# SUBSTRATE OXIDATION RATES DURING INCREMENTAL EXERCISE IN TRAINED AND UNTRAINED YOUNG ADULTS*

Şükrü Serdar BALCI[1]

Zübeyde ASLANKESER[1]

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## ABSTRACT

The aim of the present study is to examine the differences in maximal fat oxidation rate during exercise between trained and untrained young adult men. 50 healthy, trained (age= 20.75±0.31 years, BMI= 21.75±0.34 kg/m$^2$, n= 24) and untrained (age= 21.71±0.48 years, BMI= 22.19±0.41 kg/m$^2$, n= 26) young men volunteered to participate in this study. After overnight fast, subjects tested on a Monark cycle ergometer and started pedaling at an external power output of 60 W. Subjects' pedaling cadence was kept at 60 revolutions/min (rpm). Every 3.5 min, the power output was increased by 35 W until exhaustion. Maximal oxygen uptake and maximal fat oxidation rate were determined with indirect calorimetry by using an incremental exercise test on cycle. An unpaired Student's t-test was used to determine the differences between the groups.

Oxygen uptake, respiratory exchange ratio, heart rate, relative contribution of fat and carbohydrate to energy expenditure at exercise intensity that elicits maximal fat oxidation ($Fat_{max}$) were significantly different between trained and untrained subjects ($p<0.05$). Maximal fat oxidation rate was significantly higher in trained group than untrained group ($p<0.05$). On the other hand, carbohydrate oxidation rate and percent of $VO_{2max}$ at $Fat_{max}$ were similar ($p>0.05$).

The study results suggest that the trained individuals also have higher maximal oxygen uptake and fat oxidation rate than untrained young adults. Also, it can be said that the relative contribution of fat and carbohydrate to energy expenditure at $Fat_{max}$ were affected training status.

**Keywords**: Substrate oxidation rate, exercise, training status

# ANTRENMANLI VE ANTRENMANSIZ GENÇ YETİŞKİNLERDE EGZERSİZ SIRASINDA SUBSTRAT OKSİDASYON HIZI

## ÖZ

Bu çalışma, antrenmanlı ve antrenmansız genç yetişkinlerde egzersiz sırasında meydana gelen maksimum yağ oksidasyon hızının karşılaştırılması amacıyla yapıldı. Araştırmaya antrenmanlı (yaş= 20.75±0.31 yıl, n=24) ve antrenmansız (yaş= 21.71±0.48 yıl, n=26) toplamda gönüllü 50 genç yetişkin erkek katıldı. Denekler bir gece açlık sonrası dakikada 60 pedal çevirme hızı ile 60 watt yükle kademeli olarak artan egzersiz testi uygulandı. Yük her 3,5 dakikada 35 watt artırıldı, bu sırada indirekt kalorimetre ile solunum parametrelerinin ölçümü gerçekleştirildi. Test sırasında ölçülen substrat oksidasyon hızları ve maksimum yağ oksidasyonu hızının gerçekleştiği egzersiz şiddetindeki solunum değerlerinin karşılaştırılması bağımsız gruplarda t-testi ile analiz edildi. Kademeli olarak artırılan yüklerde tükenene kadar uygulanan egzersiz testi sırasında tespit edilen maksimum yağ oksidasyon hızındaki oksijen tüketimi, solunum değişim oranı, kalp atım hızı, yağın ve karbonhidratın enerji harcamasına katkıları gruplar arasında önemli düzeyde farklıydı ($p<0.05$). Genç yetişkinlerde antrenmanlı grubun maksimum yağ oksidasyon hızı antrenmansız gruptan önemli düzeyde yüksekti ($p<0.05$), buna karşın karbonhidrat oksidasyon hızı ve maksimal yağ oksidsyon hızındaki oksijen tüketiminin maksimum oksijen tüketimine oranı gruplarda benzerdi ($p>0.05$). Araştırma sonuçları maksimum oksijen tüketimi yüksek bireylerin daha yüksek yağ oksidasyon hızına sahip olduğunu göstermektedir. Maksimal yağ oksidasyon hızındaki egzersiz şiddetinde enerji üretimine yağ ve karbonhidrat katkı oranlarının antrenman durumundan etkilendiği söylenebilir.

**Anahtar Kelimler**: Substrat oksidasyon hızı, egzersiz, antrenman durumu

[1] Selçuk University, Faculty of Sports Science, Turkey

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## INTRODUCTION

Carbohydrate (CHO) and fat are the most important sources of energy for the body[17]. The greater the exercise intensity, the larger the contribution of CHO oxidation to the total energy expenditure[8], while fat oxidation interactions with activity intensity and/or type seems to be more complex[26]. In addition, substrate oxidation rates during physical activity may be affected by several factors that include the age, gender, body composition, activity duration, exercise mode, diet and training status[3,5,7,16,19,24 29].

