Aim. Circuit training is a very popular methodology in fitness programs because it allows to join together cardiovascular and strength training. The purpose of this study was to determine the physiological effects of circuit training performed at different intensities on body composition, strength and blood lactate in middle-aged subjects who had recently undergone only minimum physical training.

Methods. Forty participants (aged 50-65) were assigned to a control group (CG) or to one of the three exercise treatment groups: Endurance Group (EG), Circuit-Low Intensity Group (CLG), Circuit-High Intensity Group (CHG). The three groups exercised three times per week, 50 min per session for 12 wk using EG (N.=10), CLG (N.=10) or CHG (N.=10). Pre- and post-training, participants performed a submaximal exercise test.

Results. Among the three groups, CHG showed the greatest reductions in body weight (BW), percentage of fat mass (FM), waistline, blood lactate (produced at 100 Watt during submaximal test) and greater improvement in 6RM in horizontal leg press and underhand cable pull-downs.

Conclusion. The results obtained favored the conclusion that high-intensity exercise combined with endurance training in the circuit training technique is more effective than endurance training alone or low intensity circuit training in improving body composition, blood lactate, moreover CHG results in significantly greater strength increase compared to traditional circuit training.

Key words: Resistance training - Exercise - Body composition - Muscle strength.

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It is well known that both aerobic endurance exercise and resistance training can substantially improve physical fitness and health-related factors. While endurance training is supposed to be more effective in decreasing fat mass, resting heart rate and blood pressure, resistance training has been shown to be more effective in increasing bone mineral density, muscle strength, basal metabolism, muscle and connective tissue cross-sectional area. 1, 2 Both training methods allow to improve glucose metabolism and lipid profile. 1, 3

Finally, aerobic endurance training has a higher impact on increase of maximum oxygen uptake (VO2max) and associated cardiopulmonary variables, and it is more effective in controlling cardiovascular risk factors associated with the development of coronary artery disease.

Whereas resistance training has since long been accepted as a mean for developing and maintaining muscular strength, endurance, power, and increasing muscle mass (hypertrophy), 4 its beneficial relationship to health factors and chronic disease has been recognized only recently. 1, 2 Before 1990, resistance training was not a part of the recommended guidelines for exercise training and rehabilitation for either the American Heart Association or the American College of Sports Medicine (ACSM). In 1990, the
ACSM first recognized resistance training as a significant component of a comprehensive fitness program for healthy adults of all ages. Resistance training offers greater development of muscular strength, endurance, and mass. It also contributes to maintaining basal metabolic rate (to complement aerobic training for weight control), promotes independence, and helps to prevent falls in the elderly. Although the mechanisms for improvement may be different, both aerobic endurance exercise and resistance training appear to have similar effects on bone mineral density, glucose tolerance, and insulin sensitivity.

There is a need to maintain each of the components of fitness throughout life. Considering the above factors, any type of exercise, taken alone, seems to be inadequate for improving overall fitness. Therefore, a well-rounded exercise program consisting of aerobic and resistance exercises might be preferred, rather than one focused only on a single mode of exercise.

Moreover, recent public health recommendations have underlined the value of moderate intensity aerobic exercise for improving cardiovascular health and reducing the risk of coronary heart disease (CHD). However, reviews of training studies have found that the higher the exercise intensity, the greater the increase in aerobic fitness. Exercise of a more vigorous intensity elicits a greater increase in aerobic fitness than does moderate intensity exercise and in addiction has greater cardioprotective benefits. Clinical trials generally reported greater improvements after vigorous exercise (e.g., 60% aerobic power) compared with moderate intensity exercise for diastolic blood pressure, glucose control and aerobic capacity, but reported no intensity effect on improvements in systolic blood pressure, lipid profile, or body fat loss. Instead, few data are available on the effects played by training intensity interval training on some variables like body composition, WHR and strength compared to endurance training in older adults and, to our knowledge, no studies on middle-aged men have compared the effects of different intensities circuit training with endurance training alone. In this study we aimed to compare three different exercise protocols to assess whether the impact on body weight, fat mass, waistline, blood pressure blood lactate and strength might be different. In particular we aimed to re-evaluate the possible beneficial effects of a high intensity circuit training composed of resistance and aerobic stations in middle-aged subjects (50-65 years) who had recently undergone only minimum physical training.

