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Full Length Research Paper

Sweating, Thirst Perception and Plasma Electrolyte Composition in Women of Varying Body Mass Indices during Moderate Exercise

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ABSTRACT
Thirst is a perception, the subjective experience evoked by fluid deficits. Exercise induces sweating and subsequently electrolyte loss and thirst but there is little documented on post exercise thirst perception in women of varying body mass indices. 40 apparently healthy young women (19-25years) in the follicular phase of the menstrual cycle were used in this study. On the days scheduled for the experiment, the subjects drank 600 mls of water two hours before exercise to ensure they were euhydrated. The exercise was performed on a treadmill calibrated according to the Bruce treadmill protocol. Immediately after exercise, the subjects were weighed again. Sweat rate (L/hour) was calculated using the formula: Sweat rate (L /hour) = (Pre-exercise body weight - Post-exercise body weight)/exercise duration. Blood samples were collected from the antecubital vein of the subjects into lithium heparin bottles. The samples were immediately centrifuged to obtain the plasma for electrolyte analysis at baseline and post exercise. Thirst perception (TP)(cm) was rated after moderate exercise using a visual analogue scale (VAS). Subjects rated their TP by making a mark across the uncaliberated 10 cm scale, the ends of which were labelled "very thirsty" and "not thirsty". Results showed a significantly positive ($P<0.05$) relationship between BMI and sweating. Plasma-chloride levels increased significantly ($P<0.05$) in overweight and obese subjects, post exercise. Also, there was a significantly ($P<0.05$) positive relationship between sweat rate and thirst perception after the exercise. In conclusion, thirst perception increases with increasing BMI because of their higher fluid and electrolyte loss during exercise. Overweight, especially obese subjects have an increased risk to develop fluid and chloride imbalances than their lean counterparts during exercise. There might be need for fluid and electrolyte replacement during exercise especially in subjects with higher Body Mass Indices.

Keywords: Sweating, Thirst Perception, Blood electrolyte composition, Body Mass Index, Moderate exercise.

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INTRODUCTION

Sweating is the body's major way of getting rid of 85% body heat produced from metabolism, working muscles or from the environment. The amount of sweat produced depends on emotional states and physical activity. During exposure to heat and exercise, blood vessels near the skin surface dilate and lose their heat through sweat (Ugwu, 2007).

Women differ from men in thermal responses to exogenous heat load and heat loss as well as to endogenous heat load during exercise, because they usually have a larger ratio of body surface to body mass, a greater subcutaneous fat content, and lower exercise capacity. In addition, the changing rate of sex hormone release during the menstrual cycle modifies thermoregulation in women, so there are differences in resting body temperature and thermal responses to positive or negative heat loads depending on the phase of the cycle (Kaciuba-Uscilkoa and Grucza, 2001).

Thirst is a perception, "the subjective experience evoked by fluid deficits" (Engell *et al.*, 1987), or as explained by Johnson (2007), a motivational mechanism for the acquisition and consumption of water created in the brain as the synthesis of multiple source of information, but physiological and psychological.

Robertson, 1991 described Thirst as a conscious sensation of a need for water. Associated with the sensation of thirst is the desire to drink water and usually thirsty subjects report a dry feeling in the mouth and find that water intake brings them pleasure. Two types of thirst have been described, Volumetric Thirst and Osmometric thirst. Volumetric thirst is due to decreased volume. It is thirst caused by loss of blood volume (hypovolemia) without depleting the intracellular fluid. This can be caused by blood loss, vomiting, and diarrhea**.** Hypovolaemia is detected by kidney cells and triggers thirst for both water and salt via the renin-angiotensin system (Carlson, 2013). Osmometric thirst on the other hand occurs when the solute concentration of the interstitial fluid increases due to high intake of sodium in diet or by the drop in volume of extracellular fluids (such as blood plasma and cerebrospinal fluid) due to loss of water through sweating, respiration, urination and defecation. This causes cells to shrink in volume because of the resulting drawing out of water by osmosis from the cells thus resulting in cellular dehydration. Clusters of cells (osmoreceptors) in the organum vasculosum of the lamina terminalis (OVLT) and subfornical organ (SFO), which lie outside of the blood brain barrier can detect the concentration of blood plasma and the presence of angiotensin II in the blood. They can then activate the median preoptic nucleus which initiates water seeking and ingestive behavior.

