暑熱，輻射熱存在下における網シャツ着用の生理的意義

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Physiological Significance of Netted Shirts for Thermoregulatory Responses of Resting and Exercising Women Under Warm and Radiated Environments

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要　旨

網シャツ着用が暑熱（34°C），輻射熱（300Wの電気ストーブ）存在下でのヒトの体温調節反応にどのような影響を与えるのかを観察した．年令21～24才の3人の女性が被験者として採用された．直腸温，皮膚温，衣服気候（温度，湿度）が30分間の安静，20分間の運動期間中連続測定された．主要な知見は 1）綿長袖シャツの背部表面温度は，網シャツ着用時に無着用時にくらべ常に高かった．2）背部皮膚温と衣服内湿度は網シャツ着用時に無着用時にくらべ小さかった．3）正の貯熱量は網シャツ着用時に無着用時にくらべ少なかった．これらの知見から網シャツ着用は外界から人体への熱の進入を妨げるという点で生理的意味を有することを本論文で論じる．このような耐暑法は炎天下のラクダのそれに類似している．

ABSTRACT

We studied the effects of netted shirts upon thermoregulatory responses at warm (34°C) and radiated (electrical heater of 300W) environments.

Three females, aged 21—24 yrs, served as subjects. Physiological variables such as rectal and skin temperatures and clothing microclimate (temperatures, humidity) were continuously measured during 30min rest and 20 min exercise. Major observations were summarized as follows: 1) Back surface temperatures of cotton outer clothing with long sleeves were always greater in netted shirts wearing throughout rest and exercise. 2) Back skin temperatures and clothing microclimate humidity were smaller in netted shirts wearing. 3) Positive heat storage was lower in netted shirts wearing. We discuss that netted shirts wearing is physiologically significant in reducing external heat penetration to human body. These heat resisting mechanisms resemble those of the camel under warm and sun-radiated deserts.

Introduction

We have disclosed[1~4] that sweating rates and clothing microclimate (temperature, humidity) of sedentary and exercising women could be influenced by different fabric materials at warm and neutral ambient temperatures. However, it remains to be known what kinds of physiological implications the way of our dressing has. As a first step, therefore, we attempted to compare thermoregulatory responses between the subjects either with or without netted shirts at warm and radiated environments.

Materials and methods

Three healthy females, aged 21—24 yrs, served as experimental subjects. She entered into a bioclimatic chamber at 10:00, the ambient temperature and relative humidity of which had already been controlled at 34°C and 60% RH. Then, we measured the body weight of the semi-nude subject wearing only shorts and brassiere, attached skin thermocouples with adhesive tape on the skin surface of chest, back, arm, thigh and leg. A rectal thermocouple was inserted a distance of 12 cm beyond the anus by the subject itself. She stayed in the chamber quietly for 1 hr. After the sweat droplets on the skin surface were wiped with a dry towel at 11:00, she wore the experimental clothing of cotton shirt with long sleeves, cotton trousers and cotton socks, the weight of which being known. At this time cotton netted shirts with long sleeves were also worn between brassiere and cotton shirt with long sleeves if the effects of netted shirts were studied. She sat calmly for 30 min on a stool located on a bed scale, and then took hand exercise moderately for 20 min. During these experimental periods we measured the body weight loss continuously using the bed scale with accuracy of 1 gram, and the temperatures of the rectum and skin surfaces of 5 points mentoned above. We also measured the back surface temperature of outer clothing, clothing microclimate temperature and humidity at back site. Middle back of the subject was radiated a distance of ca. 70 cm apart from the back outer clothing by a electrical heater of 300 W throughout the experimental periods of 90 min.

