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Full Length Research Paper

Effect of exercise training intensity on body composition, lipid profile, and insulin resistance in young obese women

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To study the effect of two individual training intensities on total fat, waist circumference (WC), lipid parameters, and insulin-resistance among obese women were used. Thirty one obese women underwent 12 weeks of aerobic training. The training intensity was established according to the maximal heart-rate reserve (HRR). They were randomly assigned to one of three groups: a moderate intensity training group (G50, exercising at 50% of the HRR, n=11), a high intensity training group (G75, exercising at 75% of HRR, n=10), and a control group (GC, completed all tests but did not train, n=10). Anthropometric and biochemical measurements were performed before and after the training periods. G75 and G50 showed a significant decrease in body-mass-index (-7.1 versus -3.3%, *P<0.001* and *P<0.01*, respectively), total fat (-14.4 versus -9.5%, *P<0.001*), and in WC (-9.4 versus -8.1%, *P<0.001* and *P<0.01*, respectively). The reduction of total fat and WC were significantly correlated with body mass decrease (r=0.46 and r=0.43, respectively, *P<0.001*) among the two training groups but the change in body composition was not correlated with lipid parameters. In addition, the decrease of the homeostasis model assessment index was higher (*P<0.001*) in G50 than G75 with a significant reduction in LDLc. The training program at 50% of HRR induced a significant reduction of LDLc and a significant improvement in insulin status associated with body mass reduction, total fat, and WC. However, the training program at 75% of HRR induced more significant reduction in body mass and total fat than that at 50% of HRR.

Key words: Obese women, lipids, insulin resistance, anthropometric parameters, exercise intensity.

INTRODUCTION

The global epidemic of obesity becomes a major healthy, social, and economical burden Roux (2004). Indeed, it has been well established that obesity directly increases cardiometabolic risk by altering the insulin sensibility. Moreover, obesity causes additional health problems as it is closely associated with the development and progression of coronary heart disease (Murakami et al., 2007). In this context, a number of well-established blood markers, such as cholesterol, triglycerides, low (LDL) and high (HDL) density lipoprotein cholesterol, glucose, and insulin resistance are used as complement to the risk assessment. The insulin resistance is more prominent when fat excess is of android type. For women, this abdominal obesity is defined by a waist circumference (WC) above 88 cm (Pouliot et al., 1994). Over the past

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few decades, abdominal obesity has emerged as one of the major risk factors for diabetes, hypertension, and coronary diseases (Schneider et al., 2007). The escalation in the prevalence of abdominal obesity for men and women (Flegal, 2007) represents a major public health-problem and reinforces the need to develop effective treatment strategies. Although, caloric restriction remains the cornerstone of obesity reduction strategies (Levy and Heaton, 1993), emerging literature highlights the need to incorporate physical activity into every strategy intended to prevent weight gain as well as to maintain weight loss overtime (Coker et al., 2009).

As physical exercise provides a means of increasing energy expenditure and may help adjust energy balance for weight loss and maintenance, to date, several studies have examined the beneficial effects of exercise training on obesity (Miyatake et al., 2002; Hansen et al., 2010). However, these programs were based on constant continuous walking or on uncontrolled speed (that is, intensity) exercises. Concerning the training intensity, Houmard et al. (2004) revealed an inverse linear dose–response between exercise volume and improving insulin sensitivity independently of exercise intensity. However, Seals et al. (1984) demonstrated that after 6 months of low-intensity exercise training there were no changes in whole body insulin sensitivity (as determined by OGTT) and a reduction of 30% was observed high-intensity training. In addition, some intervention (Braun et al., 1995; Kang et al., 1996) trials show that low-intensity exercise is just as effective as more intense exercise for improving insulin sensitivity in people with mild insulin resistance. Other investigators have shown an inverse relationship between WC, waist-to-hip ratio, and exercise intensity independent of energy expenditure for men and women (Tremblay et al., 1990). Indeed, Okura et al. (2007) have suggested that twenty kilometers of walk each week prevent any WC increase and that a more vigorous exercise corresponding to jogging 32 km per week results in a reduction of WC by 6%. On the other hand, Schjerve et al. (2008) observed a significant reduction of body weight by 3 and 2% after moderate-intensity and high-intensity aerobic training, respectively.

