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Estimation of human heat loss in five Mediterranean regions

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HIGHLIGHTS

- The human body's bioheat losses are examined in this work.
- Physiological reactions of the human body are sensitive to climate changes.
- Sensible and evaporation-based heat loss of the skin is affected by wind speed.
- The present analysis indicated that 90% of heat releases from the skin.
- The present analysis proved that 10% of heat is transferred from body by respiration.

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ABSTRACT

This study investigates the effects of seasonal weather differences on the human body's heat losses in the Mediterranean region of Turkey. The provinces of Adana, Antakya, Osmaniye, Mersin and Antalya were chosen for the research, and monthly atmospheric temperatures, relative humidity, wind speed and atmospheric pressure data from 2007 were used. In all these provinces, radiative, convective and evaporative heat losses from the human body based on skin surface and respiration were analyzed from meteorological data by using the heat balance equation. According to the results, the rate of radiative, convective and evaporative heat losses from the human body varies considerably from season to season. In all the provinces, 90% of heat loss was caused by heat transfer from the skin, with the remaining 10% taking place through respiration. Furthermore, radiative and convective heat loss through the skin reached the highest values in the winter months at approximately between 110 and 140 W/m^2, with the lowest values coming in the summer months at roughly 30–50 W/m^2.

1. Introduction

The human body, which we can think of as a thermodynamic system, is fueled by nutrients with the necessary amount of oxygen. With digestion of foods taking place, thermal energy is released. An increase in the level of human activity will lead to an increase in the thermal energy released by the body. In order to ensure the continuation of a person's critical functions and enable them to have a comfortable life in the environment when s/he is at rest or at work, it is necessary to keep the body temperature within a narrow range and to constantly maintain this heat level [1].

The heat produced by metabolism that is not converted to work is needed to be released to the environment in order to feel comfortable and survive with health [2]. The amount of heat transferred from the body depends on the temperature differences between the human body and the environment to which heat transfer occurs [3]. The greater these temperature differences, the greater amount of heat release takes place [4,5]. The transfer of heat from the inner tissues of the human body to the surface of the skin is accomplished by conduction and convection [6]. If it becomes difficult for the body to expel heat with these methods, the heat firstly produced inside the body is transported to other parts of the body through the flow of blood. The nerve system of the human body controls and determines the rate of heat to be transferred to certain tissues. Then, the sweat glands come into play, and the transfer of liquid from internal regions to the skin's surface takes place. This liquid motion (mass transfer) causes the formation of drops of sweat on the skin's surface, and the evaporation of the sweat results in the expulsion of heat out of the body.

Through conduction, the body transfers heat to objects (clothing, beds, etc.) that are in direct contact with the skin and are at a lower temperature than the skin's temperature [7]. In addition to conductive heat losses, the body transfers heat by radiation to other colder objects in the surrounding area and by evaporation of sweat drops [8,9]. Breathing in and out ensures the entrance and release of air between the

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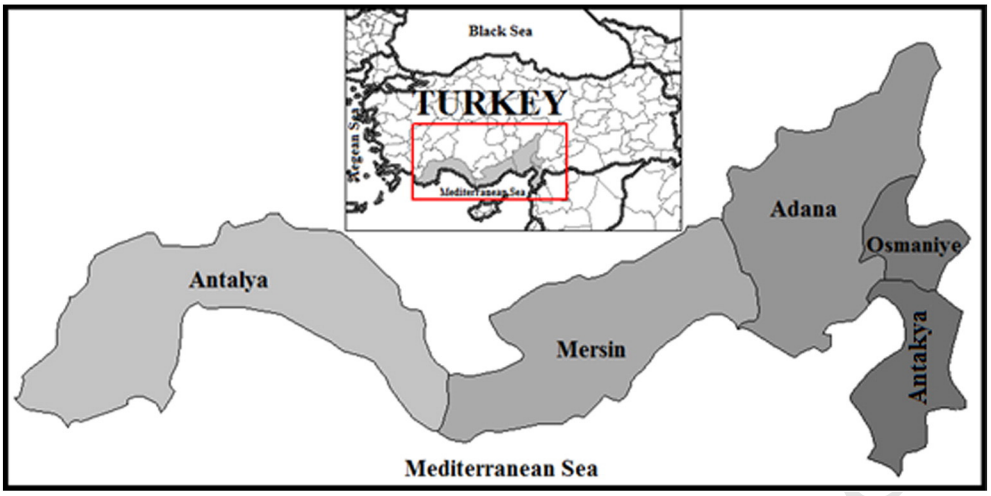

Fig. 1. Provinces in the eastern Mediterranean region.

environment and internal regions of the body and hence heat and humidity from these internal regions of the body are transferred to outside of the body as radiative, convective and evaporative heat losses [10–13].

