

Effect of Hair Style on Human Physiological Responses in a Hot Environment

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1. INTRODUCTION

The head plays an important role in thermoregulation, although it occupies only about 9% of the body surface. The brain is more thermogenic than any other tissues, and its heat production is estimated to be from 13 to 20W (Aschoff & Wever, 1958; Brengelmann, 1990). When human head is exposed to the hot environment, the subcutaneous blood flow around the head is increased, and the heat loss is increased owing to the sweat evaporation by selective brain cooling action (Rasch et al., 1991). Furthermore, the head is important in determining the thermal sensation of whole body (Nunneley et al., 1982). Especially, when the head is exposed to the hot weather, heat stress may be larger than the exposure of whole body. However, in the cold, generally the whole body is kept warm, or peripheral parts like hands and feet are heated artificially. However, head heating in the cold also has feasibility of making a certain benefit by protecting the head, which is the center of thermoregulation of the body. In addition, recently, researches on variables associated with hair styles are increasing with the spreading of total coordinated intention in the fields of clothing and cosmetology. We have reported the effects of hair style on human physiological responses in a thermal neutral environment (Kim et al., 2007) and a cold environment (Kim et al., 2008).

In the present study, we focused on examining the skin temperature on the scalp (the vertex, temporal, and occiput), humidity on the occiput, rectal temperature, skin temperatures (the forehead, back of ear, back of neck, upper back, abdomen, forearm, hand, thigh, calf, and foot), local sweat rate on the back of neck, and total body mass loss by hair styles in the hot environment.

2. METHODS

2.1 SUBJECTS

Four young healthy female subjects (24.8±4.1yrs, 164.9±2.9cm, 52.3±4.8kg, BSA 1.59±0.1m²) served as volunteers in the present study. Prior to their participation, written and informed consents were obtained from all subjects.

2.2 EXPERIMENTAL CONDITIONS AND HAIR STYLES

For a certain period, we had each subject put on the five different hair styles in a random order: ① Straight short hair (SS), ② Perm waved short hair (PS), ③ Straight long hair (SL), ④ Perm waved long hair (PL), ⑤ Ponytail style (PT) (Fig. 1). Subjects wore briefs, bra, shirts with short sleeves, and short pants. The environmental conditions of a climatic chamber were constant at $33\pm 0.5^{\circ}\text{C}$ and $65\pm 5\% \text{RH}$.

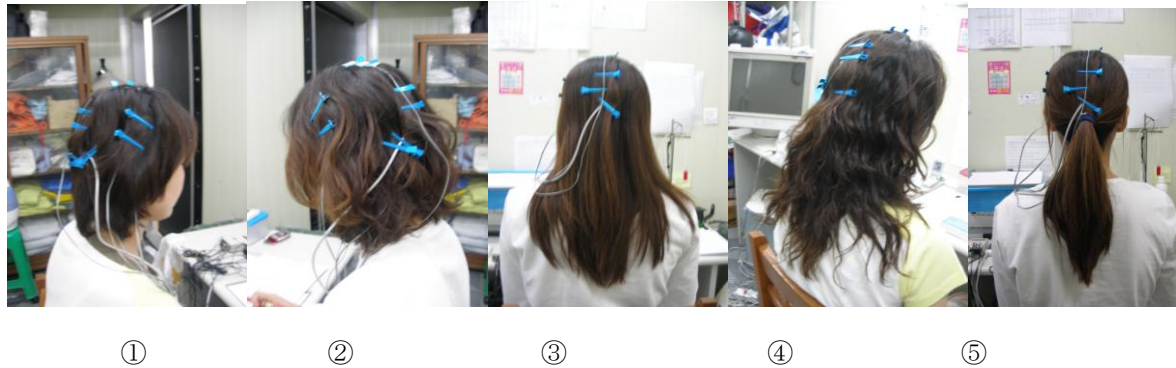


Fig. 1. Type of hair style: ① Straight short hair (SS), ② Perm waved short hair (PS), ③ Straight long hair (SL), ④ Perm waved long hair (PL), ⑤ Ponytail style (PT)

