ROLE OF SWEAT AND SODIUM LOSS ON RUNNING PERFORMANCE IN OVERWEIGHT INDIVIDUALS

Patarawadee Sainiyom[1], Karnpiraya Nithitsuthibuta[1], Juthamard Surapongchai[2], Jason Kai Wei Lee[3], and Vitoon Saengsirisuwan[1]

[1]Department of Physiology, Faculty of Science, Mahidol University

[2]Faculty of Physical Therapy, Mahidol University

[3]Department of Physiology, National University of Singapore

Abstract

Half - marathon is considered a physiological stress to the thermoregulatory system because excess of heat generated. Due to the insulation property of fat, runners with high body fat would have poor thermoregulation. Thus, overweight individuals may experience diminished loss of sweat and poor physical performance. However, no study thus far has examined the effect of body fat on sweat and sodium loss during half - marathon. Therefore, the objective of this study was to assess running performance as well as rate of sweat and sodium loss in overweight individuals during half - marathon. Nine healthy male runners (CR; %body fat < 26.1) and nine overweight male runners (OR; %body fat ≥ 26.1) participated in this study. The subjects were asked to perform two running trials. The first one was a 10 - km running during which the rate of sweat loss was determined. In the second trial, each subject underwent a self - pace half - marathon when the sweat rate and total running duration were recorded. We found that a higher (64%) of sodium loss was observed in the OR. However, %bodyweight loss in the OR was 17.5% less than that of the CR ($p < 0.05$). In addition, rate of sodium loss was positively correlated with percent body fat ($p < 0.05$, $r = 0.478$). In spite of these findings, the duration to complete half - marathon running was not significantly different between the CR and OR. Collectively, our observation indicated that the rate of sweat and sodium loss has little to no effect on running performance in overweight individuals.

Keywords: Body fat, Half - marathon, Sodium loss, Sweat rate

Corresponding Author: Dr. Juthamard Surapongchai, Faculty of Physical Therapy, Mahidol University, Email: juthamard.sur@mahidol.ac.th

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Introduction

Thermoregulatory strain usually occurs in prolong endurance sport (> 2 hours) likes half - marathon running due to an abundance of heat generated form muscle working all over the body. Subcutaneous fat is known as thermal insulation in overweight. Overweight individuals demonstrate unproductive core to skin heat dissipation; thus, their body core temperature may reach a high level (> 38.0 °c). Furthermore, the ability to vanish heat in overweight is repaired according to their low surface area to body mass ratio which does not proportionally with a high magnitude of heat accumulation during exercise. Therefore, the heat begins to store inside body that may affect hyperthermia. Besides skin heat dissipation, sweat secretion became another dominant thermoregulatory response. Overweight individuals prone to excrete high sweat rate which results in dehydration (Eijsvogels et al., 2011).

Dehydration is founded to cause performance decrement in prolong endurance sports due to these effects; plasma volume reduction, thermoregulatory strain, and electrolyte imbalance particularly sodium. Sodium homeostasis plays an important role in maintenance of body water, control rate of fluid reabsorption, conservation of plasma volume, and serum sodium concentration (Sawka et al., 2007). Inadequate sodium replacement would bring to decline of running performance (Coso et al., 2016). During two hours of half - marathon, runners can lose sodium up to 1.6 g. Each of two to three percent of body weight reduction affects to increase more 5 - 7 mEq/L of sodium losses (Stachenfeld, 2014). Nonetheless, a variation of sweat rate and sweat sodium can be resulted by various factors such as type of sports, age, gender, and diet (Barnes et al., 2019; Sawka et al., 2007). Furthermore, bodyweight was founded on a positive relationship on sweat rate (Havenith, Luttikholt, & Vrijkotte, 1995) but the effect of body fat on sweat rate was not clarified.

Effect of body fat on either of sweat rate or sweat sodium hasn't ever been studied yet in overweight who participates in half-marathon. They may get a higher degree of sweat rate (more level of dehydration) and sodium loss as well as poorer running performance compared to normal - weight individuals.

Objective

This study aims to investigate the role of sweat and sodium loss on running performance in overweight runners.

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Methods

Tools

Cardiorespiratory fitness testing

Maximum oxygen uptake (VO_{2max}) represented cardiorespiratory fitness. Bruce protocol treadmill running was used to determine VO_{2max}. for each runner. Speed and incline increased every 3-minute of running. Total running duration was used to estimate VO_{2max}.

Body fat measurement

Skinfold caliper was used to estimate percent body fat by measuring subcutaneous fat form 4 sites including triceps, subscapular, supra-iliac and mid-thigh.