Body mass index (BMI) is a measure of weight adjusted for height, calculated as weight in kilograms divided by the square of height in meters (kg/m^2).

BMI values (> $25kg/m^2$) are interpreted as evidence of being overweight or obese (Wellens *et al*., 1996). Previous studies have shown that body mass index (BMI) was related to the occurrence of heat disorders in highly trained, young soldiers (Chung and Pin, 1996). Furthermore, obesity and underweight may be related to altered physiological responses to exercise (Robinson, 1942; Amabebe *et al*., 2013; 2014).

MATERIALS AND METHODS

Subjects: A total of 40 young women (19-25years) in the follicular phase of the menstrual cycle were used in this study after assessing their health status via questionnaires and physical examination. Subjects with any form of gynaecological ailments, pregnancy, cardiovascular disease, metabolic and neurologic disorders where excluded from the study. Subjects with history of smoking and of use of hormonal contraceptives or any other medication in the last six months were not included in this study. Subjects were asked to refrain from alcohol and stimulants such as caffeine for 24 hours before testing. The population consisted of students of the University of Benin, Ugbowo Campus. They were divided into four groups. A, B, C and D. Each of these groups had a total of 10 women.

Group A consisted of underweight women (BMI < $18.5kg/m^2$).
Group B consisted of women with normal BMI ($18{\cdot}5$–$24{\cdot}9$ kg/m^2).
Group C consisted of overweight women (BMI- 25-29.9 kg/m^2).
Group D consisted of Obese women (BMI>$30kg/m^2$) (WHO, 2004).

Approval for this research was obtained from the Ethics Committee of the College of Medical Sciences, University of Benin. Participants received information about the objectives and procedures of the study and a signed an informed consent indicating agreement to participate voluntarily in the study was obtained.

Methodology

Experimental Protocol: This study was carried out in the physiology laboratory of the University of Benin. Data collection occurred in the morning (08:00 to 12:00 hours), to minimize the effects of circadian rhythm on the sweating rate (Stephenson and Kolka, 1993; Janse de Jonge, 2003).

On the days scheduled for each experiment, the volunteers drank 600 mls of water two hours before exercise to ensure that they were euhydrated (Sawka *et al*., 2007). Anthropometric data of each subject such as height (HT, m) and weight (WT, kg) were measured using a meter rule and digital weighing scale. The Body mass index of the subjects was calculated using the formula;

$$\mathrm{BMI} = \frac{\mathrm{weight\ (kg)}}{\mathrm{height}^2 (\mathrm{m}^2)}.$$

Baseline pulse rate and blood pressure were also measured. Before the exercise, the volunteers were allowed to acclimatize for 30 minutes in the laboratory, after which they were directed to empty their bladders and then weighed in order to initiate the exercise.

During the data collection, volunteers wore light clothing. Throughout the procedure, there was no fluid replacement. The exercise was performed on a treadmill which was calibrated according to the Bruce treadmill protocol designed by Robert A. Bruce in 1963. Immediately after exercise, the subjects were weighed again.

Sweat Rate: Sweat rate (L/hour) was calculated using the formula below:

$$\text{Sweat rate (L /hour)} = \frac{\text{(Pre-exercise body weight - Post-exercise body weight)}}{\text{Exercise duration}}$$

(Ugwu, 1985a; 1985b; 1985c; 1986; 1987; Ugwu and Oyebola; 1992; 1996; Casa *et al*., 2000).

Blood Collection

Blood samples were collected from the antecubital vein of the subjects (seated upright). 5mls of blood was collected into lithium heparin bottles with the use of sterile syringes and needles after cleaning the overlying skin with cotton wool soaked in methylated spirit. The samples were immediately centrifuged to obtain the plasma. All samples were properly labelled and immediately transported in ice filled containers to the laboratory for electrolyte analysis at baseline and post exercise. Sodium and potassium concentrations in the samples were measured using flame photometry (Hald, 1946) while chloride was measured using standard clinical laboratory procedures.

