COMMERCIAL-IN-CONFIDENCE

CSIRO TEXTILE AND FIBRE TECHNOLOGY

REPORT

‘Body cooling vest evaluation’

Service Agreement SA00/41 for:
Arctic Heat Products Pty Ltd

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INTRODUCTION

The purpose of this trial was to assess the influence of the 'Arctic Heat' cooling vest on skin temperature beneath the vest in conditions simulating the workload of an Australian Football game.

These vests are manufactured with 4 enclosed pockets approximately 30mm wide running laterally across the garment front and back. Gel crystals in these pockets absorb water when the garment is immersed and swell to fill the pocket space. The garment is then cooled for subsequent use. The potential cooling power of the gel is greatest when it is frozen, as the energy required to thaw it out is high relative to the energy required to change its temperature by a few degrees.

The trials described in this report investigated a range of possible cooling options, including pre-immersion in ice water and freezing in a refrigerator.

EXPERIMENTAL

Three different methods of using the vests during warm-up were evaluated as follows:

1. Immersed in an ice/water mix for 5-10 minutes and then worn in direct contact with the skin;
2. Frozen in a refrigerator overnight and then worn in direct contact with the skin;
3. Frozen in a refrigerator overnight and then worn over an AFL jersey.

With each combination, subjects also wore underpants, shorts and socks/running shoes. A further control or comparison trial was included in which subjects wore the AFL jersey without any form of pre-cooling. Four subjects were tested in all.

Each of the four treatments (control plus three cooling combinations) was evaluated by running on a treadmill in an environmental chamber with the conditions controlled to 25°C and 50% relative humidity. A bank of fans provided airflow over the subject of 2.8m/s (equivalent to an average running speed of 10km/hr). Treatments applied to each of the four individuals tested were randomised. The sequence of activities within each wear trial was as follows:

Time (min)	Activity
0-1	Move into position on the treadmill, don vest and/or jersey where applicable
1-11	Jogging to warm-up at 40% VO_2max
11-12	Remove vest where applicable, put on jersey where applicable
12-32	Running at 70% VO_2max
32-33	Remove jersey where applicable, put on vest where applicable
33-43	Further jogging under warm-up conditions (40% VO_2max)
43-44	Remove vest where applicable, put on jersey where applicable
44-64	Running at 70% VO_2max

Table 1: Activity cycle used for the climate chamber trials

For each subject, the exercise level or workload at each stage of the trial was rated in terms of %VO_2max, a parameter commonly used in physiological studies that enables the differing performance capacities of individuals to be taken into account. The warm-up workload used was 40% of VO_2max, and the full exercise workload was 70% of VO_2max.

For the purposes of this trial, relative exercise intensity was determined from the age-related maximum heart rate (220 - age in years) and the relationship shown in Figure 1[1]. This method provides a means of achieving relative exercise intensity between subjects sufficient for comparing treatments. Subjects wore a Polar Electro Sport Tester to provide real-time heart rate information to the experimental operator who then adjusted the speed of the treadmill to establish the desired heart rate within about 5%. It was relatively easy to achieve a steady heart rate within the first two or three minutes of activity and no further adjustment was usually required. The same treadmill speeds were then used for each of the three subsequent treatments.

[1] From 'Exercise Physiology – Energy, Nutrition and Human Performance', second edition, W.D. McArdle, F.L. Katch and V.L. Katch, Philadelphia 1986, page 357

