Effects of Precooling with Cold Water Ingestion on Thermoregulatory Response of Obese Men during Moderate Intensity Exercise in Hot and Humid Environment

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Objective: *1) To determine rectal temperature (T_{re}) and fluid loss (FL) of obese men (OM) compared to non-obese men (NM) during exercise in cool conditions (CC) and hot and humid conditions (HC), and 2) to investigate the effects of cold water (CW; 0.5±0.5°C) ingestion before exercise in HC in OM.*

Material and Method: *Twelve OM and 12 NM completed 2 treadmill exercise sessions, in CC and HC, in a randomized order. Each session was performed for 30 minutes at 45-50% of heart rate reserve with a 5-minute warm up and 5-minute cool down.*

Results: *There were no differences in T_{re} in response to exercise between OM and NM both in CC (OM 37.77±0.08°C, NM 37.68±0.08°C; p = 0.463) and in HC (OM 37.82±0.06°C, NM 37.85±0.06°C; p = 0.725). Heart rate, perceived exertion and thermal sensations were not significantly different between OM and NM. However, compared to NM, fluid loss (FL) was approximately 160 mL greater in OM (OM 443.33±98.65 mL, NM 283.33±108.15 mL; p≤0.001) in CC, and was 194 mL greater (OM 632.50±126.57 mL, NM 438.33±126.62 mL; p≤0.001) in HC. In HC, the 12 OM performed additional 2 bouts of exercise, with CW vs. ambient temperature water (AW; 30.5±0.5°C) ingestions prior to the start of exercise. Precooling with CW ingestion, compared to AW ingestion, showed no significant difference in T_{re} but CW was able to reduce FL (CW 646.67±139.82 mL, AW 735±126.95 mL; p = 0.010).*

Conclusion: *OM may continuously exercise about 30 minutes at moderate intensity in HC without the increase of T_{re} to dangerous levels. However, OM should drink approximately 200 mL more water in HC and 160 mL more water in CC than NM. Precooling with CW ingestion is a good method of reducing risk of exertional heat illnesses in obese individuals during exercise in HC, as it decreases the amount of FL induced by exercise.*

Keywords: *Obesity, Exercise, Precooling, Thermoregulation, Core temperature, Fluid loss, Hot environment*

J Med Assoc Thai 2016; 99 (2): 197-205
Full text. e-Journal: *http://www.jmatonline.com*

Obesity, indicated by body mass index (BMI) of >30 kg/m^2[1], is one of the world's major public health problems[2-4]. Obesity is linked to behavioral, metabolic, and genetic factors[5]. Regardless of its cause, weight gain ultimately occurs due to positive energy balance, in which energy intake exceeds energy expenditure[6]. Diet and exercise is the accepted, effective treatment approach for obesity[7-9]. Exercise, of moderate intensity, for obesity management is recommended to be aerobic in nature[8,10]. However, continuous exercise can increase core body temperature[11]. Additionally, exercise-induced dehydration due to fluid loss, mainly from sweating, can elevate core temperature to a dangerous level. Increase of core body temperature leads to malfunction of the body's organs[11-13]. In hot climates, dehydration associated with exercise occurs more rapidly, as rate of fluid loss is greater than rate of replacement[14]. Several strategies on fluid replacements have been suggested to maintain adequate hydration to reduce heat related complications[15]. Given that obesity has an independent association with exertional heat illnesses[16], hyperthermia may be more common when

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heat dissipation is limited such as in hot and humid conditions. Recent studies showed pre-cooling with cold water ingestion decreased core body temperature before exercise[17-19] and improved athlete's performances in the heat[18,19]. Thus, it is of interest whether pre-cooling prior to exercise in a hot and humid environment could effectively reduce risk of heat-related injuries in obese individuals. The current study was designed to compare core body temperature and fluid loss between obese and non-obese individuals while exercising in both cool, and hot and humid conditions. In addition, the effects of pre-cooling with cold water ingestion before exercise in hot and humid conditions were investigated in obese individuals.

