CHAPTER 2

Literature review

1. Age-related difference of thermoregulation

Because of the report that half of heat-related deaths in Japan occurred in children and elderly[Inoue et al., 2002], it is important to understand maturation-related underdevelopment and age-related impairment of the thermoregulatory responses. Thermoregulatory responses of pre-pubertal children differ from those of adults including several morphologic and physiological changes which occur during growth and maturation that disadvantage pre-pubertal children when exercising in hot and humid environments. When compared to adults, pre-pubertal children have a greater surface-area-to-mass ratio with different body composition and smaller absolute blood volume. Pre-pubertal children have a lower cardiac output a greater metabolic heat production per kilogram (kg) body mass during work and a less efficient sweating mechanism [Sinclair et al., 2007].

When ambient temperatures (T_a) exceed skin temperatures (T_{sk}), evaporation is the major mechanism for heat dissipation. Thermoregulatory responses of pre-pubertal children expose them to an increased risk of developing heat-related illnesses given that their sweat rates are less than those of adults [Inoue et al., 2002]. Additional contributing factors to differing sweat rates between prepubertal children and adults include smaller sweat glands and lower sensitivity of the sweating mechanism [Inoue et al., 2004].

Moreover, differentiation of the cutaneous vasculature due to maturation and aging-related changes on maximal cutaneous vascular conductance (CVC_{max}) may contribute to the greater skin blood flow (SkBF) of the boys and the lower SkBF of the older men when compared with that of young men [Inoue et al., 2004]. In addition, prepubertal boys could thermoregulate as efficiently as young men by greater vasodilation at the trunk during moderate exercise [Shibasaki et al. 1997a].

2. Age-related difference of heat loss effectors function in the children

Many studies have found that boys have a lower total body sweating rate and local sweating than young men during rest and exercise [Shibasaki et al., 1997a; Inoue et al., 2002; Inoue et al., 2004; Gomes et al., 2013] and have greater heat gain owing to a larger surface area-to-mass ratio. The maturation-related differences in heat loss responses vary according to body site [Inoue et al., 2009a].

The presence of underdeveloped peripheral mechanism in children was supported by a lower sweat output per gland (SGO) in responses to cholinergic and heat stimulation. The lower SGO observed in children may be a result of anatomical changes in sweat gland size with maturation. Therefore, the lower local sweat rate in prepubertal boys may be due to underdeveloped peripheral mechanisms (including the sweat gland and their surrounding tissues) rather than to an underdeveloped central drive activity [Shibasaki et al. 1997b].

3. Age-related difference of heat loss effectors function in older men

By using 60-minute passive heating, Inoue reported a reduction of sweat gland function in older men extending from lower limbs to trunk when compared with sweat gland function of young men [Inoue, 1996]. In addition to a reduction of sweat gland function, cutaneous vasodilatation was also decreased with age beginning from the region of the lower limbs and progressed sequentially to the upper body and head. The sequential reduction of cutaneous vasodilatation correlated with and may be the cause of the reduction of sweat gland [Inoue and Shibasaki, 1996]. Thus, it was proposed that age-related decrement was possibly due to changes in peripheral mechanism involving the sweat gland and was not due to changes in the central drive to sudomotor function [Inoue et al., 1999]. Therefore, aging leads to a decreased ability to maintain body temperature due in part to decreased regional sweat gland function in extremities [Inoue et al., 1991].

4. Thermoregulation during exercise

During exercise, large amounts of energy are released as heat. To prevent a continuous rise in body core temperature, physiological mechanisms to support heat loss such as cutaneous vasodilation and sweating are activated to promote the loss of excess heat. For heat loss to occur, excess heat should be transported from the body core to the skin. At rest in a comfortable environment, about 25% of heat loss is due to evaporation but heat loss by evaporation through sweating can be up-regulated in trained athletes to the rate of 3.5 L/h [Wendt et al., 2007].

During a 20-minute exercise, the internal temperature can be elevated leading to an increased sweat rate and skin blood flow. Additionally, heart rate and mean arterial pressure (MAP) was increased via a combination of central control and muscle afferent (mechanoreceptor and metaboreceptor) stimulation [Shibasaki et al., 2004].

In endurance exercise, body tissue temperatures of a marathon runner who completed the race could increase to over 40°C. These high temperatures are a function of exercise intensity and duration, and endurance athletes could often produce enough heat that required their body to adapt to training by improving heat dissipation [Kondo et al., 2009].

5. Physical-fitness related difference of heat loss effectors function

Sweat rate response was higher in trained (endurance runners) than in untrained men [Amano et al., 2011]. Sweating and cutaneous vasodilation in young women was also enhanced by long term physical training. These enhancements involved both central and peripheral heat loss mechanisms [Kuwahara et al., 2005]. Thermoregulatory and sweating responses were related to maximum oxygen uptake (VO_{2max}) and physical activity level [Havenith et al., 1995]. Moreover, short-term physical training improved heat loss responses during moderate exercise in young women by enhancing sweating to greater extent than cutaneous vasodilatation [Ichinose et al., 2009]. In addition, long-term physical training in young men was found to improve sweat gland function due to the enhanced DIR rather than AXR [Inoue et al., 2009b]. During low intensity exercise, sweat glands will be especially recruited on the trunk, but during progressive exercise, sweat glands will be recruited on the limbs rather than in the trunk [Buono, 2000].

Furthermore, the effects of physical training on the sex-difference in sweating response can be improved with increased intensity of physical training [Ichinose-Kuwahara et al., 2010]. Previous studies showed that the sweat gland function of boys and the older men were low and suggested that exercise may improve heat loss responses in older men and boy. Although, many studies have been done in both trained and untrained young men and older men subjects on heat loss effectors function, no study has been done regarding the effects of physical fitness on heat loss effectors function in high physical fitness prepubertal boy.

Therefore, the purpose of the present study is to evaluate the heat loss effectors function by measuring the local sweating rate via direct stimulation of sweat glands and via axon reflex, sweat gland density and sweating output per gland on forearm and thigh of prepubertal boys with high and sedentary physical fitness.

6. Objectives of the study

1. To determine function of eccrine sweat glands in prepubertal boys.
2. To compare function of eccrine sweat glands between sedentary and high physical fitness in prepubertal boys.

7. Hypothesis

Prepubertal boys with high physical fitness have higher eccrine sweat gland function than that of prepubertal boys with sedentary lifestyle.

8. Application advantages of this study

1. This study will provide basic knowledge concerning heat loss effector function of prepubertal boys with different physical fitness levels.

2. This study will emphasize the importance of exercise on the improvement of individual heat loss effector responses to heat stress from external environment.
3. The results will prompt additional study to further elucidate a more detailed mechanism of exercise to improve sweat gland function in children.