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Report of Health Care **Original Article**

Volume 3, Issue 3, 2017, p. 1- 7

The Effect of Prolonged and Graded Exercise Protocols on Maximal Fat Oxidation and Fat_{max} in Trained Girls

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Received: 7 February 2017
Accepted: 23 August 2017
Published online: 1September 2017

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Competing interests: The authors declare that no competing interests exist.

Citation: Moradi Z, Habibi A, Ghanbarzadeh M. The effect of prolonged and graded exercise protocols on maximal fat oxidation and Fat_{max} in trained girls. Report of Health Care. 2017; 3 (3): 1- 7.

Abstract

Introduction: The intensity and duration of exercises are the main factors of fat oxidation and carbohydrate during the exercise. The aim of this study was to investigate the effect of prolonged and graded exercise protocols on maximal fat oxidation (MFO) and Fat_{max} in trained girls.

Methods: Ten trained girls (age = 22.3 ±1.8 years old; weight= 53.3±3.4 kg; BMI= 20.6 ± 1.1 kg/m^2 and VO_{2max}= 34.2±2 ml/kg/min), attended the laboratory on seven separate occasions. In the first visit, anthropometrics and maximal oxygen uptake (VO_{2max}) measurements were assessed. In the second session, participants completed a submaximal graded exercise protocol with seven stages, 3 min per stages at intensity of 35, 40, 45, 50, 55, 60 and 65% of VO_{2max}. Next, each participant in five separate sessions consisting of 30 min prolonged exercises performed exercises in a counterbalanced order of intensity at 40, 45, 50, 55 and 60% VO_{2max}. For statistical analysis of data Shapiro Wilk and paired sample t-test ($p \leq 0.05$) were used.

Results: The results showed that there was a significant difference between MFO (p=0.01) and Fat_{max} (p=0.04) after graded and prolonged exercises.

Conclusion: It appears that prolonged exercise caused a higher MFO and Fat_{max} rather than graded exercise in trained girls.

Keywords: Graded Exercise, Prolonged Exercise, Maximal Fat Oxidation, Fat_{max}

Introduction

Fat and carbohydrates are the main sources utilized in both exercising and resting. The amount of using these two sources as substrates depends on dietary status, muscle glycogen supply, intensity, duration and the type of the exercise (1). In this regard, the intensity and duration of the exercise are the two magnificent effective factors in at and carbohydrate oxidation (1). Although it has been well documented that increased fat oxidation increases with longer training periods, choosing a proper intensity is a controversial issue (2, 3). There have been so many studies that have measured the trends of fat oxidation in various levels of intensity (4, 5, 6). However, determining a precise intensity of the exercise in which the most amount of fat oxidation occurs is difficult. Romjin *et al.* (7, 8) concluded that using 65% maximal oxygen uptake led to maximal fat oxidation (MFO), while van Loon *et al.* (9) determined this maximum at 55% of the maximal workload (equal to 57% of $VO2_{max}$, on average). Due to the obvious inequality and using prolonged exercise tests Achten *et al.* (10) introduced an alternative protocol. Achten *et al.* (10) ascertained ‘‘Fat_{max}’’ the intensity eliciting maximal fat oxidation via indirect calorimetry by means of an incremental cycling protocol with stages of 3 minutes duration (10). They found out that the fat oxidation rate reached the peak in exercise intensities between 62 ± 3 and 64 ± 4 percent of VO_{2max}, and then in a higher exercise intensity it decreased dramatically reaching a negligible amount (10, 11). Fat_{max} is usually determined in incremental tests. However, its repeatability has not been investigated yet (12). Using the 3-minute-process (10) has been criticized in some studies (3). Using the incremental exercise has affected Fat_{max} in so many factors. In other words, Fat_{max} not only depends on the ability of individual metabolism to oxidize fat acids but also it depends on the types of the procedures to determine $Fat_{max.}$ The main problem in incremental exercise tests is that substrate consumption in the latter stages is affected by exercise intensities in the former process of the test. Another problem which is more significant is the duration of the exercise performing under each intensity, because the portion of fat to supply energy increases during exercising for a long time (3, 6, 13). Due to the importance of fat oxidation in exercises, and also activities related to health, the aim of this study was to investigate the effect of prolonged and graded exercise protocols on maximal fat oxidation and Fat_{max} in trained girls.

