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Original article

Improved sweat gland function during active heating in tennis athletes

Jeong-Beom Lee [a], Soon-Bok Na [b], Tae-Wook Kim [c,*]

[a] *Department of Physiology, College of Medicine, Soonchunhyang University, Cheonan 331-946, Republic of Korea*
[b] *Department of Exercise Rehabilitation Welfare, Gachon University, Seongnam 461-701, Republic of Korea*
[c] *Global Graduate School of Healthcare, Soonchunhyang University, Asan 336-745, Republic of Korea*

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Abstract

Background: Relatively few studies on the peripheral sweating mechanisms of trained tennis athletes have been conducted. The purpose of this study was to compare the sweating capacities of tennis athletes against untrained subjects (controls).
Methods: Thirty-five healthy male volunteers participated including 15 untrained subjects and 20 trained tennis athletes (nationally ranked). Active heat generation was performed for 30 min (running at 60%VO_{2max}) in a climate chamber (temperature, 25.0°C ± 0.5°C; relative humidity, 60% ± 3%, termed active heating). Sweating data (local sweat onset time, local sweat volume, activated sweat glands, sweat output per gland, whole body sweat loss volume) were measured by the capacitance hygrometer-ventilated capsule method and starch-iodide paper. Mean body temperature was calculated from tympanic and skin temperatures.
Results: Local sweat onset time was shorter for tennis athletes ($p < 0.001$). Local sweat volume, activated sweat glands of the torso and limbs, sweat output per gland, and whole body sweat loss volume were significantly higher for tennis athletes than control subjects after active heating ($p < 0.001$). Tympanic and mean body temperatures were lower among tennis athletes than controls ($p < 0.05$).
Conclusion: These results indicate that tennis athletes had increased regulatory capacity of their sweat gland function.

Keywords: Activated sweat glands; Active heating; Sweat onset time; Sweat output; Sweating function; Tennis athletes

1. Introduction

For a given temperature, endurance-trained subjects generally display greater sweat output than their untrained counterparts through an elevated responsiveness of their sweat mechanism.[1,2] It is clear that endurance exercise training improves the sweating response to heat generation. In contrast, the sweating function was not improved in sprinters who had trained for at least 3 years as compared with untrained men, although the maximal oxygen uptake (VO_{2max}) was 33% greater in sprinters.[3] It is possible that sweat gland activity in sprinters during daily training is insufficient to improve their sweating capacity relative to distance runners, regardless of the enhanced VO_{2max}.[3]

Sprinters train at a high intensity over a relatively short duration, and the volume of training is relatively low in comparison to middle and long distance runners. Therefore, the oxygen cost of sprinting and related training may not appear to be high.[4]

A tennis player's metabolism during play in a hot environment generates an abundance of heat, which is primarily eliminated from the body by the evaporation of sweat.[5] The physical activity of playing tennis is characterized by quick starts and stops, repetitive overhead motions, and the involvement of several muscle groups during different strokes, which fluctuate randomly from brief periods of maximal or near maximal work to longer periods of moderate and low intensity activity.[6] In a previous study, the mean VO_{2max} values of tennis players were found to be 55 mL/kg/min in male players, and this level of aerobic metabolism was higher than the values reported for untrained middle aged subjects.[7]

However, it is not known whether daily training in tennis athletes can induce adaptations in sweating. Our hypothesis is that tennis athletes have an upregulation of their sweating mechanisms. Therefore, the present study compared the sweating responses and changes in sweat gland function during active heat generation between tennis athletes and untrained men.

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* Corresponding author.
E-mail address: kimtw@sch.ac.kr (T.-W. Kim).

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Table 1
Physical characteristics of the subjects (mean ± SD).

	Control ($n = 15$)	TA ($n = 20$)
Age (year)	23.6 ± 3.4	24.1 ± 3.7
Height (cm)	173.9 ± 5.2	175.0 ± 3.4
Weight (kg)	70.8 ± 6.1	67.2 ± 4.3
BSA (m^2)	1.9 ± 1.6	1.8 ± 1.4
%BF	22.5 ± 4.8	16.3 ± 2.9*
VO_{2max} (mL/kg/min)	43.2 ± 5.1	59.4 ± 3.7*

* $p < 0.001$, compared with control.
Abbreviations: %BF = percent body fat; BSA = body surface area; Control = untrained subjects; TA = tennis athletes; VO_{2max} = maximal oxygen uptake.