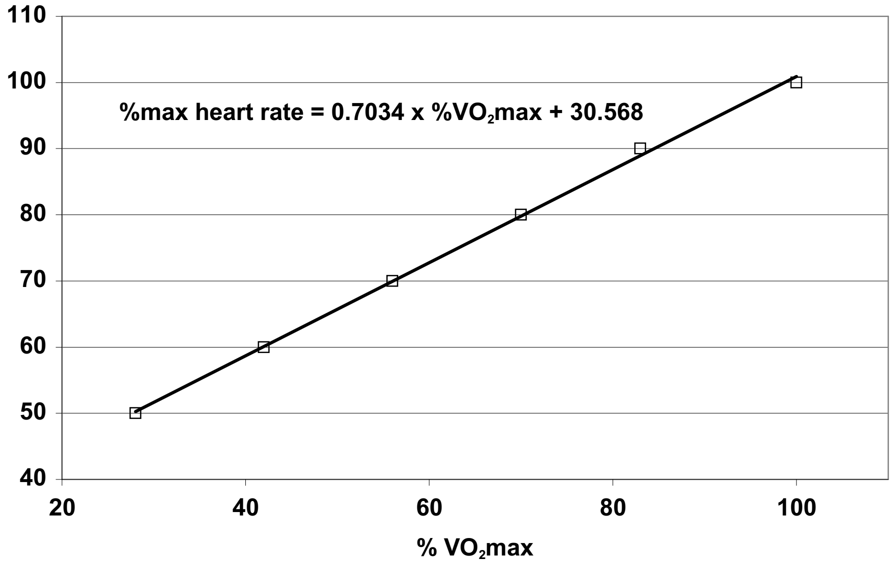

Figure 1: Relationship between %maximum heart rate and %VO_2max

Skin temperature was measured by YSI 400 Series thermistors attached directly to the skin with 5mm strips of Opsite semi-permeable adhesive film criss-crossed over the thermistor head. The connecting wires were led to a point on the right hip and held in place by Transpor tape. The thermistors were interfaced with a signal conditioner/multiplexer and the resulting voltage signal fed into to the A/D input card of a PC. A Labview routine was used to convert the signal to temperature and apply individual calibration routines for each thermistor. At 15-second intervals, fifty readings were sampled at a frequency of 1000Hz for each thermistor and averaged.

In physiological studies where skin temperature is a desired parameter temperature probes are applied to a number of specific skin locations and then combined in one of several recognised relationships to determine an average skin temperature for the whole body surface. The Arctic Heat vest only covers the torso and for the purposes of this study, temperature measurement was focused on the effects of the vest on the skin temperature of the torso rather the physiological average. Measurement sites beneath the vests were left and right sides of the back (sub scapula), chest (mid axilla) and stomach (abdomen).

RESULTS AND DISCUSSION

The number of individual temperature traces recorded during both preliminary and actual trials was in excess of one hundred. For convenience only specific examples are reproduced in this report. Figure 2 shows a typical example of skin temperature below the vest taken from a trial in which only the AFL jersey was worn, plotted together with the corresponding heart rate.

As this graph shows, the heart rate closely follows the exercise regime. After the first one-minute period the ten-minute warm-up exercise was started and heart rate of the particular subject involved rose rapidly to around 120 beats per minute. Over the same period the skin temperature decreased by a couple of degrees as sweating was activated and evaporative cooling occurred. The heart rate dropped during the pause between 11 and 12 minutes, and then rose rapidly once the higher workload started and steadied at about 155-158bpm. Skin temperature continued to fall slightly throughout the 20-minute exercise period. Small rises in skin temperature can be seen during each of the one-minute pauses. During the second cycle the skin temperature followed a similar pattern to the first, falling a degree or so further overall.