As Parsons [14] reported that heat is produced in the cells of the living body,much of the investigation into human body response to thermal environments can be regarded as the study of the distribution and dispersion of that heat. Heat that is produced by the living body's metabolism is used to maintain the temperature of the internal body around 37 °C and also the body will attempt to preserve or lose sufficient heat to the environment to try to maintain the temperature as 37 °C. A method of determining metabolic heat production is to directly measure the heat produced by the person in a whole-body calorimeter [14]. He also stated that an estimate of metabolic rate, M, can be made by measuring how much oxygen is used to 'burn' food. There are certain common basic activities such as lying, sitting, standing, walking with a load, and walking upstairs. Estimates of metabolic rate for basic activities are 45, 58, 65, and 110 W/m^2 for lying, sitting, standing and walking, respectively. The heat balance equation for the human body is $M - W = E + R + C + K + S$. The metabolic rate of the body (M) provides energy to enable the body to do mechanical work (W), and the remainder is released as heat (i.e. $M - W$). Heat transfer can be by conduction (K), convection (C), radiation (R) and evaporation (E). For the body to be in heat balance (i.e. constant temperature), the rate of heat storage is zero ($S = 0$) [14]. Total metabolic energy consists of metabolic heat production values associated with the activity of the human body and shivering energy in which the human body attempts to produce heat through muscular activity under very cold environmental conditions. Metabolic heat production by shivering and muscle strain is a more effective mechanism than the vasoconstriction of blood vessels in order to protect the body's heat balance in very cold environments. By shivering, the metabolic energy value of the human body at rest can be upgraded up to three times [10].

In the course of a day, the human body faces very different weather events in different environmental conditions. In the Mediterranean region, the weather changes from season to season, from day to day, and from hour to hour, and may vary greatly within very brief periods of time. Wind, humidity, precipitation, temperature, pressure, and cloud motion are among the variables that bring about such weather events [15,16]. The winter is the rainiest season in the semi-humid and humid Mediterranean climates found in the Mediterranean region. In the Mediterranean climate, the rate of evaporation is very high throughout the year, particularly in the summer months. The effects of these changes in weather conditions on heat transfer from the human body are greater in the provinces of Adana, Antakya, Mersin, Osmaniye and Antalya. In fact, in this extremely humid region sweat does not evaporate easily, and it builds up on the body's surface. This is quite uncomfortable, and it is for this reason that people in the provinces of the Mediterranean region prefer air-conditioned environments. People

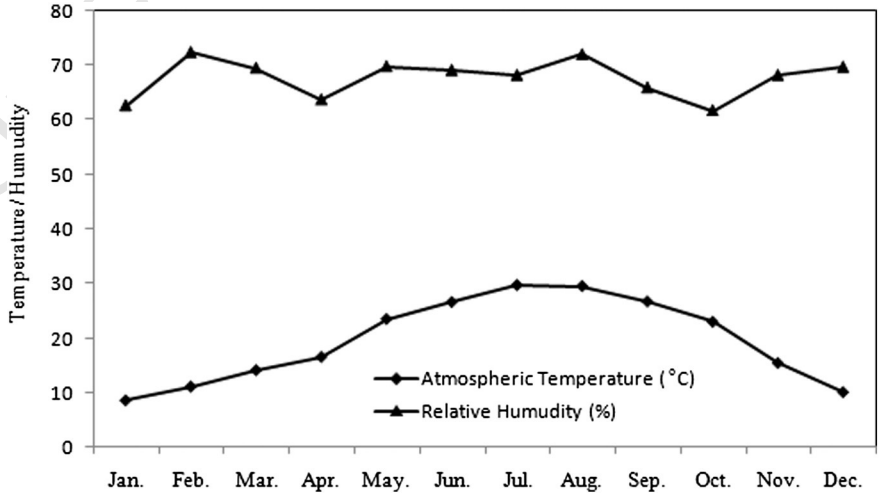

Fig. 2. Monthly variation of atmospheric temperature and relative humidity in Adana.

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