IMPACT OF NBC PROTECTIVE CLOTHING ON THE PERFORMANCE OF MEDICAL TASKS IN WARM AND COOL ENVIRONMENTS

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INTRODUCTION

Previous studies have shown that medical staff wearing nuclear, biological and chemical (NBC) protective clothing is able to perform adequately the most essential lifesaving tasks although significantly longer time to complete the procedures is needed in comparison to unprotected state (Arad et al. 1993, Bergenstadt et al. 1999). Difficulties which potentially compromised the performance are e.g., impaired manual dexterity due to the cumbersome gloves (Garner et al. 2004, King and Frelin 1984), limited visual field due to the respirator and hood (Coates et al. 2000) and movement restrictions (Garner et al. 2004). Excessive respiratory load, accumulation of sweat and reduced speech intelligibility due to the mask may also diminish performance (Krueger 2001). Most of the previous studies have been focused on the success of the medical procedures in warm environment without aspects on thermal or physiological strain. In northern countries also the effects of cold weather conditions have to be taken into consideration when emergency aid is required (Rissanen and Rintamäki 1997).

The purpose of this study was to investigate the impact of fully encapsulating NBC protective clothing on the ability to perform basic lifesaving tasks in warm and cold environments after a pre-exercise period.

METHODS

Eleven male volunteers (age 26.9 ± 7.3 yrs) with first aid skills performed three experimental sessions in random order. The subjects walked on a treadmill at 5 $km \cdot h^{-1}$ for 20 min (pre-exercise). Immediately after that the subjects moved over to the training doll and performed the lifesaving tasks at ambient temperatures of 21 °C and -5 °C. The subjects were wearing Finnish Defence Forces combat uniform at 21 °C (U) and the current Finnish Defence Forces NBC protective clothing at 21 °C (W) and at -5 °C (C). The clothing ensemble in U included short pants, t-shirt, combat uniform, socks, and rubber boots. The clothing ensemble in W included short pants, socks, impregnated activated charcoal middle wear, impermeable one-piece overall garment (polyethene coated), rubber boots, cotton gloves, rubber gloves, and a respirator. For ensemble C an additional pair of long underwear was worn under the NBC middle wear. Mean (±SD) weights of the clothing ensembles, including boots, were 4349 (± 76) g, 6063 (± 59) g and 6835 (± 152) g for U, W and C, respectively.

The lifesaving tasks were ventilation assistance (VA) and connecting an intravenous line to a training hand (IV). VA was performed with a mask and a ventilating bag (Ambu, Laerdal) for 6 min on a training doll (Resusci Anne, SkillReporter, Laerdal Medical AS, Norway). Performance time and the number of attempts required were recorded by investigator and the tidal volume of ventilation, number of successful breaths, and success rate were recorded by the training device. After the ventilation an oxygen mask was positioned on the doll's face.

IV consisted of connecting a bag of infusion solution to a training hand and an intravenous training arm (Laerdal IV trainer arm and hand, Laerdal Medical AS, Norway) using the connecting tubing. All items were on a tray in sterile packages on the floor. The skin was to be cleaned first with a moist non-woven viscose sponge pad (5x5 cm) before inserting a cannula. The cannula could be fixed to the skin either by using tape or special i.v. cannula dressing. The filled and air-free connecting tubing was to be fixed to the cannula. The performance time and number of attempts required were recorded.

Rectal (T_{re}) and skin temperatures were continuously recorded and saved into a data logger (SmartReaderPlus8, ACR Systems, Canada) at 1-min intervals. Heart rate (HR) was recorded by a heart rate monitor (Polar S610i™, Polar Electro Oy, Finland) and saved at 1-min intervals. Blood pressure (BP) was measured four times during the experiments: before the donning of the clothing, after pre-exercise, and after the VA and IV tasks by an ambulatory blood pressure monitor (ABPM-04, Meditech Ltd., Hungary).

RESULTS

All the subjects succeeded in completing the lifesaving tasks in three sets of conditions. However, due to the protective clothing, the number of breaths per min in VA increased significantly (increase of 19-25 %), as did the ventilation volume (24-36 %) (Table 1). Success rate decreased by 5-16 % due to the protective clothing. Time needed for a successful completion of the IV was 17 % and 38 % longer for W and C ($p<0.05$), respectively, in comparison with U. Cold further (by 5-35 %) impaired performance (Table 1).

Table 1. Number of breaths per min, total volume and success rate during VA, time to apply oxygen mask and time to complete IV task for the three trials. Mean ± SE, n=11.