Material and Method

Participants

Twelve obese men (OM; BMI >30 kg/m^2) aged 25±5 years and 12 non-obese men (NM; BMI 18.5-24.9 kg/m^2) aged 29±5 years, who met the inclusion and exclusion criteria, provided written informed consent to participate in the study. All volunteers were sedentary (exercise <2 times/week and <20 minutes/session within a month prior to study participation), without history of the following: thyroid diseases, cardiovascular diseases, uncontrolled diabetes (fasting blood sugar >126 mg%), hypertension (>140/90 mmHg), heat injury, being workers or residing in heated environment, or were not on medications altering the heart rate or metabolism. The study was approved by the Institutional Review Board of the Faculty of Medicine, Chulalongkorn University, and was carried out in compliance with the Declaration of Helsinki and the Belmont Report.

Experimental design

All participants visited the lab at approximately the same time of the day for all experiments. Throughout the exercise session, rectal temperature (T_{re}), fluid loss, heart rate, perceived exertion, and thermal sensations (TS) were recorded.

There were 2 parts of the study. In the first part of the study, both OM (n = 12) and NM (n = 12) performed 30 minutes of moderate intensity, treadmill exercise under cool (CC; 23-24°C, relative humidity [RH]: 75±5%), and hot and humid conditions (HC; 30-31°C, RH: 80±5%). In the second part of the study, the same 12 OM ingested cold water (CW; 0.5±0.5°C) and ambient temperature water (AW; 30.5±0.5°C) prior to moderate intensity treadmill exercise under HC. Volume of water ingested was calculated for each subject as 15.6 mL/kg of muscle mass. This amount of fluid was predetermined from average fluid loss measured in our pilot experiment in hot and humid condition. A randomized, cross-over design was used for all experiments. The washout period was 3-7 days between CC vs. HC, and between CW vs. AW ingestion. T_{re} and heart rate were continuously monitored and recorded during exercise while fluid loss (FL) was assessed by nude body weight measurement before, and immediately after exercise. Borg scale of perceived exertion (RPE)[20] and TS were assessed throughout the experiments.

Baseline measures

All participants were asked to drink enough fluid 24 hours prior to lab visits to ensure euhydration. Baseline body composition using bioelectrical impedance analysis (InBody 230 Biospace Co., Ltd., Korea) was measured within 30 minutes after urination for all visits to ensure comparable hydration status. Urine specific gravity was also determined upon arrival to the lab to ensure no dehydration. Nude body weight (Yamato DP-6100GP Yamato Scale Co., Ltd, Akashi, Japan) was recorded to ensure no weight loss or gain during the research participation. Resting heart rate (Polar FS1™ Dark Blue, Polar Electro Oy, Kempele, Finland) and blood pressure were measured prior to exercise at every laboratory visit.

Exercise intensity determination

A treadmill (Vision Fitness T9250, USA) test, to determine exercise intensity at 45-50% heart rate reserve (HRR) was performed by all OM and NM. An individual's treadmill speed and grade, obtained from this test, were used for all exercise conditions in both parts of the study. The intensity determination was tested in CC. After the resting heart rate (RHR) and the blood pressure (BP) was recorded, each participant started a 5-minute warm up at a comfortable walking speed without an incline, the treadmill speed was adjusted so that the participant performed a brisk walk. The treadmill grade was then increased by 2% every 5 minutes until 45% HRR was reached. The exercise intensity was constantly maintained at the desirable level for 30-minutes. At the end of the exercise, the participants performed another 5-minute cool down. The treadmill speed and grade at which the participants could maintain 45-50% HRR for the duration of the exercise session, were recorded to be prescribed for all exercise experiments. Replacement fluid was consumed ad libitum after exercise test completion.

Rectal temperature

To measure the core body temperature, a rectal probe (TSD 102A Fast response thermistor, BIOPAC Systems, Inc, Santa Barbara, California, USA) was inserted 10 cm above the anal sphincter. This procedure was privately performed by the participants themselves in a lateral decubitus position. The connected wire was then secured with an adhesive tape to the back skin at the lumbar level. Rectal temperature was continuously monitored and recorded.

Fluid loss assessment

FL was assessed by nude body weight on a weight scale (Yamato DP-6100GP Yamato Scale Co., Ltd, Akashi, Japan) before and after exercise. Upon exercise completion, participants wiped off their sweat with a dry towel before nude body weight was measured. FL equaled body weight loss, calculated as the difference between nude body weights measured before and after exercise session.