Although the literature present inconclusive findings, as reviewed by Hansen et al. (2004) recent studies report no significant difference in adipose tissue mass loss when comparing low- versus high-intensity exercise training programs. However, the low adhesion of obese patients in some rehabilitation programs could be explained by the training monotony. In view of the above consideration and to reduce this monotony and increase patients' adherence to weight-loss' programs, the present study intended to investigate two intermittent walking programs based on two different intensities. Indeed, the Albright et al. (2000) ACSM statement indicates that greater exercise' intensity and volume may be of greater benefit for the individual (that is, for adipose tissue mass loss). Moreover, based on the ACSM guidelines for exercise intensity, the maximal intensity achievable, considering adherence to exercise and safety would provide the greatest training benefit in managing weight loss and lipid profiles in middle-aged women (Lee et al., 2011).

Therefore, there is an urgent need for exercise physiologists to define the optimal volume, intensity, and mode of exercise prescription that will produce the most desired effects on targeted risk factors for preventing and/or treating obesity/abdominal obesity. The aim of the present study was then, to determine the efficiency of moderate-intensity (50% of HRR) and high-intensity (75% of HRR) aerobic training on abdominal obesity, body composition, insulin resistance, and lipid profile in young obese women.

MATERIALS AND METHODS

Subjects

Thirty-one obese women (age: 25.2 ± 4.8 years; height: 1.63 ± 0.06 m; body mass: 89.05 ± 10.49 kg) volunteered to participate in this study. They were randomly assigned to one of three groups: a moderate intensity training group (G50, exercising at 50% of the HRR, n=11), a high intensity training group (G75, exercising at 75% of HRR, n=10), and a control group (GC, completed all tests but did not train, n=10). Characteristics of each group's participants (mean ± SD) are shown in Table 1.

Prior to participation, all subjects were informed about the experimental procedures, the possible risks, and discomforts associated with the study and signed a written informed consent. The study was conducted according to the Declaration of Helsinki and the protocol was fully approved by the University Ethics Committee before the commencement of the assessments. The inclusion criteria were: (i) age between 20 and 30 years, (ii) body mass index (BMI) higher than 30 kg/m^2, (iii) and WC higher than 88 cm. In addition, to be included, subjects had to be able to practice physical activities. Women with diabetes mellitus and hypertension were excluded.

Anthropometric measurements

Standing height was measured to nearest 0.1 cm with a wall mounted stadiometer (Seca 216). Body mass and height were measured with participants standing without shoes in light clothes. Their body mass and body composition (fat free mass and total fat mass) were assessed by bioelectrical impedance (TANITA BODY Composition Analyzer Mode TBF-300). The validity and usefulness of bioelectrical impedance in the measurement of body composition in obese patients has been documented (Utter et al., 1999). WC (in cm), being used as a marker of central body fat (Pouliot et al., 1994), was measured with a non-deformable tape ruler between the lower rib margin and the iliac crest, at the end gentle-expiration (as recommended by international guidelines).

Training programs

The subjects of the training groups have been enrolled for 12 weeks. Participants exercised 5 d/wk under the supervision of an exercise physiologist. Heart rate was measured before each exercise with a heart rate monitor (Polar Electro S610). The exercise intensity was adjusted on an individual basis to ensure women exercised at their prescribed exercise intensity based on

Table 1. Subject characteristics before (T0) and after (T1) the intervention program in G50 (n=10), G75 (n=11) and control group (n=10).

