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Fogarty, Alison L.; Armstrong, Karen A.; Gordon, Christopher; Groeller, Herb; Woods, Brian F.; Stocks, Jodie M.; and Taylor, Nigel A. S: Thermal protective clothing and cardiovascular function 2002.
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Thermal protective clothing and cardiovascular function

Abstract

While the primary purpose of thennal protective uniforms is to minimise heat loading from hostile working environments, such uniforms also add to the physiological load by increasing metabolic rate, and limiting evaporative heat dissipation (I). Before one can provide physiological specifications for the design of thennal protective garments, one requires a thorough understanding ofthe physiological effects of wearing such unifonns. However, research in this area is dominated by field studies, with few cardiovascular variables being investigated. These field studies, while important, often bypass clothing trials under controlled laboratory conditions. As a consequence, very little is known about the cardiac output, skin blood flow orplasma volume responses associated with wearing thermal protective clothing. Therefore, weundertook a laboratorybased project to explore the mechanisms underlying the cardiovascular strain accompanying the use of thermal protective ensembles, relative to the unclothed state, during fatiguing exercise. We hypothesised that subjects would experience greater cardiovascular strain when wearing such clothing, and that this would limit their ability to perform maximal exercise.

Disciplines

Life Sciences | Physical Sciences and Mathematics | Social and Behavioral Sciences

Publication Details

Fogarty, A., Armstrong, K., Gordon, C., Groeller, H., Woods, B., Stocks, J. & Taylor, N. Thermal protective clothing and cardiovascular function. In: Tochihara, Y., editors. Environmental Ergonomics X. 0 ed. Fukuoka, Japan: International Environmental Ergonomics; 23-27 September 2002; 497-498.

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This conference paper is available at Research Online: https://ro.uow.edu.au/scipapers/395

THERMAL PROTECTIVE CLOTHING AND CARDIOVASCULAR FUNCTION

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INTRODUCTION

While the primary purpose of thermal protective uniforms is to minimise heat loading from hostile working environments, such uniforms also add to the physiological load by increasing metabolic rate, and limiting evaporative heat dissipation (1). Before one can provide physiological specifications for the design of thermal protective garments, one requires a thorough understanding of the physiological effects of wearing such uniforms. However, research in this area is dominated by field studies, with few cardiovascular variables being investigated. These field studies, while important, often bypass clothing trials under controlled laboratory conditions. As a consequence, very little is known about the cardiac output, skin blood flow or plasma volume responses associated with wearing thermal protective clothing. Therefore, we undertook a laboratory-based project to explore the mechanisms underlying the cardiovascular strain accompanying the use of thermal protective ensembles, relative to the unclothed state, during fatiguing exercise. We hypothesised that subjects would experience greater cardiovascular strain when wearing such clothing, and that this would limit their ability to perform maximal exercise.

METHODS

Seven males completed two 70-min trials of semi-recumbent, intermittent cycling (39.6°C, 45% relative humidity), wearing either the thermal protective ensemble used by NSW Fire Brigades (clothed), or shorts (control). Each trial consisted of three phases, separated by 5-min rest periods (Figure 1).

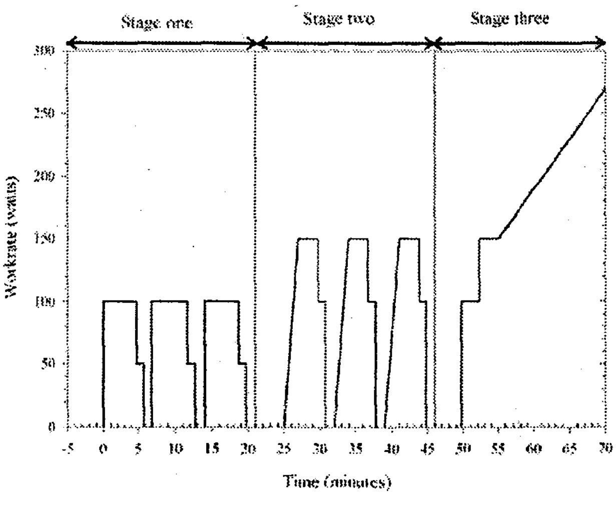

Figure 1: Intermittent work and rest protocol.

