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Original Article

Maximal fat oxidation at the different exercise intensity in obese and normal weight men in the morning and evening

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ABSTRACT

Mohebbi H, Azizi M. Maximal fat oxidation at the different exercise intensity in obese and normal weight men in the morning and evening. *J. Hum. Sport Exerc.* Vol. 6, No. 1, pp. 49-58, 2011. Introduction: Circadian rhythms regulate some metabolic and hormonal variables that affect fat oxidation rates. Thus, the purpose of this study was to investigate Maximal fat oxidation (MFO) at a different exercise intensity in obese and normal weight men in the morning and evening. Methods: MFO was measured in 12 normal weight (BMI 20-25 kg/m^2; VO_2max 45.7±3.44 ml/min/kg) and 10 obese (BMI >30 kg/m^2; VO_2max 37.2±3.6 ml/min/kg) men during incremental running exercise test with 3 min stages on the treadmill by indirect calorimetry method. Student's t-test and one-way ANOVA with repeated measures were used to analysis variables. Results: We found that fat oxidation rates and energy expenditure in both groups in the evening were higher than morning; there were no significant differences in MFO between obese and normal groups. Furthermore, the fat oxidation rate in low intensity exercise (<60% VO_2max) was similar in obese and normal weight groups, but in high exercise intensities, in normal weight men were significantly higher than obese men. Conclusion: Our results suggest that independent of exercise intensity and body fat mass, exercising in the evening is more effective on fat oxidation and decrease body fat mass; therefore, it is better for weight loss purposes in obese and normal weight men. **Key words**: MAXIMAL FAT OXIDATION, TIME OF A DAY, OBESE AND NORMAL WEIGHT MEN.

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INTRODUCTION

Daily light-dark cycle governs rhythmic changes in the behavior and/or physiology of most species. Studies have found that these changes are governed by a biological clock, which in mammals is located in two brain areas called the suprachiasmatic nuclei. The circadian cycles established by this clock occur throughout nature and have a period of approximately 24 hours (Froy, 2010). The performances, substrate oxidation as well as the effects of physical exercise are known to depend on the time of a day when the exercise is performed (Yujiro et al., 2006).

Human studies indicate that heart rate (Garet & Kirkendall, 1999), Gastric emptying, gut absorption rate and gastro-intestinal enzyme activity, all peak at certain times during the day (Goo et al., 1987). Also body temperature, oxygen consumption (Weinert & Waterhouse, 2007) and catecholamine levels (Ayako & Keiichi, 1995) are peaked in the afternoon. In addition, in the previous study we reported that energy expenditure and oxygen consumption during 30-min treadmill exercise at intensities of 65% of VO_2max, were higher at 18:00 than 08:00 (Rahmani-Nia, Azizi, & Mohebbi, 2009). Thus, we hypothesize that change in these variables can alter the substrate oxidation.

Also, fat oxidation rate in sedentary, obese subjects compare to normal weight subjects during exercise is not well documented. In obese subject defects in skeletal muscle fat metabolism has been found in post-absorptive conditions, and β-adrenergic stimulation (Ellen & Wim, 2002). Moreover, carbohydrate and fat metabolism defects may interact, especially through substrate competition. Thus, this blunted capacity to oxidize fatty acids may play an important role in the development of a positive fat balance and may increase fat storage in obese subjects (Lazzer et al., 2007).

However, Steffan et al. (1999) compared rates of fat oxidation in obese and normal weight subjects with similar VO_2max values ($ml \cdot kg^{-1} \cdot LBM^{-1} \cdot min^{-1}$) and found no difference in substrate use between the two groups (Steffan et al., 1999). Also Ranneries et al. (1998) found no difference in fat oxidation between formerly obese women and normal weight women at 50% VO_2max (Ranneries et al., 1998). However, Goodpaster et al. (2002) show that fat oxidation during cycle exercise (50%VO_2max) in obese subject was higher than lean subjects (Goodpaster et al., 2002). On the other hand, De´riaz et al. (2001) reported that an increase in intracellular muscle fat stores may facilitate the contact between intracellular fat stores and mitochondria and lead to an increase in fat oxidation rate (De´riaz et al., 2001).