Sweat loss measurement

Whole body sweat loss was estimated by measuring bodyweight at pre and post running with two - point scale weight measuring instrument. Each runner was asked to wear same cloth on both preliminary and experimental days. Weight measuring for pre and post each running trial was performed while runner wearing sneaker with all instrumental attached. For getting rid of sweat trapping in runners clothes, they were asked to wipe their clothes to dry before taking post-running weight measuring.

Sweat sodium collection

An absorbent patch was attached on participant's forearm during running to indicate whole - body sodium loss during ten kilometers running on familiarization day. Sweat is extracted from patch then applied in sodium measuring device (HORIBA LAQUA Twin Sodium Meter).

Hydration status determination

Hand-held urine refractometer was used to measure urine specific gravity which determine hydration status.

Pace and running duration record

During running, pace and running duration were recorded by GPS sports watch (Polar M430).

Experimental procedure

Eighteen healthy male runners aged between 18 - 39 years old were recruited into the study. They were sorted into control runners (CR) and overweight runners (OR) groups according to their body fat. Body fat more than 26.1% is classified to OR. All runners participated in two visits that consist of first visit of preliminary testing and familiarization trial and second visit of experimental trial. Each of visit was scheduled one week apart. The study procedure was approved by ethical committee of Center of Ethical Reinforcement for Human Research, Mahidol University.

Inclusion and Exclusion criteria

Inclusion criteria for subject recruitment were Thai male amateur runners who age between 20 – 39 years old, experiencing participation in 1 - 2 half marathon race with current

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finishing time for half marathon more than 110 minutes. For exclusion criteria, they must never experience in heat stroke or heat exhaustion within the years, no history of cardiovascular, metabolic, or respiratory diseases and musculoskeletal during study.

Preliminary testing and Familiarization trial

Characteristics data of participants were collected. Cardiorespiratory fitness (VO_{2max}) was tested. Percent body fat was measured. Participants were asked to complete a questionnaire about drinking habits, training experience and signed consent form before characteristics and cardiorespiratory fitness testing. Then, after half-hour of resting, each of them was assigned to run self-pace ten kilometers with all instrument attached in order to get similar with real environmental of study protocol. Body weight measurement was done before and after running for estimation of sweat rate. The rate of sodium loss was recorded. Urine was collected to determine hydration status. All study procedures located at standard running track at Mahidol University.

Experimental trials

Participants ran self - pace half - marathon. Bodyweight was assessed before and after running for half-marathon sweat rate. Participants who require to urinate or to feces were weighted prior and after. During running, water was provided at room temperature when participants desire to drink (ad libitum). Water intake volume was recorded, %Bodyweight loss, sweat rate (L/hr) were calculated. Pace speed (km/min) and running duration (min) were recorded. Because of saturated sweat patch during half-marathon, rate of sodium loss in familiarization was used in data analysis.

Statistical analysis

Data were analyzed by independent t-test to investigate the difference between CR and OR groups. Pearson's *r* correlation was used to evaluate the effect of body fat on sweat rate and sweat sodium. Level of significance was set at p - value < 0.05. All data were examined in SPSS statistics 22.

Results

Subjects characteristic, Running performance, and Environmental data

Table 1 demonstrates the characteristics of runners, running performance and environmental data. Body weight, BMI, and body fat were higher in the OR group while pace speed and running duration were not different between groups. Furthermore, the environmental condition was similar between groups.

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Table 1 Characteristics data, Running performance, and Environmental factor in CR and OR groups.

Variables	CR (n=9)	OR (n=9)
Age (yrs)	33.2 ± 5.9	31.1 ± 5.2
Weight (kg)	71.6 ± 6.3	87.3 ± 15.7*
Height (cm)	174.4 ± 6.6	172.9 ± 5.1
BMI (kg/m^2)	23.5 ± 1.7	29.2 ± 4.9*
Body fat (%)	19.9 ± 5.6	33.7 ± 3.5*
VO_{2max} (ml/kg/min)	48.6 ± 10.2	36.3 ± 9.3*
Body surface area (m^2)	52.3 ± 3.1	54.9 ± 5.4
Pace speed (km/min)	6.2 ± 1.1	7.0 ± 1.7
Running duration (min)	136.1 ± 21.5	150.4 ± 33.9
WBGTod (℃)	24.9 ± 4.1	23.2 ± 1.9
Humidity (%)	88.2 ± 3.9	84.8 ± 22.9

Data are expressed as means ± SD. *Significant difference from CR ($p < 0.05$)

Sweat and sodium responses

Water intake, sweat loss, and sweat rate were not different between groups (Table 2). We found that %bodyweight loss of OR was 17.5% lower ($p = 0.017$), whereas sodium loss of OR was 64% more than that of CR ($p = 0.040$).

