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Comparison between continuous and intermittent submaximal exercise at the intensity of maximal fat oxidation [1]

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Abstract
The aim of the study was to determine the rate of fat oxidation during continuous and intermittent acute endurance exercise. Eleven healthy untrained men participated in this study. Subjects performed Bruce protocol test on cycle ergometer to determine maximal oxygen consumption (VO_{2max}). The exercise intensity in which the highest fat oxidation rate occurs was determined in this exercise test for each subject. Oxygen uptake (VO_2) and carbon dioxide (VCO_2) production during the exercises were followed by respiratory gas analyzer and whole-body fat oxidation was calculated by indirect calorimeter equations. Subjects performed 45min intermittent (IE) and continuous (CE) exercises in respiratory exchange ratio (RER) at intensity correspondent at the highest fat oxidation rate (Fat_{max}). The peak fat oxidation rate was equal to 40.6% of maximum oxygen consumption of subjects. The changes occurring with time in fat (F=20.67) and carbohydrate (F=19.44) oxidation rates were statistically significant ($P<0.01$). However, the changes of fat and carbohydrate (CHO) oxidation with time did not show any statistically significant differences between the continuous and intermittent exercises ($P>0.05$). The results of the study indicate that the continuous and intermittent exercises performed at the exercise intensity ensuring maximum fat oxidation rate provide similar fat oxidation. Especially, for the individuals starting regular exercise applications newly, it can be said that similar positive results regarding fat oxidation can also be obtained by avoiding the insipidity of long lasting exercises and giving breaks.

Keywords: exercise; fat oxidation rate; cho oxidation; continuous exercise; intermittent exercise.

1. Introduction

One of the important energy resources of body is fat. They create problems unless they are exposed enough oxidation. The global increase in the prevalence of overweight and obesity is now reaching epidemic scale in both developed and developing countries (WHO, 2000). Therefore, researchers have researched whether the exercises done for a healthy life is suitable for its purpose or not for many years.

Treatments that prevent conditions like overweight and obesity are of considerable interest both to the general public and health-care professionals (Thompson et al, 1998). Probably the most important of these treatments is regular exercise that increases daily energy expenditure and fat

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oxidation. In addition, it has been shown in athletes that after endurance training, fat oxidation at a given intensity is increased that coincides with increases in performance (Hickson et al, 1977; Holloszy and Coyle, 1984). Many factors influence substrate oxidation rates such as exercise duration, exercise intensity, gender, hormonal status, diet, cardiorespiratory fitness and body composition (Brooks and Mercier, 1994; Romijn et al, 1994; Venables et al, 2005; Abildgaard et al, 2013; Chu et al, 2014; Achten and Juekendrup, 2004; Bircher and Knechtle, 2004). Although there has been growing interest in understanding the independent roles of cardiorespiratory fitness and body fatness on health outcomes, their relative importance on Fat_{max} during exercise have not been fully elucidated (Florez and Castillo-Florez, 2012).

The frequency, intensity, and duration of an exercise are generally more focused on increasing energy expenditure than on increasing fat oxidation (Rojmin et al, 1993; Phillips et al, 1996; Balci, 2012). Even though there are many studies related to the effect of high intensity interval exercises (Sidossis et al, 1997; Coggan, 2000; Talanian et al, 2007; Trapp et al, 2008) on substrate oxidation, there are few effects of intermittent exercises done with moderate and low intensity in the literature. It is thought that the effect of taking a break in lengthy exercises on fat metabolism can enlighten experts who create exercise programs.

Therefore, the aim of the study was to determine the exercise intensity when the highest fat oxidation rate occurs and the rate of fat oxidation during continuous and intermittent acute exercise. The results of the research are thought to contribute to the preparation of exercise programs for individuals with excessive fat and diseases like obesity.

2. Method

2.1. Population and sample selection

Eleven healthy untrained men (176.1 ± 1.1 cm, 72.1 ± 1.2 kg, 23.3 ± 0.5 years) who don't smoke, volunteered to participate in this study (Table 2). Eating habits and the levels of physical activity of the participants were arranged by the instructions given before the tests. At the night before the tests, it was said to subjects that they shouldn't eat and drink anything except water after 9:00 pm and were asked to avoid drinking alcohol, tea, coffee before 24 h of each test.

