A BIASED VIEW OF THE TEXAS MODEL

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Development of the TEXAS human thermal model covers more than 30 years. During that period, an effort has been made to identify dominant factors affecting physiological responses to environmental stress and exercise, and incorporate them rationally into the model. That effort has been strongly dependent on experimental data generated in various laboratories, but biological variability and a general paucity of reliable experimental data for cold immersion has hampered the work. Therefore, the extensive set of cold immersion data generated by the group at IAM and their effort to evaluate the model quantitatively is most welcome.

Although twelve subjects participated in the IAM study described in the preceding minipaper by Belyavin, Sowood, and Stallard, this paper will focus attention on the resting series for two fairly thin subjects (3 and 11), whose weights (73.0 and 73.4 Kgms) and mean skinfold thicknesses (9.02 and 9.04) closely match those of Subject JA (weight = 73.5 Kgms and mean skinfold thickness = 9.4 mm) in a similar experiment performed by Webb using the Craig bath calorimeter at DCIEM in Toronto. Subject JA was older than the two IAM subjects. While this sample is too small to support any general conclusions, these results are representative of those for the entire data set, and they illustrate the kind of problem one has in trying to "fine tune a model.".
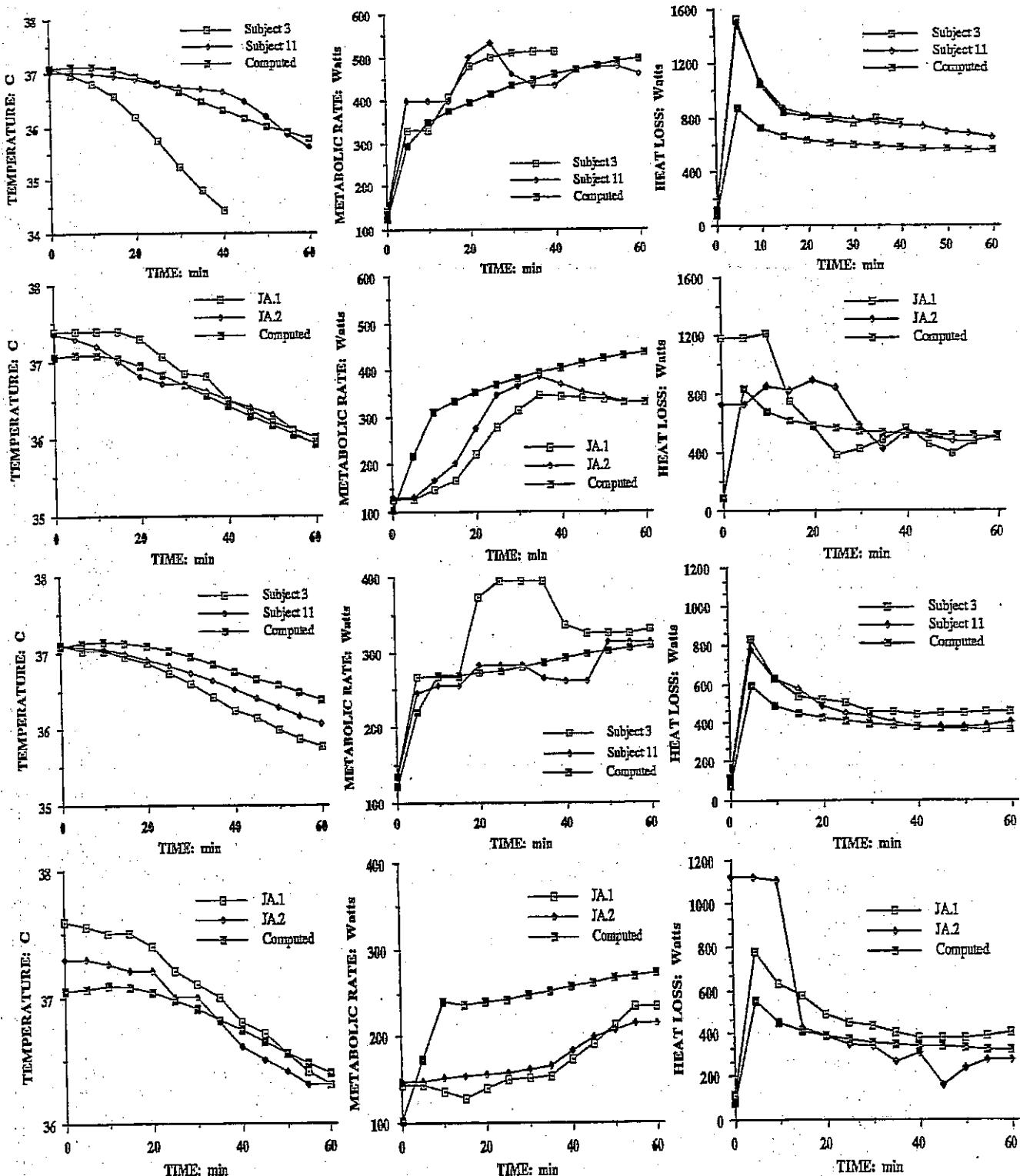
Computed and measured rectal temperature, rate of surface. heat loss, and metabolic rate are. shown on the next page for these *three* subjects during one hour immersions in 18 and 24 C water. It must be emphasized that the model discussed here is not exactly the *same* model evaluated' at IAM; the shivering controller gain has been increased by 50 percent and the vasoconstriction controller gain has been decreased by 50 percent to obtain higher rates of shivering metabolism and surface heat loss, as recommended by Belyavin, et al..