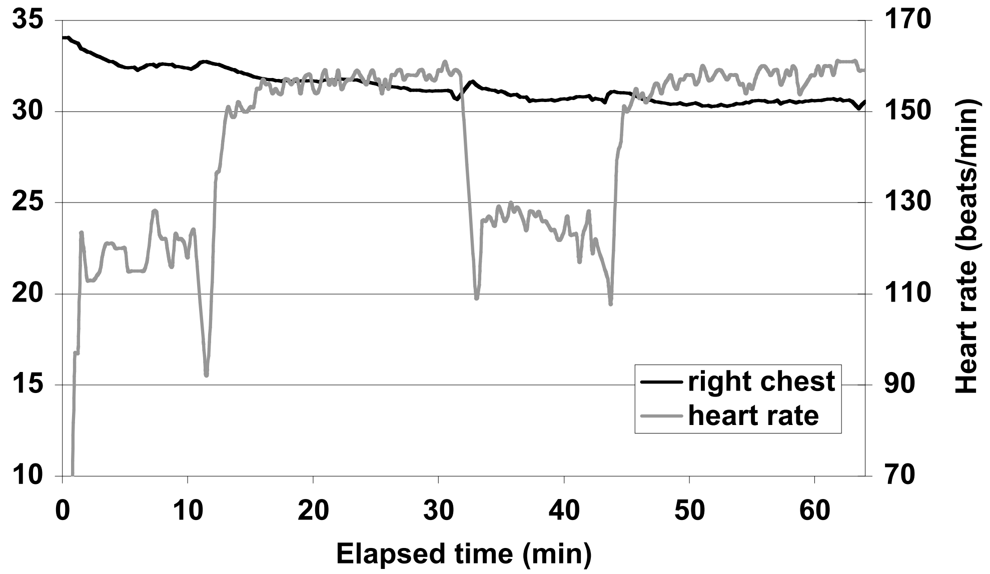

Figure 2: Typical skin temperature and heart rate response during the exercise regime when the ice vest is not worn

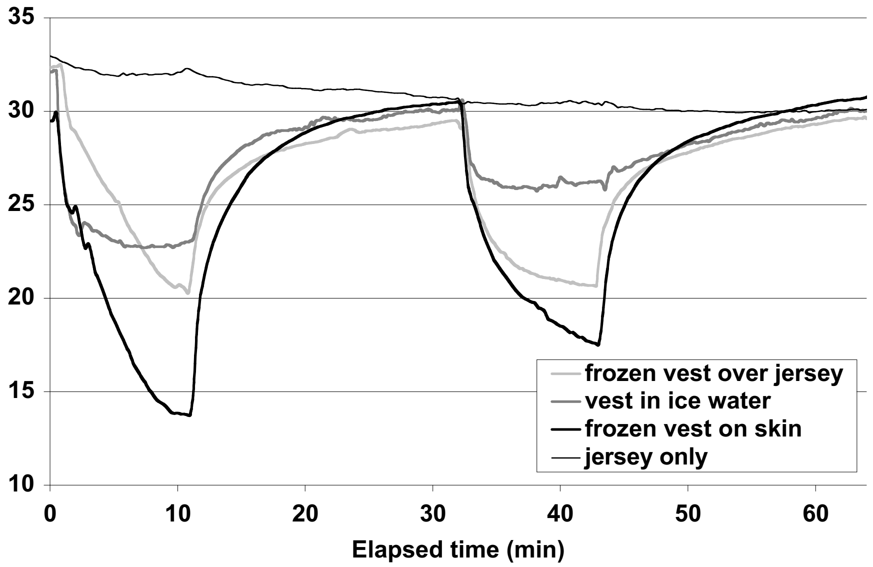

Figure 3: Typical skin temperature response for the three modes of applying the cooling vest during warm-up

Figure 3 shows examples of the skin temperature in the three trials where the cooling vest was worn during the warm-up period, together with an example of the AFL jersey worn on its own. In each case, the temperature decreased rapidly once the vest was put on, then rose rapidly after the vest was removed and the higher workload started. An important point worth noting is that this rise continued for the whole of the 20-minute exercise period in all three cases and was only just beginning to plateau at that point. During the second cycle of activities with the frozen vest the skin temperature did not fall as far as the first, as might be expected due to some thawing of the gel. Once again, during the whole of the following 20-minute exercise period the temperature continued to rise.

The lowering of skin temperature was greatest (about 16-17^{o}C) when the frozen vest was in direct contact with the skin. The frozen vest worn on the outside of the jersey was next best with a maximum decrease of around 11-12 ^{o}C. The ice water cooled vest in direct contact with the skin produced the smallest decrease of around 9^{o}C. These values do not necessarily represent the order of total cooling potential, as the area of skin contact of the wetted vest was more than double that of the frozen gel.

