# SHIVERING THERMOGENESIS IN AUSTRALIAN ANTARCTIC EXPEDITIONERS: COMPARISON OF THERMOREGULATORY MODELS

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The general response to acute cold stress is vasoconstriction and increased heat production (M) via shivering. Both skin and internal body temperatures ($T_c$) must be lower than a fixed threshold before shivering ($\Delta M = M-M_{basal}$) occurs. Several thermoregulatory models include ΔM algorithms as a $f(T_c, \overline{T}_{sk})$. Other models include ΔM as a $f$(% body fat (%BF), lean body mass (LBM)). We examined how well 3 models predict ΔM for a given cold stress in a data set of resting women and men prior to their sojourn for a year in Antarctica. Six women and 29 men (%BF ranges 10-46%) resting semi-supine, unclothed except for underwear + smock ($R_T$ =0.022 $m^2 \cdot K \cdot W^{-1}$), were exposed for 2 h to cold air. Fifteen men and 5 women completed a cold stress test (CST group: Ta=5.7±0.6SD °C;rh = 50%;V=0.2m•$s^{-1}$) and a separate group of 14 men and 1 woman completed a cool test (Cool group: Ta = 8.4±1.3SD °C). Extensive peripheral ($\overline{T}_{sk}$ and finger temperatures) vasoconstriction occurred during the CST and less so in the Cool, elevating mean resting temperature pill level ($T_c$) by +0.15-0.2°C for the first 30min followed by a mean decline in $T_c$ of -0.01°C/min. ΔM ($W \cdot m^{-2}$) at 5 time points was compared against 3 model predictions: (1) Tikuisis and Giesbrecht (Tik-G), 1999: $\Delta M = 156 \cdot (37-T_c) + 47 \cdot (33-\overline{T}_{sk}) - 1.57 \cdot (33-\overline{T}_{sk})^2 \cdot \%BF^{-0.5}$; (2) Stolwijk and Hardy (S-H), 1977: $\Delta M = [13 \cdot (T_c - 37) + 0.4 \cdot (\overline{T}_{sk}-34)] \cdot (\overline{T}_{sk}-34)$ and (3) Tikuisis et al., (Tik), 1991: $\Delta M/LBM = \{0.0422 \cdot (35.4-\overline{T}_{sk})^2\}/(\%BF)^{0.506}$. Root mean square deviation (RMS) comparing ΔM vs each model output is shown in the Table.

| Data vs Model | *RMS* ($W \cdot m^{-2}$) Men (N=14) | *RMS* ($W \cdot m^{-2}$) Men(N=15) | *RMS* ($W \cdot m^{-2}$) Women (N=5) |
|---|---|---|---|
| obsΔM vs Tik-G | 28.4±8.2 Cool group | 26.6±13.2** CST group | 29.6±15.1 CST group |
| obsΔM vs S-H | 23.2±16.3 Cool group | 34.9±14.1** CST group | 33.8±15.6 CST group |
| obsΔM vs Tik † | 23.7±15.7 Cool group | 22.9±9.3 CST group | 15.2±3.1 CST group |

[**RMS Comparison between models P<0.0001; all others NS. †Normalized to $W \cdot m^{-2}$. No women in Cool group]. RMS from the Tik-G was < then the S-H prediction in the CST group of men. All predictions were equal in RMS in the Cool groups. For %BF ≤ 20%, Tik-G was highly correlated with integrated mean body temperature ($T_{b,I}$) derived from partitional calorimetry ($R^2$=0.89; P<0.001; $\Delta M(\text{Tik-G}) = -33.5 \cdot (T_{b,I}) + 1226$). ΔM calculated from cold-air models incorporating %BF, $T_c$ and $\overline{T}_{sk}$inputs serve as reliable predictors of shivering response over a limited cold stress for both men or women.

Stolwijk, J.A.J., and Hardy, J.D., 1977. Control of body temperature. In:Handbook of Physiology-Reactions to Environmental Agents. Am.Physiol. Society, Rockville, MD, Chapter 4, pp 45-68.

Tikuisis, P., and Giesbrecht, G.G. , 1999. Prediction of shivering heat production from core and mean skin temperatures. Eur. J. Appl. Physiol. 66,221-229.

Tikuisis,P, Bell, D.G., and Jacobs, I., 1991. Shivering onset, metabolic response, and convective heat transfer during cold air exposure. J.Appl. Physiol. 70,1996-2002.

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