Perceived exertion and thermal sensation assessment

For all exercise experiments, RPE (6-20 scales) and thermal sensation (TS) were determined at baseline and at 5-minute intervals during exercise, until the end of the exercise session. Participants provided perceptive information on thermal sensation (9 point-scale; -4 to 4) ranging from very cold to very hot.

Treadmill exercise experiments

The first part of the study was conducted in a climatic chamber in which temperature and relative humidity were adjusted into either CC or HC. Humidity was adjusted to simulate the typical tropical climate as found in Thailand. CC represented temperature conditions in most fitness centers, while HC simulated the typical outdoor temperature in the afternoon at a public park where people usually go for recreational activities. In a random order, both OM and NM performed moderate intensity exercise, at their predetermined treadmill speed and grade shown to elicit 45% HRR, both in CC and HC for 30 minutes. The exercise was preceded by a 5-minute warm up and followed by a 5-minute cool down.

To investigate the effects of precooling with CW ingestion, the second part of the study was conducted only in HC. The total amount of water was divided into 4 portions and was consumed at 30, 20, and 10 minutes prior to, and immediately before the beginning of exercise (0 minute). The two water conditions (CW and AW) were assigned to each participant in a random order.

Statistical analysis

Analysis was performed using SPSS statistics software version 22 (SPSS Inc, Chicago, Illinois). Data are shown as mean (standard deviation), except RPE and TS, which are shown as median (interquartile range). Differences between groups (OM vs. NM) and conditions (CC vs. HC) were analyzed using two-way analysis of variance. Differences between 2 water temperatures were analyzed using one-way analysis of variance. Differences on RPE and TS between conditions were analyzed by Wilcoxon signed-rank test. The level of statistical significance was set at 0.05.

Results

The difference between mean ages of OM and NM was not statistically different. However, apart from having greater body weight and BMI, OM demonstrated significantly greater muscle mass, fat mass and total body water (Table 1). In addition, both subject groups

Table 1. Characteristics of obese men (OM) and non-obese men (NM) measured at rest (prior to exercise), during the baseline visit. All values are expressed as mean (standard deviation)

	OM (n = 12)	NM (n = 12)	*p*-value
Age (year)	29 (5)	25 (5)	0.071
Body weight (kg)	97.550 (10.81)	63.270 (8.88)	<0.001
Height (cm)	171.160 (4.74)	171.410 (6.77)	0.918
Body mass index (kg/m^2)	33.270 (3.36)	21.460 (2.00)	<0.001
Heart rate (bpm)	69.000 (10)	62.000 (10)	0.090
Muscle mass (kg)	36.580 (4.59)	29.050 (4.08)	<0.001
Fat mass (kg)	33.850 (7.02)	11.910 (4.17)	<0.001
Total body water (kg)	46.890 (5.22)	38.050 (4.44)	<0.001
Urine specific gravity	1.015 (0.07)	1.015 (0.08)	1.000

Table 2. Parameters involved in thermoregulation of obese men (OM) and non-obese men (NM) during exercise in cool condition (CC), measured at rest (prior to exercise) during the CC visit. Values are expressed as mean (standard deviation) unless stated otherwise

Variable	Cool condition		*p*-value
	OM (n = 12)	NM (n = 12)	
Urine specific gravity	1.015 (0.008)	1.016 (0.006)	0.889
Total body water (kg)	46.550 (6.46)	37.990 (4.77)	<0.001
Fluid loss (mL)	443.330 (98.65)	283.330 (108.15)	<0.001
Fluid loss rate (mL/min)	14.770 (3.29)	9.430 (3.61)	<0.001
Fluid loss per body weight (% L/kg of body weight)	0.440 (0.07)	0.440 (0.15)	0.881
Fluid loss per muscle mass (% L/kg of muscle mass)	1.200 (0.19)	0.960 (0.31)	0.034
Rectal temperature (°C)	37.770 (0.08)	37.680 (0.08)	0.463
Heart rate (bpm)	126.400 (2.1)	127.800 (2.1)	0.631
Rate of perceived exertion (using Borg Scale)*	15.000 (2)	15.500 (2)	0.096
Thermal sensation*	2.500 (3)	3.000 (1)	0.095