Heat storage (S) was calculated using the following equation:

$$S=0.83\times W\times\frac{2\Delta T_{re}+\Delta T_s}{3}\times\frac{1}{A}$$

0.83 : Specific heat of human body (kcal·°C^{-1}·kg^{-1})
W : Body weight (kg)
ΔT_{re} : Change of rectal temperature (°C)
ΔT_s : Change of mean skin temperature (°C)
A : Body surface area (m^2)

Results

In Fig. 1 representative temporal changes of back skin temperatures, back surface temperatures of outer clothing and clothing microclimate temperatures at back site are compared between two different clothing conditions with/without netted shirts wearing in a subject (S-2). We see back surface temperatures of outer clothing almost always higher both during rest and exercise, back skin temperatures lower especially during exercise, clothing microclimate temperatures next to skin surface clearly lower in clothing conditions of netted shirts than of non-netted shirts. We ob-

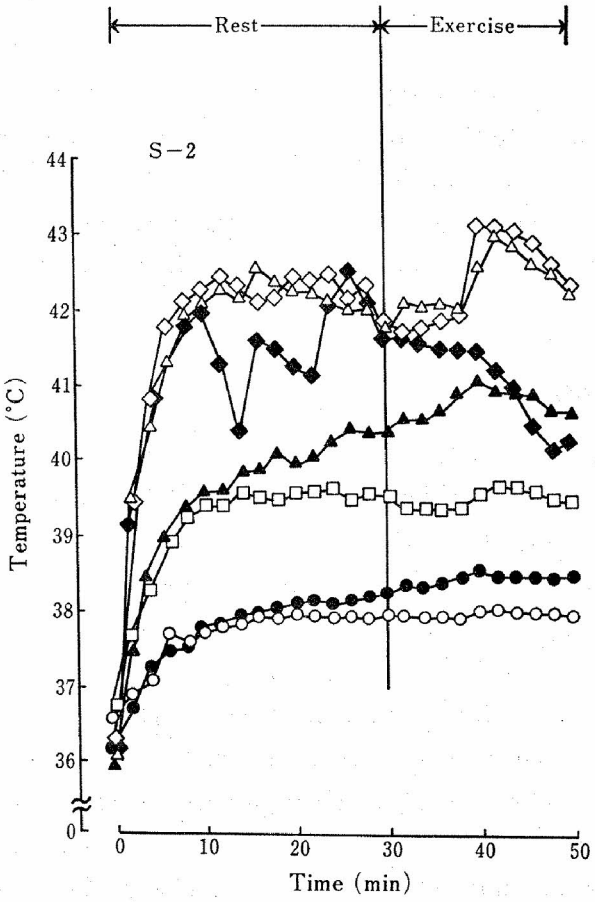

Fig. 1 Temporal changes of temperatures of back skin and clothing microclimate in a resting and exercising subject (S-2).
● and ○ : back skin temperatures in non-netted shirts and in netted shirts, respectively. ◆ and ◇ : surface temperatures of cotton outer clothing in non-netted shirts and netted shirts, respectively. □ : clothing microclimate temperatures between back skin and netted shirts. ▲ and △ : clothing microclimate temperatures next to cotton outer clothing in non-netted shirts and in netted shirts, respectively.

served same tendency in other two subjects.

Temporal changes of clothing microclimate humidity measured between back skin and netted shirts/cotton shirts are compared between two different clothing conditions of netted shirts and non-netted shirts in Fig. 2. During exercise the clothing microclimate humidity was clearly lower in netted shirts than in non-netted shirts in all three subjects without exception, and during rest it was lower in netted shirts in two (S-1, S-2) out of three subjects.

