Substrate Utilization During and After High Intensity Exercise in Healthy Lean and Obese Men

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Objective: *To compare lipid and carbohydrate use during and after a high-intensity endurance exercise bout between lean and obese subjects.*

Material and Method: *Lean and obese healthy male subjects with energetic physical activity and stable body weight were recruited to participate in the present study. The respiratory exchange ratio (RER), lipid and carbohydrate oxidation, and lipid and carbohydrate energy expenditure during resting condition, high-intensity exercise and 180 min after exercise were determined by indirect calorimetry.*

Results: *Ten lean and ten obese healthy male subjects, aged 26±4 years, completed a 300-kcal high-intensity exercise session. Resting energy expenditure and lipid energy expenditure in the obese group were significantly higher than those of the lean group. The RER, lipid oxidation, and carbohydrate oxidation were not significantly different between groups throughout the exercise period. The total energy expenditure and total lipid and carbohydrate energy expenditure were also not significantly different between lean and obese groups. During the 180-minute post exercise period, both lean and obese subjects showed a declination in RER and carbohydrate oxidation and an increase in lipid oxidation.*

Conclusion: *Substrate use during and after high-intensity exercise between healthy lean and obese subjects was not significantly different. Both groups used carbohydrates and lipids as the main substrate sources during and after high-intensity exercise, respectively.*

Keywords: *Lipid oxidation, Carbohydrate oxidation, Obesity, Exercise, Post exercise*

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Endurance exercise and regular physical activity have been found to increase total energy expenditure and lipid oxidation at rest and during submaximal exercise in both lean and obese subjects[1]. However, several impairments in obese subjects are still expressed during both resting and exercise periods[2,3]. Fat oxidation increases not only during exercise but also continues after the exercise phase or excess post exercise recovery phase (EPOC). Muscle and liver glycogen stores are mobilized to support most of the energy expenditure during exercise and lipids become the predominant energy source after exercise to spare carbohydrates and facilitate subsequent restoration of glucose homeostasis and glycogen repletion, especially during the first few hours of recovery[4,5]. Several studies have determined the effects of exercise on fat oxidation during and after exercise in lean subjects[6,7]. They found that fat oxidation was increased after high-intensity exercise[6,7]. Few studies have investigated the fat oxidation rate after exercise in obesity. Additionally, the results of the studies of fat oxidation after exercise in obese subjects are still controversial[8,9]. The aim of the present study was to compare lipid and carbohydrate use during and after high-intensity exercise bouts between lean and obese subjects.

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Material and Method

Ethical approval for the present study was granted by the Ethics Committee on Research Involving

Human Subjects, Faculty of Medicine, Siriraj Hospital, Mahidol University (Si-IRB COA. NO. Si137/2011). Lean and obese healthy male subjects aged between 20 to 35 years were recruited to participate in the present study. The present study included the subjects with BMI greater than 30 kg/m^2 (obese group) and BMI between 18.5 and 22.9 kg/m^2 (lean group). Subjects in both groups were required to have energetic physical activity and stable weight in the last three months. Subjects with cardiovascular diseases, pulmonary diseases, metabolic diseases, hypertension, dyslipidemia, impaired glucose tolerance or other related conditions that may affect exercise performance were excluded. All subjects were requested to maintain their regular diet and physical activities for three days.

Body composition was determined by dual-energy X-ray absorptiometry (Lunar Prodigy, GE Healthcare, USA). Peak oxygen consumption (VO_2 peak) was measured with an indirect calorimeter (Vmax encore 29, VIASYS Healthcare Inc., USA) using Bruce's ramp protocol[10].

On the day of the experiment, the subjects arrived at the laboratory and consumed the exact kind and amount of breakfast (610 kcal) at 7 a.m. At 9:30 a.m., subjects sat quietly for 20 minutes in the pre-exercise resting period and then performed high-intensity exercise or resting control condition at 10 a.m. The order of these conditions was counterbalanced. Each condition was regularly separated by at least one week. The high-intensity exercise was an exercise at ventilatory threshold[11], measured and calculated by the V-slope method[12] during VO_2 peak test. Energy expenditure of this high intensity exercise was also set at approximately 300 kcal to compare results between the obese and control groups[8,9]. Duration of the exercise was calculated by dividing energy expenditure (300 kcal) by energy expenditure at ventilatory threshold.

