Fluid and Electrolyte Balance and Physical Training in Hot Climate

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Introduction

One of the exacting hemostatic mechanisms of the human body which maintains its internal environment constant is temperature regulation. The oral temperature is maintained between 96.4-99.8° F., rectal temperature between 96.6-100° F.

In hot climates man often gains heat from environment and to maintain body temperature, heat must be dissipated. Physical exercise increases heat production and calls upon the channels of heat dissipation to maintain body temperature constant. Evaporation of water from respiratory passages and skin provides means of heat loss that allows dissipation of heat even to air which is hotter than the body.

Every gram of water that evaporates absorbs it 0.58 Kcal of heat. Water metabolism therefore plays an important role in maintenance of body temperature. Water balance in hot climates may be disturbed as temperature regulation takes precedence over water balance. Disturbance of water balance on the other hand, affects the circulatory system and therefore limits physical activity. It is evident that water metabolism, environmental factors and physical effort are closely related subjects.

We will consider basic concepts and data about water balance, heat regulation and the effect of physical training on them in hot environment.

Fluid Balance

In an adult of average weight, the water content of the body is distributed as seen in table I.

None of this store of water can be spared. An excess or deficit of 1% causes a noticeable adjustment. An excess increases urine formation and a deficit is corrected by drinking. In a study of Sudanese subjects (Khogali et al 1972), the total body water as measured by tritium space was found to be lower than in total body water in subjects in temperate climates (55%). A state that may be described as voluntary dehydration. Therefore water deficit in the tropics if not corrected, is more serious.

Table I

| Distribution of body water in a man of 65 kg body weight |
|-------------|---------|---------|
| Value in litres | % Body weight |
| Total body water | 42 | 60 |
| Intracellular fluid | 26.5 | 38 |
| Extracellular fluid | 15.5 | 22 |
| Interstitial fluid | 12 | 17 |
| Intravascular | 3.5 | 5 |
Water balance is maintained by channels of water gain and loss. Table II shows this balance sheet for temperate climates.

Table III reports a fluid intake, evaporative water loss and urine volume in Sudanese subjects at rest, (Mcanle et al, Halim, Mahmoud and Mostafa 1975). The environmental temperature is relatively low in both studies as the temperature may reach up to 45° C in summer. Nevertheless, evaporative loss is significantly higher, urine volumes significantly lower and fluid intake significantly higher than in temperate climates.

Mechanisms of heat exchange in hot climates

Hot climates can be classified as hot dry or warm humid. Hot dry are usually in deserts and warm humid are in the tropical rain forest areas within latitudes 10-20° from the equator.

1. From internal metabolism-Basal metabolism produces 40 Kcal/sq. metre surface area in an adult man. If there is not a mechanism of heat loss this will produce a rise in body temperature of 1° C per hour, according to the equation :
   \[
   \text{Heat gain in Kcal} = \text{Temperature change} \times \text{Wt in kg} \times \text{specific heat}
   \]

2. Imperceptible tensing of muscles
3. Specific dynamic action of food
4. Exercise

   A man running for 20 minutes produces 200 Kcal. This will raise the body temperature in an average man of 65 kg by 2.6° F. if there were no mechanisms of heat loss available. Football entails a heavy physical activity : a man weighing 65 kg will generate 7.4-9.9 Kcal/minute.

### Table II

<table>
<thead>
<tr>
<th></th>
<th>Intake mls</th>
<th>Output mls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water in food</td>
<td>801</td>
<td></td>
</tr>
<tr>
<td>Water drink</td>
<td>1300</td>
<td></td>
</tr>
<tr>
<td>Metabolic water</td>
<td>254</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2355</td>
<td></td>
</tr>
</tbody>
</table>

### Table III

<table>
<thead>
<tr>
<th>Environmental Condition</th>
<th>Fluid intake mls</th>
<th>Urine output mls</th>
<th>Evaporatory loss mls</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Study :</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air Temp 30.6° C</td>
<td>3761 (3249-4188)</td>
<td>1037 (105-1610)</td>
<td>2723 (2263-3336)</td>
</tr>
<tr>
<td>R.H. 35.4 %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wind Speed 4.4 m/s</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Second Study :</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air Temp 33.9° C</td>
<td>3950 (2500-6345)</td>
<td>1294 (500-2750)</td>
<td>2656 (1545-3920)</td>
</tr>
<tr>
<td>R.H. 35%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wind Speed 2 m/s</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
cal and 200 calories when unclothed (Adolph 1947).