However, little is known regarding patterns of substrate utilization during exercise in severely obese adolescents compared with normal-weight sedentary adolescents in the morning and evening. In addition, given the potential effects of obesity and time of a day on substrate selection during exercise, it is of particular importance to compare substrate utilization during exercise in obese and normal weight men at the different time of a day. Therefore, the objectives of the present study were to determine maximal fat oxidation (MFO) and the exercise intensity at which the fat oxidation rate was maximal (Fatmax) at a different exercise intensity in obese and normal weight men in the morning and evening.

MATERIAL AND METHODS

Twenty two healthy, untrained (VO_2max <50 ml/min/kg and physical activity less than three sessions per week) men between the ages of 19 and 25 year voluntary participated in this study. Subjects include 10 obese (BMI >30 kg/m^2) and 12 normal weight men (BMI 20-25 kg/m^2). Self-administrated questionnaires established participants to be nonsmoking, free from diabetes, hypertension, and coronary heart disease, and they were not taking medications known to influence metabolic responses. All subjects were weight stable (±1 kg) at least 3 months before our study. Subjects were instructed not to engage in any strenuous exercise on the day preceding an experimental test, and they participated in 5 separate trials spaced between 5 to 7 days from each other. The order of trials was randomized and followed a counterbalanced format. An institutional ethics review board at University of Guilan approved this study, and all volunteers provided written informed consent before participation.

Body composition

Body mass index was calculated as mass (in kilograms) divided by height squared (in square meters). Whole-body fat mass and fat-free mass (FFM) was measured by the bioelectrical impedance method (In Body 3.0, Korea) approximately 1 week before the first admission.

Testing protocol

The exercise protocol used here was adapted from a previously described and validated protocol (Achten et al., 2002) in which it was concluded that an incremental exercise test with stages of 3-min duration could be used to determine both MFO and Fatmax (Achten et al., 2002). The subjects started exercising at a speed of 3.5 km/h and at a gradient of 1%. The speed was increased by 1 km/h every 3 min until a speed of 6.5 km/h was reached. At this point, the gradient was increased by 2% every 3 min until an RER of 1 were reached. Finally, the speed was increased every minute until exhaustion. The aim of the final section of the exercise test was to obtain a measure of VO_2max within a short time. Breath-by-breath measurements were taken during exercise by using an open circuit gas analysis system (COSMED, Quark b2, s.r.l. Rome, Italy). As a result of the familiarization sessions, minimal adjustments were required during the experiment. Exercise in the morning session began at 08:00 after 8-12 h fasting (Kanely et al., 2001), and in evening session exercise began at 18:00 after 5-6 h fasting (Thuma et al., 1995).

Indirect calorimetry and calculations

Oxygen uptake (VO_2) and carbon dioxide production (VCO_2) was averaged over the last 2 min of each exercise stages that the RER was <1.0. For each of these stages, fat and carbohydrate oxidation were calculated by using stoichiometric equations (Frayn, 1983), with the assumption that urinary nitrogen excretion rate was negligible. Fat and CHO oxidation rates were then plotted as a function of exercise intensity, expressed as a percentage of maximal oxygen uptake (VO_2max). From each fat oxidation curve, several features were identified according to a previously described procedure (Achten & Jeukendrup, 2003): 1) MFO, the peak rate of fat oxidation measured over the entire range of exercise intensities, and 2) Fatmax, the exercise intensity at which the fat oxidation rate was maximal. 3) Fatmin: the exercise intensity where the fat oxidation rate reached zero (i.e., where RER ≥ 1.0).

Statistical analysis

Results are reported as the mean ± SD. Student's t-test was used to compare subject characteristics. A two-way ANOVA (obese vs. normal weight) with one factor repeated measure (time) was used to evaluate fat and CHO oxidation and energy expenditure between groups during exercise. For all statistical procedures, the significance level was set at $p \leq 0.05$.

RESULTS

Characteristics of the obese and normal weight men are reported in Table 1. Weight, Body mass index (BMI), Fat mass, fat percent and fat free mass (FFM) were significantly higher in the obese than in normal weight men ($p \leq 0.05$). Absolute VO_2max was significantly higher in the obese than the normal weight group ($p \leq 0.05$); However, VO_2max was similar when adjusted for FFM between obese and normal weight men.