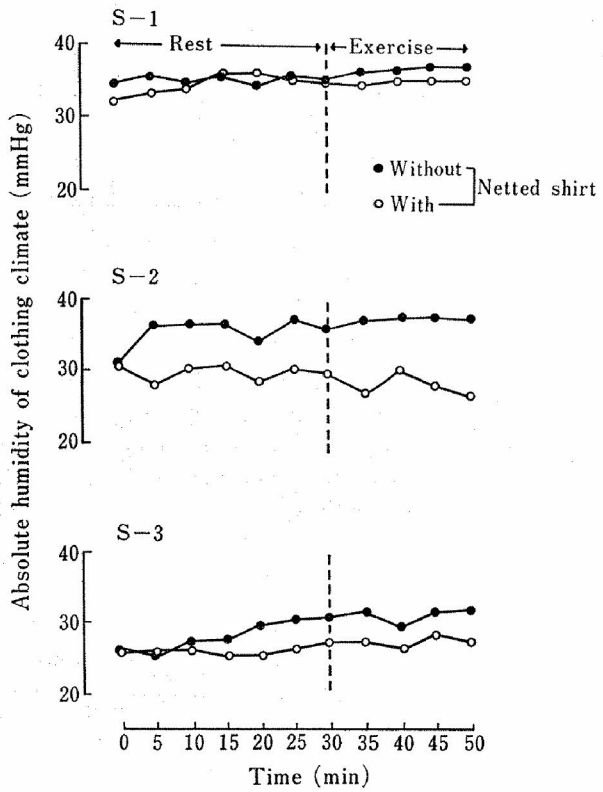

Fig. 2 Temporal changes of clothing microclimate absolute humidity measured between back skin and netted shirts/outer clothing shirt in three resting and exercising subjects (S-1, S-2, S-3). ● : non-netted shirts. ○ : netted shirts.

In Fig. 3 average values of back skin temperatures, back surface temperatures of outer clothing and clothing microclimate temperatures at back site during 20 min exercise are schematically compared between two different clothing conditions of netted shirts and non-netted shirts in two subjects (S-2, S-3). Back surface temperatures of outer clothing are ca. 1 °C greater in netted shirts. Both back skin temperatures and clothing microclimate temperatures next to back skin are ca. 0.5 °C smaller in netted shirts, although the sites for measuring clothing microclimate temperatures next to back skin are, strictly speaking, not same due to the existence of netted shirts. Clothing microclimate temperatures next to outer clothing are nearly equal or a little greater, compared with back surface temperatures of outer clothing in netted shirts.

In Fig. 4 heat storage during 50 min experimental periods is compared between two different clothing conditions of netted shirts and non-netted shirts in three subjects (S-1, S-2, S-3). Without exception heat storage is clearly greater in non-netted shirts, suggesting that heat was more easily stored from environment to human body in non-netted shirts. In other words, netted shirts have the

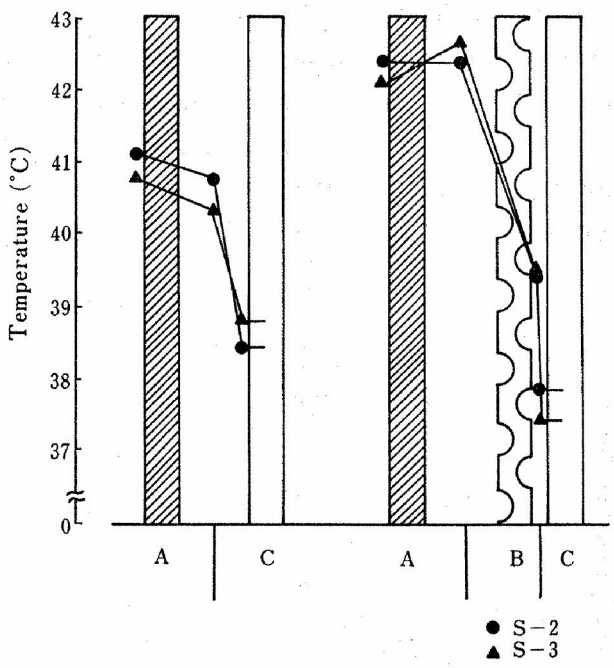

Fig. 3 Schematic representation of average values in back skin temperatures, back surface temperatures of outer clothing and clothing microclimate temperatures at back site during 20 min exercise in two subjects (S-2, S-3). Left: non-netted shirts. Right: netted shirts. A: cotton shirt with long sleeves. B: human back skin. C: cotton netted shirts.