The examples shown in Figure 3 represent the situation where the probe was located directly below the gel strip and good contact was maintained between gel strip and skin for the duration of the trial. As Figure 4 shows the temperature depression at each of the measurement points on any particular subject varies because these criteria were only met continuously in some instances by the measurement technique used.

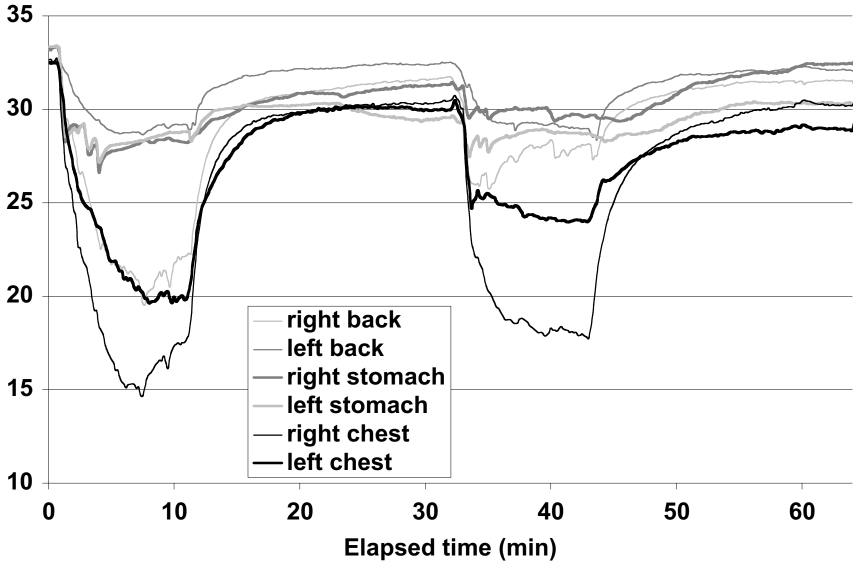

Figure 4: Skin temperatures monitored at six locations for one subject during a frozen vest on skin trial

In this example, skin temperature reduction was in excess of 15^{o}C at one of the six measurement points. During the first cycle the temperature decrease lasted for the first 6-7 of the 10 minutes the vest was worn, rising again for the last few minutes. This can be attributed to a change in the position of the vest relative to the probes due to movement of the body while exercising.

In order to combine the data for each treatment for all four subjects, the temperature reduction achieved during the warm-up period of each cycle was recorded for each measurement point then all measurement points and subjects were combined and averaged. The means are shown in Table 2.

Cycle	Jersey only	Frozen vest on skin	Frozen vest over jersey	Ice water cooled vest on skin
1	2.67	9.68	6.45	7.28
2	2.53	6.41	3.77	5.50

Table 2: Average decrease in skin temperature (in ^{o}C) beneath the vest for all subjects

As might be expected, the temperature changes are less than those observed in the best-case examples shown in Figure 3. The frozen vest in contact with the skin still produces the greatest change in temperature overall. Although in the best case examples the frozen vest worn outside the jersey produced a significantly greater effect than the vest dipped in ice water applied directly to the skin, their ranking was reversed when averaged overall. This can be attributed to the fact that the evaporative cooling of the wetted vest occurs over the whole garment rather than just the region adjoining the frozen gel and the measured skin temperature depression was not subject to probe proximity.

CONCLUSIONS

Wear trials of the Arctic Heat cooling vest have demonstrated when the water gel in the vest is frozen and then worn for 10 minutes in direct contact with the skin during light warm-up exercise, the skin temperature can be decreased by almost 17^{o}C. Skin temperature recovery following removal of the vest is initially quite rapid but even after 20 minutes of high activity is still rising slightly and not at equilibrium.

Of the three methods of use investigated (frozen and worn in direct skin contact skin, frozen and worn on the outside of an AFL jersey or dipped in ice water and then worn in direct contact with the skin) the reduction of skin temperature is greatest with the frozen vest in skin contact. Cooling the jacket in ice water before wearing in direct contact with the skin was next best followed by wearing the frozen vest over the outside of an AFL jersey.