Materials and methods

Subjects

Forty-nine adults (age, 56±2.7 years; body mass 89.2±1.09 kg; height 173±3.6 cm; BMI 29.8) responded to an invitation to participate in this study. Respondents were screened for the presence of diseases or conditions that increase the risk for adverse responses to exercise. Exclusion criteria for the study included history of recent myocardial infarction, severe cardiac arrhythmia, unstable angina, poorly controlled hypertension, poorly controlled diabetes mellitus, frequent or complex ventricular ectopy, or significant cognitive dysfunction that might interfere with one’s ability to adhere to exercise protocols. Moreover, adults in the inflammatory stage of arthritis or those receiving medical treatment for osteoporosis were also excluded from the study.

Study design

In an initial interview each participant was provided all details about the treatment protocol. All subjects gave their informed consent and the study was approved by the Ethical Commission of the Department. After providing informed consent, the participant was interviewed regarding his or her health status. A modified version of the Health Status Questionnaire was used as a screening tool. A one-year physical activity recall questionnaire for older adults was also completed during this initial visit. This activity inventory inquires as to the number of hours per week spent performing various activities from household duties to more vigorous activities.

After completion of the above each respondent was further evaluated by physical examination and maximal exercise electrocardiography under supervision of a cardiologist. This was the maximal test’s protocol: following 3 min of baseline cycling at 20 W, work-rate was increased by 1 W every 3 s (i.e., 20 W/min) until the participant was unable to continue despite encouragement. The participants cycled at a self-selected pedal rate which remained constant throughout the test (70-90 rev/min). Heart rates were continuously monitored with electrocardiography. After review of the medical records and physician consent, participants were scheduled for a 100 Watt rectangular test on cycloergometer. After these tests, participants were randomly assigned to the control
group or to one of three treatment groups (ten per group): a Control Group (CG), an Endurance Group (EG), a Circuit Low intensity Group (CLG), a Circuit High intensity Group (CHG). Subsequently, the participants trained three times per week, 50 min pre-session for a period of 12 weeks, after which the sub-maximal test were repeated.

**Experimental procedures**

Before and after the training period, percentage of body fat was assessed by skinfold measurement using Fitnext® (Montecchio Maggiore; Vicenza, Italy) software that utilises 10 skinfolds (triceps, biceps, pectoral, subbarmipt, subscapulare, supraspinale, iliocristale, mid-abdominal, anterior thigh, medial calf), 6 bone circumferences (arm, forearm, waist, hip, thigh, calf), 4 bone diameters (elbow, wrist, knee, ankle), and waistline measurement. Waistline measurement and calculation of the percentage of body fat were preferred to body mass index determination because they are more correlated to fat mass. Bone diameters were used to calculate, with the Fitnext® algorithm, the Free Fat Mass (FFM) and Fat mass (FM).

Functional assessment was performed with a 100 Watt rectangular test for 15' (70 rpm) cyclette, measuring heart rate at the 15th minute using a Polar heartbeat meter (Polar S810; Polar, Kemple, Finland) and blood lactate using SensLab Lactate Scout – Test strips (Leipzig, Germany) based on the blood lactate system oxidised with redox reaction via electrode mediation. Peak blood lactate concentration 3 min after cessation of exercise was measured. No familiarization session was performed before and after training. Tests were performed in the morning after a time of two hours from the same light breakfast; the subjects did not have any intense physical activity the day before measurement.

Subjects performed a 6-RM test on horizontal leg press and on chest press as described elsewhere. A 6 RM test is suitable to test maximal strength in subjects with little or no previous resistance training experience. Data obtained from initial test was used to determine an appropriate starting resistance training.