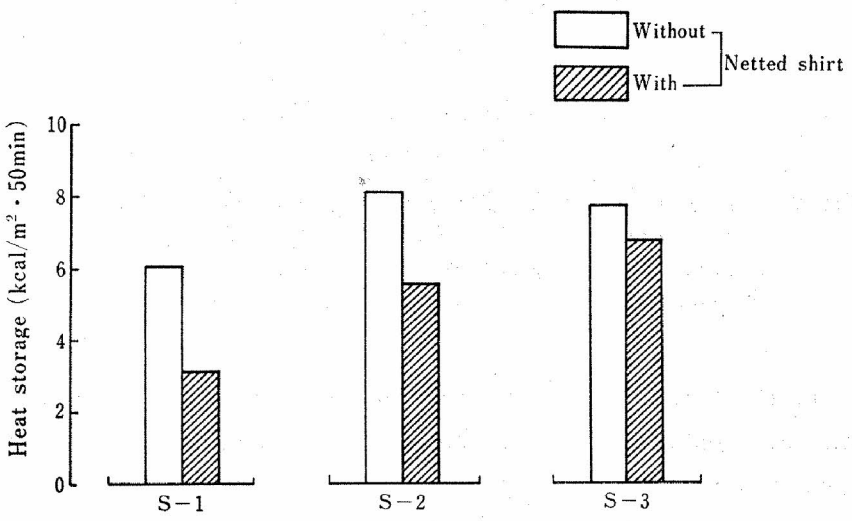

Fig. 4 A comparison of positive heat storage during 50 min experimental periods between non-netted shirts and netted shirts. White colimn: non-netted shirts. Shaded column: netted shirts.

properties to lessen the penetration of heat from surroundings to human body.

Discussion

Our present major findings are summarized as follows: 1) Back surface temperatures of outer clothing were greater in netted shirts. 2) Back skin temperatures and clothing microclimate humidi-

ty were smaller in netted shirts. 3) Positive heat storage calculated from specific heat of human body, body weight and changes of mean body temperatures, was lower in netted shirts. What mechanisms could account for these findings ?

Cotton netted shirts have the ability to absorb sweat very much. The subject sweated considerably under warm and radiated environments. Thus, some of the sweats were absorbed into netted shirts and cotton outer clothing in clothing conditions of netted shirts, while only into cotton outer clothing in clothing conditions of non-netted shirts. There were of course other sweats which evaporated directly through clothing into ambient air. With these in mind, it is very likely that cotton outer clothing might become more dry in clothing conditions of netted shirts than of non-netted shirts under the assumption that the sweating rates are equal in both clothing conditions, since both cotton shirts with long sleeves and cotton netted shirts can absorb sweat in clothing conditions of netted shirts. Therefore, evaporation occurred much more from "wet" outer clothing surface in non-netted shirts than in netted-shirts, resulting in the lowering of the surface temperature of the outer clothing due to better evaporation power. Thus, there existed different surface temperatures of the outer clothing between both clothing conditions, of netted and non-netted shirts i.e., the former is high, the latter low. These increased value of the outer clothing surface temperature in netted shirts has the physiological significance to prevent heat gain from penetrating from warm and radiated environment to human body. Actually, positive storage was smaller in netted shirts (Fig. 4). The similar heat resisting mechanisms play a role in the camel inhabiting the desert[5]. The dorsal fur surface temperature of the camel became ca. 70°C under warm and sun-radiated environment. This increased temperature of the fur surface is considered to be physiologically significant as a heat barrier from environmental heat gain.

The clothing microclimate humidity was lower in netted shirts (Fig. 2). These different humidities might depend upon the amount of clothes which can absorb water. Both cotton shirt with long sleeves and cotton netted shirts in clothing conditions of netted shirts can absorb much more sweats than of non-netted shirts, resulting in the reduction of the clothing microclimate humidity.

Back skin temperatures were lower in netted shirts (Figs. 1, 3). It might be probably ascribed to the facts that clothing microclimate temperatures measured between back skin and netted shirts were lower and evaporative cooling efficiency from skin was better in netted shirts due to lower clothing microclimate humidity. Furthermore, higher back surface temperatures of the outer clothing in netted shirts reduced heat penetration from environment to human body, resulting in the lower clothing microclimate temperatures, and hence, lower back skin temperatures.

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