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Heuristic Modeling of Thermoregulation: Basic Considerations, Potential and Limitations

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Modeling of complex physiological phenomena has been attempted extensively over the years. The principal objective of modeling is to facilitate parametric presentation of the modeled phenomena. Ancillary objectives include the development of predictive capabilities, simulation of responses to environmental extremes not readily permissible under experimental conditions, etc.

Modeling can be categorized as follows:

(One) Regression modeling based on statistical techniques.
(Two) Heuristic modeling based on first principles, e.g., the first Law of Thermodynamics.

Regression modeling requires the *a priori* availability of large experimental databases. The data are analyzed for "best fit" options and statistical regression techniques are next employed to obtain the numerical values of the various parameters. Typical equational forms, widely found in the literature, include linear, polynomial, exponential, trigonometric and combinations thereof. In most cases regression parameters and levels of confidence of the model are also presented.

The main advantage of such models derives from their simplicity. They provide a convenient means for using relatively simple and straightforward equations for presenting large databases in assessing the relationship between physiologic variables and environmental parameters. The predictive power of these models is limited in the majority of cases, however, to the range of values for which the experimental databases were obtained. Thus, extrapolation beyond the original experimental range, although mathematically possible, may yield physiologically invalid values. Additionally, these models are usually "steady-state" ones, lacking time-dependent properties. While this is acceptable in a variety of cases, it may present a serious hindrance in other.

Heuristic modeling is very different in that it attempts to derive, rather than regress, the relationship between physiologic variables and environmental parameters from the mathematical expressions of natural laws. The underlying assumption is that natural phenomena are governed by certain laws. While these laws may be complex they are, nevertheless, amenable to relatively simple mathematical representation. For instance, the first Law of Thermodynamics (also referred to as the law of conservation of energy) may be expressed by an equation combining variables such as temperature, tissue physical and geometric properties, metabolic heat production, blood perfusion and time. These variables are cast into a differential equation for which boundary and initial conditions are specified. Once a solution to this equation, analytic or numeric, is obtained the predictions of the model need to be verified against experimental data.

This methodology has the potential of providing a powerful tool for describing and studying the responses of the thermoregulatory system under a variety of conditions and as a function of time. There are, in principle, no limitations on the range of parametric values for which the simulation applies but care must be exercised when analyzing the results.

In this lecture examples to the two types of models will be presented. Prediction and simulation capabilities of both modeling types will be discussed as well as their limitations.

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