CHAPTER 1

Introduction
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INTRODUCTION

Man is fundamentally homeothermic, with inherent ability to withstand a wide range of heat stress within a narrow gradient of internal body temperature. However, when humans are exposed to extremely hot environment, the combination of heat stress, dehydration and physical activity impose challenges for physiological adjustment. Further, owing to industrial production processes and hot climatic stresses, prolonged combined exposure affects human health, performance and safety (Olesen 1995). Work in hot environment alters circulatory, thermoregulatory and metabolic functions and the time for which exposure may be continue depends upon factors, such as energy expenditure, nature of physical activity performed, diet, individual susceptibility to heat and the severity of the hot environment. The hyperthermia that develops is a determining factor for heat exhaustion.

The unique thermoregulatory mechanism allows the human being to cope up with the hot environment to a great extent; however, the physiological strain increases with the accumulation of heat until exhaustion (Sawka et al. 1992). At this stage, also known as tolerance time, man becomes uncomfortable, physically and mentally inefficient and ineffective, and susceptible to heat related injuries. Heat Related Injuries (HRI), also referred to as the heat related illnesses,
encompass a variety of disorders, e.g., heat cramps, heat exhaustion, heat syncope, heat stroke (Wildeboor and Camp 1993). It is important, therefore, to understand the magnitude of physiological strain that humans can tolerate and the factors that modify human tolerance to heat. However, it is always difficult to identify heat tolerance limit of a person. For the population in the tropics, the information in this regard is limited (Nag et al. 1986). This is primarily due to the inherent difficulties to arrive at the heat susceptibility/tolerance limit of men in direct determination by longitudinal studies. Knowledge of such information assists in improving safety guidelines for human heat exposures (Montain et al. 1994).

Since heat stress and strain are multi-factorial, its measurements are extremely important in ascertaining the level of heat exposure. Thermal indices e.g., Effective Temperature Basic (ET-B), Wet Bulb Globe Temperature (WBGT) have been widely used for the assessment of heat stress and strain. A thermal index essentially integrates thermal, physical and personal factors into a single number. Although a large number of indices have been developed, relatively few have survived the test of time and used today. Each of the thermal indices has certain advantages that make it suitable for use in specific environmental conditions. An ideal heat stress index is yet to evolve that effectively integrates the climatic, physical and personal factors and correlate to one or more physiological responses. Several heat stress indices have been practiced in the past decades. Some indices may correlate well with the physiological responses to
one set of conditions but may not correlate well with the responses to others, particularly in extremely hot environment (Beshir and Ramsey 1988).

In spite of inherent difficulties, to arrive at uniform criteria, there is a sustained endeavor to evolve a consensus on the guidelines to modify the working conditions and to establish safe exposure limits. International agencies like World Health Organization (WHO), International Standards Organization (ISO), European Union (Malchaire 1990) developed standards and guidelines for human exposure to heat. These guidelines generally do not reflect conditions of the tropical environment. Wide difference exists in the physiological criteria adopted by various investigators in finding out the imminent heat collapse or terminating the heat exposure; these may in part, account for differences in tolerance times obtained by different investigators. As advocated in the criteria document (NIOSH 1986), a greater understanding is needed concerning this issue to ensure permissible working environment.

In addition, the state of hydration of an individual influences the human heat tolerance; however, the relationship of the thermal indices to the state of hydration and limit of tolerance is not clearly known. Since hypohydration reduces work performance and tolerance, an obvious question arises whether hyperhydration improves performance (Nadel et al. 1980). Current knowledge suggests that hypohydration elevates body core temperature ($T_c$) (Sawka and Pandolf 1990) and reduces tolerance time (Sawka et al. 1985) during physical activity in a hot environment. The term dehydration (body fluid deficit) denotes the dynamic loss of body fluids or the transition from euhydration (normal body
fluid content) to dehydration. The detrimental effects of dehydration include plasma volume decrease, decline in cardiovascular performance, drastic drop in sweat rate, skin blood flow (SKBF) and increase in rectal temperature ($T_r$) and muscle temperature. Such disturbances impair physical as well as mental performance (Pichan et al. 1988), and also pose threat to health and safety (Montain and Coyle 1992). Studies (e.g., Sawka et al. 1996; Deschamps et al. 1989) indicate that hyperhydration (body fluid replacement) attenuates the thermo-regulatory disturbances to a large extent. Hyperhydration delays the development of dehydration, and enables the person to undertake physical activity at a lesser risk of hyperthermia. Hyperhydration maintains sweating and SKBF, thereby preserves the human ability to dissipate heat, reduces cardiovascular strain, and increases thermal tolerance (Sawka et al. 1996).

It has been observed that active humans do not voluntarily replace all the water lost during prolonged exposure to heat (Hubbard et al. 1990). Regulation of water balance is a complex process involving the interaction of fluid intake, composition of fluid ingested, gastrointestinal absorption, blood volume, renal excretion rate, and osmotic pressure of body fluid spaces, and hormonal and neural regulations (Sawka and Pandolf 1990). Different means of rehydration through ingestion of hyperhydrating agents such as water, carbohydrates, electrolyte supplement and glycerol have been practiced (Lyons et al. 1990; Armstrong et al. 1997). For individuals who often engage in prolonged hot environment, it is important to identify the most efficacious means of rehydration. Several studies have shown that glycerol-induced hyperhydration improves
cardiovascular responses, temperature regulation and exercise performance under warm/hot environmental conditions (Montner et al. 1996; Lyons et al. 1990). However, no conclusive evidence is yet available about the influence of hyperhydration in reducing thermal strain and preventing development of dehydration (Latzka et al. 1997).

A general understanding emerges that the strategies that minimize the physiological stress and strain are likely to contribute to enhance work performance, i.e., ability to work in heat. Therefore, assessment of human heat tolerance, influence of hyperhydration, estimation of safe exposure time, and selection of suitable thermal indices might help in measuring the severity of the environment and physiological strain, and alleviating the risk of health hazards of working population in the extremely hot climate.
OBJECTIVES OF THE STUDY

With these basic premises and understanding of the complexities associated with the effect of heat on health, performance and safety, the present research work was undertaken with the following specific objectives.

- To observe human heat tolerance limit, in combined exposure of work and heat with reference to exposure in extremely hot-dry and hot-humid environment.
- To study the applicability of different thermal indices in heat tolerance assessment and to ascertain permissible heat exposure.
- To examine the effect of hyperhydration in improving thermoregulatory adjustment and human tolerance to work in heat.