$Fat_{max}$ is the exercise intensity at which the highest rate of fat oxidation was observed[2]. It has been that high fat oxidation rates can be beneficial for a large variety of individuals. Trained athletes use more fat than untrained individuals even during intensive exercise performed at the same percentage of $VO_{2max}$[9]. Also, in previous reports, training have been shown to increase fat oxidation during exercise[7, 18]. Achten et al. (2002) reported that fat oxidation rates are high over a large range of exercise intensities. Also, the exercise intensities above $Fat_{max}$, a marked drop in fat oxidation was observed[1].

Nordby et al. (2006) have stated that the percent $VO_2$ at $Fat_{max}$ are lower in trained (44±2%) than untrained (50±1%) men[22]. Also, Stisen et al. (2006) have reported that the relative exercise intensity that elicited the highest rate of fat oxidation was 56±3% and 53±2% $VO_{2max}$ in endurance trained and untrained women, respectively[28]. Venables et al. (2005) reported that $Fat_{max}$ was performed at 52% $VO_{2max}$ in adult men[29]. Also, Achten and Jeukendrup (2003) have observed that $Fat_{max}$ was performed at 63±9.8 % $VO_{2max}$ in trained men[2]. These studies have shown that the relative exercise intensity that elicited the maximal fat oxidation are quite different (44-63 % $VO_{2max}$).

Many studies have been conducted to maximal fat oxidation during exercise, but the choice of the optimal exercise intensity is still unclear. Randell et al. (2017) reported that the exercise intensity that elicited the $Fat_{max}$ in athlete population have a large range (22.9 to 88.8 % $VO_{2max}$)[25]. Also, information on the fat oxidation rate differences between trained and untrained subject during incremental exercise test is lacking compared with continuous exercises. The primary objective of this investigation was to evaluate the differences in substrate oxidation during acute incremental exercise between endurance trained and untrained subject. Also, determination of exercise intensity at maximal fat oxidation for subjects with different training status.

## METHODS

**Participants:** 50 healthy, trained (age=20.75±0.31 years, $VO_{2max}$=63.01±0.69 ml/kg/min, n=24) and untrained (age=21.71±0.48 years, $VO_{2max}$=49.23±0.89 ml/kg/min, n=26) young adult men volunteered to participate in this study. This study was approved by the local ethics committee. The procedures and risks were thoroughly explained to the participants, and their written and informed consent was obtained.

**Experimental Protocol and Exercise Test:** Subjects were barefoot and in their underwear for the anthropometric measurements. Weight was measured with a Seca scale and height with a stadiometer that was incorporated into the scale. Body mass index was calculated for all participants. Body fat estimations were made by using the four-site (biceps, triceps, subscapular and suprailiac) skinfold (Holtain caliper) technique according to the method of Durnin and Womersley (1974)[12].

The exercise protocol used here was adapted from Achten et al. (2002) in which it was concluded that an incremental exercise test with stages of 3.5-min duration could be used to determine maximal fat oxidation rate and $Fat_{max}$[1]. Briefly, after overnight fast, the subjects tested on a cycle ergometer (Monark 839E) and started pedaling at an external power output of 60 W. Subjects' pedaling cadence was kept at 60 revolutions/min (rpm). Every 3.5 min, the power output was increased by 35 W until exhaustion. Also, maximal oxygen uptake ($VO_{2max}$) was determined with indirect calorimetry by using an incremental exercise test on cycle.

All participants were tested at the same time of day to minimize the effects of diurnal biological variation. In the two days prior to the experimental trials, participants were instructed to abstain from strenuous exercise and fast for at least 10 hours before the exercise tests.

**Indirect Calorimetry and Calculations:** Breath-by-breath measurements were taken throughout exercise by using an indirect calorimetry (Cosemed K4B[2], Italy). During incremental exercise tests, average values for $VO_2$ and $VCO_2$ were calculated over the last 2 min of every stage. CHO and fat oxidation during the tests were calculated according to the stoichiometric equations[13] assuming that the urinary nitrogen excretion rate was negligible:

CHO oxidation ($g \cdot min^{-1}$)= $4.55*VCO_2 - 3.21*VO_2$

Fat oxidation ($g \cdot min^{-1}$)= $1.67*VO_2 - 1.67*VCO_2$

The relative contributions to energy expenditure from CHO and fat oxidation were calculated using the following equation[11]:

% Fat = [(1-RER)/0.29]*100

% CHO = [(RER-0.71)/0.29]*100

**Statistical Analysis:** The data were tested for normal distribution with the Kolmogorov-Smirnov test and for homogeneity of variances with Levene's test. Unpaired t-tests were used to compare mean values between trained and untrained groups. The analyses were run using the SPSS 16.0 for Windows statistical package. Statistical significance was set at a $P < 0.05$ level and data are expressed as mean ± standard error mean.