Table 1. *Characteristics of the obese and normal weight men.*

	Obese		Normal weight	
Age (year)	22.7±2		22.08±1.5	
Height (cm)	177±4.4		173±6.1	
Weight (kg)	102±11.3†		67.6±7.3	
BMI (kg/m^2)	32.5±2.2†		22.3±1.1	
Fat mass (kg)	31±8.2†		10.6±2.9	
Fat (%)	29.9±5.3†		14.8±3.9	
FFM (kg)	71.5±6.1†		56.8±7.3	
HR maximum (beat/min)	196.8±0.78		197.7±1.3	
	AM	**PM**	**AM**	**PM**
VO_2max (ml/min/FFM)	53.1±3.3	52.4±1.8	54.64±3.2	53.99±2.9
VO_2max (ml/min/kg)	37.2±3.6†	36.9±0.23†	45.7±3.44	45.3±3.2
MFO (mg/min/FFM)	6.57±0.93	7.16±1.1∗	6.12±1.5	7.18±1.5∗
FATmax (%VO_2max)	40.2±4.4†	45.1±6†∗	47±9.8	53.2±7.2∗
FATmin (%VO2max)	90.5±3.8	93.1±4.3	93.6±2.7	92.9±2.7
Body temperature (C^0)	36.9±0.23	37.2±0.15∗	37±0.17	37.2±0.24∗

Values are means ± SD. FFM, Fat-free mass; BMI, Body mass index; HR, heart rate; MFO, maximal fat oxidation.
†: Significantly different from normal weight ($p \leq 0.05$).
∗: Significantly different from morning ($p \leq 0.05$).

Our results show that fat oxidation rates (mg/min) in both groups, at all exercise intensities in the evening were higher than morning ($p \leq 0.05$) (Figure 1). There were no significant differences in CHO oxidation in the morning and evening for both groups. In obese men, MFO (mg/min/kgFFM) in the evening (7.16±1.1) was significantly higher than morning (6.57± 0.93) ($p \leq 0.05$). In addition, in normal weight men MFO was significantly higher in the evening (7.18±1.5) than morning (6.12±1.5) ($p \leq 0.05$). There were no significant differences in MFO between obese and normal weight groups in the evening and morning. We found that fat oxidation rates (mg/min/kgFFM) at 60%, 70% and 80 % VO_2max in the morning and evening in normal weight men were significantly higher than obese men ($p \leq 0/05$) (Figure 3). The findings of Borg scales show that rate of perceived exertion (RPE) in both groups in evening was lower than morning (Figure 2).

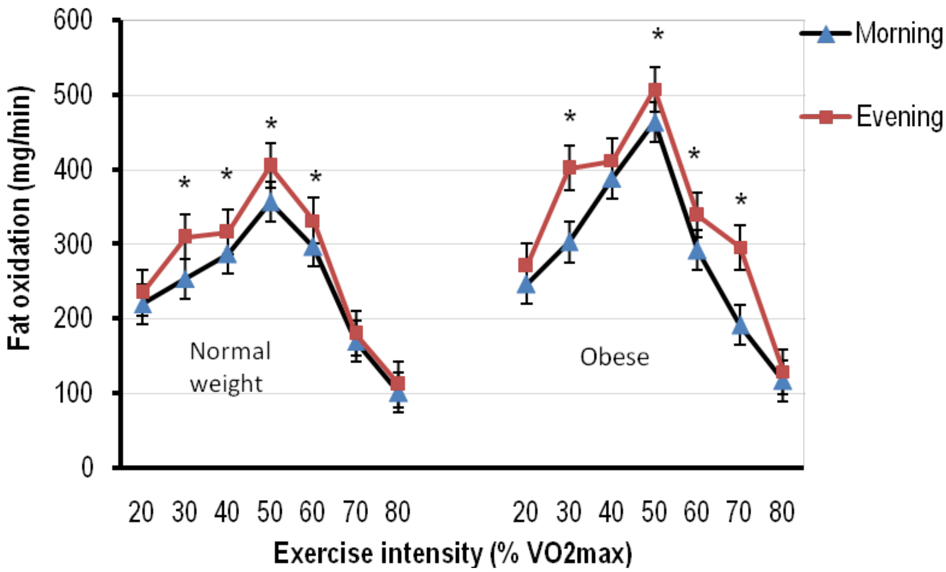

Figure 1. *Comparison Fat oxidation rates in the evening and morning in obese and normal weight men (*p≤0.05).*