The principal problem is that experiments which should produce similar results do not always do so. Results shown on the next page indicate that significantly higher metabolic and surface heat loss rates were measured in the IAM experiments than in the DCIEM study. That presents a dilemma for the analyst, since there is no basis for preferring one set of data over the other, although the use of thermal flux transducers to estimate total rate of heat loss from the skin is probably not as accurate as using a bath calorimeter. Nevertheless, one must assume that a rational basis exists for the observed differences, and the most plausible one is that conditions in the IAM pool were significantly different from those in the DCIEM calorimeter.

Since heat transfer coefficients at the skin-water interface were probably higher in the vigorously stirred water of the IAM pool than in the slowly flowing water of the DCIEM calorimeter, a higher water velocity was used in the IAM simulations than in the calorimeter simulations. Increasing the water velocity caused computed rates of metabolism and surface heat loss to increase approximately 60 Watts each after 60 minutes of immersion in 18 C water. Even *so*, the model yields values that are smaller than those measured in the IAM pool and higher than those measured in the DCIEM calorimeter. Unfortunately, there is no obvious explanation for the residual differences.

Differences in the time course of shivering metabolism are. also apparent in the central vertical panel of figures on the next page. The IAM subjects tended to shiver more quickly than subjects in the DCIEM calorimeter. Results computed with the new parameters mentioned above are reasonably consistent with the IAM observations, but that leaves unresolved the reason for the slower responses observed in the calorimeter.

Additional suggestions from the IAM study can be incorporated into the TEXAS model. For example, the oscillation observed in computed metabolic rate, which does not seem to have a physiological basis, was eliminated by requiring an exponential decrease in the shivering component driven by decreasing central temperature. The observation that fat subjects probably shiver less vigorously than thin subjects having identical skin and central temperatures provides welcome confirmation of something that we have felt was true. Although a considerable amount of computational effort will be required to modify the model so that it agrees more closely with the larger data set now available, it needs to be done andt should yield a model that *can* be used with greater confidence.

Comparison of **computed** and **measured** values of rectal temperature, metabolic rate, and rate of surface heat loss for IAM Subjects **3** and **11** and DCIEM Subject JA (replicate **runs) during** immersion in water at 18 **C** (upper two panels) and **24** C (lower two panels). Note especially the difference between metabolic rates measured in the two laboratories. The IAM rates tend to rise more rapidly and reach a higher level than the DCIEM values, for reasons that are not well understood.