For resting control condition, the subjects sat quietly and comfortably on a recliner for the same time as the high-intensity exercise. After an exercise or resting control condition, each subject sat quietly and comfortably on a recliner for 180 minutes to measure the data during the post exercise period. Oxygen consumption (VO_2), carbon dioxide production (VCO_2), respiratory exchange ratio (RER), lipid oxidation, carbohydrate oxidation, energy expenditure (EE), lipid energy expenditure (LEE) and carbohydrate energy expenditure (CEE) were recorded by Vmax encore 29.

For high intensity exercise, the variables were assessed five times: pre-exercise, during exercise, and three times hourly post exercise. For resting control condition, the variables were assessed four times hourly.

The sample size was calculated with the effect size of 1.59 and power 80%; therefore, ten subjects were enrolled in the present study. The normal distribution of data was tested by the Kolmogorov-Smirnov goodness of fit-test. Two-way mixed ANOVA was used to compare the RER, lipid oxidation, carbohydrate oxidation, EE, LEE and CEE in pre-exercise, exercise, and post exercise periods between groups. Bonferroni's correction was used for post hoc analysis.

Results

Ten lean and ten obese subjects, aged 25.70$\pm$3.95 and 25.60$\pm$3.92 years old, respectively, voluntarily participated. Independent t-test demonstrated the significant differences in body weight (64.91$\pm$5.85 and 96.29$\pm$13.63 kg), body mass index (BMI) (21.61$\pm$1.21 and 31.94$\pm$2.50 kg/m^2) and body fat percentage (19.92$\pm$8.10 and 35.91$\pm$5.07%), respectively, between groups.

For resting control condition, RER, lipid oxidation and carbohydrate oxidation in lean and obese groups were not significantly different. The obese subjects showed significantly higher EE and LEE than lean subjects at 1st, 2nd, and 3rd assessments, whereas no significant difference was observed in CEE between groups, as shown in Table 1.

No significant difference was found in the exercise intensity and duration of exercise between the lean and obese groups. Exercise intensity of the lean group was 66.60$\pm$4.69% VO_2 peak, and that of the obese group was 68.97$\pm$7.11% VO_2 peak. The durations were 29.60$\pm$4.38 minutes in the lean group and 28.30$\pm$5.83 minutes in the obese group. No significant differences in any variables were observed at all assessments except EE in the 2nd hour after exercise and LEE in the 1st hour after exercise. However, total EE and total LEE were also not significantly different between lean and obese groups as shown in Fig. 1.

Discussion

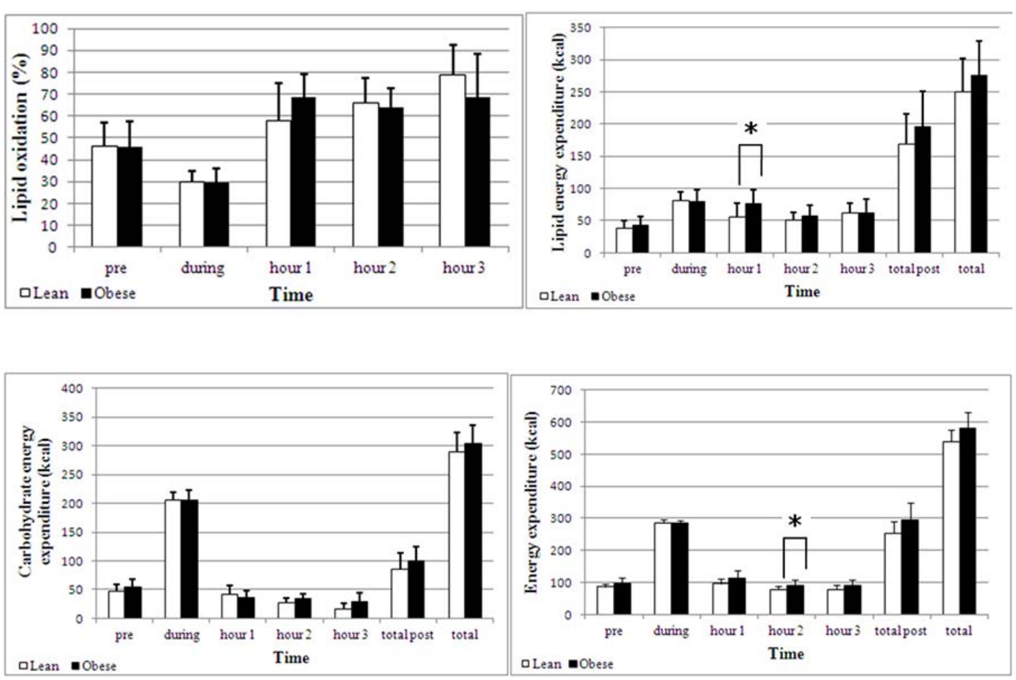
The present study compared several variables including RER, lipid oxidation, carbohydrate oxidation, EE, LEE and CEE in healthy lean and obese subjects at rest, during and after high-intensity exercise.