2.2. Exercise protocol

The subjects came to the laboratory on 3 different days for i) anthropometric measurements and the incremental exercise test for the determination of $VO_{2\,max}$ and Fat_{max}; ii) a 45-min continuous exercise test at the intensity corresponding to Fat_{max}; iii) a 45-min intermittent exercise (15 min x 3 bout, 5 min rest between bouts) test at the intensity corresponding to Fat_{max}. There were at least 3 days between the tests and warm up was done for 5 min before all tests.

2.3. Measurements

Subjects were weighed wearing nothing but their underwear. Weights and heights were measured with a beam balance scale and stadiometer to the nearest 0.1 kg and 0.5 cm, respectively. Body mass index (BMI) was calculated by the weight in kilograms divided by the square of the height in meters. In all subjects' four skinfold thicknesses (biceps, triceps, subscapular, suprailiac) were measured in triplicate, by the same observer. Measurements were made on the right hand side of the body using a Holtain caliper and body fat percentage was calculated by Durnin and Womersley (1974) formula.

Oxygen uptake and carbon dioxide production during exercises were observed by a portable gas analysis system (Cosmed K4 b 2, Italy). Calibrations of air in the room, gases and analyzer turbine were done before each practice. Each test data was saved from the analyzer to a laptop. The collected data included: time, breathing frequency (Rf), tidal volume (Vt), ventilation (VE), oxygen consumption (VO_2), carbon dioxide production (VCO_2), heart rate (HR), environmental temperature and pressure. Energy expenditure, and total CHO and fat oxidation rates were estimated from VO_2 and VCO_2 by using stoichiometric equations (Frayn, 1983).

CHO oxidation (g/min) = $4.55\ VCO_2 - 3.21\ VO_2$
Fat oxidation (g/min) = $1.67\ VO_2 - 1.67\ VCO_2$
The percentage of CHO and fat oxidation were calculated using the following equations (Dumortier et al, 2005):
% Fat = [(1-RER)/0.29]*100
% CHO = [(RER-0.71)/0.29]*100

Energy expenditure while resting was calculated by using the equation of Weir (1949). The average values for VO_2 and VCO_2 were calculated over the last 2 min for every stage of the modified Bruce treadmill test, and the Fat $_{max}$, $\%VO_{2\,max}$ at which the highest fat oxidation observed, VO_2 and RER at the Fat $_{max}$ variables were identified (Acthen et al, 2003).

Subjects performed a graded exercise test commencing at 60 W to determine the peak VO_2 (VO_{2max}) on, followed by 35 W increments every 3 min on the ergometer (Nordby et al, 2006). Exercise intensity corresponding to Fat $_{max}$ was determined in this test for each subject. The test was ended when the heart rate reached the peak level, RER exceeded 1.1 value or subject didn't achieve 60 r.p.m.

2.4. Research ethics

The study was approved by Non-invasion Clinical Ethics Committee of Selcuk University Faculty of Physical Education and Sports Sciences, and a consent form was obtained from each subject.

2.5. Evaluation data

Statistical analyses were performed using SPSS for Windows (Chicago, IL, USA). Statistical significance was set at a $P<0.05$ level and the data are expressed as mean ± SEM. The data were tested for normal distribution with the Kolmogorov-Smirnov test and for homogeneity of the variances with Levene's test. The statistical evaluation of the data was accomplished by using a two-way analysis of variance with repeated-measure design. The two factors (2×9) were exercise types (continuous and intermittent exercise) and the repeated measures (fat and CHO oxidation rate for each 5 min). When the time effect was significant in the ANOVA of repeated measures, one-way analysis of the variance with post-hoc Bonforoni test was applied to identify the tests and/or times responsible for the difference. Paired t-tests were used to compare mean values between continuous and intermittent exercises.

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3. Results

Table 1: Participants' characteristics and physiological parameters at Fat $_{max}$ during graded exercise test (n=11)

Variables	$\bar{X}$	±	S_x	Min- Max
Age (years)	23.3	±	0.5	21.0 – 27.0
Height (cm)	176.1	±	1.1	171.6 – 182.0
Weight (kg)	72.1	±	1.2	63,0 – 78.0
Body fat (%)	16.2	±	0.7	13.3 – 20.3
VO_{2max} (ml/kg/min)	38.6	±	1.4	30.4 – 45.6
Fat_{max} RER	0.80	±	0.02	0.7 – 0.9

$\bar{X}$± S_x; Arithmetic mean± standard error of the mean, VO_{2maks}; maximal oxygen consumption, Fat_{max} RER; respiratory exchange ratio at the intensity corresponding to Fat_{max} (VCO_2/VO_2).

