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Comparison of density and output of sweat gland in tropical Africans and temperate Koreans

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ABSTRACT

Modification of sweating could be due to changes in activated sweat gland density (ASGD) and/or activated sweat gland output (ASGO). The present study determined regional and inter-ethnic differences in ASGD and ASGO during passive heating between tropical natives (African, $n = 22$) and temperate natives (Republic of Korean, $n = 25$). Heat load was carried out by immersing the half body into a hot water bath for 30 min. Tympanic temperature (Tty) and skin temperature (Ts) were measured. Mean body temperature (mTb) was calculated. Sudomotor activities including sweat onset time, sweat rate, ASGD, and ASGO were examined in eight regions of the skin. Africans had smaller increase in mTb during passive heating than Koreans. The onset time of sweating was much more delayed in Africans compared to Koreans. In response to thermal load, ASGD and ASGO differed between body regions in Africans and Koreans. In most skin regions, ASGD and ASGO were lower in tropical Africans compared to those in temperate Koreans. Trunk portion including chest, upper back, lower back, abdomen had greater swear rate, ASGD, and ASGO compared to peripheral segments including upper arm, forearm, leg, and thigh in both ethnic groups. Distribution patterns of ASGD over the body appeared to be similar in both Africans and Koreans at the peak of thermal loading. In conclusion, the present study demonstrates that sudomotor activity in tropical Africans is reduced with lower ASGD and ASGO over the body surface compared to temperate Koreans.

1. Introduction

There are over 30 climatic zones around the world. People physiologically adapt to the climate they are living in.

Long-term acclimatization causes body shape changes in response to the environment (Bogin and Rios, 2003). Generally, tropical people are thin and tall. They have much greater surface area to body mass ratio than those who dwell in cold zones of the Earth (Katzmarzyk and Leonard, 1998; Roberts, 1953). This allows tropical people to rely more on dry heat loss than on evaporative heat loss (Falk and Dotan, 2008; Tochihara et al., 1995). In addition, a tall and linear body can minimize heat gain from sun exposure in a dry environment while maximizing sweat evaporation through increased exposure to convective currents (Lambert et al., 2008).

The onset of sweating is delayed in tropical natives with lower sweat volumes (Bae et al., 2006; Lee et al., 2002; Ogawa and Sugenoya, 1993). Decreased sweating in tropical natives can provide them advantages in sustaining thermoregulation by preserving body fluid and osmoregulation (Sawka and Coyle, 1999).

Modification of the sweat rate can result from changes in activated sweat gland density (ASGD) and/or activated sweat gland output (ASGO). ASGD and ASGO are altered depending on age, sex, and exercise training (Inoue et al., 2004; Kondo et al., 2001; Lee et al., 2014b). Changes in forearm sweating rate rely on both ASGD and ASGO during the initial period of exercise and passive heating, whereas further increases in sweat rate are dependent on increases in ASGO (Kondo et al., 2001). The heat loss effector function decreases with aging, which may affect ASGO and ASGD (Inoue et al., 2004). Sweat onset time is progressively increased while sweat rate, ASGD, and ASGO are decreased with increasing age in both sexes (Lee et al., 2014b).

However, how ASGD and ASGO are changed in tropical natives is currently unknown. Especially, the distribution pattern of ASGD and ASGO over the body between tropical natives and temperate natives has not been reported. The objective of this study was to determine the regional and inter-ethnic differences in ASGD and ASGO between tropical natives (Africans) and temperate natives (Republic of Koreans) during passive heating.

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2. Methods

2.1. Subjects

Twenty-five healthy male Republic of Korea subjects (temperate natives) and 22 healthy male Africans (tropical natives) volunteered for this study. African subjects were from Federal Republic of Nigeria, United Republic of Tanzania, Republic of Senegal, Republic of Ghana, Republic of Kenya, and Republic of Chad. They were Republic of Korea International Cooperation Agency trainees (students) and academic researchers at Sunmoon University and Soonchunhyang University. The mean annual ambient temperature in Korea during the period of study (December 2010 to January 2015) was 11.65 °C with 68.25% relative humidity. Experiments on tropical Africans were conducted within 2 weeks of their arrival to the Republic of Korea. Republic of Korea subjects had a mean height of 175.73 ± 5.67 cm, mean weight of 74.48 ± 6.14 kg, mean age of 26.20 ± 4.96 years, mean percent body fat of 22.16 ± 4.83%, and mean body surface area (BSA) of 1.87 ± 0.17 m^2. Corresponding characteristics for tropical Africans were height 177.08 ± 3.45 cm, weight 72.49 ± 4.71 kg, age 27.10 ± 5.81 years, percent body fat 21.30 ± 3.91%, and BSA 1.88 ± 0.15 m^2. BSA) was calculated using the Du Bois formula (Du and Du, 1916). Body fat percentage was measured using the bio-impedance method (InBody 520, Seoul, Korea). Each subject provided written informed consent after being thoroughly acquainted with the purpose and experimental procedures as well as any potential risks. We paid great attention to all subjects in accordance with the Helsinki Declaration of 1975.

2.2. Measurement and experimental procedure

Experiments were done at the same time of day (2–5 p.m.) to control for the influence of the circadian rhythm of body temperature (Lee et al., 2013; Lee et al., 2009; Lee and Kim, 2014a; Lee et al., 2007; Maughan et al., 2010). Subjects fasted for 8 h before each experimental intervention and refrained from alcohol, caffeine, smoking, exercise, and medication use 24 h before the test. They were given tap water (5–7 mL/kg) 4 h before heat loading on the day of the study to maintain a sufficient level of hydration throughout the experiment. However, no subject consumed water during heat loading. Upon arrival at the climate chamber, each subject wore light indoor clothing without shoes and socks. Each subject sat in a chair in a relaxed posture for 60 min to become acclimated to the chamber climate prior to commencement of experiments.