2.3 MEASUREMENT AND EXPERIMENTAL PROCEDURES

The skin temperature was measured on the scalp (the vertex, temporal, and occiput) and the humidity was measured on the occiput. Skin temperature (T_{sk}) was measured on ten body sites (the forehead, back of ear, back of neck, upper back, abdomen, forearm, hand, thigh, calf, and foot) at one minute intervals using a thermistor. Mean skin temperature (mean T_{sk}) was estimated using the DuBois equation. Core temperature (T_{re}) was measured at the rectum. Local sweat rate for 60 min was measured on the back of neck by using filter paper methods. The change of total body mass (ΔWt) was calculated through the difference between before and after semi-nude body weight using a weighing scale (Sartorius, F150S, Germany; sensitivity 1g). Subjects were seated in a thermally environment for 30 min and then moved to the climatic chamber controlled at $33\pm 0.5^{\circ}\text{C}$ and $65\pm 5\% \text{RH}$ for 60 min. Each subject conducted 10 trials in the present study, because all trials were repeated twice (4 subjects \times 5 conditions \times 2 repetitions = 40 times).

3. RESULTS

Table 1 shows the summary of thermal responses by hair styles in a hot environment. The skin temperature and humidity on the scalp did not show any significant differences among the five different hair styles, but the vertex skin temperature ($36.0\sim 36.3^{\circ}\text{C}$) was higher than temporal and occiput skin temperature ($35.4\sim 36.1^{\circ}\text{C}$). According to our preceding study, in the neutral ($21\pm 0.5^{\circ}\text{C}$ and $55\pm 5\% \text{RH}$) and cold environmental ($12\pm 0.5^{\circ}\text{C}$ and $45\pm 5\% \text{RH}$) condition, the skin temperature on the scalp did not showed any significant differences among five different

hair styles, but the temporal skin temperature was the highest, while the vertex skin temperature was the lowest. The differences among the skin temperatures on scalp in the hot environmental condition were not larger than those in the neutral and cold environmental condition. Figure 2 shows the changes of humidity inside occiput, back of ear skin temperature, back of neck skin temperature, upper back skin temperature, mean skin temperature, and rectal temperature during 60 min exposure by hair styles in a hot climatic chamber.

Humidity on the occiput in the hot environmental condition was higher than those in the neutral and cold environmental condition. Humidity on the occiput was the highest in the ponytail style (PT), while it was the lowest in the perm waved short hair style (PS). The same results also showed in the neutral and cold environmental condition. Skin temperature on the back of ear and on the back of neck were the highest in the perm waved short hair style (PS), while they were the lowest in the ponytail style (PT). The skin temperature on the upper back was the highest in the straight long hair style (SL). Mean skin temperature and rectal temperature had no significant differences among hair styles, but they were the highest in the ponytail style (PT). Figure 3 shows the total body mass loss and local sweat rate on the back of neck during 60 min exposure by hair styles in a hot climatic chamber. Total body mass loss and sweat rate on the back of neck were lower in the straight short hair (SS) and perm waved short hair (PS), while they were higher in the ponytail style (PT).

Table. 1. Thermo physiological responses during 60 min exposure in a hot climatic chamber

