# UPPER- AND LOWER BODY SENSITIVITY TO COLD AT REST AND DURING EXERCISE

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## *INTRODUCTION*

Only limited research has investigated the effects of exercise on thermal sensitivity. Using the method of limits, Kemppainen *et al*. (1985) measured the temperature at which the initial cool and warm sensation is felt (cool and warm thresholds) of five male participants. This was done in three different conditions: before the start of exercise, whilst cycling (100, 150, 200 and 250 W) and 15 min after the end of exercise. The gaps between the warm and cool thresholds, known as thermal limens, were calculated. Results showed that thermal limens increased as a function of increasing work load in all tested skin regions. The effect of work load on thermal limens was most marked in the leg and least in the palm of the hand. Changes in skin temperature ($T_{sk}$) related to the exercise were found but these were low in comparison with the changes in thermal limens. After 15 min of post-exercise rest, thermal threshold values returned close to the initial resting levels. Although very informative, Kemppainen's data does not provide any indication as to what extent sensitivity to cold is reduced in terms of thermal sensation ratings during exercise. Moreover, the limited body locations tested provide little information on the distribution of the changes in thermal sensitivity in response to exercise. The first aim of the present study was therefore to compare thermal sensitivity to cold at rest and during exercise using a modified magnitude estimation method. Furthermore, current knowledge on regional differences in sensitivity to cold is limited to one or two locations per body segment (e.g.: Stevens, 1979; Lee *et al*, 2010). As a result, little is known on the variations in thermal sensitivity within body segments. Therefore, the second aim of the present study was to investigate sensitivity to cold in 28 body locations including several testing sites in each body segment.

## *METHODS*

Following approval of the experimental protocol from the Loughborough University Ethical Advisory Committee, 14 recreationally active male participants (21.7 ± 2.6 years; 179.1 ± 6.6 cm; 72.9 ± 8.4 kg) were recruited from the student population. After providing written informed consent all participants attended the laboratory on two separate occasions, with at least 48 hours between the sessions. The first session required anthropometric measurements of height, weight, and skinfolds thicknesses. These were taken using a 7-point calliper method specific to male population for calculation of body fat percentage (Jackson and Pollock, 1978). Maximal oxygen consumption ($\dot{V}O_{2\,max}$) was then estimated using a modified version of the Astrand-Rhyming sub-maximal cycling test (Åstrand and Rhyming, 1954). In preparation to the experimental session, participants were subsequently familiarised with the testing procedures and practiced the thermal sensitivity test.

Upon arrival in the laboratory for the second session, participants changed into their own shorts, socks and trainers. The investigator marked each of the 28 testing sites on their skin using a washable marker. These were all on the left-hand side of the participants, and were distributed across the body as follows: head = 2; front torso = 7; back = 7; upper limb = 6; lower limb = 6. Participants self-inserted a rectal thermometer (Grant Instruments, Cambridge, England) 10 cm beyond the rectal sphincter for measurement of core temperature ($T_c$). Four skin thermistors (Grant Instruments, Cambridge, England) were attached to the upper arm, chest, thigh and calf for calculation of mean $T_{sk}$ (Ramanathan, 1964). Skin and rectal temperature sensors were connected to an Eltek/Grant 10 bit, 1000 series data logger (Grant Instruments, Cambridge, England) recording temperature at 2 second-intervals.

After preparation, participants were taken to the laboratory ($T_a$ = 21.4 ± 0.7°C; RH = 43.2 ± 4.4%) where they initially remained seated for a 10 minutes stabilisation period. Thermal sensitivity to cold was then tested at each body site in a balanced order. Local $T_{sk}$ was first measured at the stimulus site with a non-contact infrared thermometer (Fluke 566, Washington, USA). The 25 cm$^2$ thermal sensitivity tester (NTE-2, Physitemp instruments Inc., USA) set at 15°C was then placed directly onto the skin over the marked site, and participants were instructed to rate thermal sensation immediately after contact. A thermal sensation scale for innocuous cold stimuli was used, where 0 indicates “no cold sensation”; 10 “extremely cold” and >10 “painfully cold”. The site was then re-warmed with a hand warmer. Once all 28 body sites had been tested, the exercise condition was carried out. Participants cycled at 60 rpm with a workload corresponding to 60% of their $\dot{V}O_{2\,max}$ for 20 min on an electromagnetically braked cycle ergometer (Lode Excalibur, Groningen, The Netherlands). After this warm-up period, exercise intensity was decreased to 30% $\dot{V}O_{2\,max}$ and the thermal sensitivity test was repeated. For testing sites on the lower limb, participants temporarily stopped cycling, in order to allow an accurate measurement to be taken.