Heat gained or lost by radiation depends not only on the temperature of surroundings but on the colour and texture of clothes. White clothes are thus considered more suitable in the tropics because they minimise heat gain.

Heat loss by evaporation of water

Insensible perspiration is of relatively minor importance: Evaporation of water from expired air equals approximately 0.035 gms of water for every litre of expired air depending on environmental temperature and relative humidity. This can be of significance during heavy exercise when ventilatory minute volume may exceed 60 litres.

Thermal sweating

Production of sweat is a costly physiological event. In air temperature from 82-86° F, temperature regulation results mainly from heat loss by convection and radiation.

As ambient temperature increases, sweating is evoked in quantities enough for thermoregulation. An increase in humidity increases the rate of sweating as evaporation of sweat becomes less efficient. Sweat rates are also dependent on solar irradiation. For the same environmental temperature, sweat rates are higher during the day than during the night (Adolph 1947).

Sweat rates are higher during physical effort due to the increase in metabolism rate which depends on work load. (Table IV) shows the effect of exercise on body temperature during different loads of physical efforts.

E. F. Adolph and associates (1947) carried out extensive work on sweat rates in men walking while carrying different loads in the desert. They recorded sweat rates as high as 1 litre/hour and from studies on hot humid chambers losses as high as 3.5 litres/hour.

In Ohio State University, fluid loss of 2 litres to 7 litres/hour have been recorded in football players.

In a recent study, Halim, Mahmoud and Mustafa (1975) recorded evaporative water losses in soccer players in Sudan and Somalia (Table V). Evaporative water losses were greater in Somalia due to higher humidity. It is interesting to note that the losses were significantly lower in the 2nd half compared to the first half. This can be explained by the effect of slight dehydration resulting from the first half. It should be pointed out that the temperature in both studies was a relatively moderate temperature for tropical and desert climates, and that the effect of solar radiation was not operative as they were evening matches.

Consequences of increased sweat rates

Sweat continues in the face of increasing dehydration although at lower rates. 2% weight loss causes violent thirst.

Rectal temperature increases linearly with degree of dehydration reaching 2° C at 10% weight loss. Pulse rates increase with dehydration 40 beats above normal at 8% loss of body weight.

The main constituent of sweat apart from water and intake is sodium chloride. A daily
intake of 20 gms of salt was found to be sufficient for workers in a hot climate. If it was less than 6 gms/day, the workers showed higher pulse rates and rectal temperature and poorer cardio-vascular adjustment (Adolph 1947). Generally for every litre of sweat loss, an allowance of 3 gms of salt intake should be made.

Syndromes related to physical effort in hot climate

1. Muscle cramps: This is very common among athletes in the tropics. It is due to the inadequate replacement of salt lost in the sweat.

2. Heat Exhaustion: Characterised by inability to continue muscular work. Symptoms and signs are due to circulatory failure resulting from water and electrolyte depletion.

3. Heat stroke: This is the most serious of heat disturbances. More common in hot humid climates. Major signs are failure of sweating; hyperpyrexia, heat induced tetany and coma resulting from brain damage.

Protective Measures

1. Natural acclimatisation. Repeated exposure to hot climate results in acclimatisation. The effect of repeated exposure to hot environment is higher capacity for activity and less discomfort from heat. Acclimatisation begins in 4-6 days and is complete in 10-14 days.

Specific changes occur in skin:
   a) Increased peripheral conductance,
   b) Increased sweating capacity,
   c) Lower threshold of skin temperature for initiation of sweating,
   d) Lower concentration of NaCl chloride in sweat.

This results in increased plasma ALDosterone and therefore a minimisation of salt loss.

The degree of adaptation can be determined by measuring skin tempera-
ture, heart rate and rectal temperature which will be lower as adaptation proceeds. Fig. 3 shows these changes in men exposed to hot environment for several days. (E. G. Folk Jr., 1974).

From the above, it is clear that teams from temperate climates visiting tropical countries are at a disadvantage. For competitive sports in the tropics, such teams should have training in hot weather to develop some degree of acclimatisation.

2. Clothing : Light clothing is preferable to protect against solar radiation and not to interfere with evaporation of sweat.

3. Fluid intake : Proper hydration and adequate salt intake. Hydration prior to sports events is recommended as long as it is in small repeated volumes so as not to cause respiratory embarrassment or nausea due to stomach dilation.

The construction of stadia lighted for evening events in countries with adverse climatic conditions should be encouraged.

A. H.

References