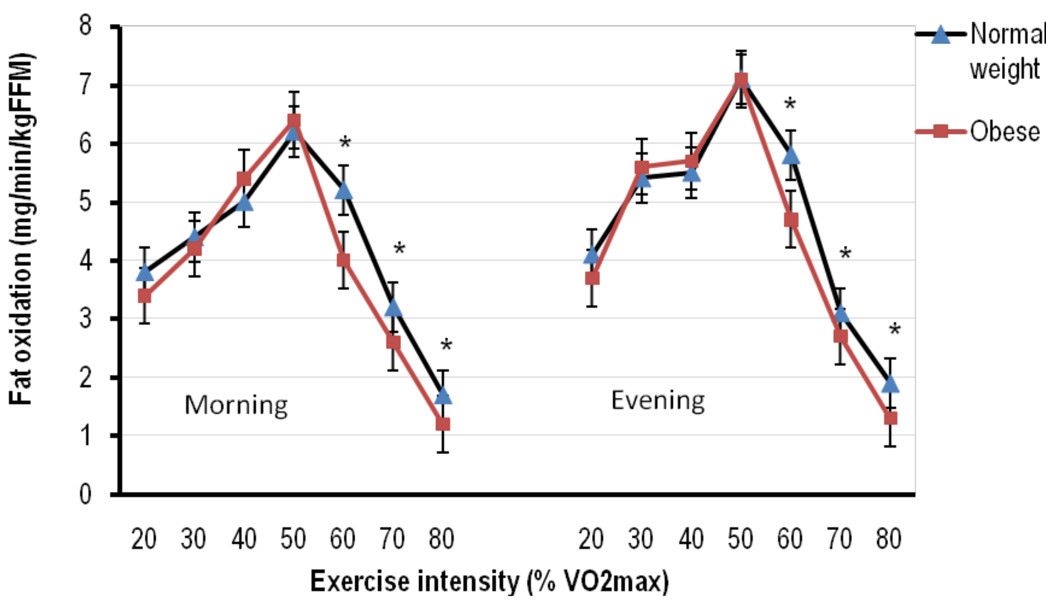

Figure 2. *Comparison Fat oxidation rates in obese and normal weight men in the evening and morning (*p≤0.05).*

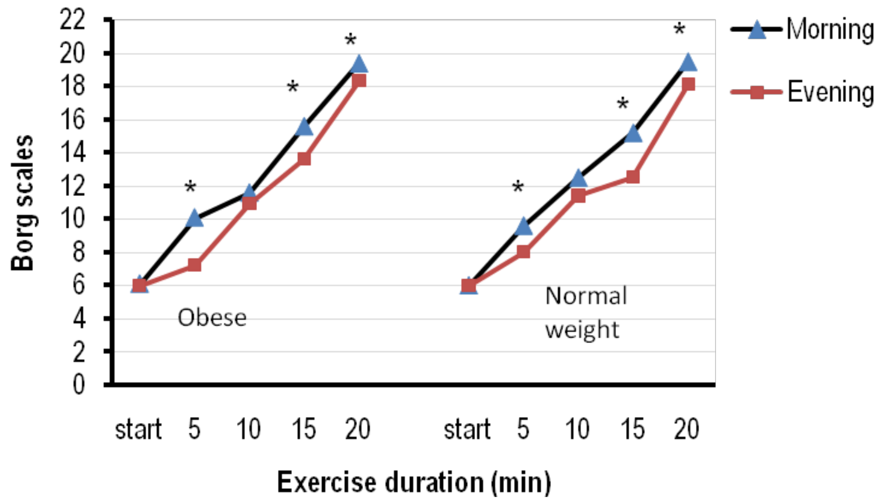

Figure 3. *Comparison RPE in the evening and morning in obese and normal weight men (*p≤0.05).*

Fatmax occurred at an exercise intensity around 45.1±6% and 40.2±4.4% VO_2max in obese and 53.2±7.2% and 47±9.8 % VO_2max in normal weight groups in the evening and morning respectively. Fatmax was significantly higher in the evening than morning in both groups (p≤0.05). Fatmin in the morning was found at (≥ 93.6 ± 2.7% VO_2max) in normal weight and (≥ 90.5 ± 3.8% VO_2max) obese groups, and Fatmin in the evening were found at≥(92.9 ± 2.7% VO_2max) in normal weight and ≥(93.1 ± 4.3% VO_2max) obese groups.

Furthermore, the results show that energy expenditure at all exercise intensities in the evening was higher than morning in both groups. Absolute energy expenditure (kcal/min) was significantly higher in the obese than normal weight groups (p≤0.05); However, energy expenditure was similar when adjusted for FFM between obese and normal weight men (Figure 4).