Table 2: Differences in respiratory parameters, CHO and fat oxidation between the continuous and intermittent groups during exercises.

Variables	CE mean	±	S_x	IE	±	S_x	t
Rf (breaths/min)	24.93	±	0.32	23.74	±	0.92	1.09
VE (L/min)	30.79	±	0.72	32.84	±	1.17	-1.31
VO_2 (ml/min)	1121.50	±	24.10	1213.23	±	46.48	-1.45
VCO_2 (ml/min)	983.12	±	19.64	1056.03	±	41.98	-1.30
RER (VCO_2/VO_2)	0.88	±	0.01	0.87	±	0.01	0.39
HR (beats/min)	113.76	±	2.14	122.27	±	3.21	-1.95
Fat oxidation (gr/min)	0.23	±	0.02	0.26	±	0.02	-0.98
CHO oxidation (gr/min)	0.87	±	0.05	0.91	±	0.07	-0.45

S_x; standard error of the mean, CE; continuous exercise, IE; intermittent exercise, t; difference of means, Rf; respiratory volume, VE; ventilation, VO_2; oxygen uptake, VCO_2; carbon dioxide production, RER; respiratory exchange rate (VCO_2/VO_2), HR; heart rate.

Changes in CHO oxidation, fat oxidation, Rf, VE, RER and HR were not different between intermittent and continuous exercise groups (P>0.05) (Table 2).

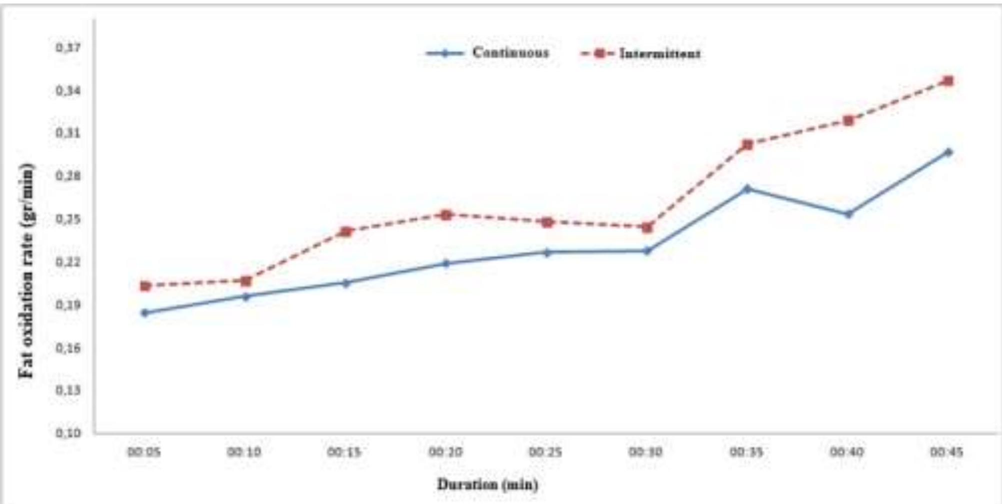

Figure 1: Changes in fat oxidation during continuous and intermittent exercises (gr/min)

The changes in fat oxidation for the 5 minute sections of the exercises were significant in the intermittent and continuous exercises (F=20.67; P<0.01). The fat oxidation rate in the last 15 min of the both exercise groups was significantly higher compared to the first 30 min (P<0.01). Fat oxidation rates were similar during 45 min exercises for both groups (F=0.92; P>0.05). Furthermore, fat oxidation rates were not different in both groups (time effect F=0.87, time-exercise interaction P>0.05) (Figure 1).