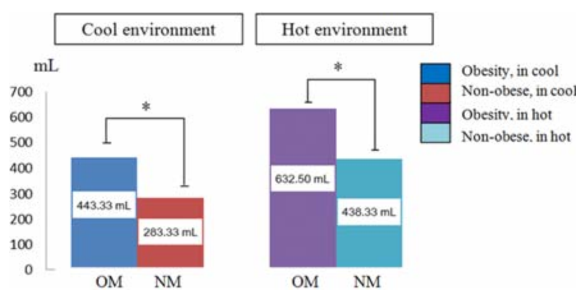
* Values are expressed as median (interquartile range)

visited the lab for all experiments with similar urine specific gravity within normal levels. Within each group, the levels of total body water were also comparable among visits. Therefore, both urine specific gravity and total body water indicated normal hydration levels of the participants in all experiments (Table 1).

Part 1: The effects of exercise in HC and CC in OM compared to NM

When exercise was performed in CC, both OM and NM demonstrated similar core temperature (T_{re}) and heart rate. Average T_{re} of obese subjects during exercise in CC and HC were similar (37.77 (0.08)°C vs. 37.82 (0.06)°C, $p = 0.036$). Compared to NM, OM showed a greater rate of FL, as well as total FL (Table 2). The total loss of fluid as a result of exercise in CC was approximately 160 mL higher in OM (Fig. 1). However, when body weight (BW) was taken into account, the ratio of FL (FL/BW) was similar (4.4 mL/kg) between OM and NM. Interestingly, when muscle mass was taken into account for FL, OM showed a greater loss than NM. This suggested that FL due to exercise in CC was normalized by weight of body mass, not muscle mass.

When exercise was performed in HC, OM showed similar T_{re} and heart rate compared to NM. In HC, OM lost fluid at a faster rate than NM. The total FL as a result of exercise in HC was approximately 194 mL higher in OM (Table 3). However, when body weight was taken into account, the proportion of FL between OM (6.4 mL/kg) and NM (6.8mL/kg) were similar. The magnitude of difference in FL between OM and NM was greater in HC than in CC (Fig. 1). In HC, such difference did not reach statistical significance when muscle mass was considered. Taking into consideration both CC and HC, total body weight appeared to be a better universal factor to use as reference for FL normalization for both OM and NM.



* The differences were statistically significant, $p<0.05$

Fig. 1 Fluid loss of OM and NM during exercise in cool and hot environment conditions.

Part 2: The result of pre-cooling with cold water (CW) compared to ambient temperature water (AW) before OM exercised in HC

The current study tested whether drinking cold water (CW) decreases the rise in core body temperature in HC when compared to ambient temperature water (AW) in OM (Table 4). Fig. 2 showed that drinking CW prior to engaging in continuous exercise did not differentially change T_{re} compared to

Table 3. Parameters involved in thermoregulation of obese men (OM) and non-obese men (NM) during exercise in hot condition (HC) measured at rest (prior to exercise) during the HC visit. Values are expressed as mean (standard deviation) unless stated otherwise

Variable	Hot condition		*p*-value
	OM (n = 12)	NM (n = 12)	
Urine specific gravity	1.013 (0.006)	1.012 (0.009)	0.799
Total body water (kg)	47.380 (5.69)	37.990 (4.63)	<0.001
Fluid loss (mL)	632.500 (126.57)	438.330 (126.62)	<0.001
Fluid loss rate (mL/min)	21.080 (4.22)	14.600 (4.22)	<0.001
Fluid loss per body weight (% L/kg of body weight)	0.640 (0.09)	0.680 (0.16)	0.473
Fluid loss per muscle mass (% L/kg of muscle mass)	1.730 (0.25)	1.500 (0.36)	0.086
Rectal temperature (°C)	37.820 (0.06)	37.850 (0.06)	0.725
Heart rate (bpm)	134.600 (2.3)	137.900 (2.3)	0.325
Rate of perceived exertion (using Borg Scale)*	16.000 (4.0)	16.000 (1.0)	0.332
Thermal sensation*	4.000 (1.0)	4.000 (0.0)	0.356

* Values are expressed as median (interquartile range)

Table 4. Effects of pre-cooling on parameters in obesity during exercise in hot and humid conditions