	G0		G50		G75	
	T0	**T1**	**T0**	**T1**	**T0**	**T1**
Anthropometrical parameter						
BMI (kg/m^2)	33.2 ± 1.8	33.3 ± 1.7	34.1 ± 3.6	32.9 ± 3.8*	32.9 ± 1.8	30.5 ± 2.4***
Body mass (kg)	85.8 ± 9.6	85.4 ± 9.6	94.3 ± 10.4	91.2 ± 11.2***	86.7 ± 10.5	81.4 ± 10.4***
%Fat mass	41.7±2.8	41.86±2.9	43.6±2.6	40.87±2.9**	40.79±3.2	37.12±4.05***
Fat Mass (kg)	35.9 ± 5.7	35.9 ± 5.9	41.3 ± 6.2	37.4 ± 6.6***	35.6 ± 6.6	30.4 ± 6.5***
Fat free mass (kg)	50.4 ± 4.5	50.1 ± 4.4	53 ± 4.5	53.9 ± 5.3	51.6 ± 4.3	51.4 ± 4.4
WC (cm)	100.7 ± 9.8	100.5 ± 9.5	106.4 ± 8.1	97.8 ± 6***	100.1 ± 5.3	90.7 ± 5.5***
Biochemical parameter						
CT (mmol/L)	4.4 ± 0.5	4.5 ± 0.5	4.8 ± 0.7	4.4 ± 0.8	5 ± 1	4.5 ± 0.9
TG (mmol/L)	0.96 ± 0.59	1 ± 0.56	0.9 ± 0.3	1 ± 0.4	0.7 ± 0.2	0.8 ± 0.2
HDL-C (mmol/L)	1.1 ± 0.4	1.1 ± 0.4	1 ± 0.4	1 ± 0.3	1.3 ± 0.7	1.2 ± 0.3
LDL-C (mmol/L)	3.6 ± 0.6	3.7 ± 0.6	3.8 ± 0.6	3.2 ± 0.7*	3.7 ± 1.3	3.3 ± 0.9
Glucose (mmol/L)	4.94 ± 0.64	4.87 ± 0.67	5.03 ± 0.71	4.62 ± 0.46	4.63 ± 0.31	4.46 ± 0.51
Insulin (µUI/L)	11 ± 6.2	11.2 ± 6.3	10.4 ± 4.7	6.6 ± 3.2**	8 ± 5.1	5.7 ± 3.2*
HOMA-IR	2.48 ± 1.54	2.53 ± 1.7	2.35 ± 1.11	0.74±0.66***	1.65 ± 1.07	1.13 ± 0.63*
Energy intake (kcal/day)	2809 ± 571	2770 ± 575	2576 ± 566	2363 ± 458	2894 ± 682	2665 ± 424

BMI, body mass index; WC, waist circumference; TC, total cholesterol; TG, triglycerides; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; HOMA – IR, homeostasis model assessment index. *, *P*< 0.05; **, *P*< 0.01 and ***, *P< 0.001* post-versus preprogram in the three groups.

each woman's target heart rate (HR) calculated from Karvonen's method (Karvonen et al., 1957) which is based on the maximal HRR:

Resting HR + 0.50 [(HRmax − Resting HR) for (50% of HRR)

Resting HR + 0.75 [(HRmax − Resting HR) for (75% of HRR)

HRmaximum (HRmax) was predicted via the following formula:

HRmaxTheoretical = 220-age (bpm).

The duration of exercise for the two training groups was the same. Exercise progressed from 20 to 25 min during the first week to 40 min by the end of the 3rd week and 55 min from the end of the 7th week.

During exercise sessions, subjects were wearing a cardio-frequency meter (Polar Electro S610) to record and follow their HR and to guarantee the maintenance of the requested exercise intensity. At least 2 HR readings were taken during each exercise session and recorded in a log book to monitor compliance to the prescribed exercise intensity. The exercise training intensity was adjusted each two weeks according to the improvement of the resting HR. Exercise intensity has been classified as moderate (Walking, at 50 % HRR), and high (Jogging, at 75 % HRR) (Kay et al., 2006).

During the third session of each week, in addition to walking or jogging, each group performed 15 min additional exercises of strength training (Abdominal exercises, back exercises and squats). These exercises consisted of 3 sets of 10 repetitions with a 30 s recovery in-between for the weeks 1 to 3. Thereafter, the number of repetitions increased to 20 from the weeks 4 to 6 and to 30 for the remaining period (weeks 7 to 12).

Diet intervention

No specific diet has been recommended. Participants in all of the groups were encouraged to continue their normal nutritional habits during the study period. Before and after intervention a dietary survey was conducted by a dietician. Each individual's diet was calculated using the Bilnut 2.01 software package (SCDA Nutrisoft, Cerelles, France) and the food composition tables published by the Tunisian National Institute of Statistics in 1978.