	SS	PS	SL	PL	PT
Vertex skin T (°C)	36.1(0.2)	36.3(0.5)	36.3(0.8)	36.0(0.4)	36.0(0.6)
Temporal skin T (°C)	35.4(0.4)	36.1(0.8)	35.5(0.5)	35.5(0.6)	35.8(0.3)
Occiput skin T (°C)	35.7(0.2)	36.1(0.8)	35.4(0.8)	35.5(0.6)	35.6(0.7)
Humidity inside occiput (%R.H.)	64(3)	60(16)	68(12)	69(9)	72(7)
Forehead skin T (°C)	36.4(0.2)	36.3(0.3)	36.3(0.1)	36.3(0.3)	36.0(0.3)
Back of ear skin T (°C)	36.6(0.2)	36.7(0.3)	36.5(0.5)	36.6(0.2)	36.3(0.3)
Back of neck skin T (°C)	36.6(0.2)	36.9(0.4)	36.8(0.3)	36.7(0.5)	36.3(0.1)
Upper back skin T (°C)	35.7(0.4)	35.8(0.3)	36.1(0.3)	36.0(0.6)	35.8(0.4)
Tsk (°C)	34.6(0.2)	34.5(0.5)	34.4(0.6)	34.7(0.3)	35.0(0.1)
Tre (°C)	37.2(0.1)	37.3(0.3)	37.3(0.3)	37.2(0.1)	37.4(1.2)
Total body mass loss (g/m ² /hr)	41.9(9.3)	54.8(18.1)	58.3(21.1)	57.7(11.3)	65.3(16.7)

Sweat rate on the back of neck (mg/12cm ² /hr)	515.5(105.9)	478.8(242.3)	551.3(312.4)	538.3(73.5)	556.5(265.3)
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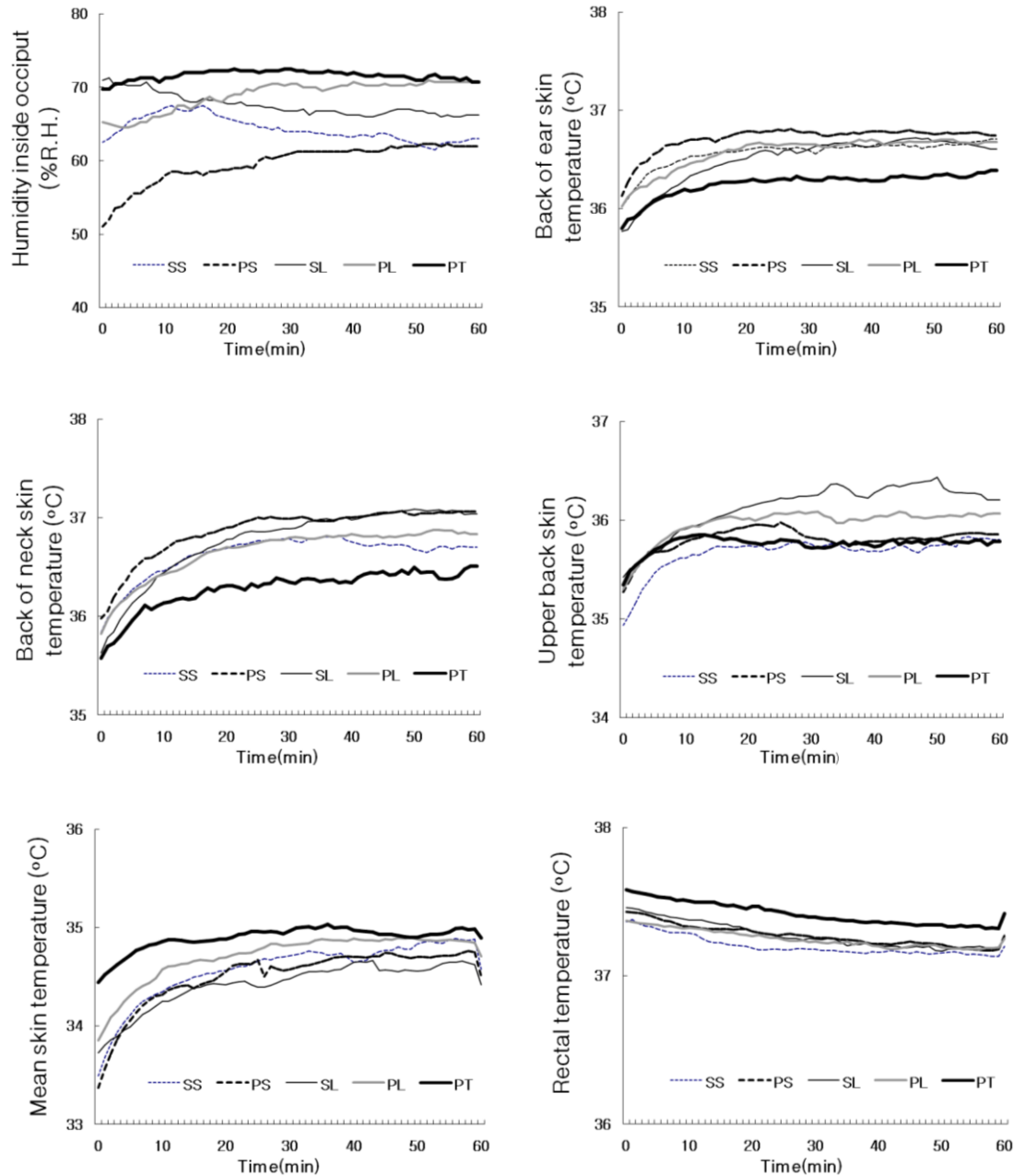