Variable	Hot and humid conditions		*p*-value
	CW (n = 12)	AW (n = 12)	
Urine specific gravity	1.014 (0.008)	1.017 (0.007)	0.236
Total body water (kg)	47.358 (5.412)	46.967 (5.634)	0.367
Fluid loss (mL)	646.670 (139.82)	735.000 (126.95)	0.010
Fluid loss rate (mL/min)	21.550 (4.66)	24.500 (4.23)	0.010
Fluid loss per body weight (% L/kg of body weight)	0.660 (0.12)	0.750 (0.10)	0.006
Fluid loss per muscle mass (% L/kg of muscle mass)	1.770 (0.33)	2.010 (0.29)	0.006
Rectal temperature (°C)	8.000 (1.0)	8.000 (1.0)	0.317
Heart rate (bpm)	15.000 (1.0)	15.000 (2.0)	0.119
Rate of perceived exertion (using Borg Scale)*	1.000 (1.0)	2.000 (1.0)	0.007
Thermal sensation*	3.000 (1.0)	3.000 (0.0)	0.083
Urine specific gravity	37.570 (0.07)	37.630 (0.05)	0.296
Total body water (kg)	130.800 (1.7)	134.100 (1.9)	0.024

* Values are expressed as median (interquartile range)

AW ingestion. However, FL was significantly lower with CW than with AW consumption (Fig. 3). Heart rate, rate of FL, FL corrected by body weight and FL corrected by muscle mass were all lower with CW ingestion. Both urine specific gravity and total body water assessed before the start of exercise showed no significant difference between CW and AW conditions, suggesting comparable baseline hydration status. RPE and thermal sensation were not affected by the temperature of water ingested before the exercise.

Discussion

As T_{re} during exercise, both in CC and HC, of OM was not significantly different when compared to NM, obese subjects were able to tolerate 30 minutes of moderate exercise without significant change of core body temperature. Although previous studies[21] reported similar 24-hour core body temperature between obese and non-obese individuals, the present study was the first to investigate core body temperature response in obesity during exercise in HC, particularly

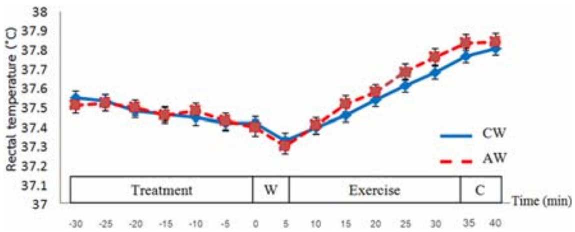
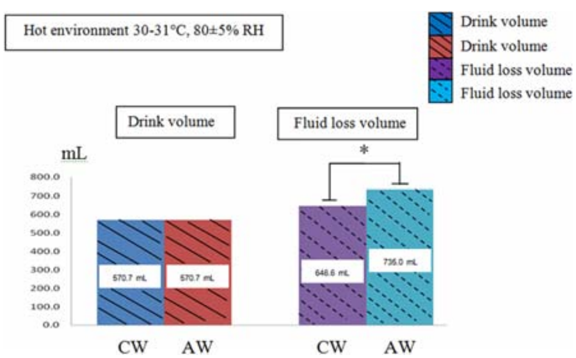


Fig. 2 Rectal temperature in cold water (CW) ingestion compared to ambient temperature water (AW) ingestion before exercise in hot & humid environment in obese men (n = 12), W = warm up, C = cool down.



* The differences were statistically significant $p<0.05$

Fig. 3 Drink volume and amount of fluid loss during exercise in hot & humid environment (30-31°C, RH: 80±5%) in obese men (n = 12); CW = cold water ingestion; AW = ambient temperature water ingestion.

with high humidity. The issue about exercise in hot and humid condition is crucial for obese individuals, especially as exercise is highly recommended for weight management. However, the current study specifically shows that obese individuals may continuously exercise for 30 minutes at moderate intensities in hot conditions, with high humidity, without serious concerns on the increase of body temperature to dangerous levels. The present study demonstrated that in either CC or HC, OM lost more water than the control group. This supports a previous study by Eijsvogels et al[12], which reported a greater reduction in body weight after prolonged (30-50 km) walk at self-selected speed in obese participants when compared to lean participants. It is possible that the greater loss of fluid with exercise in obese individuals is a thermoregulatory mechanism to maintain body temperature both in CC and HC. Hence, obese individuals are potentially at a higher risk for dehydration than lean subjects. However, the results from this study showed it is safe for obese individuals to exercise, with moderate intensity, even in hot and humid conditions such as the typical climate of Thailand without risking hyperthermia.