**Diet**

No changes were made in the diets of the three groups in order to avoid entering another variable into the work protocol. Inquiries were made to make sure that none of the subjects had experienced a loss of weight of more than ± 0.3 kg in the past few months. The diet of the three groups analysed using DietComp® software demonstrated a substantial similarity: 63% carbohydrates, 17% proteins, 20% lipids. In addition, to verify that none of the subjects modifies the nutritional behaviour during the intervention protocol an assessment of current dietary intake was performed using the Italian version of the food frequency questionnaire developed and validated in the context of the European Prospective Investigation into Cancer and Nutrition (EPIC).17

The questionnaire confirmed that subjects maintained the same diet regards percentage of nutrients and Kcal/die.

The participants were therefore in an effectively steady state as regards the calorie balance prior to the entry of the physical exercise variable.

**Training protocols**

The participants trained three times a week (with at least 1 day of rest between session) and 50 min per session for 12 weeks under the supervision of qualified trainers with degrees in Human Movement Sciences and certified members of the Italian Fitness Federation (FIF) and supervised by the researchers (Table I). All participants continued the training protocols through the full length of the study without any case of injury.

To set up the intensity of aerobic training we have used the maximum HR (Heart Rate) obtained in the maximal test above described; moreover, in CHG we have used Karvonen's formula to establish the HRR (Heart Rate Reserve).

Each session included a warm-up and cool-down period involving 5 min of low-intensity walking and light stretching activities.

While one group (CG) did not change its sedentary life style, the subjects involved in training were distributed into the following three groups:

1. EG: these participants trained on treadmills. Intensity was maintained at 65% of estimated maximum HR, and RPE (Rate of Perceived Exertion) was maintained between 11 and 13. When the HR response was less than 60% of estimated reserve and the RPE response was under 11, the intensity of the work was increased until these criteria were met. The initial
duration of the endurance work was 30 min per session, and the duration was increased by 3 min wk⁻¹ until a maximum of 40 min was achieved and maintained throughout the remainder of the program. Each session included a warm-up and cool-down period involving 5 min of low-intensity walking and light stretching activities. At the end of the running, subjects performed 4 sets of 20 reps of abdominal crunches.

2. CLG: the participants trained by alternating 8' of endurance on treadmills at 65% of estimated maximum HR with training at resistance exercise stations (back: underhand cable pulldowns; chest: chest press; shoulders: lateral shoulder raise; lower limbs: horizontal press; abdomen: 1 set of 20 reps abdominal crunches at the end of each resistance exercise station) performed in 3 sets of 15 repetitions maximum (RM) with 60" recovery. Each session included a warm-up and cool-down period involving 5 min of low-intensity walking and light stretching activities.

3. CHG: the participants trained by alternating 8' of endurance on treadmills (performed for 3' at 65% and 1' at 75% of estimated HRR), with training at resistance exercise stations (back: underhand cable pulldowns; chest: chest press; shoulders: lateral shoulder raise; lower limbs: horizontal leg press; abdomen: 1 set of 20 rep abdominal crunches at the end of each resistance exercise station performed with 3 sets of Rest Pause).

Every set performed with Rest Pause technique consists in: 6 RM, 20" recovery, two reps, 20" recovery, one rep.

When subjects were able to exceed the assigned numbers of repetitions the resistance was increased during the next scheduled workout to achieve the target number of repetitions at the exhaustion.

Statistical analysis

One-way multivariate analysis of variance (MANOVA) was used to compare the mean ages, heights, weights, physical activity scores across all groups. Whenever significant differences in values occurred, multiple comparisons tests (useful for identifying where significant differences occurred between pairs of groups) were performed using a post-hoc Tukey-Kramer test, considered the most powerful method for all pairwise comparisons. Alpha significance level was set at 5% (and was adjusted for multiple comparisons).

Results

The study was based on 40 participants selected among 49 respondents to the initial invitation. Of the 7 respondents who did not participate in the study, 3 withdrew before providing informed consent, whereas 4 had signs or symptoms consistent with elevated risk according to the ACSM guidelines, or their physicians did not provide medical clearance for their participation.

Among the reasons for failing medical screening were recent history of chest pain and uncontrolled blood pressure. Two subjects did not reach the 80% attendance. None of the drop out left the program as a result of injuries or adverse responses to the treatment. Therefore, the data presented here come from 40 subjects equally distributed among the four groups (CG N
TABLE II.—Groups comparison in body weight, fat mass, waistline and blood lactate after 12 wk of training.

