

## METABOLIC HEAT PRODUCTION IN THE FINGER

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### INTRODUCTION

Upon cold exposure, the fingers are highly susceptible to injury since blood flow, which is reduced due to vasoconstriction, is their **primary** source of heat (1). This leaves metabolism as an important secondary source of heat. However, the lack of muscular tissue in the lower finger limits the amount of heat that can be produced metabolically. Predictions of the metabolic rate ( $mr$ ) of tissue often involve use of the  $Q_{10}$  relationship expressed as (2,3)

$$mr = mr_o \cdot Q_{10}^{(T - T_o)/10} \quad (1)$$

where  $T$  is the tissue temperature and the subscript o refers to a reference value. Although it is known that the value of  $Q_{10}$  decreases with increasing temperature, its value is usually approximated as 2 (2,3). An experiment was conducted to measure heat flux from the finger during thermal stress and with the circulation of blood completely occluded. This leads to a determination of both  $mr_o$  and  $Q_{10}$  values.

### METHODS

Eleven healthy resting males had their forearm and hand immersed in a water bath held constant at either 20 or 38°C. After steady state was attained, arterial blood was completely occluded to the forearm for a period of 30 min. During this period, heat flux was continuously measured at four sites on the second phalanx of the middle finger using heat flux transducers.

Data were combined to obtain mean values of heat flux ( $hf$ ) at each site. Assuming uniform temperature in the finger at steady state, the metabolic heat production is then given by (4)

$$mr = 2 \cdot hf / r \quad (2)$$

where  $r$  is the radius of the finger. From the Arrhenius equation (3), the tissue activation energy (in J/mole) is given by

$$\Delta H^o = 8.31 \cdot \ln \frac{mr_{38}}{mr_{20}} \cdot \left[ \frac{T_{38} - T_o}{T_{38} \cdot (T_{38} + 10)} - \frac{T_{20} - T_o}{T_{20} \cdot (T_{20} + 10)} \right]^{-1} \quad (3)$$

where the tissue temperatures are in degrees Kelvin. Further, the values of  $Q_{10}$  and  $mr_o$  are given by

$$Q_{10} = \exp \left[ \frac{10 \cdot \Delta H^o}{8.31 \cdot T_i \cdot (T_i + 10)} \right] \quad (4)$$

and

$$mr_o = mr_i \cdot \exp^{-\left[ \frac{\Delta H^o \cdot (T_i - T_o)}{8.31 \cdot T_i \cdot (T_i + 10)} \right]} \quad (5)$$

where the subscript i refers to either the 20 or 38°C water immersion condition.

## RESULTS

Steady state heat flux was attained within **10 min** after occlusion during both immersion conditions. Data of the final **20 min** of occlusion were therefore analyzed. Overall mean heat fluxes were **0.600** and **1.380 W/m<sup>2</sup>** for **20** and **38°C** water immersions, respectively. Approximating tissue temperature by water temperature (a difference of less than 0.1°C can be expected at steady state (3) and choosing **35°C** as the reference temperature, the mean activation energy for the four sites is **36,567 J/mole**. From Eq. 4, the mean  $Q_{10}$  values are **1.65** and **1.56** for tissue temperatures of **20** and **38°C**, respectively. And from Eq. 5, the mean reference metabolic rate is **253.3 W/m<sup>3</sup>**.

## CONCLUSIONS

The  $Q_{10}$  value found for the finger data in this study is about **20%** less than the value usually assumed for biological tissue, i.e., **2**. A lower value of  $Q_{10}$  indicates that the change in metabolic rate with a change in tissue temperature is less than previously assumed. Rather than requiring a **10°C** change in temperature to incur a doubling effect on metabolism in the finger, approximately **15°C** is required.

The reference value of **253 W/m<sup>3</sup>** found for the metabolism of the finger at **35°C** is about 31% less than currently assumed for **skin**, connective tissue, and bone (2). Consequently, the finger's dependence on blood flow for heat during cold stress is quite important, as previously suggested by Raman and VanHuyse (5). To what extent the values of  $Q_{10}$  and  $mr_o$  found for the finger are applicable to **similar** tissues elsewhere in the body is not known and requires further investigation.

## REFERENCES

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