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THERMOREGULATION AT ALTITUDE

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Data collected at the Physiology of Extreme Environments Lab, Imperial College London.

Background

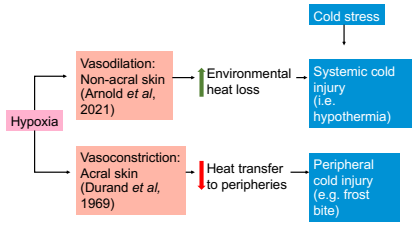
Introduction

Once an occupational hazard among fishermen and soldiers, cold injury now increasingly affects recreation seekers as the popularity of winter sports rises (Zafren *et al.* 2014). Hypoxia may increase risk of systemic (e.g. hypothermia) and peripheral (e.g. frost bite) cold injury through manipulating vaso-dynamics.

Microanatomy of the skin

The skin is the largest organ of the body and performs an active role in thermoregulation. Arteriovenous anastomoses (AVA) control blood flow into the superficial venous plexus allowing high variation in thermal gradients (Yousef, Alhajj and Sharma, 2022). Due to this wide variation small changes in cutaneous innervation may significantly impair temperature control.

Acral, non-hairy skin, covers the fingers, palms, nose, ears and plantar surface of the feet and contains a large portion of AVAs (Minson, 2003). Innervation is via vasoconstrictive, sympathetic adrenergic nerves. Non-acral, hairy skin, covers the rest of the body and is innervated by vasoconstrictive sympathetic adrenergic nerves and vasodilatory sympathetic cholinergic nerves. Due to varying innervation hypoxia affects the two skin types differently.



Previous research has shown that hypoxia elevates the risk of peripheral and systemic cold injuries through distinct effects on acral and non-acral skin. This study aims to clarify these mechanisms and address caveats.

Current limitations

- The mainstay of literature conducts experiments at room temperature. This is a poor simulation for high-altitude environments as the vasoactive effects of cold stress may confound results. Additionally, studies under cold stress often fail to include head cooling.
- No studies have simultaneously demonstrated acral constriction and non-acral dilation.
- No studies have investigated varying thermoregulatory responses to hypoxia at anatomical sites within the acral/ non-acral domain.

Aim

Determine the effect of hypoxia on acral and non-acral thermodynamics, during cold stress.

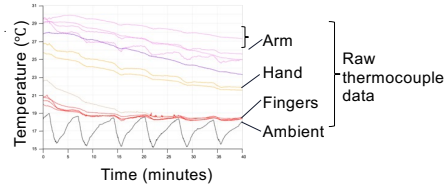
The hypothesis states that under cold stress, hypoxia will:
1. reduce acral skin temperature; and
2. increase non-acral skin temperature.

Method

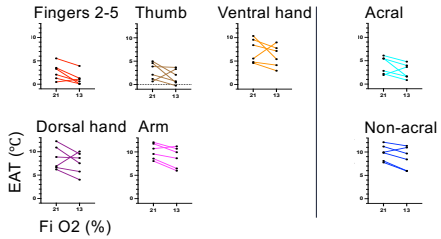
- Participants (N=6) lay supine in a cold room at 15℃ for 40 minutes.
- Twelve thermocouples record skin temperature across acral and non-acral skin of the non-dominant arm.
- Ambient temperature and oxygen saturation (SpO2) are continuously recorded.
- The protocol is performed once under normoxia (FiO_2=21%) and once under hypoxia (FiO_2 = 12%).
- Analysis performed using MatLab (2023) and GraphPad Prism (2022).

Results

Interpreting the raw data

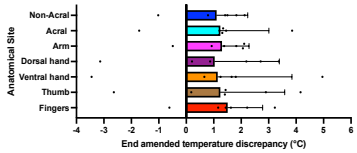


Absolute end temperature



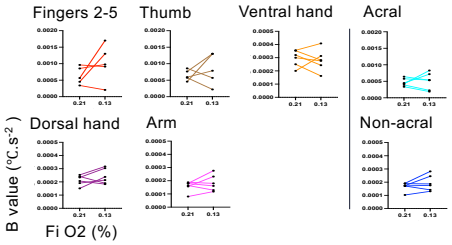
- End amended temperature (EAT) is the difference between the mean ambient temperature and the end skin temperature.
- Negative gradients connecting paired data in five of six participants indicate lower EAT during hypoxia.
- The Wilcoxon rank test is deemed not significant.

Hypoxic vs. normoxic end temperatures



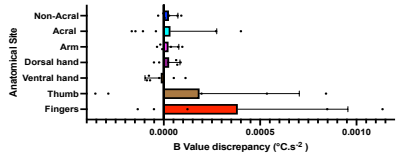
- EAT discrepancy compares hypoxic and normoxic EAT.
- Data points are plotted with mean and standard deviation.
- Positive means may indicate that hypoxic repeats have lower EAT.
- There is wide variation in the data and the Wilcoxon rank test not significant.

Cooling rate



- B value shows the exponential decay constant. High values demonstrate a faster cooling rate.
- Participant responses varied, showing no clear trends.
- Wilcoxon rank test was deemed not significant.

Cooling rate discrepancies



- B value discrepancy compares hypoxic and normoxic repeats.
- Data points are plotted with mean and standard deviation.
- Positive means may indicate faster cooling during hypoxia.
- Wide variation and Wilcoxon rank test is not significant.

Conclusion

This study explored hypoxia's impact on acral and non-acral thermoregulation under cold stress. In five of six participants, EAT was lower during hypoxic repeats at all sites; consistent with vasoconstriction in acral skin as per hypothesis 1. However, this contradicts expected vasodilation in non-acral skin, contrary to hypothesis 2. The high variation in B values suggest this analysis method may be overly sensitive to data artefacts. A larger study (N = 30+) is needed to confirm these trends. This may take the form of an adapted protocol in an expedition setting. Understanding hypoxic cold injury is key to improving medical care at altitude. Future research may facilitate use of novel therapies such as supplemental oxygen and vasoactive medications for the prevention and treatment of cold injury.

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