## RESULTS

The physical characteristics of the subjects are presented in Table 1. Age, height, body weight and BMI variables were similar for the trained and untrained groups subjects ($p>0.05$). Also, body fat percentage, $VO_{2max}$ and $HR_{max}$ were significantly different between trained and untrained subjects ($p<0.05$).

Oxygen uptake, respiratory exchange ratio, heart rate, relative contribution of fat and carbohydrate to energy expenditure at exercise intensity that elicits maximal fat oxidation ($Fat_{max}$) were significantly different between trained and untrained subjects ($p<0.05$).

**Table 1. Physical characteristics of the participants**

| | Trained (n=24) | | | Untrained (n=26) | | |
|---|---|---|---|---|---|---|
| | Mean | ± | SEM | Mean | ± | SEM |
| Age (years) | 20.75 | ± | 0.31 | 21.71 | ± | 0.48 |
| Height (cm) | 178.92 | ± | 0.95 | 177.89 | ± | 0.54 |
| Weight (kg) | 69.66 | ± | 1.32 | 70.23 | ± | 1.39 |
| BMI (kg/m$^2$) | 21.75 | ± | 0.34 | 22.19 | ± | 0.41 |
| Body fat (%) | 9.92 | ± | 0.33 | 12.62 | ± | 0.62* |
| $VO_{2max}$ (ml/kg/min) | 63.01 | ± | 0.69 | 49.23 | ± | 0.98* |
| $HR_{max}$ (beat/min) | 186.75 | ± | 1.95 | 192.73 | ± | 1.15* |

*Significantly different from trained group ($p<0.05$). BMI; Body mass index, $HR_{max}$; Maximum heart rate $VO_{2max}$; Maximum oxygen uptake.

Maximal fat oxidation rate was significantly higher in trained group than untrained group ($p<0.05$).

On the other hand, carbohydrate oxidation rate and percent of $VO_{2max}$ at $Fat_{max}$ were similar ($p>0.05$).

**Table 2. Substrate oxidation rates at $Fat_{max}$ for trained and untrained groups**

| | Trained (n=24) | | | Untrained (n=26) | | |
|---|---|---|---|---|---|---|
| | Mean | ± | SEM | Mean | ± | SEM |
| $VO_2$ at $Fat_{max}$ (ml/kg/min) | 40.90 | ± | 0.96 | 31.32 | ± | 0.95* |
| RER at $Fat_{max}$ | 0.84 | ± | 0.01 | 0.87 | ± | 0.01* |
| HR at $Fat_{max}$ (beat/min) | 139.88 | ± | 2.25 | 158.92 | ± | 2.31* |
| Fat oxidation at $Fat_{max}$ (g/min) | 0.84 | ± | 0.03 | 0.56 | ± | 0.04* |
| CHO oxidation at $Fat_{max}$ (g/min) | 1.92 | ± | 0.11 | 1.94 | ± | 0.09 |
| Contribution of fat to EE (%) | 55.31 | ± | 1.89 | 44.53 | ± | 2.75* |
| Contribution of CHO to EE (%) | 44.69 | ± | 1.89 | 55.47 | ± | 2.75* |
| $VO_2/VO_{2maks}$ at $Fat_{max}$ | 0.65 | ± | 0.01 | 0.64 | ± | 0.02 |

*Significantly different from trained group ($p<0.05$). $VO_2$; Oxygen uptake. RER; Respiratory exchange ratio. HR; heart rate. CHO; Carbohydrate. EE; Energy expenditure

