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Contents

Thermal responses to exercise while wearing industrial protective headwear

Abstract

This report describes a study designed to evaluate the effects of selected safety headwear products. Three conditions were compared: no helmet, a standard helmet, and helmet with side impact protection. Thermal responses to exercise and the effects of exercise-induced thermal stress and fatigue were investigated.

Keywords

Personal protective equipment, Thermal responses, Firefighters, Hardhat, Side impact protection, Head protection, Industrial protective headwear.

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Introduction

Fighting wildfires involves the risk of head injury and therefore, head protection has been designated mandatory personal protective equipment. The concept of "due diligence" in worker safety requires that an employer will provide employees with the best safety protection available. In the case of headwear, side impact helmets are viewed as providing superior overall protection. In 1999, Alberta's Occupational Health and Safety determined all employees in operations would be required to use Canadian Standards Association (CSA) certified protective headwear (CSA Z94.1-92 (CSA 1992)) that provides lateral protection against impact (Figure 1).

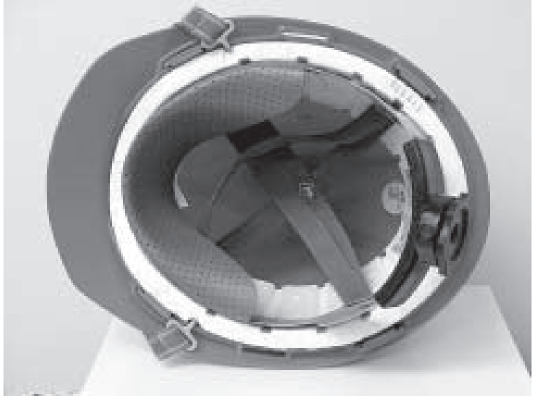

Figure 1. An example of a hardhat with side impact protection.

Most manufacturers meet the CSA standard for side impact protection by including an expanded polystyrene (EPS) liner inside the helmet to absorb impact energy. Because the EPS liner fits tightly against the head, it reduces airflow between the helmet and the environment. The liner also restricts the head size adjustments that can be made to the suspension system. Other researchers (Abeysekera and Shahnavaz 1988) have found a strong association between increased dome temperature, thermal discomfort, and reduced compliance with mandatory safety headwear requirements.

In response to concerns of the Alberta wildland firefights about discomfort caused by this headware, primarily due to the heat and poor fit, FERIC initiated a study conducted by the Faculty of Physical Education and Recreation at the University of Alberta. The study evaluated the effects of selected safety headwear products, worn by Alberta Sustainable Resource Development's firefighters, on thermal responses during sustained exercise. The issue of discomfort and reduced protection due to poor fit, although

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of significant concern, is not addressed in this report.

Objectives

The specific purpose of the study was to document thermal response to exercise under three headwear conditions. The three conditions were: the "standard" helmet (SH), ANSI Z89.1-1986 (ANSI 1986); the "side-impact" helmet (SI), CAN/CSA Z94.1-92; and a control condition (no helmet). The objectives of the study were to:

- Investigate the effect of selected safety headwear designs on body temperature during sustained exercise.
- Identify any differences in thermal responses to exercise between helmet conditions.
- Investigate the effects of exercise-induced thermal stress and fatigue on select aspects of psychomotor function.

Methods

Sixteen male subjects provided written informed consent to participate in the study that had previously received approval from the Research Ethics Committee in the Faculty of Physical Education and Recreation, University of Alberta. Each subject completed a medical examination with a physician to screen for contraindications to participation. The study consisted of two phases and in total, each subject performed five exercise tests. The first phase consisted of a graded exercise test on a motor-driven treadmill to determine selected parameters of aerobic fitness and work capacity. In the second phase, a practice session and three exercise challenges were completed, and thermal responses to the exercise with the two helmets were compared to a control (no helmet) conditions (Figure 2). In each test, subjects completed 45 minutes of strenuous exercise while outfitted in the personal protective equipment typically worn by wildland firefighters. Headwear conditions were assigned randomly and subjects were not aware of the overall purpose of the study or its relationship to the helmet they were wearing.

Figure 2. Test subject on the treadmill, without helmet.

Measurements of core body temperature were obtained continuously from a Cortemp CT200 miniaturized ambulatory recording system. This system consists of a miniature transmitter that sends temperature readings by telemetry to an external receiver. The subjects swallowed the transmitters that later passed through the digestive system.