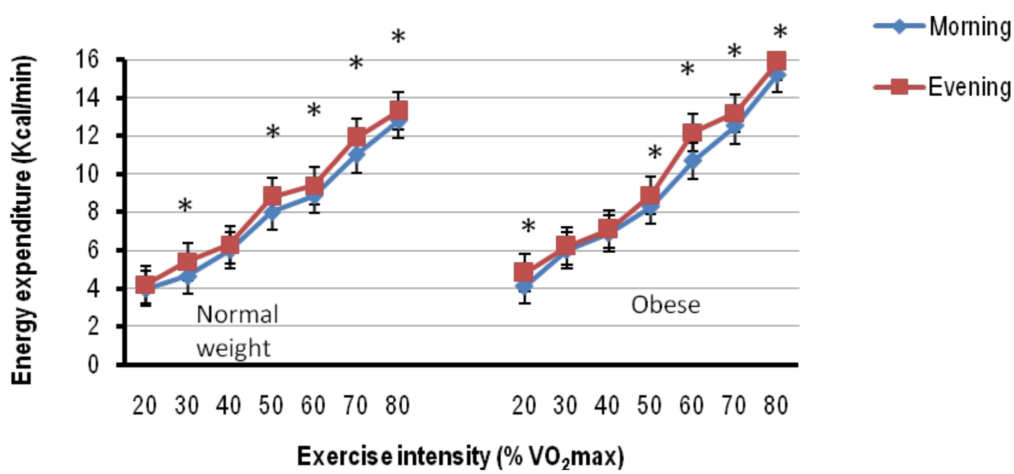

Figure 4. *Comparison EE in the evening and morning in obese and normal weight men (*p≤0.05).*

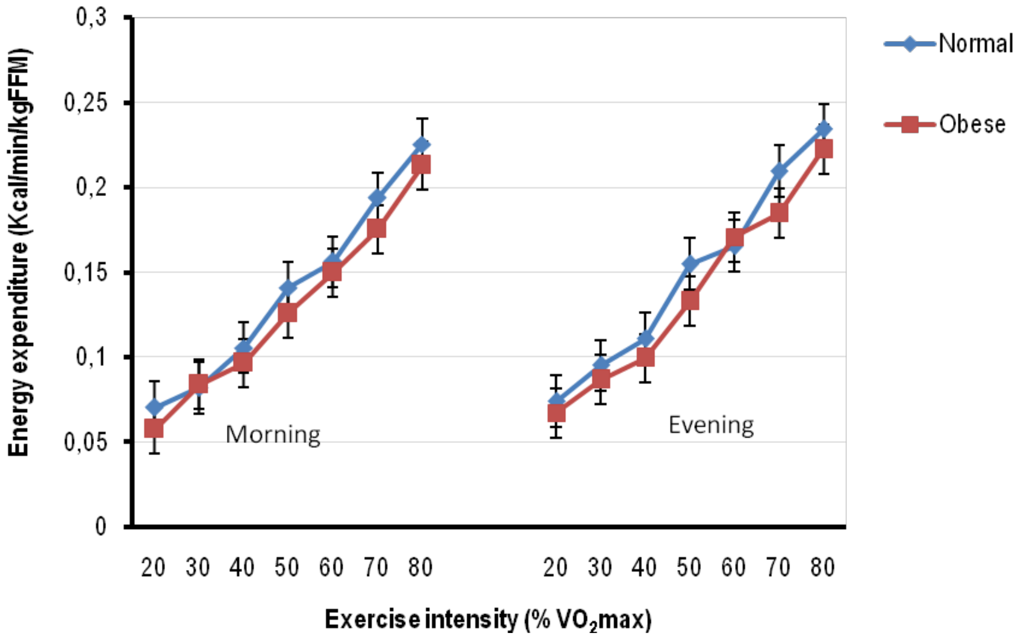

Figure 5. *Comparison EE in obese and normal weight men in the evening and morning (*p≤0.05).*

DISCUSSION

Previous studies demonstrated that training status had a significant effect on the substrate utilization (Van loon et al., 1999). We found that there are no significant differences in VO_2max (ml/min/kgFFM) between obese and normal weight men. Thus training status cannot effect on comparing results between groups.