The total exercise time (min) was recorded using a stopwatch.

Thirst rating: Thirst perception (TP)(cm) was rated after moderate exercise using a visual analogue scale (VAS) (Thompson *et al.*, 1991; Takamata *et al.*, 1994). Subjects rated their TP by making a mark across the uncaliberated 10 cm scale, the ends of which were labelled "very thirsty" and "not thirsty". This was done after adequate instructions on completing the VAS. The visual analogue scale is an indirect approximation of the plasma osmolality (Robertson *et al.*, 1982)

Statistical analysis: All results were presented as Means ± SEM. Statistical analyses were performed using Graph Pad Prism 5.0 and Microsoft Office Excel, 2007. Comparisons between groups were assessed using Analysis of Variance (ANOVA). A linear regression plot and correlation analysis were used to show relationship between results of different groups. The level of statistical significance was set at $P<0.05$.

RESULTS

The anthropometric baseline data from the participants are shown in Table 1. There were significant differences ($P<0.05$) in the ages, weights, systolic blood pressures, diastolic blood pressures, pulse rates and body surface areas of the four groups studied but there was no significant difference ($P>0.05$) in the heights of the four groups

The Correlation between body mass index and sweat rate in all four groups of study is shown in Figure 1. A significant quadratic correlation was observed ($P<0.001$, $r=0.5651$). Participants with a high body mass indices demonstrated higher sweat rates compared with subjects with low body mass indices.

Figure 2 shows the Plasma Sodium ion concentration at baseline and post exercise in underweight, normal weight, overweight and obese women. N=40; means ± SEM. There was no significant difference in plasma Sodium ion baseline and post exercise in all the BMI groups.

The Plasma potassium ion concentration at baseline and post exercise in underweight, normal weight, overweight and obese women are presented in Figure 3. There was no significant difference in plasma potassium ion at baseline and post exercise in all the groups of women.

Table 1:
Anthropometric and Baseline Data

Anthropometric Data Parameters	Underweight	Normal Weight	Overweight	Obese
Age (years)	22.50±0.87*	20.80±0.66*	21.30±0.68*	20.60±0.73*
Body Mass Index (kg/m^2)	17.49±0.23*	21.75±0.57*	27.36±0.56*	34.98±1.01*
Weight(kg)	46.65±0.96*	57.09±1.74*	73.01±2.56*	94.45±3.57*
Height (m)	1.63±0.02	1.61±0.02	1.63±0.03	1.64±0.02
Systolic Blood Pressure (mmhg)	104.00±3.06*	109.00±3.15*	111.00±2.33*	115.00±3.73*
Diastolic Blood Pressure (mmhg)	65.00±2.24*	66.00±2.67*	63.00±1.53*	71.00±3.15*
Pulse Rate (Beats/minute)	66.35±0.92*	71.60±1.05*	81.55±2.22*	96.10±2.27*
Body Surface Area (m^2)	1.45±0.02*	1.60±0.03*	1.82±0.05*	2.07±0.05*

*Mean difference statistically significant at P<0.05; SEM (standard error of mean)

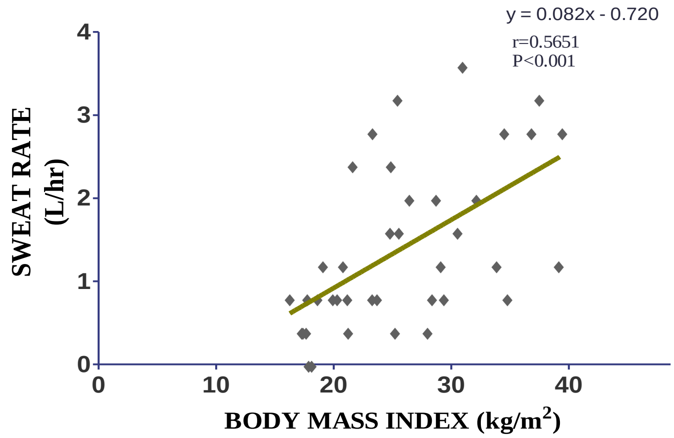

Fig. 1
Correlation between BMI and sweat rate in the different BMI groups during 15 minutes of moderate exercise. N=40; mean ± SEM

