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# Human-body exergy balance calculation under un-steady state conditions

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ABSTRACT

We investigated the rationality and accuracy of human-body exergy balance calculation under un-steady state conditions for our immediate thermal environment changing due to a series of behaviour such as walking outdoors and coming into a mechanically air-conditioned space. We set up an experiment that the subjects stayed in two rooms, one with natural ventilation and the other with mechanical air-conditioning. According to "energy" calculation, input energy rate almost the same as the total of output energy rate, within which a portion by sweat secretion in naturally ventilated room was larger than that in mechanically air-conditioned room. On the other hand, according to "exergy" calculation, the large portion of input exergy rate consisting mainly of metabolism and liquid water by sweat secretion was found to be consumed. In naturally ventilated room, the exergy consumption rate increases by walking and then decreases gradually towards the end of staying, but in mechanically air-conditioned room it suddenly became large right after entering and dropped more sharply than in naturally ventilated room. This is because the liquid water by sweat, which has wet exergy, dispersed into the surrounding air very rapidly in mechanically air-conditioned room whose humidity is very low. The measured values of sweat evaporation rate were larger than the calculated values based on the two-node model although their patterns of variation were similar to each other. Conventional air conditioning for cooling, which necessitates a large input of exergy by electricity, was found to result in a large amount of human-body exergy consumption.



## 1. Introduction

All of we humans live in a variety of thermal environment around us such as a case of walking into a room from outdoors with harsh weather or vice versa and a series of changes throughout one season or throughout a longer period from one season to the following seasons. In order to establish a rational strategy of controlling the built environment for human's health and thermal comfort with low-exergy systems [1], it is important to have a better understanding on the adaptability of human body to thermal environment variation through the thermoregulatory system.

Against the thermal environmental variations, the human thermoregulatory system works in order to make the body-core temperature remain unchanged within a narrow range that was developed over the long history of biological-system evolution. For example, in many places of Japan, where it becomes hot and humid from mid June to mid September, those who lived there used to adapt by sweat secretion and its evaporation to make the body-core temperature unchanged. Moderate sweat secretion and its evaporation must play a key role in adaptation of human body to hot and humid environment in summer time that occurs throughout Japan except Hokkaido.

In contemporary urban environment, whether we like it or not, we have to expose ourselves to a variety of thermal environmental conditions. For example, in such a case of having to exhaust a large amount of heat due to walking right after we come into buildings from hot and humid outdoors for commuting, shopping and so on, if this excess heat is exhausted by means of active cooling system such as air-conditioning units which often tend to provide very low air temperature and humidity, our body experiences a large temperature and humidity differences between outdoors and indoors inevitably. Over the last few decades, compact air-conditioning units have been widely spread in Japan [2] and also other countries but their careless use tend to have caused the indoor temperature and relative humidity being very low. For this reason, our immediate environmental temperature and humidity result in fluctuating very sharply, and such a series of sharply changing conditions may have caused a state of human-body thermoregulatory system working less effectively.

In order to avoid such harsh change in thermal environment, it should be a good idea to make a full and smart use of passive system such as a combination of natural ventilation and radiant

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