2. Materials and methods

2.1. Subjects

The physical characteristics of the subjects are summarized in Table 1. Thirty-five healthy male volunteers participated; 15 untrained subjects (had not performed regular physical activity in the previous 1 year, control) and 20 trained tennis athletes (nationally ranked) who had 7–12 years of training and who had been training an average of 25 h per week (an average of 5 days each week, self-reported). Percent body fat (%BF) and VO_{2max} were significantly higher for tennis athletes than control subjects. All of the subjects had lived their whole life in the city of Cheonan, Republic of Korea, which is located in the southwest part of Korea (126°52′N, 33.38′E) and extends northeast (130°4′N, 43.0′E). No differences in mean age, height, weight, or body surface area were observed between the groups. Each subject returned a informed written consent to participate in the study after being thoroughly acquainted with the purpose and the experimental procedures, as well as any potential risks. The subjects were fasted for 8 h and instructed to refrain from alcohol consumption or smoking 24 h before the test. The volunteers also refrained from medications during the testing period. All experimental protocols were approved by the Soonchunhyang University Research Committee, and the procedures complied with the 2000 Declaration of Helsinki of the World Medical Association.

2.2. Measurement and experimental procedure

All experiments were conducted in the city of Cheonan. The tests were performed in a climate chamber from 2:00 p.m. to 5:00 p.m., and the environmental conditions were maintained at 25.0°C ± 0.5°C, 60.0% ± 3.0% relative humidity, and 1 m/s air velocity. Subtle interpersonal variability result in human body temperatures being their lowest at 4:00 a.m., and at their highest from 4:00 p.m. to 6:00 p.m.[8] Thus, we conducted this experiment during 2:00 p.m. and 5:00 p.m. to control for the influence of the body temperature circadian rhythm, as described previously.[9–14] After the subjects arrived in the laboratory, urine specific gravity was tested with a urine strip (Uriscan, Seoul, Korea) to confirm hydration equilibrium. These test results were confirmed by visually inspecting the color change of the strip. The measurements were delayed until recovery to a normal range in cases in which the test strip color change exceeded the reference range of 1.010–1.025. The subjects were given ~5–7 mL/kg of tap water at 4 h before test on the day of the study, in order to maintain a sufficient level of hydration throughout the experiment. However, no subjects consumed water during the test.

2.3. Setting of physical loading and testing

To precisely determine the exercise intensity, a physical loading test was conducted 1 week before the experiment for all subjects. In the physical loading test, the VO_{2max} of each individual was measured. The VO_{2max} was obtained by applying the Bruce protocol with a Quinton Medtrack SR 60 treadmill (Quinton, Bothell, WA, USA) and a Quark Pulmonary Function Testing Lung Volumes Module 2 metabolic test system (COSMED, Rome, Italy). The average physiological responses to tennis match play have been reported to be rather modest, with mean exercise intensities generally less than 60%–70% of VO_{2max}.[7] Therefore, the physical loading test was terminated by subject declaration (until the subject became exhausted), and the 60%VO_{2max} was calculated.

2.4. Tympanic temperature (T_{ty}) measurements

After 60 min of rest, the T_{ty} was recorded during active heating (running on a treadmill for 30 min at 60%VO_{2max}). The T_{ty} was assessed by inserting a model TSK7 + 1 thermistor probe (Songkitopia, Inchen, Korea) with a small spring into the left ear canal (K923, Takara, Yokohama, Japan). The probe was connected to a model CF-T1 personal computer (Panasonic, Tokyo, Japan) and a model K-720 data logger (Technol Seven, Yokohama, Japan). As the thermistor probe contacted the tympanic membrane, the subject felt slight discomfort and could hear a scratching noise. The inner pinna was then filled with small cotton balls in order to secure the probe in place.[10]

2.5. Mean body temperature measurements

The skin temperatures (T) on the chest (T_{chest}), upper arm (T_{arm}), thigh (T_{thigh}), and leg (T_{leg}) were measured using model PXK-67 thermistor thermometers (Technol Seven) connected to a model K-720 data logger (Technol Seven).[10] The mean skin temperature ($\bar{T}_{sk}$) was calculated as $0.3 \times (T_{chest} + T_{arm}) + 0.2 \times (T_{thigh} + T_{leg})$.[1,7] The mean body temperature ($\bar{T}_b$) was calculated from the T_{ty} and $\bar{T}_{sk}$ using the formula by Ramanathan[15] as cited by Sugenoya and Ogawa:[16]
$\bar{T}_b = (0.9 \times T_{ty} + 0.1 \times \bar{T}_{sk})$.

2.6. Measurements of local sweating rate and sweat onset time

During heat loading, the sweating rate at the chest, abdomen, back, and thigh were continuously recorded by the capacitance hygrometer-ventilated capsule method. In brief, dry nitrogen gas was flowed at a constant flow rate of 500 mL/min into a capsule (9.621 cm^2 in area) attached to the skin at the point to be measured.[10] The humidity of the effluent gas was evaluated with a model H211 hygrometer (Technol Seven). The sweating