ADAPTATION TO RESPIRATORY PROTECTIVE EQUIPMENT: FACT OR FICTION?

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INTRODUCTION

It is widely assumed that wearing military chemical protective equipment (known as individual protective equipment, IPE), particularly a respirator, causes a decrement in physical work performance (Carr et al 1980, Fine and Kobrick 1985, White and Hodous, 1987). Many studies examining the effects of IPE on work performance look at short wearing periods of up to 15 minutes. Van de Linde (1988) carried out a study in which military personnel wore protective equipment in the field for a maximum of 22.5 hours. Subjects wore different combinations of protective clothing and a respirator. The results showed that the measured decrement of 18-20% did not change during the day's wear. This current study was performed to find out if any adaptive changes occurred in measured respiratory parameters during intermittent three-hour periods of respirator wear throughout a two week study period.

METHOD

Twenty male military volunteers participated in this study. All subjects were experienced in respirator wear and received training in the study methods until no further improvement in test performance was seen. Prior to participation each subject underwent a thorough medical examination, received a briefing about the study methods, and signed a consent form. The study protocol was approved by an independent Ethics Committee.

The subjects' ages ranged from 18 to 38 years with a mean of 24 $\pm$ 4.5 years, mean weight was 76.9 kg $\pm$ 12.9 kg, and mean height was 175.5 $\pm$ 8.4 cm. The volunteer subjects were a mixture of smokers and non-smokers. Each subject performed standard spirometry and flow/volume assessment tests to measure respiratory frequency (Rf), minute ventilation (V_E), tidal volume (V_T), inspiratory capacity (IC), inspiratory time as a percentage of the total respiratory cycle (TI/Ttot), expiratory time as a percentage of the total respiratory cycle (TE/Ttot), inspiratory time as a percentage of the expiratory time (TI/TE), maximum ventilatory volume, (MVV), peak expiratory flow (PEF), and peak inspiratory flow, (PIF) using a Masterlab test system (Jaeger).

Before performing any of the tests, subjects had a minimum of four hours instruction and practice in the use of the equipment, as well as their previous military training and experience. The test sessions were performed at three different times of day. The first test each day (performed between 0900 hours and 1000 hours) was always carried out as a control, using a mouthpiece and noseclip (designated MP), to see if there were any changes in normal values as the study progressed. The other two tests (performed between 1200 hours and 1300 hours, and 1600 hours and 1700 hours respectively) on each day were performed when wearing a respirator (designated R) after it had been worn continuously for three hours.

The mouthpiece deadspace was approximately 50mls. The respirator was adapted so that the inhalation and exhalation valves were connected directly to the heated pneumotachograph of the Masterlab test system. The additional dead space of this adapted respirator and associated tubing was approximately 160mls. Subjects did not wear a noseclip inside the respirator when performing tests in it.

Flow/Volume Assessment: During each test session maximal flow-volume loops were recorded. This manoeuvre was repeated three times with short breaks between each repetition. The best of the three tests was saved for later analysis. The tests were all performed with the subjects standing upright at the test equipment. Spirometry: Subjects breathed quietly on the mouthpiece for 50 seconds to establish baseline values for tidal volume and breathing frequency. When a stable reading had been obtained for each of these parameters subjects were instructed to perform standard spirometry manoeuvres, these were also carried out standing in an upright position. Maximum Ventilatory Volume: Subjects were instructed to breathe as rapidly and deeply as possible for ten seconds in order to move the maximum amount of gas into and out of their lungs.

The mean values for each measured parameter (eg Rf, IC, MVV) for day 1 vs day 2, day 1 vs day 3, and day 2 vs day 3 of testing in the MP condition were compared using Student's t-test to see if there was any difference

between them that could be attributed to adaptation to the test conditions. The mean values for all subjects were then compared for the MP vs R in the morning test, and MP vs R in the afternoon test for each test day separately and then for all tests combined (analysis of variance using repeated measures). For all analyses, a probability of 0.05 or less was taken as significant.

RESULTS

The study did not specifically examine diurnal variation effects on the results obtained for R. However, there were no obvious time of day effects in any of the parameters measured. When comparing the two test conditions there was a significant difference (at least $p<0.01$) between the MP and R each day for Rf, which increased, and V_E ,V_T ,IC, MVV, PEF, and PIF which all decreased. (See table below). There were no significant differences between MP and R for the ratios of inspiratory and expiratory time compared to the timing of the whole respiratory cycle or in their ratio to one another.

DIFFERENCE BETWEEN MP AND R

Test day	Rf $no.min^{-1}$	VE $l.min^{-1}$	VT $l.min^{-1}$	IC l	TI/T_{TOT}	TE/T_{TOT}	TI/TE	MVV $l.min^{-1}$	PEF $l.sec^{-1}$	PIF $l.sec^{-1}$
Day 1 am	0.86	-3.16	-0.21	-0.16	0.08	0.09	0.15	-25.00	-2.31	-3.55
Day 2 am	1.49	-2.29	-0.17	-0.22	0.07	0.10	0.14	-34.78	-2.14	-3.44
Day 3 am	1.49	-2.47	-0.21	-0.28	0.07	0.09	0.13	-26.13	-1.58	-3.58
Day 1 pm	1.28	-2.31	-0.17	-0.08	0.07	0.10	0.14	-30.61	-2.13	-3.30
Day 2 pm	0.37	-3.55	-0.24	-0.33	0.05	0.07	0.11	-32.88	-2.16	-3.67
Day 3 pm	0.55	-2.72	-0.06	-0.34	0.05	0.06	0.10	-22.12	-1.83	-3.60
Mean of all days	1.01	-2.76	-0.18	-0.24	0.07	0.09	0.13	-28.59	-2.02	-3.52

The differences between the MP and R remained fairly constant for most parameters measured. The exceptions to this were MVV which reached a peak of difference in the middle of testing and Rf which appeared to show smaller differences between the two conditions during the afternoon test session on test days 2 and 3.

DISCUSSION AND CONCLUSIONS

The differences in respiratory performance between MP and R remained constant for most of the measured parameters. The pattern associated with MVV may be due to a learning effect in spite of the thorough training that each subject received, since this test is very technique dependent for consistent results. The differences seen in Rf each afternoon may simply be a time of day effect since the subjects were allowed to eat a normal lunchtime meal and then spent the afternoon sitting quietly wearing a respirator which would have had a significant soporific effect. From this data, it is suggested that habituation to wearing a respirator does not produce any significant change in measured respiratory function values for either the respirator or mouthpiece test condition. The results suggest that the changes in respiratory function induced by wearing a respirator are not ameliorated by training in the form of intermittent training sessions of three hours of wear during a two week period.

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