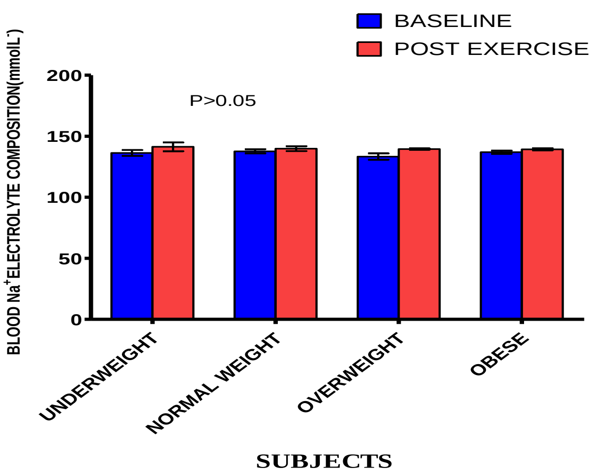

Fig. 2
Baseline and post-exercise sodium concentration. Each bar represents Mean ± SEM of 40 participants.

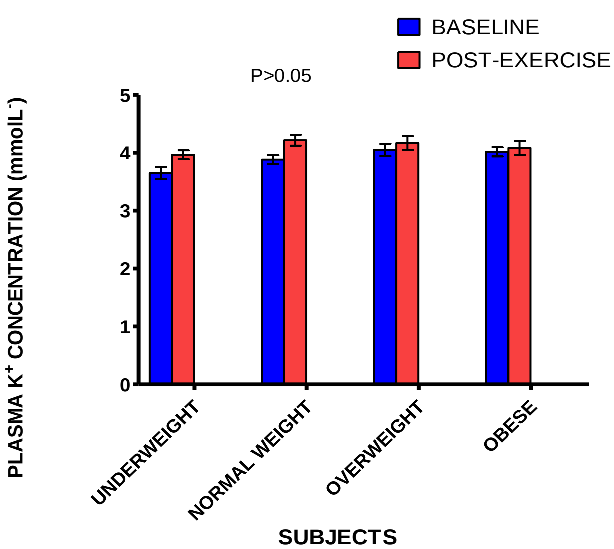

Fig. 3
Baseline and post-exercise potassium concentration. Each bar represents Mean ± SEM of 40 participants.

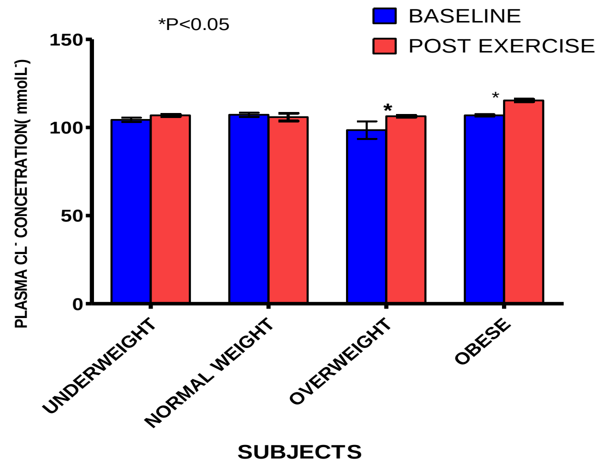

Fig. 4
Baseline and post-exercise chloride concentration. Each bar represents Mean ± SEM of 40 participants