At resting control condition, EE and LEE in obese subjects were higher than those in lean subjects while other variables were comparable. It may reflect

Table 1. Mean (SD) of all variables for resting control condition in lean and obese subjects

Period	1st hour	2nd hour	3rd hour	4th hour
Respiratory exchange ratio				
Lean	0.85 (0.03)	0.85 (0.03)	0.83 (0.05)	0.80 (0.04)
Obese	0.84 (0.03)	0.84 (0.04)	0.82 (0.04)	0.81 (0.03)
Lipid oxidation (% utilization)				
Lean	52.22 (8.63)	52.11 (11.96)	57.21 (17.11)	68.71 (14.96)
Obese	55.83 (10.91)	55.65 (12.31)	61.68 (12.98)	66.09 (9.56)
Carbohydrate oxidation (% utilization)				
Lean	47.78 (8.63)	47.89 (11.96)	42.79 (17.11)	31.29 (14.96)
Obese	44.17 (10.91)	44.35 (12.31)	38.32 (12.98)	33.91 (9.56)
Energy expenditure (kcal)				
Lean	86.99 (6.69)	79.19 (6.05)	72.68 (8.57)	74.07 (12.40)
Obese	100.64 (14.07)*	96.05 (13.98)*	91.13 (10.83)*	88.68 (10.87)*
Lipid energy expenditure (kcal)				
Lean	43.68 (6.67)	40.11 (10.71)	41.01 (15.11)	51.06 (18.05)
Obese	54.97 (15.51)*	51.58 (13.16)*	54.88 (14.30)*	56.63 (8.46)
Carbohydrate energy expenditure (kcal)				
Lean	43.31 (9.57)	39.08 (9.07)	31.67 (12.11)	23.01 (9.35)
Obese	45.66 (10.47)	44.48 (13.79)	36.25 (11.83)	32.05 (11.50)

* Significant difference between lean and obese (*p*<0.05)



pre = pre-exercise; during = during high-intensity exercise; hour 1 = 1st hour post-exercise; hour 2 = 2nd hour post-exercise; hour 3 = 3rd hour post-exercise; total post = the summation of 3 hours post-exercise period; total = the summation of during exercise and total post-exercise periods

Fig. 1 Substrate utilization and energy expenditure for high-intensity exercise at pre-, during, and post-exercise in lean and obese subjects.
* Significant difference between lean and obese (*p*<0.05)

the pattern of the difference in lipid use between lean and obese subjects in the present study. This finding was in accordance with previous research reporting higher fat use during resting control condition of obese subjects[13,14]. They indicated that the increase in lipid oxidation related to the increased availability of free fatty acids in obese subjects[13].