Table 2 Water intake (L/hr), Sweat loss (L), Sweat rate (L/hr), Bodyweight loss (%), Rate of sodium loss (mmol/L) in CR and OR groups.

Variables	CR	OR
Water intake (L/hr)	0.4± 0.2	0.5 ± 0.2
Sweat loss (L)	2.1± 0.3	2.2 ± 0.6
Sweat rate (L/hr)	0.9 ± 0.1	0.9 ± 0.3
Bodyweight loss (%)	2.9 ± 0.3	2.4 ± 0.5*
Rate of sodium loss (mmol/L)	31.9 ± 12.6	52.3 ± 19.1*

Data are expressed as means ± S.D. *Significant difference from CR ($p < 0.05$)

Rate of sodium loss was positively correlated with %body fat ($p = 0.04$, $r = 0.478$), as shown figure 1.

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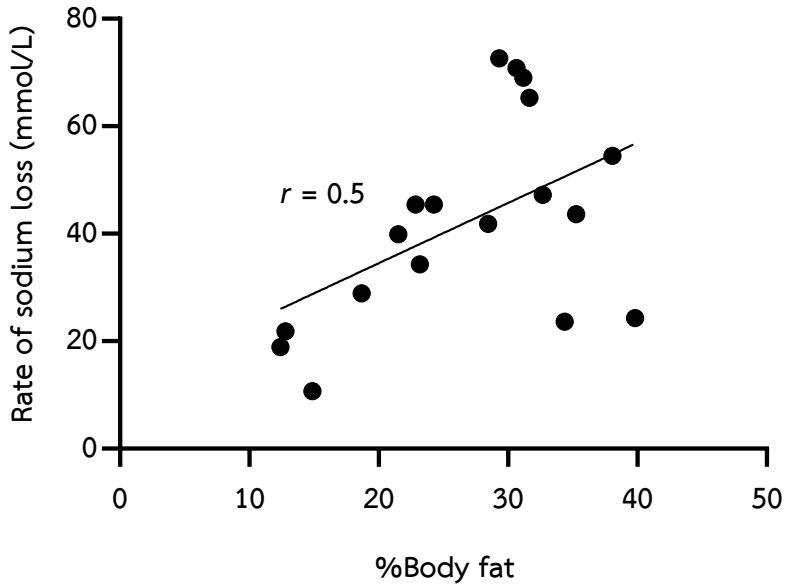

Figure 1 Correlation between %body fat and rate of sodium loss (mmol/L).

Discussion

The results from the present study indicated that half-marathon running induced dehydration (%bodyweight loss > 2%) in both CR and OR. Even though no differences in sweat rate and running performance were observed between groups, we found that OR had a lower value of %bodyweight loss and a higher level of sweat sodium loss when compared with CR. Our findings suggested that (1) degree of dehydration was lower in OR and (2) different levels of dehydration and rate of sodium loss did not significantly affect exercise performance in half-marathon running.

Due to the insulation property of body fat, a higher thermoregulatory strain and compensatory sweat secretion is expected in overweight individuals. In support of this, it has been reported that sweat rate in overweight subjects was significantly higher than that of the lean individuals during both exercise (Eijsvogels et al., 2011) and exercise in the heat (Bar-Or, Lundegren, & Buskirk, 1969). In contrast to such notion, the present study showed no significant difference in sweat rate between CR and OR. This finding suggested that the sensitivity of sweat response and its compensatory mechanism in OR may be impaired. It is important to note that the VO_{2max} value in OR was significantly lower than that of CR. As it has been demonstrated that sweat onset and sensitivity was positively associated with aerobic capacity (Lee, Kim, Min, & Yang, 2014), a lower value of VO_{2max} might be one factor responsible for impaired compensatory sweat loss in OR. In addition, a significant reduction

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in active sweat glands in trunk (58%) and limbs (14%) and an inverse relationship between skinfold thickness and number of active sweat glands have been reported in obese men under heat stress (Bar-Or, Magnusson, & Buskirk, 1968). A decrease in active sweat glands in obese individuals might be another cause of impaired compensatory sweat loss in OR.

