as indicated earlier. Here reference is made to an earlier report from this laboratory (4) in which it was shown that, in the MOPP4 condition, VO_{2max} was reduced by 25% when compared to VO_{2max} in typical exercise clothing. Moreover, the mean $V_{E_{max}}$ was reduced from 148 to 81 $L \cdot min^{-1}$, BTPS (or -45% decrement), reflecting the severely reduced ability to move large volumes of air in and out of the M17A1 mask. The fact that the highest packload condition only required a fraction of 34% of the subjects' mean VO_2 , and thus a proportionate fraction of $V_{E_{max}}$, is consistent with the failure to find a difference between the clothing conditions. The same study showed that the M17A1 mask could accommodate a flow rate up to $-50 L \cdot min^{-1}$ ATPS and still maintain a breathing resistance similar to most breathing valves used during maximal aerobic capacity testing. The mean V_E for the two 75% bw loads was 42 and 46 $L \cdot min^{-1}$ BTPS for U and CDE conditions, respectively.

An additional consideration is the increased heat load that would need to be dissipated while walking in CDE. That is, a greater circulatory load, and thus energy cost, would be incurred as more blood was sent to the periphery. However, Avellini (5) has shown that there is little difference in core temperature (rectal) after marching at 4.8 kph for 90 min (37.5 vs 37.75°C) for U and CDE conditions, respectively. The fact that the subjects of the present study only walked for 30 min suggests that the core temperature difference would be even smaller than those reported by Avellini.

CONCLUSIONS

It was concluded that the effect of increasing loads from 0% body weight progressively to 75% of body weight results in a linear increase in oxygen cost and a slightly curvilinear rise in heart rate.

Wallcott et al. report used 4.3% more O_2 , on average, at no load and 3.5% more at the 25% bw load. These differences, though small, are likely significant and may be attributed to lower levels of fitness. In this regard Morgan et al. (3) showed that as the fitness and performance of endurance runners increased, their running economy improved as well, i.e., the

Further, the effect of CDE in the MOPP4 condition demonstrated little effect on VO_2 and consequently, aerobic energy cost. Likewise, heart rate showed little effect of the CDE clothing condition.

Finally, it is proposed that the lack of differences found between the clothing conditions was due to small difference in core temperature changes, similar breathing resistances for the M17A1 mask breathing valves and the Rudolph breathing valve at mild to moderate exercise intensities.

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