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Effect of properties of sports surface and clothing materials on human thermal load under hot environment

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Abstract

The physiological reaction and mental action of a human body was observed for four different sports surfaces and for clothing of six different colours during exercise to gain a better understanding of human thermal conditions outdoors. The radiative properties of each surface and clothing were determined before the experiments; thus, human thermal load including environmental conditions was calculated. Different radiation properties were quantitatively determined to affect human thermal load; in addition, one type of functional sportswear prototype for reducing thermal load by property modification was evaluated. Subjective results indicate that for future clothing design, other thermal properties have to be considered along with the radiative properties.

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Keywords: Reflectance; Radiation; Ground surface; Human thermal condition; Exercise; Sportswear.

1. Introduction

The thermal environment is one of the most important factors determining human performance. For example, Nakamura (2013) found a connection between heat-related disorders and changes in climatic conditions in Japan. A possibility of a hot environment having non-lethal effects on humans is easily recognized. Dugas (2010) showed that sports performance reduced in extremely hot environments because of human thermoregulation that maintains

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the body temperature below the critical temperature. As mentioned by Fanger (1973), the thermal conditions of the human body can be well described by employing the notion of human energy balance; therefore, the authors have attempted to understand human energy balance under different environmental conditions. Human energy balance is affected by multiple factors such as radiation, heat convection, and inner heat production. Radiative heat transfer is especially important in outdoor scenarios, and our environment is made up of various materials such as ground surface and clothing. Therefore, the properties of these materials may strongly affect our thermal condition and outdoor performance. However, to date, only few research studies have quantitatively addressed the relationship between the human thermal conditions and thermal environment in the proximity of a human body. The present study was conducted to gain a better understanding of outdoor human thermal conditions in different radiative environments. The practical goal pursued by the present study was to establish better sports environments even in hot seasons by modifying the materials surrounding the humans.

2. Experiments

Field measurements were performed to grasp the relationship between human thermal conditions, human thermal perception, and thermal properties in the proximity of a human body. The sports materials considered in this study were (1) sports surface materials and (2) clothing materials. First, the properties of the materials were determined. Measurements were performed to determine the radiative properties of sports surfaces such as an asphalt road, an athletic field, a football field, and a tennis court (Fig. 1), as well as clothing materials made of black, blue, green, red, white, and yellow colour cotton. The materials considered were typical sports materials. To analyse the heat stress of the human body, the surrounding weather factors and the physiological response of the human body were measured.

2.1. Measurements of material properties

In architecture or civil engineering, field measurements of albedo typically involve the use of a radiometer for measuring the incident and reflected radiant fluxes; the measurement process used in the present study conformed to the ASTM-E-903 standard, as was shown by Prado (2005).

2.1.1. Properties of ground surfaces

Field measurements of solar reflectance from four different sport surfaces were performed in an open space during summer. The net radiometer (EKO MR-60) was located above the surface, and global solar radiation $S\downarrow$ [W/m^2] and reflected solar radiation $S\uparrow$ [W/m^2] were measured in 1-min intervals. Because all surfaces were sufficiently large and uniform, the surface reflectance ρ_{sur} [N.D.] could be calculated as the ratio of reflected to global solar radiations:

$$\rho_{sur} = \frac{S\uparrow}{S\downarrow} \quad (1)$$

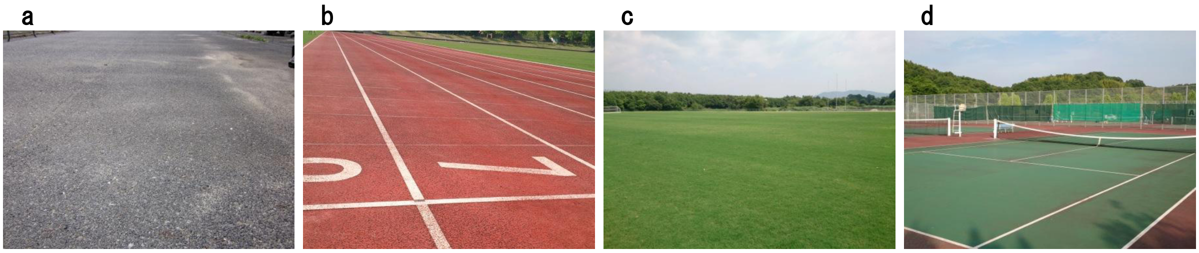

Fig. 1. Measurement sites: (a) asphalt road; (b) athletic field; (c) football field; (d) tennis court.