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# **HUMAN BEHAVIORAL TEMPERATURE REGULATION: AN EXERCISE APPROACH**

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## **ABSTRACT**

Behavior represents our most preferred and effective modality by which body temperature is regulated. However, knowledge concerning the control of this behavior in humans is relatively limited. Therefore, the overall purpose of this thesis was to further our understanding of the control of human thermoregulatory behavior. This was accomplished by firstly establishing self-paced exercise and heat stress as a thermal behavioral model, while secondly the control of this behavior was investigated. In the first part of this thesis, voluntary reductions in exercise intensity have been found to be associated with thermal discomfort and reductions in heat production, which presumably improved heat exchange between the body and the environment over time, and ultimately aided body temperature regulation. Thus, these experimental data associatively indicate that reductions in exercise intensity in the heat are thermoregulatory behaviors, suggesting that self-paced exercise in the heat is a valid model by which to evaluate human thermal behavior. The studies presented in the second part of this thesis systematically evaluated the control of this behavior. It was subsequently demonstrated that skin temperature and the accompanying alterations in thermal perception and the percentage of peak oxygen uptake elicited by a given exercise intensity are all modulators of exercise intensity, and thus thermal behavior, in the heat. Notably, reductions in peak oxygen uptake appear to play a minimal role. Importantly, these studies strengthened the associations observed in the first part of this thesis by specifically establishing a causative relationship between exercise intensity and temperature regulation. Furthermore, the experimental observations also indicated that thermal behavior during self-paced exercise is ultimately initiated by the perception of effort response. In conclusion, the findings presented in this thesis suggest that a voluntary reduction in exercise intensity occurring in the heat is a thermoregulatory behavior, and that this behavior can be directly elicited by changes associated with elevations in skin temperature. During such instances, thermal perception and the percentage of peak oxygen uptake elicited by a given exercise intensity have been uniquely identified as contributors to this behavior. The findings of this thesis improve our understanding of the control of human thermoregulatory behavior.

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## LIST OF ABBREVIATIONS

### A

ANOVA	Analysis of variance
A-V O <sub>2</sub>	Arteriovenous oxygen content difference
A-V CO <sub>2</sub>	Arteriovenous carbon dioxide content difference

### B

bpm	Beats per minute
BSA	Body surface area

### C

$\dot{C}$	Rate of heat exchange via convection
°C	Degrees centigrade
CO <sub>2</sub>	Carbon dioxide
CNS	Central nervous system
$\dot{C}_{res}$	Rate of heat exchange from respiratory conduction

### D

DBP	Diastolic blood pressure
-----	--------------------------

### E

$\dot{E}$	Rate of heat loss via evaporation
EEG	Electroencephalogram
$\dot{E}_{max}$	Maximal rate of evaporative cooling for heat balance
EMG	Electromyogram
$\dot{E}_{req}$	Required rate of evaporative cooling for heat balance
$\dot{E}_{res}$	Rate of heat exchange from respiratory evaporation

### G

g	Gram
---	------

### H

h	Hour
$h_c$	Convective heat transfer coefficient
HR	Heart rate
HRpeak	Peak heart rate
%HRpeak	Percentage of peak heart rate
HSI	Heat strain index
H <sub>2</sub> O	Water

### J

J	Joule
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**K**

$\dot{K}$	Rate of heat exchange via conduction
$K^+$	Potassium
Kg	Kilogram
kJ	Kilojoule
kPa	Kilopascal

**L**

L	Liter
LCG	Liquid conditioning garment
LF	Linear factor
LR	Lewis relation

**M**

m	Meter
$\dot{M}$	Metabolic rate
MAP	Mean arterial pressure
$m_b$	Body mass
min	Minute
mmHg	Millimeters of mercury
mmol	Millimole
mOsm	Milliosmole

**N**

$Na^+$	Sodium
--------	--------

**O**

$O_2$	Oxygen
-------	--------

**P**

$P_A$	Ambient water vapor pressure
$PO_{RPE\ 16}$	Power output at a rating of perceived exertion of 16
$PO_{70\%}$	Power output at 70% of maximal rate of oxygen uptake
PSI	Physiological strain index
$P_{Sk}$	Saturated water vapor pressure at the skin

**Q**

$\dot{Q}$	Cardiac output
$\dot{Q}_{peak}$	Peak cardiac output
$\% \dot{Q}_{peak}$	Percentage of peak cardiac output

**R**

$r$	Correlation coefficient
$\dot{R}$	Rate of heat exchange via radiation
RER	Respiratory exchange ratio
RPE	Rating of perceived exertion
rpm	Revolutions per minute

**S**

$s$	Second
$\dot{S}$	Rate of heat storage/loss
SD	Standard deviation
SBP	Systolic blood pressure
SEM	Standard error of the mean

**T**

$T_A$	Ambient temperature
$T_{aHYP}$	Anterior hypothalamic temperature
$\bar{T}_b$	Mean body temperature
$T_C$	Core body temperature
thermoTRP	Temperature sensitive transient receptor potential ion channel
TPR	Total peripheral resistance
$\bar{T}_{Sk}$	Mean skin temperature
TRPM8	Transient receptor potential ion channel Melastatin 8
TRPV1	Transient receptor potential ion channel Vanilloid 1
TRPV3	Transient receptor potential ion channel Vanilloid 3

**V**

$v$	Air velocity
$\dot{V}CO_2$	Rate of carbon dioxide elimination
$\dot{V}O_2$	Rate of oxygen uptake
$\dot{V}O_{2max}$	Maximal rate of oxygen uptake
$\dot{V}O_{2peak}$	Peak rate of oxygen uptake
$\% \dot{V}O_{2peak}$	Percentage of the peak rate of oxygen uptake

**W**

W	Watt
$\dot{W}$	Rate of heat exchange from the generation of external work

**Y**

y	Year
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