Mean core temperature (T_c: oesophagus, auditory canal, rectum: YSI type-401, Yellow Springs Instrument Co. Inc., Yellow Springs, OH, U.S.A.), cardiac frequency (Model PE3000, Polar Electro Sport Tester, Kempele, Finland), stroke volume (impedance cardiography: Surcom Inc., MN, U.S.A.), cardiac output, mean arterial pressure (MAP: auscultation), forearm blood flow (venous-occlusion plethysmography: EC4 Plethysmograph, D.E. Hokanson Inc., U.S.A.), change in plasma volume (• PV: haematocrit and haemoglobin concentration) and overall sweat (mass) losses were measured.

RESULTS

In the clothed trials, subjects experienced significantly shorter times to fatigue (52.5 versus 58.9 min), which occurred at lower peak work rates (204.3 versus 277.4 watts), and at a higher T_C (37.9 versus 37.5°C) ($P<0.05$). Despite a greater overall gross sweat loss in the clothed trial (923.0 versus 547.1 g•m^{-1}•hr^{-1}; $P<0.05$), • PV remained equivalent between the two conditions.

When data were averaged across each trial, the thermal clothing had a significant main effect upon cardiac frequency, cardiac output and forearm blood flow (Figure 2). However, there was no main effect on stroke volume, indicating that the cardiac output response was chronotropically driven.

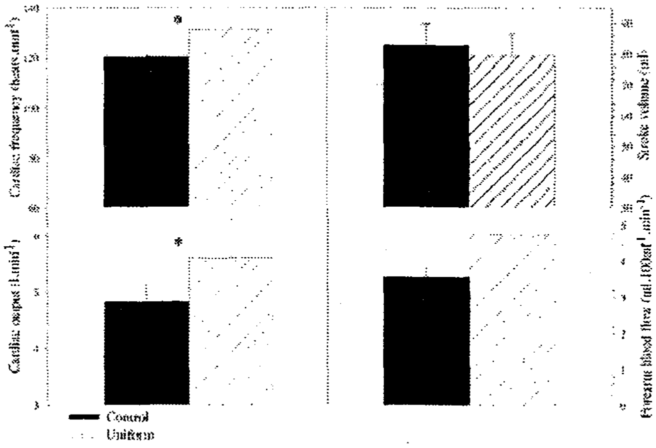

Figure 2: Cardiac frequency, stroke volume, cardiac output and forearm blood flow averaged across intermittent rest and exercise trials. Data are means with standard errors: * = significant difference between conditions.

There was a significant interaction between time and clothing on cardiac frequency. Thus, as time proceeded, the difference between the two conditions became more pronounced.

DISCUSSION

During the clothed trials, as might be expected, the subjects experienced greater thermal and cardiovascular strain. However, while the uniform reduced exercise tolerance, it did not affect the exercise-specific, posture-specific or climate-specific cardiovascular responses observed at the point of volitional fatigue. Furthermore, neither cardiac output nor forearm blood flow were compromised during the clothing trial. Indeed, these were both elevated.

We had predicted that, with such high air temperatures and workloads, the thermal protective clothing would elevate cardiovascular strain to the point where blood pressure regulation would be compromised. The dual need to supply blood to both the working muscles and the skin was expected to reduce venous return, central blood volume and stroke volume. This change was further expected to lead to a reduction in skin blood flow. The fact that neither of these changes occurred in the current trials indicate that these variables did not limit either sub-maximal or maximal exercise in the clothed state.

ACKNOWLEDGEMENTS

The project was funded by a research grant from the New South Wales Fire Brigades (Australia).

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