Mean $T_{sk}$ and $T_c$ at the start of the thermal sensitivity test were compared between rest and exercise using paired-samples t-tests. Differences between sites were analysed with a two-way repeated-measures ANCOVA, using body site and conditions as independent variables and pre-stimulus $T_{sk}$ as a covariant. In order to identify any statistical differences in mean thermal sensations at individual sites between conditions, a series of paired-samples t-tests was completed.

## *RESULTS*

Mean $T_{sk}$ increased from 29.8 ± 0.8°C at rest, to 30.9 ± 1.3°C during exercise ($p < .01$). Similarly, an increase from 37.1 ± 0.3°C to 37.6 ± 0.4°C was observed in $T_c$ ($p < .01$).

Despite individual variations in absolute sensation, a clear pattern of distribution was observed within all participants. The highest values were consistently observed on the lateral abdomen and lateral back. The posterior upper leg followed as area of next highest thermal sensations. In contrast, areas of particularly low thermal sensations included the dorsal surfaces of the hand and forearm, as well as the palm site of the hand.

The ANCOVA indicated a significant effect of initial local $T_{sk}$ on thermal sensation ($p = .047$), with a greater $T_{sk}$ resulting in a greater thermal sensation. After controlling for this effect, there was a significant effect of body site, $F(27,728) = 5.14$; $p < .001$ and condition, $F(27,728) = 10.58$; $p < .01$ on thermal sensation. However the interaction between body site and condition was not significant, $F(27,728) = 1.07$; $p = .37$.

The ANCOVA revealed a total of 31 significant differences existed between body sites ($p < .05$). The typical threshold for significance between body sites was a difference of approximately 1.7 thermal sensation units.

Paired samples t-tests revealed that although thermal sensation decreased in 22 out of the 28 locations tested during exercise, this was significant in only 11 sites ($p < .05$). These differences are presented in Table 1. A typical difference in thermal sensation of approximately 0.8 was the threshold for significance between rest and exercise.

| **Body site** | **Mean difference (rest – exercise)** | ***t*** | **P value** |
|---|---|---|---|
| Forehead | -0.48 | -0.63 | 0.54 |
| Cheek | -0.17 | -0.31 | 0.76 |
| Neck – lateral | 0.25 | 0.44 | 0.67 |
| Chest – central | 0.75 | 1.36 | 0.20 |
| Chest – lateral | 0.83 | 1.76 | 0.11 |
| Upper abdomen – central | 0.33 | 0.72 | 0.49 |
| Upper abdomen – lateral (*) | 1.25 | 3.19 | 0.01 |
| Lower abdomen – central | 0.58 | 0.90 | 0.39 |
| Lower abdomen – lateral (*) | 1.25 | 4.10 | 0.00 |
| Upper arm – anterior | 0.08 | 0.25 | 0.81 |
| Lower arm – anterior (*) | 1.42 | 3.03 | 0.01 |
| Hand – palmar | -0.75 | -1.68 | 0.12 |
| Upper leg – anterior | 0.33 | 0.63 | 0.54 |
| Middle leg – anterior | -0.67 | -1.20 | 0.25 |
| Lower leg – lateral | -0.50 | -0.88 | 0.40 |
| Neck – posterior (*) | 0.83 | 2.28 | 0.04 |
| Upper back – lateral (*) | 1.00 | 3.07 | 0.01 |
| Upper back – central (*) | 0.75 | 2.28 | 0.04 |
| Middle back – lateral (*) | 1.67 | 3.46 | 0.01 |
| Middle back – central (*) | 1.17 | 3.39 | 0.01 |
| Lower back – lateral (*) | 1.58 | 3.17 | 0.01 |
| Lower back – central (*) | 1.17 | 3.39 | 0.01 |
| Upper arm – posterior | 0.25 | 1.00 | 0.34 |
| Lower arm – posterior | 0.33 | 0.65 | 0.53 |
| Hand – dorsal | -0.33 | -0.49 | 0.63 |
| Upper leg – posterior (*) | 1.17 | 2.88 | 0.01 |
| Middle leg – posterior | 0.17 | 0.28 | 0.78 |
| Lower leg - posterior | 0.58 | 1.10 | 0.29 |