	U	W	C
Number of breaths	12.9 ± 1.8	15.4 ± 2.8*	16.1 ± 2.3*
%change		19	25 (5)
Total volume, ($ml \cdot min^{-1}$)	7358 ± 1059	9117 ± 1566	9975 ± 1619*
%change		24	36 (9)
Success rate in VA, (%)	65 ± 31	56 ± 40	62 ± 40
%change		16	5 (-)
Time for O_2 mask, (s)	10.8 ± 1.6	14.5 ± 1.3*	19.6 ± 3.7*
%change		34	81 (35)
Time for IV line, (s)	188 ± 20	221 ± 21	259 ± 23*
%change		17	38 (17)

Change in % for each variable from U for W and C and from W for C in parenthesis. * $p<0.05$ in comparison to U.

Rectal temperature increased to significantly higher level during pre-exercise for C (37.7 ± 0.1 °C) in comparison to U and W (37.4 ± 0.1 °C), while T_{sk} and finger temperatures were significantly higher for W (Figure 1). Increase of HR was marked for W and C during the lifesavings tasks (Figure 2).

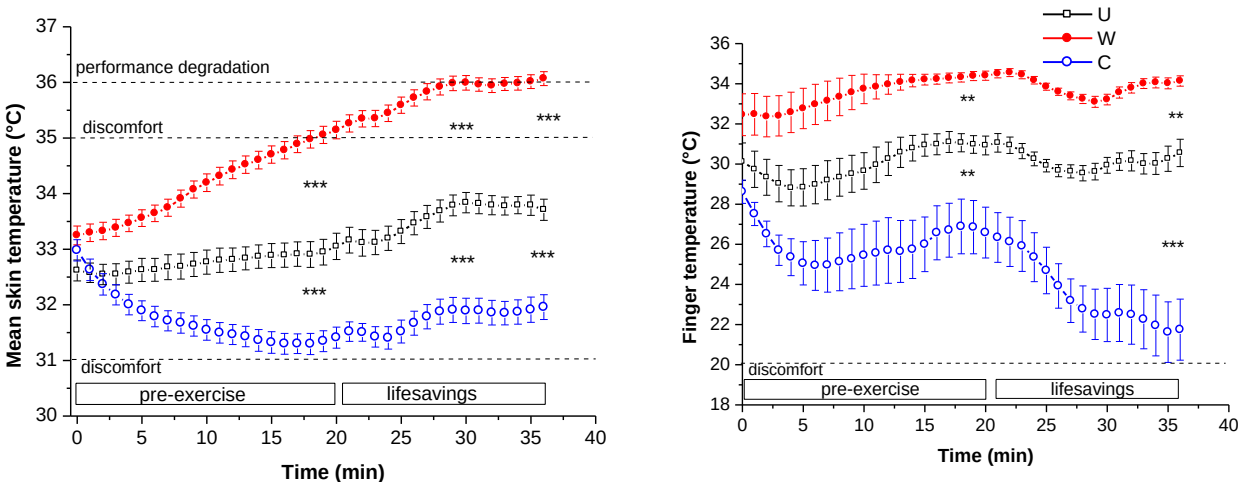

Figure 1. Mean skin temperature and finger temperature during pre-exercise and lifesaving tasks during the three trials. *** $p < 0.001$ between all trials at the end of pre-exercise, VA and IV. Mean ± SE, n=11.

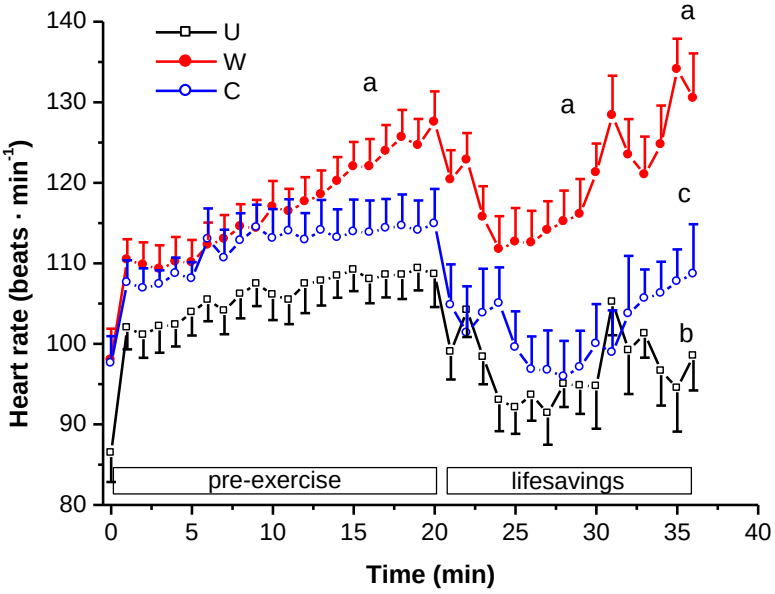

Figure 2. Mean heart rate during pre-exercise and lifesaving tasks for the three trials. **a** indicates $p<0.001$ between U and W at the end of pre-exercise, VA and IV, **b** indicates $p<0.05$ between U and C and **c** indicates $p<0.001$ between W and C at the end of IV. Mean ± SE, n=11.