Biochemical analysis

Blood samples have been obtained from 7:00 to 8:00 h after ~12 h fasting. Samples have been collected in lithium heparinated containing tubes and immediately centrifuged at 4°C. Total cholesterol (TC), triglycerides (TG), HDL-C and glucose levels have been measured for all subjects before and after the interventional program using enzymatic methods. The inter-assay coefficients of variability (CV) were of: 1.7, 2.2, 2.0 and 2.3%, respectively (Elitech for lipid parameters and Biomagreb for glucose).

Insulin has also been measured with an immune-enzymatic method Acess of Beckman coulter with intra assay CV of 2 to 4.2% and inter-assay CV of 3.1 to 5.6%. LDL-C was calculated using the Friedewald formula (Friedewald et al., 1972). Insulin resistance has been assessed using the homeostatic model assessment for insulin resistance (HOMA-IR). The HOMA-IR has been computed as follows:

HOMA-IR = [insulinemia (µU/mL) × glycemia (mmol/L)] / 22.5 (Wallace et al., 2004).

Statistical analysis

Statistical analysis has been performed using SPSS version 11. All values are expressed as mean ± standard deviation. Differences among the three groups have been examined using one way ANOVA, and a Scheffe's post-hoc test has been applied when these results were significant. Paired *t*-tests have been used to assess changes within groups for all variables. To evaluate the

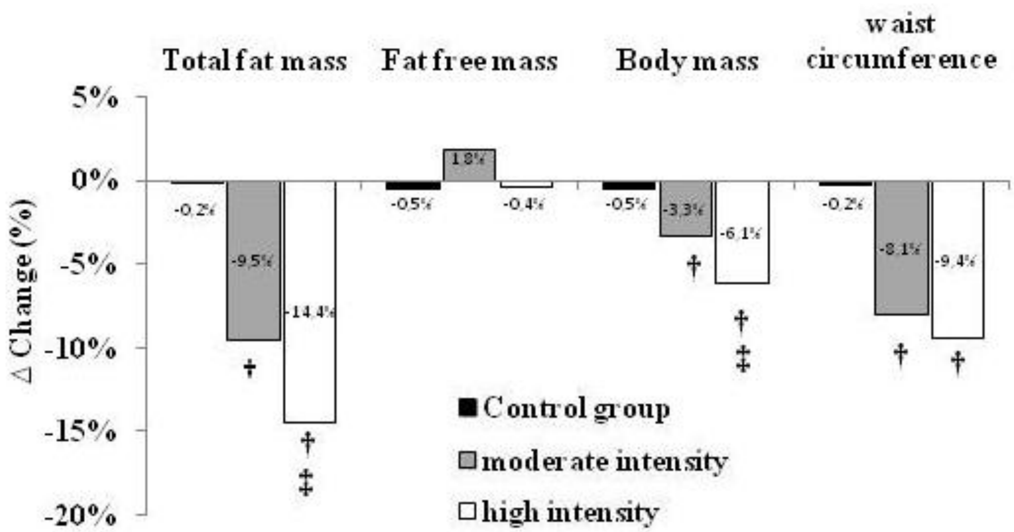

Figure 1. Percentage changes of total fat mass, fat free mass, body mass, and waist circumference in the three groups after the program. †Significant variation in comparison with control group; ‡Significant variation in comparison with moderate intensity.

relationships between parameters, Pearson correlation analysis has been performed. A probability level of 0.05 was selected as the criterion for statistical significance.

RESULTS

Baseline characteristics were not different among groups (Table 1). Anthropometric and related biochemical characteristics before and after the intervention program are shown in Table 1.

Adherence to the diet and exercise programs

Attendances at the exercise sessions were not different among exercise groups (G50=95.4% and G75=96.1%). Analysis of the daily dietary intake records indicated that the relative energy did not change within the exercise groups throughout the training period. Indeed, in comparison with the baseline period, daily caloric intake did not change within all groups (Table 1).

The changes in body mass index, body mass and fat free mass after the intervention program, BMI and body mass (BM) has decreased in G50 and G75. These changes have been significantly pronounced in the G75 (Figure 1). Fat free mass (FFM) was preserved in G75 and tended to increase in G50 (+0.95 kg; 1.8% $P>0.05$). However, there were no changes in these parameters (BMI, BM, and FFM) in the control group.

