



Hand and Forearm Cooling: Exploring Deep-Body Cooling in Hyperthermic Individuals

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Introduction

- The efficacy and utility of upper-limb cooling in hyper-thermic individuals is well established, and it is a feasible and effective cooling intervention to alleviate heat strain in the workplace.
- The purpose of this study was to evaluate that practice during recovery from ambulatory exercise performed in the heat (33°C, 70% relative humidity) at each of three speeds: light, intermediate and moderate intensity.
- Hypothesis:** "Heat extraction accompanying upper-limb cooling would be faster following the highest work rate during recovery after exercise"

Methods

1. Subjects

N	Sex	Age (y)	Height (cm)	Weight (kg)	VO _{2max} (ml/kg/min)
8	Male	24 ± 2	176.4 ± 8.1	74.9 ± 7.2	52.3 ± 6.9

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2. Experimental procedures and measurements

• Water-perfused sleeves for hand and forearm cooling

The sleeves consisted of an inner mesh layer (85% nylon and 15% polyurethane) and an outer layer (92% polyester and 8% polyurethane) with 4 m of PVC tubing.

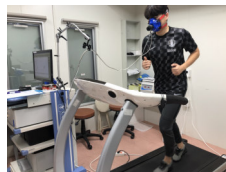
The sleeves were donned as soon as possible after exercise ceased, and a 20-min recovery commenced. Water pumped through the sleeves was cooled to a mean inlet temperature of 6.3±0.2°C.



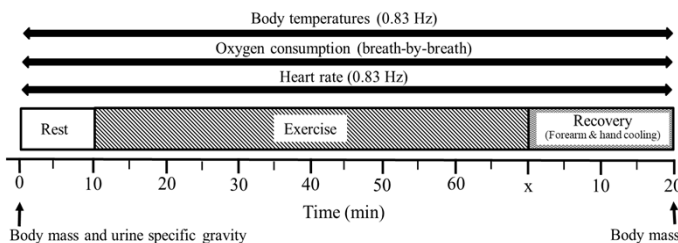
• Whole body heating during exercise in 33°C and 70%RH

Subjects exercised at each of three speeds (Trial A, B, and C). When rectal temperature reached 39°C, subjects stopped running. Subjects immediately adopted a seated position and donned the sleeves, which were perfused with 6.3°C water, during a 20 min recovery.

	Trial A	Trial B	Trial C
Speed	6 km.h ⁻¹	8 km.h ⁻¹	10 km.h ⁻¹
Intensity	Light	Intermediate	Moderate
%VO _{2max}	41.6±9.4	59.7±7.2	67.3±11.7



• Experimental protocol and measurements



Deep-body temperatures were measured continuously (5-s intervals) from auditory canal and the rectum. Skin temperatures (17 sites) were also measured continuously.

Oxygen consumption (open-circuit respirometry) was measured using an automated system (breath-by-breath).

• Heat extraction = Mass flow × Specific heat × Temp. difference

where, Heat extraction = removal of thermal energy from the skin (J.min⁻¹);
Mass flow = water flow through the sleeve (L.min⁻¹); Specific heat = specific heat of water (4.186 J.g⁻¹.°C⁻¹);
Temp. difference = difference between inflowing and outflowing water temperatures (°C).

Results

1. Physiological responses during rest, exercise & recovery

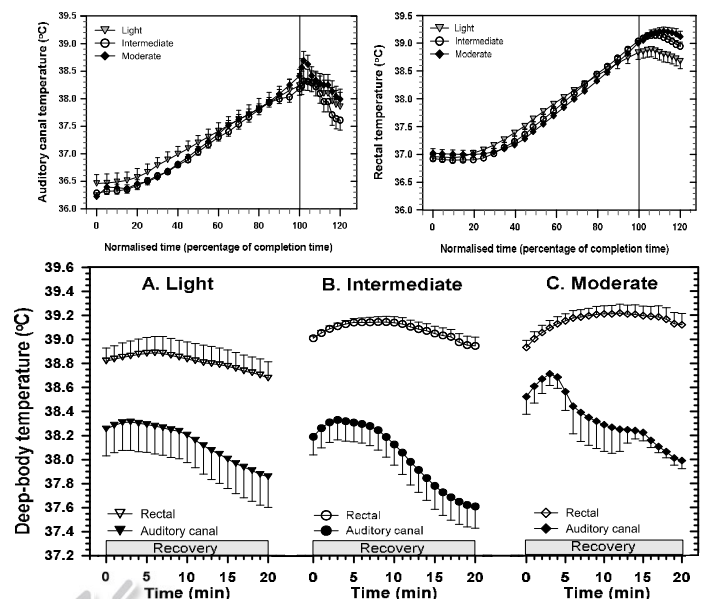
Stage	Variables	Light	Intermediate	Moderate
Baseline	Oxygen consumption (mL.min ⁻¹)	404 (26)	431 (37)	383 (16)
	Heart rate (b.min ⁻¹)	76 (3)	75 (2)	75 (3)
	Auditory canal temperature (°C)	36.3 (0.2)	36.0 (0.1)	36.0 (0.2)
	Rectal temperature (°C)	37.0 (0.1)	36.9 (0.1)	37.0 (0.1)
	Mean skin temperature (°C)	34.3 (0.1)	33.9 (0.5)	34.5 (0.1)
Exercise	Oxygen consumption (mL.min ⁻¹)	1589 (70)*‡	2398 (130)	2631 (53)
	Heart rate (b.min ⁻¹)	166 (4)*‡	177 (5)	184 (4)
	Auditory canal temperature (°C)	38.2 (0.2)	37.9 (0.3)	37.9 (0.1)
	Rectal temperature (°C)	38.8 (0.1)	38.9 (0.1)	38.8 (0.1)
	Mean skin temperature (°C)	37.0 (0.3)	37.1 (0.3)	36.9 (0.4)
Recovery	Oxygen consumption (mL.min ⁻¹)	527 (28)	576 (56)	601 (28)
	Heart rate (b.min ⁻¹)	121 (5)	119 (5)	121 (4)
	Auditory canal temperature (°C)	37.9 (0.3)	37.7 (0.2)	38.1 (0.1)
	Rectal temperature (°C)	38.7 (0.1)*	39.0 (0.1)	39.2 (0.1)
	Mean skin temperature (°C)	36.0 (0.3)	36.3 (0.3)	36.2 (0.5)
	Finger temperature (°C)	33.5 (0.4)	35.0 (0.7)	33.9 (1.2)

2. Heat extraction

- No difference among the 3 trials: -11.2±0.5 W (light), -11.8±0.6 W (intermediate) and -12.3±0.5 W (moderate).

3. Deep-body temperatures

- The auditory canal cooling rates were 0.03°C.min⁻¹ (light), 0.04°C.min⁻¹ (intermediate) and 0.05°C.min⁻¹ (moderate)(*P*=0.06). That same outcome during cooling was not evident within the rectal temperatures.



Conclusions

- Heat extraction from hyperthermic individuals, using upper-limb cooling, appears to be equally rapid, regardless of how fast heating occurred, providing those people attained the same level of hyperthermia prior to treatment.
- Due to the thermal inertia of the rectal tissues, rectal temperatures will not yield meaningful information when used in combination with rapidly changing thermal states during recovery after exercise.