The present study also investigated whether precooling with cold water ingestion prior to exercise in hot and humid environment would result in better thermoregulation, than ingestion of ambient temperature water. It has been known that obesity is a susceptible risk to heat injury as heat transfer, one of the mechanisms for thermoregulation, is potentially limited. The notion that precooling may reduce core temperature prior to exercise was attractive as it may yield a particular benefit to obese individuals in terms of reduced risk of heat injury. Although drinking 15.6 mL/kg of muscle mass of cold water (0-1°C), 30 minutes prior to the beginning of exercise session, did not significantly change T_{re}, it was able to reduce the amount of FL. A previous study showed that at rest in hot conditions (35°C, RH: 60%), by drinking cold water in non-obese young men, T_{re} was reduced by 0.5°C[17]. This discrepancy may be due to different characteristics of subjects, difference in environmental conditions, the higher humidity in this study, or a lower ability to dissipate heat, particularly via evaporative heat loss.

Precooling has shown to help maintain thermoregulation, such as decrease RPE and thermal sensation[17], and even improved exercise performance[17,18]. In athletes, precooling with CW ingestion has been shown to decrease HR, sweat rate, RPE and thermal sensation during exercise in the heat[18]. In contrast, the present study found that precooling was able to decrease thermal sensation before, but not during exercise. It should be noted that perceived rating of exertion and of thermal sensation is biased prone, and cannot be masked by using a blinded study design. However, the results of the present study suggested that thermal comfort induced by drinking cold water before the start of exercise did not last throughout the duration of the exercise session.

Several methods of precooling have been tested in previous studies[17-19,22]. In the present study, precooling with cold water ingestion appeared to reduce exercise intensity as heart rate during exercise was reduced. However, the subjects were not aware as RPE was not different when ingesting either cold water or ambient temperature water prior to exercise. It was likely that the reduction in heart rate during exercise was related to cold water induced fluid preservation. In addition, as cold water ingestion allowed obese subjects to feel more comfortable with heat and was able to decrease FL, an improved endurance performance may be expected. Delayed dehydration during exercise with cold water ingestion appeared to be more beneficial as it allowed obese individuals to exercise longer.

Conclusion

The present study showed that obese individuals were able to safely exercise at moderate intensity for 30 minutes in hot and humid environment without a significantly increased core body temperature. A simple method of precooling, i.e. drinking cold water before engaging in exercise, was beneficial as it reduced FL. Since ice-cold water is conveniently available, precooling with cold water ingestion should be implemented by the obese population prior to exercise to avoid exertional heat illnesses.

What is already known on this topic?

Prior to engaging in exercise, pre-cooling with cold water ingestion can improve endurance exercise performance in athletes.

Individuals who exercise in hot environment are prone to exertional heat stroke when the body temperature rises to a certain level.

What is study adds?

Before engaging in exercise in the hot and humid environment (30-31°C, 80±5% RH), drinking ice-cold water is superior to room-temperature water as it reduces the loss of body fluid due to exercise. Thus, cold water ingestion before exercise preserves body fluid of obese individuals.

In obese individuals, it is safe to exercise for 30 minutes in hot and humid environment, as it only causes a slight increase in body temperature.

Acknowledgement

The authors are grateful to all participants who devoted their time and effort in this study. The study was supported by the Ratchadapiseksompotch Fund, Faculty of Medicine, Chulalongkorn University, RA57/040.

Potential conflicts of interest

None.