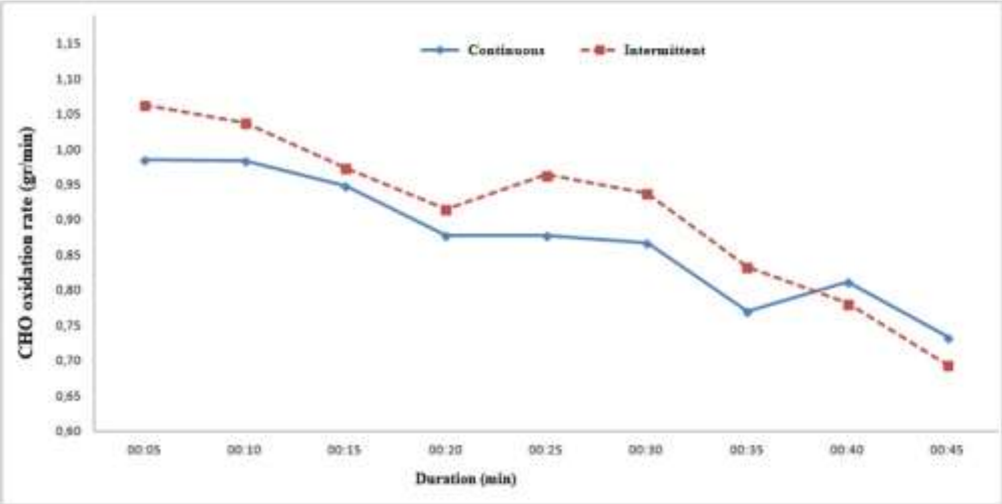

Figure 2: Changes in CHO oxidation during continuous and intermittent exercises (gr/min)

CHO oxidation rates calculated for the 5 minute sections of the exercises were statistically significant (F=19.44; P<0.01). However, the change of CHO oxidation rate with time did not display any statistically significant differences between continuous and intermittent exercises (time effect F=0.87, time-exercise interaction P>0.05). CHO oxidation rates were similar during 45 min exercises for both groups (F=0.21; P>0.05) (Figure 2).

4. Discussion

It is important that the fat oxidation rate should be increased to regulate metabolism during exercises done for health. It is known that the energy used in moderate and high intensity exercises is mostly CHO. It was determined that maximal endurance exercises increase the fat oxidation rate considerably during submaximal exercises. Researches in which many subject involved support the knowledge that long lasting and continuous exercises increase fat oxidation during exercise thereby decrease the using CHO as energy source. Although studies were applied mostly on overweight men, it was observed that these exercises increase the fat oxidation rate on women, old and obese individuals (Acthen and Jeukendrup, 2004).

In the research carried out in connection with exercise types; with similar work-load when compared to bicycle ergometer with running exercise on treadmill, fat oxidation rate is considerably higher on exercise done on the treadmill (Acthen et al, 2003). Studies analyzing energy metabolism during exercises revealed that even though fat oxidation rate increases at the beginning of the exercise; when the intensity of the exercise gets increased, CHO oxidation rate increases much more. Therefore, in exercise programs aiming at decreasing the percentage of body fat, the type and the intensity of the exercise gains importance (Nordby, 2006). Thus, in this study, 45 minute continuous and intermittent aerobic exercises were done at the intensity of maximum level of fat oxidation that was determined as personal. The changes of these exercises at intervals of 5 minute were statistically researched and comparisons were made.

In this study, the peak fat oxidation rate is equal to 40.6% of maximum oxygen consumption of subjects. There are a lot of researches to determine the peak fat oxidation rate on individuals with different ages, genders and training situations. It is stated that maximum oxygen consumption on untrained individuals VO2max is 47-52 %, on trained individuals within the range of 59-64% of exercise intensities peak fat oxidation speed was reached (Acthen and Jeukendrup, 2004; Pillard, 2007). Croci et al. (2014) reported that peak fat oxidation rate was 46% VO2max in overweight and 45% in lean males. Venables et al. (2005) carried out a research on 300 subjects whose age range is 18-65 on treadmill and stated that the maximal fat oxidation rate occurs when the exercise intensity is 44.9% for men and 51.9% for women.

Achten et al. (2002), applied on young trained cyclists to determine the exercise intensity needed to be applied to obtain the speed of maximum fat oxidation, it was figured out that in bicycle ergometer, exercise intensity applied three minutes 35 W load increment is in accordance with the determination of maximal fat oxidation rate of trained individuals. Also, it was stated that when the exercise intensity (59-65%) of maximal fat oxidation is exceeded, the usage of CHO increases rapidly.

