METABOLIC HEAT PRODUCTION IN THE FINGER

Peter Tikuisis and Michel B. Ducharme
Defence and Civil Institute of Environmental Medicine
North York, Ontario, Canada

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)

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

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 continously 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)

$$mr = 2 \cdot hf / r \tag{2}$$

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

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

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

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

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 linal **20 min** of occlusion were therefore analyzed. Overall mean heat fluxes were **0.600** and **1.380** W/m^2 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^3.

CONCLUSIONS

The Q_{10} value found for the linger 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^3 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 linger'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 linger **are** applicable to **similar** tissues elsewhere in the body is not known and requires further investigation.

REFERENCES

1. Tikuisis P. **1989,** Prediction of the thermoregulatory response for clothed immersion in cold water, *Eur. J.* Appl. Physiol. 59, **334-341.**

2. Werner J. and Buse **M. 1988,** Temperature profiles with respect to inhomogeneity and geometry of the human body, *J.* Appl. Physiol. **65(3), 1110-1118.**

3. Schmidt-Nielsen **K. 1975,** *Animal Physiology* (Cambridge University Press, London), **616677.**

4. Sekins K.M. and Emery A.F. **1982,** Thermal science for physical medicine, In J.F.Lehmann and J.V.Basmajian (eds) Therapeutic *Hear* **and** *Cold* (Williams & Wilkins, Baltimore), **97-99.**

5. Raman E.R and VanHuyse V.J. **1975,** Temperature dependence of the circulation pattern in the upper extremities, *J.* Physiol. **249, 197-210.**