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ผลของการให้ความเย็นด้วยการดื่มน้ำเย็นต่อการตอบสนองของการควบคุมอุณหภูมิของร่างกายขณะออกกำลังกายระดับปานกลางในที่ร้อนชื้นของคนอ้วน

ปิยเชษฐ์ ตะสิงห์, อรอนงค์ กุละพัฒน์, สมพล สงวนรังศิริกุล, กษิภัคดิ์ ไก่แก้ว

วัตถุประสงค์: 1) เพื่อศึกษาเปรียบเทียบอุณหภูมิแกนกลางของร่างกาย (Tre) และการสูญเสียน้ำ (FL) ของคนอ้วน (OM) เปรียบเทียบกับคนน้ำหนักปกติ (NM) ในขณะออกกำลังกายทั้งในที่อากาศเย็น และในที่อากาศร้อนชื้น, 2) เพื่อศึกษาผลของการดื่มน้ำเย็น (0.5±0.5°C) ก่อนการออกกำลังกายในที่ร้อนชื้นของคนอ้วน

วัสดุและวิธีการ: อาสาสมัครเป็นชายอ้วนจำนวน 12 คนและชายน้ำหนักปกติ 12 คน ทำการออกกำลังกายด้วยการเดินเร็วบนลู่วิ่งกลใน 2 สภาวะ คือในที่อากาศเย็นและในที่อากาศร้อน ลำดับการทดลองโดยการสุ่มในแต่การทดลองจะประกอบไปด้วยการออกกำลังกาย 30 นาที ที่ความหนัก 45-50% ของอัตราการเต้นของหัวใจสำรอง โดยมีการอบอุ่นร่างกาย 5 นาที และผ่อนกาย 5 นาที นอกจากนี้ชายอ้วนทั้ง 12 คนยังได้ทำการทดลองผลของการดื่มน้ำเย็นเปรียบเทียบกับการดื่มน้ำอุณหภูมิห้อง (30.5±0.5°C) ก่อนออกกำลังกายในที่อากาศร้อนชื้น

ผลการศึกษา: อุณหภูมิแกนกลางของร่างกายในคนอ้วนเปรียบเทียบกับคนน้ำหนักปกติไม่มีความแตกต่างกันในขณะออกกำลังกายทั้งในที่อากาศเย็น (OM 37.77±0.08°C, NM 37.68±0.08°C; p = 0.463) และในที่อากาศร้อน (OM 37.82±0.06°C, NM 37.85±0.06°C; p = 0.725) อัตราการเต้นของหัวใจ ความรู้สึกเหนื่อย และความรู้สึกร้อน ไม่มีความแตกต่างอย่างมีนัยสำคัญทางสถิติระหว่างคนอ้วนเปรียบเทียบกับคนน้ำหนักปกติ อย่างไรก็ตามคนอ้วนมีปริมาณการสูญเสียน้ำในขณะออกกำลังกายมากกว่าคนน้ำหนักปกติประมาณ 160 มล. ในที่อากาศเย็น (OM 443.33±98.65 มล., NM 283.33±108.15 มล.; p≤0.001) และประมาณ 194 มล. ในที่อากาศร้อน (OM 632.50±126.57 มล., NM 438.33±126.62 มล.; p≤0.001) การดื่มน้ำเย็นก่อนออกกำลังกายในที่ร้อนส่งผลต่ออุณหภูมิแกนกลางของร่างกายขณะออกกำลังกายไม่แตกต่างจากการดื่มน้ำอุณหภูมิห้อง แต่การดื่มน้ำเย็นสามารถลดการสูญเสียน้ำในขณะออกกำลังกายในที่ร้อนได้ดีกว่า (CW 646.67±139.82 มล., AW 735±126.95 มล.; p≤0.010)

สรุป: คนอ้วนสามารถออกกำลังกายแบบต่อเนื่องนาน 30 นาที ด้วยความหนักระดับปานกลางในที่อากาศร้อนชื้นโดยไม่มีการเพิ่มขึ้นสูง ของอุณหภูมิแกนกลางของร่างกายจนถึงขั้นเป็นอันตราย อย่างไรก็ตามคนอ้วนควรจะดื่มน้ำก่อนออกกำลังกายเพิ่มเติมจากคำแนะนำในคนน้ำหนักปกติประมาณ 200 มล. ในที่อากาศร้อน และประมาณ 160 มล. ในที่อากาศเย็น การดื่มน้ำเย็นก่อนออกกำลังกายเป็นตัวเลือกที่ดีสำหรับคนอ้วนเพราะสามารถลดปริมาณการสูญเสียน้ำขณะออกกำลังกายในที่อากาศร้อนได้