## DISCUSSION

The main finding of the present study was that $Fat_{max}$ was similar (approximately 65 $\%VO_{2max}$) for trained and untrained young adult men while maximum fat oxidation rate was higher in trained group than in untrained. It has been generally accepted that regular physical activity programs increase fat oxidation rate at rest[6] and during exercise[30]. Also, it is known that a significant positive correlation between maximal fat oxidation rate and $VO_{2max}$[25]. Schwindling et al. (2014) have stated that maximal fat oxidation rate was significantly higher in the highly endurance trained group than in the endurance trained group (0.55 ± 0.22 and 0.32 ± 0.07 g/min, respectively), also the intensity that elicited $Fat_{max}$ was not significantly different between the groups (64±12 and 55±14 $\%VO_{2max}$, respectively)[27]. Also, Stisen et al. (2006) have indicated that $Fat_{max}$ was 56±3% and 53±2% $VO_{2max}$ for endurance trained and untrained women, respectively[28]. However, Nordby et al. (2006) have showed that the relative exercise intensity that elicited $Fat_{max}$ is different in trained and untrained subjects. The percent $VO_2$ at $Fat_{max}$ in their study was higher in untrained (50±1%) than trained (44±2%) individuals[22]. Venables et al. (2005) have reported that $Fat_{max}$ was performed at 52% $VO_{2max}$ in adult men[29]. Also, Achten and Jeukendrup (2003) have confirmed that $Fat_{max}$ was performed at 62.5±10.4 % and 62.3±9.6 $VO_{2max}$ in low and high $VO_{2max}$ trained men, respectively[2]. On the

other hand, Lima-Silva et al. (2010) have observed that $Fat_{max}$ was significantly lower in the low $VO_{2max}$ runner group than in the high $VO_{2max}$ runner group (0.29±0.10 and 0.47±0.17 g/min, respectively) but the intensity that elicited $Fat_{max}$ did not differ between groups (64.4±14.9 and 61.6±15.4 $\%VO_{2max}$)[20]. Inconsistencies in findings of the studies may be partly explained by the different study designs and the exercise mode.

Reliability of the $Fat_{max}$ protocols can be questioned[10,21] have examined that the reliability of $Fat_{max}$ and it was occurred at 59% $VO_{2max}$ in the first test and at 63% $VO_{2max}$ in the second one. It has been known that maximal fat oxidation rate is higher during treadmill test compared with the cycle ergometer test. However, the intensity that elicited $Fat_{max}$ is similar for the treadmill and the cycle ergometer test. The reason for this is that treadmill test resulted in higher maximal oxygen uptake than cycle ergometer test[4]. In this study, test protocol was adopted from Achten et al. (2002). Also, they reported that a continuous incremental exercise test on a cycle ergometer with 3-min stages and 35-W increments in work rate allows for valid assessment of $Fat_{max}$ and a $Fat_{max}$ zone in well-trained athletes. Fat oxidation rates appeare to be high over a large range of exercise intensities[2].

In present study, the relative contribution of fat oxidation at $Fat_{max}$ to total energy expenditure was 55% for trained and 45% for untrained. Similarly, Schwindling et al. (2014) have reported that the relative contribution of fat oxidation at $Fat_{max}$ to total energy expenditure was significantly different between the highly endurance trained and in the endurance trained group (32 % and 25 %, respectively)[27]. Bergman and Brooks (1999) have observed that trained subjects exhibited a greater contribution of lipid to total energy expenditure at 22 and 40% $VO_{2max}$ with greater absolute rates of lipid oxidation at same intensities. The relative contribution of fat oxidation to total energy expenditure at 22% $VO_{2max}$ in which there was the highest the rate of fat oxidation, was 59% for trained and 41% for untrained subjects. Also, contribution of lipid to total energy expenditure at 22 and 40% $VO_{2max}$ were higher in trained than untrained subjects. However, it at higher exercise intensity was similar for the groups[7]. Interestingly, the researchers found that the contribution of fat oxidation to energy expenditure was very low compared with our results. It has been widely believed that the contribution of fat oxidation to total energy expenditure is believed to decrease once exercise intensity exceeds 60–75% $VO_{2max}$, becoming negligible at about 85% $VO_{2max}$, which is termed $Fat_{min}$[14,23]. On the other hand, Hetleid et al. (2015) have reported that the relative contribution of fat oxidation during the high intensity intermittent exercise (85% $VO_{2max}$) to total energy expenditure was 33% for well-trained and 17% for trained athlete[15].

This study has a few limitations: Fat oxidation rate and its relative contribution to energy expenditure during exercise may be influenced by age, gender, body composition, activity duration, activity type. Also, macronutrient composition and energy balance of the diet may influence substrate oxidation rates. The subjects were informed of diet and content, but they were not monitored during the previous day before the experiment.

## CONCLUSIONS

The study results suggest that the trained individuals also have higher maximal oxygen uptake and fat oxidation rate than untrained young adults. Also, it can be said that the relative contribution of fat and carbohydrate to energy expenditure at $Fat_{max}$ were affected training status.

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