During and after high-intensity exercise, EE in the 2nd hour after exercise and LEE in the 1st hour after exercise of the obese group were higher than those of the lean group. However, no significant differences in other variables were observed between the lean and obese groups, especially the total EE and total LEE. These results mean that the EE and lipid use throughout exercise and three hours after exercise were not different between lean and obese groups. In contrast to this present finding, it has been reported that RER in obese subjects was higher after high-intensity exercise[9]. Obesity is usually associated with high levels of insulin, diminished function and decreased number of β_2-adrenoceptors and limited adipose tissue blood flow[2,3]. Thus, these obesity-associated conditions can likely suppress lipid oxidation in obese subjects. This mechanism leads to a metabolic disorder in obese subjects, especially during exercise[2,3]. However, the discrepancy between the two studies may be due to the subject criteria because this study recruited only physically active obese subjects without other metabolic abnormalities to rule out other confounding factors. Therefore, our observation suggests that obesity by itself does not affect the type of substrate use during exercise and throughout the post exercise period. Many factors affecting substrate use were controlled in the present study including nutrition, physical activity, measurement error from hyperventilation and the lactate system and abnormal physiological conditions. However, levels of glycogen, glucose, triglyceride or FFA were not reported. Further investigations are warranted.

Conclusion

In summary, it can be concluded that healthy obese men without metabolic disease had higher resting EE and resting LEE than lean men. The response of substrate use during and after high-intensity exercise was comparable between lean and obese subjects.

What is already known on this topic?

Exercise can stimulate fat oxidation during and after exercise in lean subjects. The results of one research[9] reported the declination of lipid oxidation after exercise in obese individuals compared with lean individuals.

What this study adds?

Compared to lean subjects, healthy obese subjects used more resting energy expenditure and resting lipid energy expenditure. However, the responses of substrate use during and after high intensity exercises were not significantly different between the two groups.

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Potential conflicts of interest

None.

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การใช้ไขมันและคาร์โบไฮเดรตในช่วงออกกำลังกายและช่วงฟื้นตัวหลังออกกำลังกายในชายน้ำหนักตัวปกติและชายอ้วนที่มีสุขภาพดี

อโนมา สันติวรกุล, เบญจมาศ ช่วยชู, วันทนีย์ เกรียงสินยศ, วิฑูร แสงศิริสุวรรณ, วรรธนะ ชลายนเดชะ

วัตถุประสงค์: *การศึกษาครั้งนี้เปรียบเทียบการใช้ไขมันและคาร์โบไฮเดรตเป็นสารให้พลังงานในขณะออกกำลังกายและหลังออกกำลังกายในชายน้ำหนักตัวปกติและชายอ้วนสุขภาพดี กลุ่มละ 10 ราย*

วัสดุและวิธีการ: *วัดค่าอัตราการแลกเปลี่ยนคาร์บอนไดออกไซด์และออกซิเจน ปริมาณการใช้ไขมัน และคาร์โบไฮเดรตเป็นสารให้พลังงาน ปริมาณพลังงานที่ใช้ และปริมาณพลังงานจากไขมันและคาร์โบไฮเดรตที่ใช้ในขณะพักและออกกำลังกาย 300 กิโลแคลอรี่ ที่ระดับหนัก โดยตลอดการศึกษามีการควบคุมอาหารและกิจกรรมระหว่างวันให้คงที่*

ผลการศึกษา: *ขณะพัก ชายอ้วนใช้ปริมาณพลังงานและปริมาณพลังงานจากไขมันมากกว่าชายน้ำหนักปกติ โดยที่ขณะออกกำลังกายและหลังออกกำลังกายไม่พบความแตกต่างอย่างมีนัยสำคัญทางสถิติของอัตราการแลกเปลี่ยนคาร์บอนไดออกไซด์และออกซิเจน ปริมาณการใช้ไขมันและคาร์โบไฮเดรตเป็นสารให้พลังงานของ 2 กลุ่ม ในช่วงหลังออกกำลังกาย 180 นาที พบการลดลงของอัตราการแลกเปลี่ยนคาร์บอนไดออกไซด์และออกซิเจนและปริมาณการใช้คาร์โบไฮเดรตเป็นสารให้พลังงาน และพบการเพิ่มขึ้นของปริมาณการใช้ไขมันเป็นสารให้พลังงาน*

สรุป: *แม้ขณะออกกำลังกายจะมีการใช้คาร์โบไฮเดรตเป็นสารให้พลังงานมาก แต่หลังออกกำลังกายมีการเพิ่มขึ้นของการใช้ไขมันเป็นสารให้พลังงานทั้งในกลุ่มชายน้ำหนักปกติและชายอ้วนสุขภาพดี*