Methods

In this semi-experimental research, the participants were 10 trained female university students. Each participant had been an athlete for two years and had exercised at least three days a week before. Other criteria to qualify the study were having a good condition, being trained, lacking casualty, being nonsmoker, and having no disease. Participants got ready to take part in the study after being familiarized with the research design. The test was given at 8:00 to 11:00 a.m. to all subjects. The participants were asked to fast the night before the test. The individual characteristics of the subjects are presented in Table1. In the first session in the laboratory the height of participants were measured by a digital height gauge and their weight were measured by a digital scale. Then their fat percentages were estimated through bioelectrical impedance by Body Composition device (INBODY3/3, model OLAMPIA, made by Jawon Korean company). Afterwards, VO_{2max} was measured by Maximal Bruce Test. In the second session, participants completed a submaximal graded exercise protocol with seven 3-min stages (Graded Exercise) at 35, 40, 45, 50, 55, 60 and 65% VO_{2max} (14). Next, participants performed 30 min prolonged exercises at the intensities of 40, 45, 50, 55 and 60% VO_{2max} in five separate days, at one week interval (16). Table 2 shows the intensity of exercises of participants (% VO_{2max}), which comprise two kinds of protocols (prolonged exercise and graded exercise). In order to compare variables of two types of exercises, the same intensities were chosen, compared, and analyzed statistically. Participants started exercising on a treadmill at the intensity of 35% VO_{2max}. The intensity was increased every 3 minutes from 35, 40, 45, 50, 55, 60 and 65% of VO_{2max}, until reaching the seventh stage respectively. Heart rate was measured by Polar electrocardiograph during the test. Meanwhile, the oxygen consumption and carbon dioxide exhaustion were measured through gas analyzer (model GANSHORN, made in Germany) and were recorded in a computer using an LF8 software. Following that, with the assumption that the amount of urinary nitrogen is negligible, fat oxidation rate was measured by using the following equations to measure substrates (15).

Fat Oxidation (g/min) = 1.67 VO2- 1.67 VCO2

According to the above equation, V_{CO2} and V_{O2} have been considered as liters per minute and fat oxidation as grams per minute. A scatterplot of fat oxidation rate versus exercise intensity was constructed for each participant. The individual exercise intensity in which Fat_{max} occurred, and the corresponding MFO was shown. These graphs illustrate MFO, Fat_{max} and the range of exercise intensities whereby fat oxidation rates are within 10% of Fat_{max} (range of exercise intensities whereby fat oxidation rates are within 10% of MFO (10). Next, each participant in five separate sessions, at one week interval completed a 30 min prolonged exercise at the intensity of 40, 45, 50, 55 and 60 % VO_{2max} counterbalanced order. Following that, the average energy consumption and carbon dioxide exhaustion were measured to determine the fat oxidation rate during 30 min of the protocol which was divided in to four last- two- minute of time points (3rd, 10th, 20th and 30th min). As it was mentioned before, scatterplots of fat oxidation rate versus exercise intensity for each participant was plotted. These graphs illustrate MFO, Fat_{max} and the range of exercise intensities whereby fat oxidation rates are within 10% of Fat_{max}. The data was obtained by a gas analyzer software (LF8) as a standard form for all participants. Shapiro Wilk test was applied to determine having a normal data distribution. In order to determine the equality data variances, Leven's test was utilized. The comparison of Fat_{max} and MFO between graded and prolonged exercises were done through the paired sample t-test ($p \leq 0.05$).

Results

Mean and standard deviation of participant's anthropometric characteristics are illustrated in Table 1. Fat oxidation rate during the two types of exercises of participants has been shown in Table 3; also the MFO and Fat_{max} of participants have been shown in Table 4. The results of paired sample t-test in Table 4 showed that there was significant difference between MFO ($p=0.01$) and Fat_{max} ($p=0.04$) after graded and prolonged exercises.

Table 1. Mean and standard deviation of individual characteristics

Variable	Mean ± Standard Deviation
Age (year)	22.3±1.8
Height (cm)	160.8±4.5
Weight (kg)	53.3±3.4
BMI (kg/m^2)	20.6±1.1
Body Fat (percent)	25.5±2.9
VO_{2max} (ml/kg/min)	34.2±2

Table 2. The intensity of participants activities (% VO_{2max})

Exercises / Stage	Graded Exercise Intensity (% VO_{2max})	Prolonged Exercise Intensity (% VO_{2max})
Stage 1	35	40
Stage 2	40	45
Stage 3	45	50
Stage 4	50	55
Stage 5	55	60
Stage 6	60	-----
Stage 7	65	-----

Table 3. Fat oxidation rate (g/min) during two types of exercises

Protocol / Intensity	Graded Exercise Mean	Graded Exercise SD	Prolonged Exercise Mean	Prolonged Exercise SD
35%VO_{2max}	0.07	0.04	-----	-----
40%VO_{2max}	0.08	0.03	0.12	0.07
45%VO_{2max}	0.07	0.02	0.11	0.08
50%VO_{2max}	0.06	0.02	0.15	0.09
55%VO_{2max}	0.08	0.03	0.12	0.06
60%VO_{2max}	0.05	0.03	-----	-----
65%VO_{2max}	0.06	0.03	-----	-----

Table 4. The results of paired sample t-test for MFO and Fat_{max} in graded and prolonged exercises

Variable	Protocol	Mean	SD	df	t	p
Fat_{max} (g/min)	Graded Exercise	0.08	0.03	9	2.23	0.04
	prolonged Exercise	0.15	0.09			
MFO (g/min)	Graded Exercise	0.11	0.03	9	3.05	0.01
	prolonged Exercise	0.21	0.08			

