CHAPTER 2

General Methodology
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The objective of the thesis outlined in Chapter 1 was examined by selected experimentation. An attempt was made to develop a biophysical expression, in order to estimate heat exchange variables with reference to extremely hot tropical climatic conditions. The expression took into account the heat transfers across layers or compartments of the body. The details of the biophysical expression and associated database are given in Chapter 3. The experimental evaluation of the proposed derivation was undertaken based on longitudinal investigation in simulated climatic chamber condition (Fig. 2.1).

The study was undertaken on the adult, male volunteers, drawn from the industrial sector of Ahmedabad city. The volunteers were motivated to participate in the investigations, as mentioned in Table – 2.1. Male volunteers were selected for both dry- and humid-heat exposures. The limit of tolerance, changes in work capacity to longitudinal exposures, including the process of acclimatization and influence of work and rest were ascertained on the basis of thermoregulatory and cardio-respiratory
parameters along with the biophysical analysis of response variables. In this part of the country, most of the time in a year temperature remains in the range of 35 - 40°C, and summer temperature reaches nearly 45-47°C, with relative humidity varying in-between 40-60%. Therefore, we selected winter season (the months of October to February) to carry out the studies and to eliminate the natural conditioning to heat of the summer months.

The experimental protocol was initiated with a larger sample size, but due to longitudinal nature of the studies, some subjects could not complete the entire spell of experimentation. Finally, we could complete the full protocol of experimentation with 29 subjects, who were homogenous in their physical characteristics and socio-economic background.

Since experiments were undertaken during the winter months, the selected volunteers were temporarily free from the influence of heat acclimatization effects. The pattern of the subject’s habitual physical activity and the experience of exposure to high heat were noted. Selection of subjects was based upon evidence of good health and absence of complicating factors such as cardiovascular and pulmonary problems.
Fig 2.1 CLIMATIC CHAMBER
Table - 2.1: Investigations Undertaken

<table>
<thead>
<tr>
<th>Study</th>
<th>No. of Expt. (No. of Sub. x No. of Treatment)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development of a biophysical derivation of heat balance equation</td>
<td></td>
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<tr>
<td>Examination of the process of acclimatization, based on short duration (2h) consecutive exposure to high heat.</td>
<td></td>
</tr>
<tr>
<td>Dry Heat : (8 x 8)</td>
<td>64</td>
</tr>
<tr>
<td>Humid Heat : (7 x 7)</td>
<td>49</td>
</tr>
<tr>
<td>Assessment of human work capacity (maximal oxygen uptake and oxygen debt) in consecutive high heat exposures.</td>
<td></td>
</tr>
<tr>
<td>Dry Heat : (5 x 8)</td>
<td>40</td>
</tr>
<tr>
<td>Humid Heat : (6 x 7)</td>
<td>42</td>
</tr>
<tr>
<td>Influence of Work-Rest scheduling in thermoregulatory responses to extremely hot climate.</td>
<td></td>
</tr>
<tr>
<td>Dry Heat : (2 x 8)</td>
<td>16</td>
</tr>
<tr>
<td>Humid Heat : (1 x 8)</td>
<td>8</td>
</tr>
</tbody>
</table>

The subjects were explained the protocol of experiment and were advised not to indulge in any additional heavy activity during experimental period and to remain indoors as far as possible, the day before the experiment. The subjects were asked to take sufficient sleep and no alcohol consumption was allowed during the days of experiments. The volunteers dressed in short pant during the experiment.
Climatic Chamber

The studies were carried out in a walk-in-environmental chamber (Hot-Pack International, USA). Most of our experiments were carried out in two kinds of simulated situations a) High temperature, low humidity (Dry heat) and b) High temperature, high humidity (Humid heat). The chamber had the facility of heating, refrigeration, humidification and dehumidification. The chamber could be used for a wide range of air temperature (-10°C to + 60°C) and humidity (20-100% RH).

Work Load

Fahrrad's bicycle ergometer was used for the subjects to perform the physical work of different intensities in the climatic chamber.

Environmental measurements:

The basic environmental measurements required for the assessments of heat stress are the following:

(1) Ambient Temperature and Humidity

The dry bulb ($T_a$) and wet bulb temperature ($T_{wb}$) of the ambient air was measured with the help of sling psychrometer to validate the set temperature of the environmental chamber. The measurements were taken close to the subjects in order to have accurate temperature and humidity readings near to the working subject.
Air velocity (V)
Airflow inside the chamber was maintained in between 0.4 to 0.6 m/s. Air velocity inside the chamber was measured with the help of silvered Keta thermometer, with a cooling range of 130-125 °F (54.4-51.7°C) and also with the help of a thermo-anemometer. The measurement was important to determine the convective and evaporative heat exchanges.

(2) Radiative Temperature (T_g)
The standard 6 inches black globe thermometer was used to measure mean radiant temperature.

Physiological Measurements:
During experimentation, the physiological responses such as heart rate, body core temperature, skin temperature and sweat production were recorded.

(1) Body core temperature (T_{cr})
The body core temperature of the subjects were continuously monitored, using a deep body thermometer (Type NPT2, Deep Body Thermometer LTD, UK). The instrument was originally designed by the British Medical Research Council (Fox et al. 1973; Solman and Dalton 1973). The measurement reliability of the device has been described by Nag and Pradhan (1985).
(2) **Heart rate (HR)**

Minute to minute heart rate changes were monitored by recording ECG through a Backman R612 Dynograph (Beckman, USA). In addition to that an observer constantly noted the palpation with the help of a stethoscope.

(3) **Skin Temperature**

The skin temperature profiles of local areas (seven locations) were monitored using a multi-channel telemthermometer (Aplab, India). Seven body locations were selected to calculate the mean skin temperature. These locations were: Forehead, back, upper arm, hand, thigh and feet.

The weighting factors of different local areas are given below to calculate average Skin temperature \( T_{sk} \),

\[
T_{sk} = 0.095 T_{sk(Head)} + 0.245 T_{sk(Back)} + 0.255 T_{sk(Trunk)} + 0.125 T_{sk(Arm)} + 0.035 T_{sk(Hand)} + 0.205 T_{sk(Thigh)} + 0.040 T_{sk(Feet)}.
\]

The method of calculation was taken from Nag *et al.* (1980). This value of the mean skin temperature was utilized in subsequent analysis.

(4) **Oxygen consumption/Metabolic heat**

The minute to minute pulmonary ventilation was recorded using a calibrated KM respirometer (Zentralwerkstatt Gottingen, Germany). A paramagnetic oxygen analyzer (Syvron-Taylor, U.K.) was used for
analyzing oxygen content in the expired air. These data were utilized to
determine VO₂ and metabolic rates.

(5) Sweat loss

The sweat loss was obtained from the initial and final body weight, with
the correction for water intake, urination and clothing. The weighing
balance was accurate to ± 25 gm.

The subjective responses like irritation, nausea, and dizziness etc., were
noted. In spite that all subjects were highly motivated to heat exposure
programme, protective care (e.g. medical attention, water-cooled assistive
garment as a standby) was taken for any eventuality.

The data collected from different experiments were subjected to statistical
treatment to obtain summary statistics and also to establish
interrelationship of different variables. Linear regression analysis and
necessary tests of significance were undertaken. A statistical software
package, SPSS version no. 6.1 was used for the same.