The subjects provided ratings of perceived exertion (RPE) at five minute intervals throughout the sub maximal exercise trials using the 15 point Borg scale (Borg 1982). The numbers reported ranged from 6 to 20 with the odd numbers assigned description from very, very, light (RPE=7) to very, very, hard (RPE=19). Perceptions of thermal distress (PTD) were reported using a 9 point psychophysical scale. On this scale, numbers

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range from 1 to 9 with odd numbers assigned descriptions from "My body temperature is comfortable" (PTD=1) to "The heat is unbearable" (PDT=9).

Immediately before and after each exercise challenge, subjects completed a series of psychomotor skill tests. Participants were asked to perform upper limb movements, making a three segment sequencing movement to manipulate lights of various colours on a panel. The tests recorded reaction time, movement time, and any errors made.

Results and discussion

Thermal response to exercise

Core body temperature increased during the exercise trial in all three conditions. When the helmet conditions were compared to the control, no difference was evident between the standard and side impact helmets (Figure 3). Temperature within the helmets was highest in the side impact helmet, both before and during exercise (Figures 3 and 4) and the rate of increase was also slightly higher for the side impact helmet compared to the standard and control. Based on this study, increased helmet dome temperature does not appear to have a significant effect on core temperature, the main index of heat stress.

The study found that absolute helmet dome temperatures reached 26.5, 27, 29.6º C for the control, SH and SI conditions, respectively (Figure 4). The higher dome temperatures in the side impact helmet may be explained by the increased padding and reduced airflow. The standard helmet is not padded and therefore has greater head to helmet clearance. Logically, the design of the side impact helmet would tend to trap heat in its dome. We would expect that radiant heat from the sun or fire would exacerbate this situation and would result in greater thermal discomfort.

Perceived thermal distress at the head, a subjective rating of heat within the helmet, was greater in both helmet conditions during exercise compared to the control condition. However, despite the higher helmet dome temperature with the side-impact helmet, there was no difference in the perceived distress between subjects wearing the two helmets.

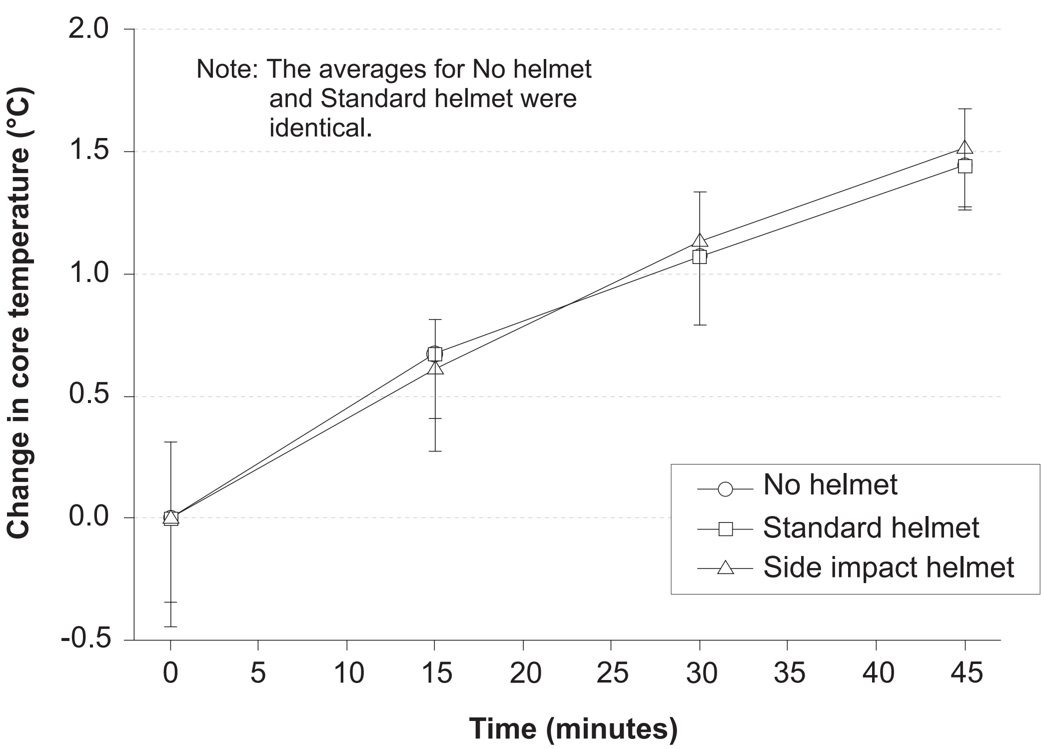

Figure 3. Change in core temperature during 45 minutes of treadmill exercise under selected headwear conditions. All changes in temperature from the pre-test baseline are significant ($p \leq 0.05$), but there are no differences between headwear conditions. The vertical lines indicate standard deviation. N = 16