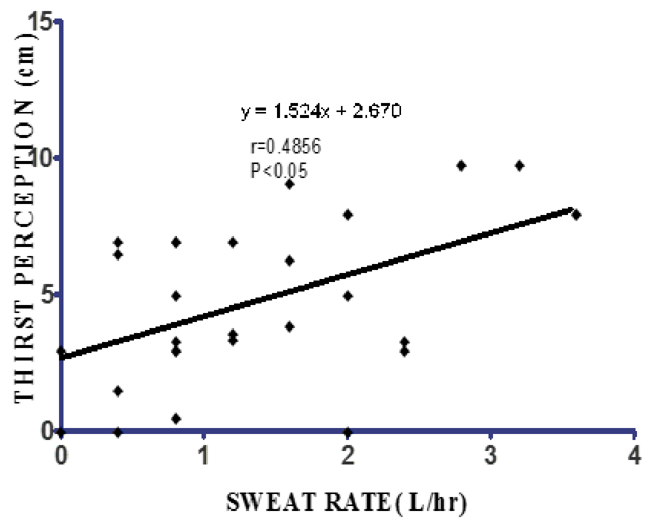

Fig. 5
Correlation between sweat rate and taste perception in women of different BMI groups during 15 minutes of moderate exercise. N=40; mean ± SEM

DISCUSSION

Obesity is a liability when exercising because the specific heat of fat is much greater than that of muscle tissue. Excess fat increases the insulatory properties of the body surface and retards conduction of heat to the periphery (Nunnely, 1978). On the other hand, individuals who are underweight are at a high risk of malnutrition and impaired thermoregulation. It was observed from this study that obese women produced a significantly higher sweat rate than all the other groups of women. A significant quadratic correlation was observed between body mass index and sweat rate. This is probably because of their larger body surface area and a greater number of sweat glands so as a result, obese subjects typically have larger fluid losses (Havenith and van Middendorp, 1990). It is well documented that exercise-induced or heat-induced hypohydration increases the osmotic pressure of the plasma, and therefore the plasma becomes hypertonic when the dehydration is induced by sweat output (Nose et al., 1988a; Nose et al., 1988b; Noakes, 1992). Sodium, potassium, and their principle anion, chloride, are the primary electrolytes responsible for the elevated blood tonicity during hypohydration. The plasma hypertonicity that results in mobilisation of fluid from the intracellular to the extracellular fluid compartments, enables the defense of the plasma volume in hypohydrated subjects (Nose et al., 1988a; Pichan et al., 1988; Sawka, 1992). This is in agreement with our study as we observed that the overweight and obese ladies showed a significant increase ($P<0.05$) in plasma chloride post exercise. There was however no significant difference in plasma chloride at baseline and post exercise in the other BMI groups. We also observed no significant difference in plasma sodium and potassium ion at baseline and post exercise in all the BMI groups.

Sawka et al. (1985) observed that a low to moderate level of hypohydration (up to 3%), primarily reduced plasma volume with little effect on plasma osmolality. It was postulated that the reduced blood pressure activated Arginine vasopressin (AVP) release, which decreased renal water clearance and defended osmolality.

When plasma osmolality increases, the secretion of Arginine vasopressin increases in plasma. This increase leads to an increase in urine osmolality and at the same time, an increase in osmolality of the blood stimulates the thirst centers located in the anterior hypothalamus. Thirst is also stimulated by hypovolemia. Hypovolemia frequently stimulates baroreceptors and angiotensin II production. Hypovolemia is frequently accompanied by hypertonicity. Hypertonicity stimulates osmoreceptors. Both sets of receptors act on the hypothalamus to stimulate thirst. This could be a possible explanation for the significant quadratic correlation was observed between thirst perception and sweat rate in our work. Subjects with a higher sweat rates demonstrated higher thirst perception. Therefore, the increased thirst perception with increasing BMI in our study might be the consequence of their higher plasma electrolyte levels and decreased plasma volume (that is, more dehydrated status) due to higher sweat rates post exercise compared to lean counterparts.

In conclusion, obese and underweight women demonstrated significantly higher and lower sweat rates respectively than the other groups of women. Significantly higher post exercise plasma chloride was also observed in overweight and obese groups of women as well as positive relationships between sweat rate and thirst perception. These changes suggest that overweight, especially obese subjects have an increased risk to develop fluid and chloride imbalances than their lean counterparts during moderate intensity exercise and underweight women might be at a thermoregulatory disadvantage because of their reduced body fat.

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