CONTRIBUTIONS OF PERIPHERAL AND CENTRAL COOLING TO THE DECREMENT IN ARM PERFORMANCE

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INTRODUCTION

Several studies have demonstrated that cold exposure elicits large decrements in the performance of physical tasks **(1-3).** These effects have important implications for work output or survival during activities which may expose humans to the cold. In most previous studies on the effect of cold on manual performance, cold exposure has not been extreme (1-3) and performance decrement could only be attributed to local effects of cooling of the tissues involved in task performance. Since systemic hypothermia was not induced in any of these studies the effect of central cooling was not addressed.

We have previously quantified physical performance during severe cold stress which led to an actual hypothermic state **(4). As** expected the performance decrement was greater than previously reported **(1-3).** However, it was not clear whether the greater effect was due to central cooling, greater local cooling of the arm, or a combination of these two factors. We have also documented significant impairment of cognitive ability during mild hypothermia and attributed at least some of these effects to central nervous system cooling **(5).** In light of these findings it seems likely that physical performance could also be affected through a central cooling effect.

Based on the limitations of previous research, the following questions remain unanswered. Does central nervous system cooling have a direct effect on arm performance? If so, what are the relative contributions of these central effects to the overall performance decrement? Do these contributions vary with different types of tasks (i.e. fine *vs* gross; dynamic *vs* static etc.)? In an effort to address these questions a protocol was developed in which the temperatures of one arm and the rest of the body could be independently controlled. **A** series of manual finger, hand and arm tests were then performed under various temperature combinations to isolate and determine the relative contributions of local/peripheral and central/core body cooling on the decrement in arm performance.

METHODS

Six subjects were studied. Biceps temperature (T_{arm}), at a depth of 20 mm, and esophageal temperature (T_{es}) were measured. Subjects were immersed in a **tank of** water (body **tank)** for 70 min. under 3 conditions: 1) cold body-cold arm (CBCA); 2) warm body-cold arm (WBCA); and 3) cold body-warm arm (CBWA). In the later two conditions, subjects placed their dominant arms in a separate arm *tank*. Water temperature (T_w) in each tank was independently controlled. In conditions requiring cold body and/or cold arm, T_w in the appropriate tanks **was** 8°C. In conditions requiring warm body and/or warm arm, T_w in the appropriate tanks was adjusted between 29 and 39°C so body/arm temperatures remained unchanged from baseline. **A** battery of fine and gross motor tests was administered. Fine motor tasks included finger dexterity, bolt threading, and speed of finger movement. Gross motor **tasks** included speed of **arm** movement, grip strength, and a peg and ring test, On each day tests were performed before immersion and starting 15, 45, and 70 minutes after entering the water.

For each test a 2-way ANOVA for repeated measurers was employed with 3 temperature conditions, with 4 times in each condition. The Fischer PLSD test was employed for post hoc comparisons of performance means. Simple correlations were calculated between temperatures and performance variables. In conditions in which colinearities between predictors (T_{arm} and T_{es}) were evident, partial correlations (6) were performed to allow any common variance between the predictors to be accounted for in the analysis. Accordingly, partial correlation analysis was performed for the CBCA condition only.

RESULTS

In CBCA, T_{es} decreased from an average of 37.2 to 35.6 "C and T_{mus} decreased from 34.6 to 22.0 "C. In WBCA, T_{mus} decreased from 34.2 to 18.1 "C (T_{es} = 37.0 "C), and in CBWA, T_{es} decreased from 37.1 to 35.8 "C (T_{mus} = 34.4 "C).

By the end of immersion, there were significant decrements (39.2 to 84.7 %) in the performance of all tests in CBCA and WBCA conditions ($P<0.01$). Scores for each test were similar in these two conditions and the decrements were considerably greater than in CBWA ($P<0.02$). During CBWA, there was a significant decrement only in finger dexterity ($P<0.02$). Partial correlations (correcting for the colinearity between T_{es} and T_{mus}) for the CBCA condition are presented in Table 1. T_{mus} accounted for the greatest variance in performance decrement [partial r^2 (r^2p) ranging from 88 to 96%) while T_{es} accounted for up to 10% of the variance (r^2p) in some tasks. The total variance explained by temperature changes for each task is given by $\sum r^2$.

	Fine Motor Tasks			Gross Motor Tasks		
	Finger Movement	Bolt Threading	Finger Dexterity	Arm Speed	Grip Strength	Peg and Ring Test
T_{mus}	0.88	0.90	0.88	0.94	0.96	0.90
T_{es}	0.10	(N.S.)	0.10	0.06	0.04	(N.S.)
$\sum r^2$	0.98	0.90	0.98	1.00	1.00	0.90

CONCLUSIONS

Independent control of arm and core temperatures allowed assessment of the relative contributions of peripheral and central cooling to the decrement in arm performance. In bolt threading and the peg and ring test, only muscle temperature was correlated to the decrease in performance. Although both muscle and core temperatures were correlated to the decrement in the other tasks, the core contribution was minimal (4-10%). Under these conditions of mild hypothermia the decrement in arm performance is due almost entirely to local effects of arm tissue cooling. However, the core temperature contribution may increase as hypothermia becomes deeper.

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