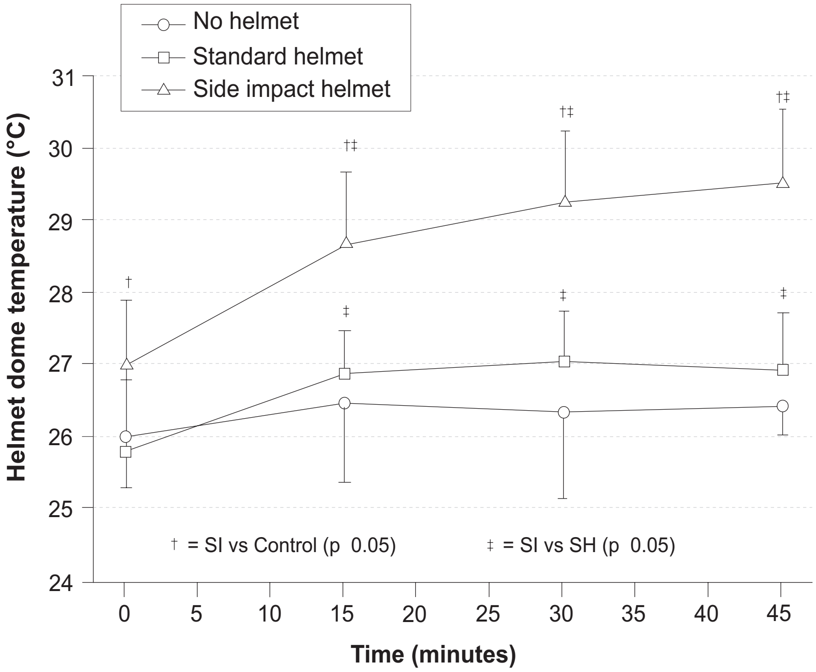

Figure 4. Helmet dome temperature during 45 minutes of treadmill exercise under selected headwear conditions. Significantly different relationships are identified on the graph by symbols. The vertical lines indicate standard deviation. N = 16

Effects of thermal stress and exercise on psychomotor responses

The test results showed no significant differences between the helmet conditions. The participants were able to follow the instructions and complete the tasks irrespective of the helmet conditions. No significant differences in performance were found between the SH and SI conditions.

Conclusions

The investigation examined the effects of two designs of protective headwear on thermal stress during exercise, compared to a no-helmet control. Dome temperature inside the side impact helmet was higher than the other two conditions. However, the perception of head temperature was the same for the side-impact and the standard helmets. Similarly, perception of whole body heat stress and perceived exertion during exercise were not different for the three conditions. All helmet conditions resulted in similar increases in core body temperature. The psychomotor dimensions involved in motor performance were not adversely affected by the helmet manipulations. The results of this study show that the type of protective headgear did not affect heat accumulation during strenuous, constant load treadmill exercise.

The findings suggest that the side impact helmet does inhibit heat release from the head compared to the standard helmet. However, this difference did not contribute to higher levels of measured or perceived thermal stress during exercise. While the results did not show higher perceptions of thermal distress specific to either the head or generalized to the whole body in the side impact condition, we believe that under other conditions (e.g., radiant heat and/or work of longer duration) the differences may be more pronounced. The working environment may have a larger role in thermal discomfort than measured under the conditions of this study.

References

Abeysekera, J.D.A.; Shahnavaz, H. 1988. Ergonomics evaluation of modified industrial helmets for use in tropical environments. Ergonomics 31: 1317–1329.

American National Standards Institute (ANSI). 1986. ANSI Z89.1-1986. Type I Protective Headwear for Industrial Workers. Washington, D.C.

Borg, G.A. 1982. Psychological bases of perceived exertion. Medicine and Science in Sport and Exercise 14: 377–381.

Canadian Standards Association (SCA). 1992 CAN/CSA Z94.1-92 Industrial Protective Headwear. Rexdale, Ont.