Fig. 2. Changes of humidity inside occiput, back of ear skin temperature, back of neck skin temperature, upper back skin temperature, mean skin temperature, and rectal temperature during 60 min exposure by hair styles in a hot

climatic chamber (SS: Straight short hair ,PS: Perm waved short hair ,SL: Straight long hair , PL: Perm waved long hair, PT: Ponytail style).

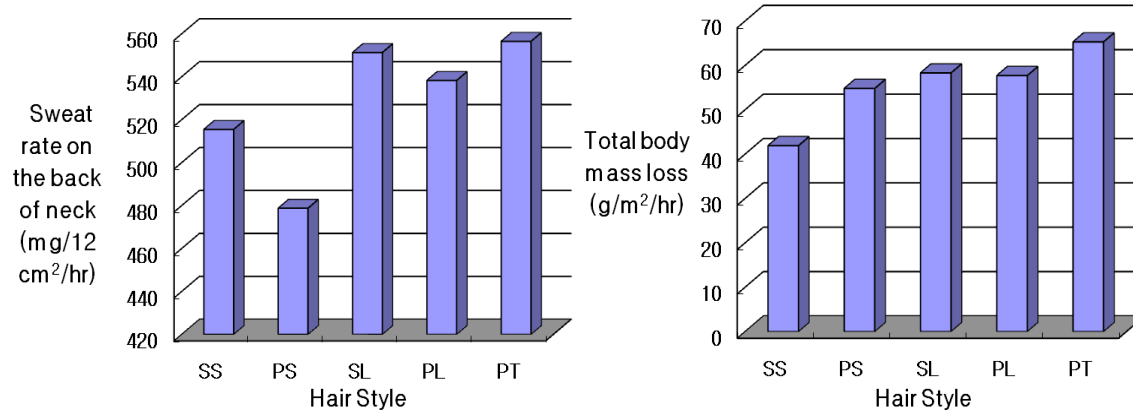


Fig. 3. Total body mass loss and sweat rate on the back of neck during 60 min exposure by hair styles in a hot climatic chamber (SS: Straight short hair ,PS: Perm waved short hair ,SL: Straight long hair , PL: Perm waved long hair, PT: Ponytail style).

4. CONCLUSION

We found out that the hair style affected thermo physiological responses, such as skin temperature and humidity on the scalp, the back of ear skin temperature, the back of neck skin temperature, upper back skin temperature and total body mass loss ,even though this study had no significant differences among hair styles. In the result, we acquired fundamental data to enable the improvement of the current hair clinic system, wigs, functional hats, and helmets.

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