Discussion

The purpose of this study was to compare the MFO and Fat_{max} between graded and prolonged exercise protocols. The intensity (Fat_{max}) that elicits MFO during a graded exercise test has been suggested as a reference method to prescribe exercise training in which optimizing fat oxidation is the goal (10). The main advantage of the Fat_{max} test is that the MFO is determined with the use of a single graded exercise test protocol, rather than undertaking several constant load tests performed with different workloads on different days (3). Despite the easiness of the graded exercises, there are some potential limitations for these protocol exercises that affect the reliability of the Fat_{max} (14). Firstly, the rate of fat oxidation has been observed to increase as the duration of exercise progresses (3, 6) suggesting that Fat_{max} also has the potential to change across time. Further, the carry over effects between consecutive stages of graded exercise tests may influence substrate oxidation, particularly during the latter stages of the protocol (14).

In this study, fat oxidation rate was measured across 30 min of prolonged exercises at 40, 45, 50, 55 and 60% of VO_{2max} and there were no significant differences. However, it was observed that longer exercise durations may promote enhanced fat oxidation (3, 6). In the initiating time of exercises with low intensity, a great portion of carbohydrate is consumed. With increasing the time of exercises, fat free acid (FFA) gets released and further fat is oxidized (3). In addition, Lipolysis stimulation and FFA availability are enhanced during prolonged exercise, primarily because of an increase in catecholamines and a decrease in insulin levels (16, 17). In the present study, a significant difference has been seen in both graded and prolonged exercises protocols in the intensity in which the MFO occurs. In agreement with our findings, Bircher *et al.* (18) reported that the protocol that was more time consuming indicated a higher Fat_{max} intensity and MFO than those indicated by the shorter protocol, although the increments for both protocols were small. Moreover, Chenevière *et al.* (6) reported that the Fat_{max} intensity and MFO during incremental exercise were increased after 1 hour of constant load exercise, compared with those before constant load exercise. In contrast, Achten *et al.* (10) concluded that exercise duration did not affect Fat_{max} intensity. However, their study was designed to compare several constant exercise workloads which had been set at relatively large differences. The duration of each exercise was selected so similar that they become equal in energy expense (EE) of 2.8 mega Joule (MJ). Nevertheless, the workloads of 95 to 270 watt (W) for the duration of each prolonged exercise in time interval of 35 to 80 minutes were taken into account (10). Furthermore, they tuned the intensity based on the only maximal amounts of ergometric (for instance % VO_{2peak}) which might have resulted in the workload of heterogeneous metabolism due to the conditional individual metabolism (10).

The results of the present study showed that MFO between the two types of exercises was significantly different. Some conducted studies which compared MFO between two kinds of graded and prolonged exercise protocols in different intensities, have observed similar results (6, 18, 19). Chenevière *et al.* (6) have reported that one hour prolonged exercise with moderate intensity, increases Fat_{max}, MFO and fat oxidation rate with large amount of intensity in incremental test. In contrast, Alkahtani reported that there was not a significant difference in elicited MFO and average of fat oxidation rate in graded exercise test compared to moderate intensity interval test (MIIT) (20). In their research MFO in graded activity was compared with fat oxidation average during thirty minutes of interval activity with moderate intensity (20). The 30-min MIIT included 5-min repetitions of workloads 20% above and 20% below the MFO intensity. Various kinds of intensities have different metabolic responses. Studies show that applying high intensity at the early stages of exercises with low and high intensities, can lead to more fat oxidation (21, 22). Therefore, fat oxidation rate in thirty minutes interval activity can be affected by the order of intensity of activities in each stage of the test. In addition, a recent study showed that there was not a significant difference between the MFO in overweight 10 year-old boys who exercised at 40, 45, 50, 55 and 60% VO_{2max} during 30 min constant load exercise compared with graded exercise test (16). It might be because of the different rate of substrate oxidation between adults and children (23). The physiologic and metabolic characteristics of children bodies during exercises are different from adult needs. Increasing fat oxidation compared to carbohydrate in children bodies during moderate intensity activities decreases the dependability on glycogen as a main metabolism (24). The source of energy to do the prolonged activities activates in children is somehow more dependent on fat oxidation compared to adults in terms of releasing FFA, glycerol and growth hormone (25). The differences between scientific reports in MFO values are probably due to the differences in procedures of methods, the intensity and duration of the exercises, the primary level of physical fitness of participants and the individual differences.

Conclusion

According to the results of the present study it appears that prolonged exercise caused a higher MFO and Fat_{max} rather than graded exercise in trained girls.

Ethical issues

No applicable.

Authors' contributions

All authors equally contributed to the writing and revision of this paper.

Acknowledgments

I would like to express my sincere gratitude to all professors who assisted me to conduct an edition to this research. Also, I am grateful to all participants who took part in this research.

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