EFFECT OF AIRWAY ORIFICE AND BODY CORE TEMPERATURES ON RESPIRATORY HEAT LOSS

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INTRODUCTION: Distribution of intra-airway temperatures suggest that most of the exchange of heat during a breathing cycle occurs within the upper airway (1, 2). An exception to this may occur when hyperventilating cold air shifts the thermal burden at least partially into the lung (3), such as occurs during exercise in cold air. This increased lung thermal burden may be exacerbated by low body core temperatures, resulting in reduced airway wall temperatures and diminishing upper airway warming of the inspired airstream. How this shift affects respiratory heat loss (RHL) is unknown, though Hoke, et al. (4) suggested that RHL was unaffected by ambient air temperature (T_{amb}) at an elevated minute ventilation (V_E = 40 L/min) with ambient air pressures. Whether this is true of both nasal and oral breathing is unclear but potentially important because humans are generally nasal breathers until V_E exceeds **30** L min^{-1} (5). The object of this study was to quantify the separate effects of upper airway and body core temperatures on RHL during nasal and oral breathing.

METHODS: Airstream (T_a), orifice, and rectal (T_{re}) temperatures were measured in 6 male subjects before and after 2 hour cold (1.1±0.2°C) water immersions wearing protective clothing under **3** experimental conditions: a) control: ambient temperature (T_{amb}) = 23.0±0.4°C, change in rectal temperature (ΔT_{re}) = 0°C; b) pre-immersion: T_{amb} = 4.7±0.2°C, ΔT_{re} = 0°C; and c) post- immersion: T_{amb} = 22.9±0.2°C, ΔT_{re} = -1.0±0.2°C. To discern changes in airstream washout temperatures, a temperature sensor needed to be developed which permitted normal breathing, had a small mass, and could provide simultaneous measurements of airstream and airway orifice surface temperatures during nasal or oral breathing. Each of the sensors used in this study consisted of a stainless steel wire (.51 mm dia.) ring onto which four thermocouples (.051 mm dia. welded bead, type T) were attached. The nasal sensor had a ring diameter of 13 mm while the oral sensor had a 28 mm diameter. Airstream and orifice temperatures were measured simultaneously with these probes placed at either the lips or each nares. T„ T_{re}, and orifice temperatures were measured at rest under each condition during quiet (f = 22.9±0.9 min^{-1}) and rapid (f = 39.9±3.9 min^{-1}) nasal and oral breathing. Subjects voluntarily increased f while attempting to maintain a constant tidal volume estimated at 500 mL. RHL was calculated from the difference between end-inspiratory and -expiratory T, and estimated minute ventilation.

Data Treatment: The dependent variable used in the analyses was RHL. Breathing frequency was calculated from the peak to peak frequency of peak expired T,. Multivariate analysis of variance was used to assess the significance of type of breathing (nasal vs. oral), T_{amb}, and breathing frequency (*f*) on RHL. Contrast analysis was used to assess how RHL is affected by ΔT_{re}. Data from both nostrils was pooled because missing data precluded

Significance was at the $p < 0.05$ level.

RESULTS: Figures 1 and 2 show RHL as a function of environmental condition, breathing rate, and whether breathing was nasal or oral. RHL rose significantly with increasing **f** ($p<0.001$) but fell with greater ΔT_{re} ($p<0.001$). No significant differences were observed as a breathing was nasal or oral ($p<0.01$). Orifice temperatures and RHL did not correlate (r = 0..21).

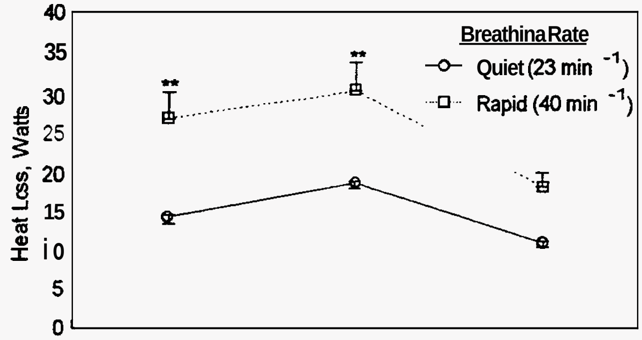

Figure 1. RHL during nasal breathing (±SEM).

CONCLUSIONS: This study shows that breathing rate and core temperature influence RHL independent of T_{amb}. This suggests that RHL may increase during exercise even in mild ambient conditions. Upper airway conditions appear to have little effect on RHL, since neither the breathing pathway nor orifice temperature had a significant effect on RHL.

Oral Breathing

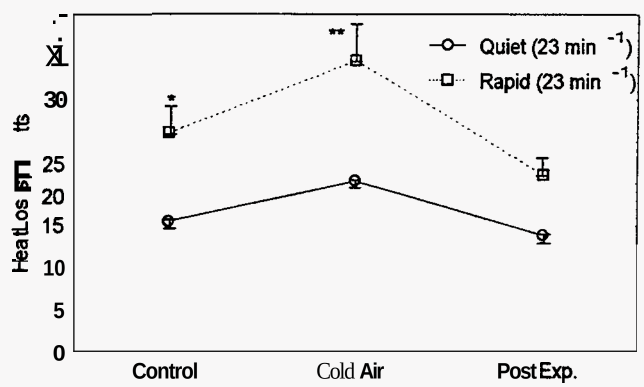

Figure 2. RHL during oral breathing (±SEM).

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