The changes in total and abdominal fat measured via anthropometry. In comparison with controls, a significant reduction in total fat mass and WC have been observed within the two training groups. However, the average reduction of total fat has been significantly greater in G75 ($P<0.05$).

In the training groups, total fat and WC reduction exhibited a significant positive correlation with mass loss (r=0.46 and r=0.43, $P<0.001$ in G75 and G50, respectively).

Biochemical analysis

Glucose metabolism parameters

After the intervention period, marked effects have been noticed in glucose metabolism: Insulin levels, Homa-IR, and glucose have been decreased in the two training groups (Figure 2). This improvement in insulin resistance has been significantly greater in G50 than G75.

Lipid profile

For lipid profile, a significant reduction in LDL-c has been observed in G50 but not in G75. However, there have been no differences among the groups in the absolute change of any other variable. For the control group, no changes were marked for all measurements after the intervention period (Figure 3).

DISCUSSION

The present study has examined the effect of the exercise intensity on anthropometric and biochemical parameters in young obese women. The two training

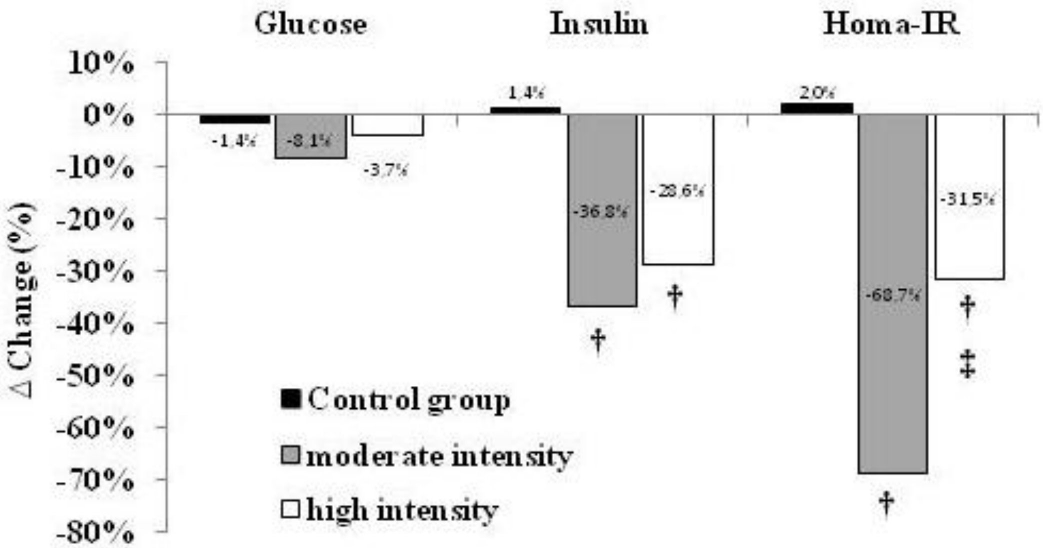

Figure 2. Percentage changes of HOMA-IR in the three groups after the program. †Significant variation in comparison with control group; ‡Significant variation in comparison with moderate intensity.

