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A Research on Characteristics of Human Heat Stress in Dynamic Hot Environment

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Abstract

Because of the global warming phenomenon, extremely high temperature weather occurs more frequently than ever before in recent years, which is leading to a growing number of occupational heat damage incidents. Researches show that when exploded in extreme hot environment for a period of time, human body, especially for those who do manual labor work, may suffer various kind of heat damages including heat stroke, heat exhaustion, heat syncope and heat hyperventilation, etc. the heat damage risk increases with the rising of exposed time as well as labor intensity. Meanwhile, China definitely is the largest labor market, where the number of laborers reached 0.8 billion in 2005. These people are much more likely to be exposed in extreme hot environment and more likely to suffer from heat injuries. However, there is not a scientific management system on high temperature working environment in China. Therefore, basic research on human heat stress in hot environment needs to be done, in order to promote the establishment of relative laws, regulations and standards.

In this research, 20 adult subjects (11 males and 9 females) are chosen to conduct the experiment in an artificial climate chamber. Taking air temperature (33\textdegree C, 35\textdegree C, 39\textdegree C) and relative humidity (30\%, 60\%, 85\%) into consideration, 8 environment conditions are set according to principle of orthogonality. Exposed in stated environment, the subjects are told to fill in thermal sensation questionnaire. Several physiological parameters are monitored, including oral temperature, skin temperature, blood pressure, heart rate, etc. Besides, the labor intensity is changed from sitting still to walking on a treadmill during the experiment.

By setting these experiment conditions, several conclusions are expected to be drawn as follows. First, summarize the relationship between human core temperature or metabolic rate and environmental parameters. Second, observe the heat stress characteristics during different environment and labor intensity. Last but not least, analyze the individual difference and gender difference in heat response to extreme hot environment.

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Keywords: Dynamic hot environment; Heat stress; Human Thermal Sensation; Heart Rate; Skin Temperature

1. Introduction

Thermal stress is defined by the National Institute for Occupational Safety and Health as the total thermal loads caused by environment and human body, which is a description of the degree of thermal load in extreme hot environment. High temperature environment means the temperature is beyond the human comfort range of 21±3\textdegree C, that is over 24\textdegree C. Generally the environment...
will affect working efficiency when it’s over 29 ℃. According to the heat balance between environment and human body, living environment over 35 ℃ and the production environment over 32 ℃ are generally defined as high temperature environment, and it is considered as high humidity environment when the relative humidity reaches 60%. In addition, according to relative standard, the production labor can be defined as work in hot environment when the average WBGT index is over 25 ℃ [1].

When human core temperature is 36 ℃~38 ℃, the risk of illness is the lowest [2]. In certain environmental temperature range, human body can keep a relatively stable core temperature through thermoregulation. When temperature sensors receive internal and external environment stimulation, the temperature regulating center will accordingly cause the activity of endocrine gland, skeletal muscle, skin, blood vessels and sweat glands, so as to adjust the body heat production and dissipation [3]. However, when the environment temperature reaches certain extreme degree or human body is exposed in high temperature and humidity environment for a period of time, the thermoregulation won’t be able to function well. At this time it may occur certain thermal maladjustment including heat stroke, heat exhaustion, heat syncope, heat hyperventilation etc [4]. The difference in age, gender and health condition may cause obvious individual varieties in tolerance of high temperature. Therefore, it is necessary to research the physiological feature in hot environment of various human crowds, so as to afford theoretical foundation for practical living and production activities.

Dai et al [5] put forward a sweating rate predicting model which could predict body sweating rate in special thermal environment, and verified the model through experiment in artificial climate warehouse. Lv et al [6] chose over 100 healthy male undergraduates and conducted high temperature and humidity environment exposure experiment, and discovered that human body reached the limit when oral temperature and diriage increased to 38 ℃ and 1%. Gao [7] conducted similar experiment on male and female subjects and discovered obvious difference between male and female, for example, oxygen consumption ability affected male subjects more obviously and bodily parameters mainly affected female subjects; female subjects’ tolerance time in hygrothermal environment is longer than that of male subjects, however male subjects’ tolerance time in dry and hot environment is longer than that of female subjects. Zheng [8] concluded that environment parameters affected physiological parameters in different degrees. Heart rate, oral temperature, eardrum temperature and thermal sensation were mainly affected by temperature, and the intensity of labor affected oxygen consumption, metabolic rate, sweating rate and rectal temperature most significantly.

2. Methods

1.1 Subjects

20 healthy college students, including 11 male and 9 female, were randomly selected to test their physiological parameters in high-temperature environments.

1.2 Environmental Parameters

According to the world meteorological organization, high temperature weather is defined as the days when the daily maximum temperature is over 32 ℃ for at least 3 consecutive days. In china, the standard of the high temperature weather yellow alert is that the daily maximum temperature is over 35 ℃ for 3 consecutive days, and the red alert standard is that the maximum temperature reaches 40 ℃ within 24 hours. Referring to the standards above, 3 temperatures were selected as experimental conditions, which were 33 ℃, 35 ℃ and 38 ℃.

At the same time, 30%, 50% and 85% were selected as the humidity levels which represented the typical characteristics of 3 main parts of China: northern area (dry), central area (moderate) and southern area (wet).

8 conditions were set according to principle of orthogonality, including 33 ℃/30%, 33 ℃/50%, 33 ℃/85%, 35 ℃/30%, 35 ℃/50%, 35 ℃/85%, 38 ℃/30%, 38 ℃/50%. In preliminary stage some subjects couldn’t tolerant the extreme condition and quit the experiment, therefore the 38 ℃/85% was not taken into consideration.

1.3 Experimental Procedures

Subjects were told to attend experimental site 20 minutes in advance to wear the equipment, rest for a while, measure the initial weight and begin the experiment. Firstly, subjects should sit for 30 minutes in outside room (26 ℃/50%) , then enter the inside room (phytotron, designed condition) , sit doing office work for 50 minutes, after that walk at a speed of 1.2m/s on a treadmill for 20 minutes, at last, return to the outside room, sit for 50 minutes and measure the final weight. Heart rate and skin temperature were monitored during the whole procedure. Except for the 20 minutes on treadmill, the subjects should fill in a questionnaire and measure the oral temperature and blood pressure every 10 minutes. The procedure is showed in Figure.1 as follows.
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