It is well established that the capacity of sodium reabsorption at sweat glands is not effective at high sweat rate, so the rate of sodium loss is positively correlated with sweat rate (Buono, Claros, Deboer, & Wong, 2008). Sodium reabsorption is achieved by activation of epithelial sodium channel (ENaC) in sweat glands. The activity of ENaC was generally regulated by cystic fibrosis transmembrane conductance regulator (CFTR). Previous study reported that high sweat sodium is a condition that can also be observed in healthy athletes, which involved with dysregulation of ENaC and CFTR (Brown, Haack, Pollack, Millard-Stafford, & McCarty, 2011). In the present study, the rate of sodium loss in sweat in OR was higher than that of CR, with a comparable level of sweat rate between groups. In addition, a novel finding from this study is a positive correlation between %body fat and rate of sodium loss in sweat. Thus, the higher rate of sodium loss in sweat in OR might be related with the effect of higher body fat on ENaC and CFTR function. Further study is required to elaborate this concept.

Conclusion

In the present study, half-marathon running induced dehydration in both CR and OR. When compared with CR, OR appear to have a lower value of %bodyweight loss and a higher level of sweat sodium loss. A lower value of %bodyweight loss in OR could be explained by aerobic fitness and number of active sweat glands. Meanwhile, we hypothesize that an increase in body fat might modulate the function of ENaC and CFTR, resulting in a higher level of sweat sodium loss.

Suggestions

Further research is required to investigate the function of ENaC and CFTR in overweight individuals.

References

Bar-Or, O., Lundegren, H. M., & Buskirk, E. R. (1969). Heat tolerance of exercising obese and lean women. *Journal of Applied Physiology, 26*(4), 403-409. doi:10.1152/jappl.1969.26.4.403

Bar-Or, O., Magnusson, L. I., & Buskirk, E. R. (1968). Distribution of heat-activated sweat glands in obese and lean men and women. *Hum Biol, 40*(2), 235-248.

Barnes, K. A., Anderson, M. L., Stofan, J. R., Dalrymple, K. J., Reimel, A. J., Roberts, T. J., Randell, R. K., Ungaro, C. T., & Baker, L. B. (2019). Normative data for sweating rate, sweat sodium concentration, and sweat sodium loss in athletes: An update and

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analysis by sport. *Journal of Sports Sciences, 37*(20), 2356–2366. https://doi.org/10.1080/02640414.2019.1633159

Brown, M. B., Haack, K. K. V., Pollack, B. P., Millard-Stafford, M., & McCarty, N. A. (2011). Low abundance of sweat duct Cl− channel CFTR in both healthy and cystic fibrosis athletes with exceptionally salty sweat during exercise. *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology, 300*(3), R605-R615. doi:10.1152/ajpregu.00660.2010

Buono, M. J., Claros, R., Deboer, T., & Wong, J. (2008). Na+ secretion rate increases proportionally more than the Na+ reabsorption rate with increases in sweat rate. *J Appl Physiol (1985), 105*(4), 1044-1048. doi:10.1152/japplphysiol.90503.2008

Del Coso, J., González-Millán, C., Salinero, J. J., Abián-Vicén, J., Areces, F., Lledó, M., Lara, B., Gallo-Salazar, C., & Ruiz-Vicente, D. (2016). Effects of oral salt supplementation on physical performance during a half-ironman: A randomized controlled trial. *Scandinavian Journal of Medicine & Science in Sports, 26*(2), 156–164. https://doi.org/10.1111/sms.12427

Eijsvogels, T. M., Veltmeijer, M. T., Schreuder, T. H., Poelkens, F., Thijssen, D. H., & Hopman, M. T. (2011). The impact of obesity on physiological responses during prolonged exercise. *Int J Obes (Lond), 35*(11), 1404-1412. doi:10.1038/ijo.2010.277

Havenith, G., Luttikholt, V. G. M., & Vrijkotte, T. G. M. (1995). The relative influence of body characteristics on humid heat stress response. *European Journal of Applied Physiology and Occupational Physiology, 70*(3), 270-279. doi:10.1007/BF00238575

Lee, J. B., Kim, T. W., Min, Y. K., & Yang, H. M. (2014). Long distance runners present upregulated sweating responses than sedentary counterparts. *PLoS One, 9*(4), e93976. doi:10.1371/journal.pone.0093976

Sawka, M. N., Burke, L. M., Eichner, E. R., Maughan, R. J., Montain, S. J., & Stachenfeld, N. S. (2007). American College of Sports Medicine position stand. Exercise and fluid replacement. *Med Sci Sports Exerc, 39*(2), 377-390. doi:10.1249/mss.0b013e31802ca597

Stachenfeld, N. S. (2014). Sodium ingestion, thirst and drinking during endurance exercise. *Sports Science Exchange, 27*.

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