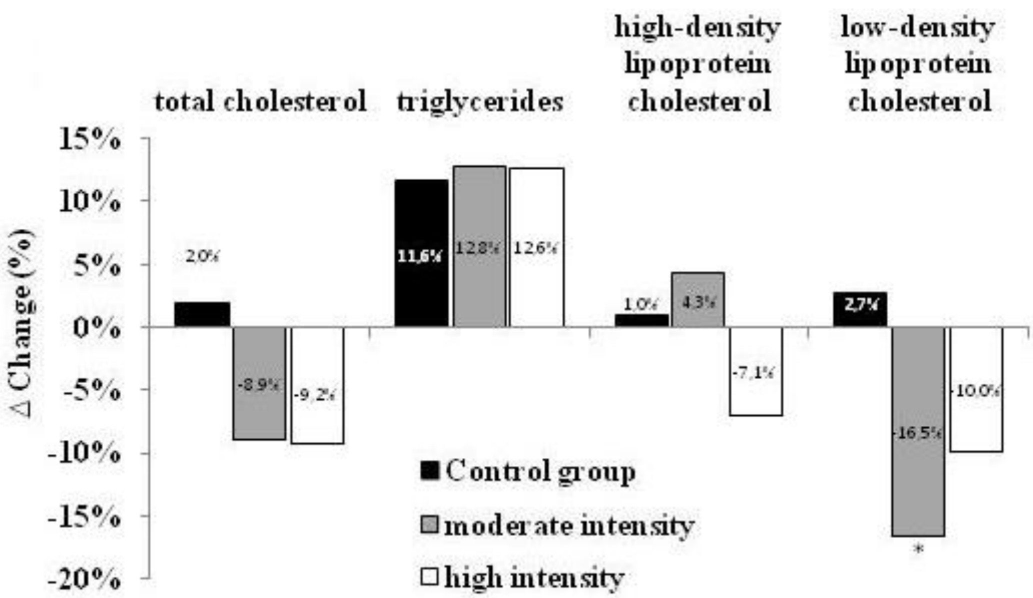

Figure 3. Percentage changes of total cholesterol, triglycerides, high-density lipoprotein cholesterol, and low-density lipoprotein cholesterol in the three groups after the program. †Significant variation in comparison with control group; ‡Significant variation in comparison with moderate intensity.

intensities have been linked with a reduction in body mass, total fat mass, and WC. Moreover, a good correlation between weight (body mass) loss and WC reduction in a somewhat dose-response manner was observed.

Indeed, the results showed 8.0 and 9.6% reductions of WC as a consequence of 3.0 and 5.3 kg decreases in body mass in G50 and G75, respectively. A reduction in total fatness has also been observed (-9.5 % in G50 and -14.6 % in G75). Obesity is characterized by an impaired ability for fat mobilization and utilization, and aerobic exercise training is able to contract this metabolic dysfunction (Perez-Martin et al., 2001). Indeed, physical activity enhances catecholamine secretion (Garrigue et al., 2006), and elevated catecholamine stimulate lipolysis via β adrenergic receptors, which are particularly abundant in visceral fat (De Glisezinski, 2007). Since adipocyte hormonal sensitive lipase is activated and triglyceride (TG) is hydrolysed, adipocyte volume will be reduced (Despres et al., 1991a).

In recent years numerous studies have shown an inverse relationship between WC, waist-to-hip ratio, and exercise intensity independent of energy expenditure for men and women (Tremblay et al., 1990). Similarly, Okura et al. (2007) have suggested that twenty kilometers of walk each week prevent any WC increase and that a more vigorous exercise corresponding to jogging 32 km per week results in a reduction of WC by 6%. In the present study, high intensity exercise had more favourable effects with regard to reducing anthropometric parameters. In this context, it has been shown that lipid contribution to energetic metabolism is dependent on exercise intensity and duration (Garrigue et al., 2006). High intensity exercise requires glucose catabolism while low intensity exercise needs lipid oxidation as a principal source of energy (Brooks and Mercier, 1994). However, 24 to 48 h after high intensity exercise, lipid oxidation, known as post-exercise lipolysis, is higher than after moderate intensity exercise (Kiens et al., 1993). During post-exercise, glucose metabolism is turned away to restore muscle glycogen stocks (Kiens et al., 1993). Thus, high intensity exercise can be an effective way to support slimming (Bensimhon et al., 2006). Yet, the decrease of muscle mass is an “adverse effect” of many slimming programs (Bouchard et al., 1990). In the present study, changes in fat-free mass have been less visible in both training groups. Furthermore, 10 to 15 min of strength training per week have been introduced for enhancing the impact of walking and jogging on body composition and promote gains in lean body mass. There is preservation and a trend towards a reduction in lean mass among the G75 group facing a significant improvement in lean body mass in the G50 group. Indeed, the improvement in muscle mass is one of the specific adaptations to training and exercise (Ross et al., 2000). At G50, although the exercise intensity was lower, improving muscle mass was more pronounced than that noted in G75, this may be due to the greater reduction in body weight observed in the second group.

