THERMOREGULATION AND MUCOSAL IMMUNITY: THE EFFECTS OF ENVIRONMENTAL EXTREMES

By

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Summary

The main objectives of this thesis were to: 1. investigate the effects of acute and chronic hypoxia on human thermoregulation and mucosal immunity, specifically salivary immunoglobulin A (s-IgA) and salivary alpha-amylose during mild cold exposure at rest (Chapter 4 and 5), 2. identify the effectiveness of four practical field re-warming methods for the field treatment of cold casualties on thermoregulation and metabolism (Chapter 6), 3. examine the s-IgA response during and following mild hypothermia (Chapter 7) and 4. determine the efficacy of three field protection methods for the prevention of heat loss in non-shivering cold casualties using an in vitro torso model exposed to -18.5°C, 0°C and 18.5°C for four hours (Chapter 8).

Two hours of exposure to a simulated high altitude of 4000m, regardless of hypoxic acclimatisation, did not alter core or mean skin temperature during cold exposure. Nonetheless, hypoxia reduced metabolic heat production which may cause thermoregulatory implications during longer bouts of cold exposure. Chronic hypoxia reduced thermal sensitivity to the cold which may lead individuals to neglect appropriate behavioural thermoregulation and increase the risk of local and whole body cold injuries. Given s-IgA responses were unaffected by hypoxia in the cold before and following the 18 day mountaineering expedition suggests individuals are not at risk from URTI upon arrival to altitude.

During a three hour ‘awaiting rescue’ scenario following cold water immersion to reduce core temperature, a triple layered, metallised survival product with cells to trap heat and self-activating chemical heat pads was more superior at re-warming cold individuals compared to other methods tested. The insulative attribute of this survival bag may reduce possible shivering-induced fatigue and the subsequent increase in heat loss during more prolonged periods of cold exposure (> 4 hours).

A reduction in core temperature (≥ 1.5°C) resulting from cold water immersion and subsequent cold air exposure suppressed the usual daily s-IgA response which may increase susceptibility to illness and infection (i.e. URTI, common colds, influenza) if re-warming is not initiated immediately.

A non-shivering, in vitro torso model demonstrated that a triple-layered, metallised survival product with cells to trap heat and self-activating chemical heat pads was the most superior of three field cold protection methods to reduce heat loss during exposure to a variety of ambient temperatures (-18.5°C, 0°C and 18.5°C) for four hours.

It would appear when individuals experience cold stress at sea level or altitude, a triple-layered, metallised survival product with cells to trap heat and self-activating chemical heat pads may be the optimal light-weight field treatment to counteract the potential onset of hypothermia. For non-shivering casualties, this survival product may greatly reduce heat loss creating a longer survival time while waiting for evacuation to superior medical treatments (e.g. hospitals).

The overall aim of this thesis was to clarify the immediate health risks for individuals exposed to the extreme environments of cold and/or hypoxia, and if simple countermeasures which can be easily administered, offer suitable protection in the field to reduce such risks. The key message of this thesis is that individuals exposing themselves to cold and/or hypoxia when un-acclimatised to such conditions should carry self-administering survival bags and follow a specific programme of monitoring thermoregulation and upper respiratory symptoms in order to remain free of illness (e.g. rhinovirus, bronchitis) and peripheral or central cold injury (e.g. hypothermia and frostbite).
Declaration

This work has not been previously accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

Signed…………………………………………………… (candidate)

Date…………………………………………………………

Statement One

This thesis is the product of my own investigations, except where otherwise stated. Other sources are acknowledged giving explicit references.

Signed…………………………………………………… (candidate)

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Statement Two

I hereby consent for my thesis, if accepted, to be available for photocopying and for interlibrary loan, and for the title and summary to be made available to outside organisations.

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**Publications**

I was involved in all aspects of protocol design, data collection, data analyses and preparation of manuscripts for publication and the following thesis chapters. However, I also gratefully acknowledge input from the other named authors for each publication. The following is a list of publications arising from the material presented in this thesis.

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List of Abbreviations

\(\alpha\)  
Alpha

\(\degree C\)  
Degrees Celsius

\(\degree C/h\)  
Degrees Celsius per hour

\(\mu mol\)  
Micromole

ANOVA  
Analysis of Variance

ATP  
Adenosine Triphosphate

BAT  
Brown Adipose Tissue

BB  
Blizzard Bag

BB+HP  
Blizzard Bag with Heat Pads

BIA  
Bio-electrical Impedance Analysis

BMR  
Basal Metabolic Rate

CAT  
Cold Air Test

CHO  
Carbohydrate

CIVD  
Cold Induced Vasodilation

\(cm\)  
Centimetre

CNS  
Central Nervous System

CO  
Cardiac Output

CON  
Control Trial

CV  
Co-efficient of Variation

ELISA  
Enzyme-Linked Immunosorbent Assay

EMG  
Electromyography

FFA  
Free Fatty acid

FFM  
Fat Free Mass

\(FIO_2\)  
Fraction of Inspired Oxygen
Ft  Feet
g  Gram
g·ml⁻¹  Grams per millilitre
h  hour
Hb  Haemoglobin
HR  Heart Rate
HSD  Honestly Significant Difference
IgA  Immunoglobulin-A
IgG  Immunoglobulin-G
IgM  Immunoglobulin-M
Kg  Kilogram
kJ  Kilojoule
L  Litre
m  Metre
M  Metabolic Heat Production
MAP  Mean Arterial Pressure
Min  Minute
mg  Milligram
MJ⁻¹  Per Millijoule
mL  Millilitre
ml·kg⁻¹  Millilitres per kilogram
mmol  Millimole
mOsmol  Milliosmole
MPS  Metalized plastic sheeting
MR  Metabolic Rate
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<td>$T_b$</td>
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<tr>
<td>UN</td>
<td>Un-acclimatised</td>
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<tr>
<td>URS</td>
<td>Upper respiratory symptoms</td>
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<td>URTI</td>
<td>Upper Respiratory Tract Infection</td>
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<td>$V_E$</td>
<td>Ventilation</td>
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<td>$\text{W} \cdot \text{m}^{-2}$</td>
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