Our results show that fat oxidation rates (mg/min) and energy expenditure (kcal/min) in the evening were higher than morning. Studies indicate that body temperature, mean power and peak power (Souissi et al., 2004) aerobic power (Hill et al., 1992) time to the exhaustion, peak oxygen consumption and aerobic system response (Hill, 1996), in the evening were higher than morning. In addition, peak catecholamine levels observed in the evening (Ayako, 1999). Thus, increase in these metabolic and hormonal variables can elevate fat oxidation rates in the evening compare to morning in both groups. The findings of the Borg scale show that RPE in the evening was lower than morning in both groups, that indicate there was less stress on subjects in the evening. It maybe causes more fat oxidation in the evening than morning in both groups. In the previous study, we reported that EE and VO_2 in the evening were higher than morning, and RER was lower (Rahmani-Nia, Azizi, & Mohebbi, 2009), that maybe show more fat oxidation in the evening than morning.

The concept of Fatmax has received a great deal of attention in recent years (Achten et al., 2002, 2003; Venables et al., 2005). This is due to an effort to recognize that facilitation of fat metabolism is of importance for both aerobic performance and health-related benefits of exercise. Fatmax was defined as the intensity where the greatest Fat oxidation was observed. In the current study, we found that Fatmax occurred around 45.1±6% and 40.2±4.4% VO_2max in obese and 53.2±7.2% and 47± 9.8% VO_2max in normal weight groups in the evening and morning respectively. The mean Fatmax found currently is close to what was reported by Bergman and Brooks, (1999) showed that Fatmax occurred at 40% VO_2peak in trained individuals, where as untrained individuals reached their Fatmax at 59% VO_2peak (Bergman & Brooks, 1999). The current Fatmax, however, is much lower than that reported by Knechtle et al. (2004), who have observed that the greatest Fat oxidation took place at 75% VO_2peak in highly trained individuals (Knechtle et al., 2004). It appears that, Fatmax is a measure that is fitness dependent. The impact as to whether and how aerobic training would affect Fatmax has yet to be elucidated.

We show that there were no significant differences in MFO (mg/min/kgFFM) between the obese and normal weight groups in the evening and morning; However, at the high exercise intensity (>60% VO_2max) fat oxidation in normal weight men was significantly higher than obese men.

Goodpaster et al. (2002) reported that during submaximal exercise obese subjects derived a greater proportion of their energy from fatty acid oxidation than lean subjects (Goodpaster et al., 2002). In contrast, Wade et al. (1990) found that heavier men oxidized less fat during exercise than lean men (Wade et al., 1990). In addition, Lazzer et al. (2007) reported that at different steps of exercise intensity, fat oxidation rates tended to be higher in obese than in non obese adolescents for exercise intensity lower than 40% VO_2max and tended to be lower for exercise intensity higher than 40% VO_2max (Lazzer et al., 2007). Studies show that obesity is associated with a diminished capacity to oxidize fat. Impairments in the ability to mobilize fatty acids from adipose tissue and to oxidize fatty acids in skeletal muscles have been reported in obese subject during exercise (Ellen & Wim, 2002). Additionally, the capacity to increase muscle blood flow during high exercise intensity may be blunted in obese subjects, possibly also contributing to a lowered FFA supply to the muscle cell (Ellen & Wim, 2002), and causes decrease whole-body fat oxidation, specially at high exercise intensities, in obese compare to lean subjects.

In fact, in many usual programs of exercise training obese subject's exercise above their maximal fat oxidation rate point, i.e. at the intensity level where fat oxidation rates are quite low. Thompson et al. (1998) have shown that low-intensity long duration exercise result in a greater total fat oxidation than moderate intensity exercise of similar energy expenditure (Thompson et al., 1998). We suggest that in obese men, exercise intensity prescription could be done at the maximal fat oxidation rate point. At these power outputs, fat utilization remains sustained, whereas it breaks down at higher intensities.

CONCLUSION

In conclusion, our data show that in obese men, MFO (mg/min/kgFFM) in the evening (7.16±1.1) was significantly higher than morning (6.57± 0.93) ($p\leq0.05$). In addition, in normal weight men MFO was significantly higher in the evening (7.18±1.5) than morning (6.12±1.5) ($p\leq0.05$). Fat oxidation rates were similar in obese and normal weight men at the exercise intensity lower than 60% VO_2max and tended to be higher in normal weight than obese men for exercise intensity higher than 60% VO_2max. Also, at all exercise intensities, fat oxidation rates were higher in the evening than morning. Thus we suggest that independent of exercise intensity and body fat mass, exercising in the evening is more effective on fat oxidation and decrease body fat mass; therefore, it is better for weight loss purposes in obese and normal weight men.

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