2.3. Heat loading

Heat loading was conducted in the city of Cheonan (Chungnam), Republic of Korea. Cheonan is located in the southwest part of Korea (126°52′N, 33.38′E). It extends northeast (130°4′N, 43.0′E). The environmental conditions of the test room were maintained at temperature of 26.5 ± 0.3 °C and relative humidity of 60 ± 3.0% with air velocity of 1 m/s. Heat load was carried out by immersing the half body into a hot water bath (42 ± 0.5 °C) for 30 min. Previous studies have used a range of similar thermal intensity (Kim and Lee, 2013; Lee and Kim, 2014a; Shin et al., 2013). These subjects might have felt some discomfort during this process. Thus, a 120 s break was provided after 5, 10, 20, and 30 min of heat loading.

During heat loading, the rate of sweating on the eight regions of the skin (chest, upper arm, upper back, lower back, abdomen, thigh, forearm and leg) was continuously recorded by the capacitance hygrometer-ventilated capsule method (Lee et al., 2015; Lee et al., 2007; Matsumoto et al., 1993). Sweat gland densities on the same skin areas were measured using iodine-impregnated paper (Lee et al., 2009; Lee et al., 2014b). Sweat output per single gland (μg/min/single gland) on the same skin areas was obtained by dividing the sweating rate (mg/cm^2/min) by sweat gland density (count/cm^2) (Lee et al., 2009; Lee et al., 2014b).

2.4. Tympanic temperature (T_{ty}), mean body temperature (mTb), and mean skin temperature (mTs) measurements

T_{ty} and temperature of the eight regions of the skin (chest, upper arm, upper back, lower back, abdomen, thigh, forearm, and leg) were measured with a TSK7 + 1 thermistor probe (Songkitopia, Incheon, Republic of Korea) and a K923 small spring (Takara, Yokohama, Japan). The probe was connected to a *CF*-T1 personal computer (Panasonic, Tokyo, Japan) and a K-720 data logger (Technol Seven, Yokohama, Japan). mTs was calculated using the following equation as described previously (Ramanathan, 1964): $mTs = 0.3 \cdot (Ts_{chest} + Ts_{arm}) + 0.2 \cdot (Ts_{thigh} + Ts_{leg})$. mTb was calculated using the following formula as described previously (Ramanathan, 1964; Sugenoya and Ogawa, 1985): $mTb = (0.9 \cdot T_{ty} + 0.1 \cdot mTs)$.

2.5. Statistical analysis

Values are presented as mean ± standard deviation (SD). Statistical significance was assessed by *t*-test for comparison between temperate Koreans and tropical Africans. When P value was < 0.05, statistical significance was indicated.

3. Results

Africans had significantly lower resting mTb than Koreans (36.07 ± 0.11 °C *vs.* 36.22 ± 0.17 °C, $P < 0.05$). After heat loading, mTb was increased by 1.41 °C ($P < 0.001$) in Africans. It was increased by 1.72 °C ($P < 0.001$) in Koreans. There was a significant ($P < 0.01$) difference in ΔT between the two ethnicities (Table 1).

All local sweat onset times in the eight regions of skin were delayed in Africans compared to those in Koreans. Sweating was initiated much slowly in Africans (5.24 ± 1.85 min ~ 5.84 ± 2.51 min after the start of heat loading). Sweating began much sooner in Koreans (3.05 ± 1.28 min ~ 3.60 ± 1.46 min after the start of heat loading, Table 2).

Local sweat rates in all eight regions of skin were much smaller in Africans compared to those in Koreans. The highest sweat rate was found at the lower back area of Africans and Koreans (0.37 ± 0.11 *vs.* 0.60 ± 0.20 mg/cm^2/min, $P < 0.001$). The smallest sweat rate was found in the thigh area of Africans and Koreans (0.10 ± 0.12 *vs.* 0.18 ± 0.09 mg/cm^2/min, $P < 0.01$, Table 2).

All local ASGD values in the eight regions of skin in Africans were much smaller than those of Koreans. The smallest ASGD in the thigh area was 12.28 ± 7.42 count/cm^2 in Africans *vs.* 19.63 ± 4.73 count/cm^2 in Koreans ($P < 0.05$). The greatest ASGD in the lower back area was 39.75 ± 15.90 count/cm^2 in Africans *vs.* 58.75 ± 22.99 count/cm^2 in Koreans ($P < 0.05$, Table 2).

Table 1
Comparison of the tympanic temperature (Tty) and mean body temperature (mTb) between tropical Africans and temperate Koreans during heat loading.

Locations	Group	Before heating (°C)	After heating (°C)	△T(°C)
Tty	Temperate Koreans	36.71 ± 0.18	38.26 ± 0.24***	1.55
	Tropical Africans	36.68 ± 0.15	37.80 ± 0.21***	1.12++
mTb	Temperate Koreans	36.22 ± 0.17	37.94 ± 0.19***	1.72
	Tropical Africans	36.07 ± 0.11+	37.48 ± 0.12***	1.41++

Values are presented as mean ± SD. Statistically significant difference between temperate Koreans (Koreans) and tropical Africans (Africans), $^{+}P < 0.05$, $^{++}P < 0.01$; difference between before and after heating, $^{***}P < 0.001$. △T represents the change in temperature.