Aerobic activities such as walking at a low or moderate intensity, largely involve slow twitch fibre. In response to the training stimulus, slow fibres become larger. The increase in fat free mass oxidative capacity, as a classical response to exercise training, results in increased whole body fat oxidation at rest, during exercise, and during post-exercise (Kiens et al., 1993; Bahr and Sejersted, 1991). This is important since fat free mass preserves the oxidative capacity of lipids utilisation and constitutes the largest stocking capacity for glucose disposal in parallel to the liver. Moreover, there is some evidence for the complementary roles of reduced visceral fat and increased muscle mass on improving glucose control (Castaneda et al., 2002). Indeed, the increased muscle fat content in a sedentary obese individual may simply be a marker of a metabolically inefficient muscle, which itself is a surrogate for physical inactivity. Accordingly, the decrements in muscle fat have been correlated with the improvement of the insulin resistance in previous studies (Janiszewski and Ross, 2007; Holloszy, 2005). In this context, the higher insulin sensitivity observed in G50 compared to G75 can be explained by the higher increase in lean body mass in the first group. In agreement, other investigators (Braun et al., 1995; Kang et al., 1996) have also reported that low-intensity exercise is just as effective as more intense exercise for improving insulin sensitivity in people with mild insulin resistance.

As outlined by Despres et al. (1991b), the improvement in insulin resistance may play a central role in lipid metabolism. Indeed, insulin inhibits hormonal sensitive lipase in adipose tissue (decrease in circulating free fatty acid), stimulates lipoprotein lipase (metabolism of triglyceride-rich lipoproteins) and lecithin cholesterol acyl transferase (transforming HDL_3 in HDL_2), modulates hepatic lipase activity (HDL catabolism), and activates LDL receptors (LDL catabolism). In addition, it has been demonstrated that insulin inhibits phospholipid transfer protein (PLTP) and cholesteryl ester transfer protein (CETP) (Utter et al., 1999). Plasma CETP reduces HDL-C levels through the transfer of cholesteryl esters from HDL toward very low density lipoprotein (VLDL) and LDL leading to a plasma lipid phenotype with higher atherogenicity (Barter et al., 2003). Plasma PLTP facilitates the transfer of a number of amphipathic compounds and increases the production of atherogenetic apoliprotein-B containing lipoproteins by the liver (Jiang et al., 2001). Altogether, these data suggest a reduction in VLDL, small density LDL, HDL_3, and an increase in HDL_2. Thereby, triglyceride levels and circulating LDL with low cholesterol content will decrease, along with a high amount of HDL_3. Therefore, total HDL-c cannot predict this latter event. Indeed, the present results showed a significant decrease of LDL-c (-16.5%) associated with a more significant improvement in insulin resistance in G50 as previously observed by Despres et al. (1991b). In the absence of a significant decrease in energy intake, these changes in the two groups can thus be attributed to the intensity of exercise training.

However, the present study has some limitations. First, the intervention programs have been of relatively short duration for obesity managing studies. Even though, some significant and interesting results have been shown. Second, the relatively small number of participants may have underpowered the study, and we may have been unable to detect true difference effects among training’s programs on lipid metabolism. The absence of determining the total energy expenditure could be another limit of this study, since this parameter could be an explicative and determinant factor of the registered results. However, it is known that the energy expenditure depends on the intensity and duration of the exercise (Newsholme et al., 1998), and whether it is for jogging or walking there is a linear relationship between energy expenditure and exercise speed. Thus, for the same period of time, the higher the exercise intensity the greater the energy expenditure is, as this is the case in the G75 group. For this reason, additional studies with large cohorts, with prolonged exercise duration are required.

The present study demonstrates that both aerobic exercise training at moderate intensities and high-intensity improve the weight loss and decrease the total fat mass. Moreover, training at 75% of HRR may induce more significant reduction in body mass and total fat in comparison with training at 50% of HRR. However, the low exercise intensity is more effective for improving insulin resistance and LDL-c levels during weight loss compared to high exercise intensity. These are novel observations and provide strong support for the recommendation be helpful to develop exercise programs that take into account the patient's clinical and physical status as well as her/his exercise preference. Although, the recommendation to progress to 60 min of continuous exercise may present a challenge to some obese individuals who perceive this exercise type as a barrier to participation, the present study' results suggest that shorter intermittent bouts of exercise result in weight loss that is not different from longer exercise sessions. Thus, intermittent exercise is encouraging patients' adherence and should be considered when prescribing exercise to adults seeking weight loss.

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