The present study, on the fat oxidation rate calculated in the 5 minute parts of exercise, it was seen that changes occurred in time are statistically important. While in both exercise practices the fat oxidation rate occurring in the last 15 minutes were significantly higher than the fat oxidation rate occurring in the first 30 minutes, the fat oxidation speed displayed similarities in continuous and intermittent exercises. Also, changes taking place in time during the fat oxidation rate didn't display a significant difference between continuous and intermittent exercises. In another study done in parallel with this, in continuous and intermittent exercises including similar work load, it was stated that there was no significant difference in terms of fat and CHO oxidation on energy expenditure (Achten et al, 2002). Essen et al. (1977) reported that a 60 minute continuous submaximal aerobic exercise practice and metabolic answers towards the exercise practices comprised of 15 seconds of practicing and 15 seconds of resting ranges done in similar workload and oxygen consumption were similar. In addition to this, when changes in substrate oxidation rates in bicycle ergometer at the level of 50% of 90 minute maxVO_2 during continuous and intermittent exercises, it was figured out that there was no significant difference on total energy expenditure; however, in intermittent exercises the fat oxidation rate was lower than continuous exercises (Warren et al, 2009). On the other hand, Gerber et al. (2014) stated that more fat loss observed with the high intensity intermittent exercise when compared with continuous steady state exercise.

In spite of this, it is known that high intensity intermittent exercises generate fat acid oxidation more than continuous moderate exercises (Chilibeck et al, 1998). Although in continuous and intermittent exercise practices done with equal oxygen consumption, a difference wasn't figured out in total energy expenditure, there was a difference at the rates of used substrate, it was determined that in spite of the continuous exercise practice, in intermittent exercise practice fat oxidation rate was almost less then three times, despite this CHO oxidation rate displayed 1,5 times higher (Christmass et al, 1999). In another research, it was reported that although similar hormonal changes were seen in both moderate aerobic exercises applied in two sections and at once with an hour period, repetitive exercise applied in two sections proved clearer high fat oxidation than exercise applied at once (Goto et al, 2007). In the studies conducted on younger age groups, it was determined that short-time sprint, interval exercises led more fat oxidation than 30 minute intermittent exercise. Also, when considered the choices of participants, it was stated that short-time interval exercises were preferred more (Crisp et al, 2012).

The present study has a few limitations. First, fat oxidation during exercise may be influenced by many factors (e.g., age, gender, body composition, activity duration, activity type, diet, and training status). Second, energy balance and macro nutrient composition of the diet may influence substrate oxidation rates. The participants were informed about dietary measures and content the previous day before the tests (Jeukendrup and Wallis, 2005; Balci, 2012).

In the study, in the last 15 minutes of the intermittent exercises and only in the last 5 minutes of the continuous exercises, it was seen that fat oxidation rate was more dominant than carbohydrate in substrate oxidation rates. According to the results, it was seen that maximum fat oxidation was observed in the range of large exercise intensity (25-60% $MaxVO_2$) and when intensity needed for maximum fat oxidation is exceeded, the fat oxidation rate decreases considerably. It can be said that besides exercise intensity factors such as age, gender, type of exercise, content and amount of nutrition taken before and after the exercises, body composition can affect the fat and CHO oxidation rates in the process of recovery during and after the exercises.

5. Conclusions and recommendations

In this research, in the last 15 minutes of intermittent exercises and only in the last 5 minutes of continuous exercises, fat oxidation rate was higher than carbohydrate in substrate oxidation rates; it was seen that at submaximal level when exercises got extended, used energy source was formed mostly by fat. It drew the attention that in survey carried out in the literature search, intermittent aerobic exercises were preferred rather than continuous exercises not to be boring. Because of having acquired similar results in the fat oxidation rate, it is suggested that at exercise level in which maximal fat oxidation rate occurs, at least 45 minute and more intermittent exercises should be done to steer away from monotony and to increase the applicability of regular physical activities.

Factors affecting fat oxidation rates in exercise programs to prove positive changes at significant level on body composition should be taken into consideration. As a result of this study done in parallel with these factors, during intermittent and continuous exercises a significant difference on total energy expenditure and substrate oxidation rate was not found.

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