**Table 1 Significance levels of the rest-exercise comparison analysed with paired samples t-tests**

## *CONCLUSIONS*

In the present study, a thermally sensitive body location was defined as one showing a strong (great) thermal sensation in response to the fixed 15°C thermal stimulus. As shown in Table 1, cycling at 30% $\dot{V}O_{2\,max}$ decreased thermal sensitivity in the majority of the locations tested, although this was only significant in 11 body sites. These results are in line with Kemppainen *et al*. (1985) who found an increase in thermal limens during exercise. One logical explanation for this is the increase in $T_{sk}$ with exercise, resulting in thermoreceptors being stimulated with a greater $\Delta T_{sk}$, which will increase the impulse frequency and in turn influence thermal sensation. This was confirmed in several studies looking at the effects of skin temperature on warm and cool threshold (Lele, 1954; Hirosawa *et al*., 1984). The present data confirm that $T_{sk}$ may in part explain the decrease in sensitivity, as suggested by the significant increase in mean $T_{sk}$ and the local $T_{sk}$ being a statistically significant covariate in the ANCOVA. This may not be the only explanation however; indeed, a large body of literature has suggested that neural and hormonal mechanisms occurring during exercise are likely to influence the response to both noxious and innocuous stimuli. This is often referred to as the analgesic effects of exercise, and is thought to be due to a reduction in the transmission of sensory information to the thalamus and somatosensory cortex associated with one of the following: movement, increased activity in proprioceptive and muscles afferents, increase in arousal, and reduction in attention. Refer to Koltyn (2000) for a complete review of literature on this topic. Regarding the distribution of changes in thermal sensitivity during exercise, our results suggest that the sites with the largest decrease in sensitivity are located within the back. Interestingly, the sites on the extremities (forehead, cheek, lower legs and hands) showed a slight increase in thermal sensitivity. Although not statistically significant, this may be linked with the redistribution of skin blood flow during exercise, as local $T_{sk}$ was lower in these body sites during exercise compared with rest.

The distribution of thermal sensitivity is in agreement to a certain degree with Stevens (1979) who found that the sensitivity to cold was greatest for the trunk, least for the face and intermediate for the limbs. The present data also suggest that the lowest sensitivities at rest are found on the posterior forearm and on both sides of the hands, areas which had not been tested by Stevens. Regarding body sites within the same segment, the present results suggest important variations especially on the front torso and back, where the lateral areas seem to generally be more sensitive than the centre. To the best of our knowledge, these disparities have not been established before. This variation is thermal sensation may be due to variations in several physiological variables. The two most commonly reported parameters are the uneven distribution of cutaneous thermoreceptors and the existence of a weighing of thermoafferent information by the integration centre in the central nervous system (Burke and Mekjavić, 1991). In addition, the rate of change in skin temperature in response to the thermal stimulus may explain part of the results. Indeed, it is well establish that different areas of the body "release" heat more readily than others. This is mainly due to variations in skin blood flow. Li and colleagues (2005) investigated this by exposing a 400 $cm^2$ of the skin to an ambient temperature of 20°C while the rest of the body was covered. This was repeated in several locations, and results suggested that the lateral chest and lateral abdomen showed the greatest rate of change in $T_{sk}$, followed by the back of the thigh. These locations correspond quite well with some of the most sensitive regions found in the present study, suggesting that rate of change in $T_{sk}$ may at least partially explain the variations found. Finally, hair distribution on the human male torso, and more specifically on the abdominal regions, may also explain some of the results. Setty (1967) suggested that the most common varieties of abdominal hair patterns in Caucasian males have a specific pattern, with the central abdominal regions being hairy in comparison to lateral areas. Since this was not measured in the present study, further research would be useful in order to explore whether a relationship exists between local levels of hairiness and thermal sensitivity.

Summarising, the present data provides the distribution of local thermal sensitivity to cold, including several locations in each body segment. The lateral abdomen and lateral back were found to be the most sensitive regions of the body. Furthermore, the current study provides further evidence that thermal sensitivity to cold decreases during periods of exercise. However, sensitivity decreases differently over the body surface and even increases in certain specific body regions.

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