Blood pressure increased significantly during the pre-exercise and lifesaving tasks compared to the rest value measured before the experiments (Figure 3). During IV systolic and diastolic BP dropped by 14.8 and 6.5 mmHg for W, respectively.

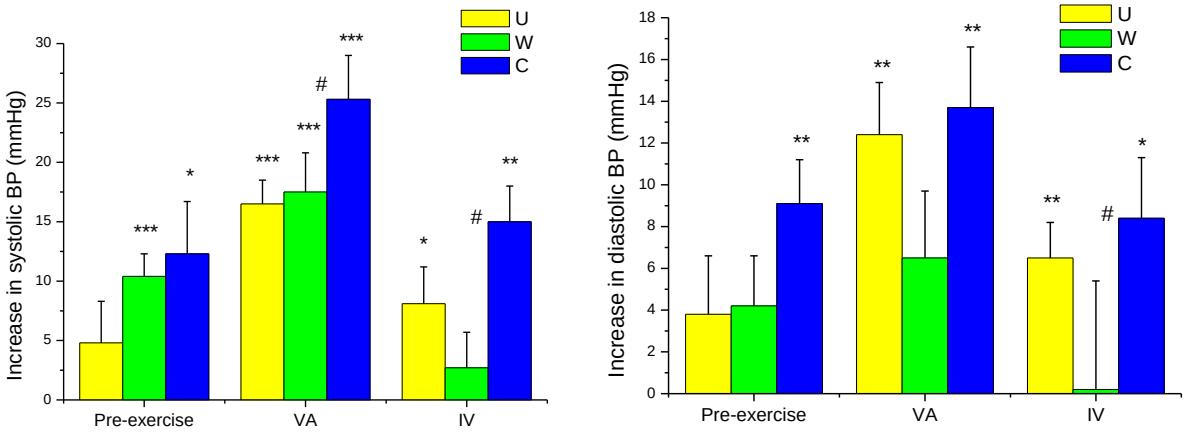

Figure 3. Increase of systolic and diastolic blood pressure at the end of pre-exercise, VA and IV from the rest value. Mean ± SE, n=11. * - *** $p < 0.05$ - 0.001 in comparison to the rest value, # $p < 0.05$ between W and C.

DISCUSSION

The results show that both the ventilation assistance and the IV line connection could be completed while wearing NBC clothing in warm and cold environment. However, there was a tendency towards a hastened VA (increased number of breaths per min) when NBC clothing was worn, especially in the cold. One reason for the difficulty to maintain correct ventilation frequency could be the loss in tactile sensitivity. On the other hand, according to distraction effect, discomfort caused by cold could momentary switch off attention from the primary task and lead to impaired performance (Vaughan 1977).

Increase of core and surface temperatures as well as heart rate indicated increased thermal and physiological strain of the subjects while wearing protective clothing. Physiological load and discomfort due to encapsulation and thermal strain probably impeded concentration and may have altered, in addition to the loss of tactile sensitivity, the frequency of ventilation of the VA task. Development of heat strain at the end of the lifesaving procedures was also seen as a drop in systolic and diastolic BP when protective clothing was used in the warm environment. Some of the subjects felt dizziness during and after the IV task. Increasing of heart rate especially during the skill demanding IV task also indicated that protective clothing with mask and gloves resulted in a greater effort when performing the task compared to non-protective state.

Cold environment further increased the performance times in our study. Time needed for completion the IV increased being 17 % longer for C than for W. Reasons for longer performance times in the cold may be that plastic tubes, bags, and tapes became stiffer due to cooling and more difficult to handle than in a warm environment. Moreover, decreased finger and hand temperatures impair tactile and dexterity performance of the hands.

CONCLUSIONS

Wearing of chemical protective clothing impairs the ability to perform lifesaving procedures (by 16-34 %) in warm conditions. Cold exposure further decreases performance by 5-35 %. In warm

condition, heat strain plays a significant role during the performance, even during a relatively short and easy first aid study protocol. In mild cold conditions, heat strain is negligible but stiffness of medical equipment and protective clothing due to cooling may deteriorate the performance of the lifesaving tasks.

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