<table>
<thead>
<tr>
<th>Variables</th>
<th>EG</th>
<th>CLG</th>
<th>CHG</th>
<th>CG</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>BW (kg)</td>
<td>87.6±1.5</td>
<td>84.6±1.3</td>
<td>86.8±1.4</td>
<td>83±1.1</td>
</tr>
<tr>
<td>FM%</td>
<td>28.3±0.8</td>
<td>25±0.8</td>
<td>27.2±0.5</td>
<td>24.8±0.5</td>
</tr>
<tr>
<td>Waistline (cm)</td>
<td>110.7±1.3</td>
<td>108±1.3</td>
<td>111±1.5</td>
<td>107.2±1.5</td>
</tr>
<tr>
<td>Blood Lactate↑</td>
<td>5.7±0.3</td>
<td>5.5±0.2</td>
<td>6±0.2</td>
<td>5.6±0.3</td>
</tr>
<tr>
<td>Heart Rate↑</td>
<td>138±9</td>
<td>133±7</td>
<td>136±5</td>
<td>132±8</td>
</tr>
</tbody>
</table>

Values are mean and SD. EG: Endurance Group; CLG: Cardio Low Group; CHG: Cardio High Group; BW: body-weight; FM: fat mass; ↑ Blood lactate and HR values were obtained during the 15th minute of the rectangular test at 100 W.

10: EG N 10; CLG N 10; CHG N 10). ANOVAs of the group characteristics revealed no inter-group differences in age, height, weight, or physical activity scores before the training period. The groups did not differ in number of sessions attended.

The values of the parameters measured before and after the 12 weeks of training are reported in Table II. As can be seen in Figure 1, body-weight was significantly reduced in CHG and CLG compared to CG, whereas CHG showed greater and significant reduction in percentage fat mass than CLG, EG. Waistline (Figure 1) was significantly reduced only in CHG compared to CG, without significant difference when CHG was compared to CLG and EG.

Moreover, as shown in Table II, blood lactate (produced at the end of a submaximal cycloergometer test) exhibited a significant reduction in CHG compared to CG, without significant difference when CHG was compared to CLG and EG. HR showed a significant decrease in CHG compared to CLG and EG. As expected horizontal leg press 6 RM test (Figure 2) showed significant increase in CHG compared to CLG, EG and CG, and in CLG respect to CG and EG versus CG, while EG shows no significant differences versus CLG. In 6 RM chest press test (Figure 2) in post-training period highlights the significant performance increase in CHG versus all other groups, while CLG had great improvement compared to EG and CG. There were no significant difference between CG and EG.

Discussion

This study comparatively investigated the benefits of three exercise training protocols with respect to several physiological factors. To our best knowledge, this is the first study which is focused on the effects of selected training methods typical to the world of fitness (circuits training combining cardiovascular training with high intensity resistance training) on this parameters in middle-aged overweight subjects (50-65 years) with very little recent physical training.

Body weight, body fat and waistline, and blood lactate

The participants were overweight middle-aged subjects with elevated waistline values. Weight loss in obese patients can improve or prevent many of the obesity-related CV risk factors (i.e., insulin resistance and type 2 diabetes mellitus, dyslipidemia,
hypertension, and inflammation) and can improve diastolic function. Moreover, these benefits are often found after only modest weight loss (5% of initial weight) and continue to improve with increasing weight loss.19

Exercise recommendations to treat or prevent obesity have focused mainly on aerobic activities. However, resistance training may also assist in weight control because it increases muscle mass. Weinsier et al. demonstrated that, on theoretical ground, a gain of 1 kg in muscle mass should increase resting energy expenditure by approximately 21 kcal/d.20 An increase in muscle (or lean body) mass as a result of resistance training contributes to the maintenance of or increase in resting or basal metabolic rate.21 Such an increase in metabolic rate may complement the increase in caloric expenditure produced by aerobic training to assist with weight control.

In this study, after 12 weeks of training, all three training groups showed reductions in percentages of body fat, and such reduction was more significant (P<0.05) in CHG than in CLG, EG and CG.

The greater reduction of body fat in CHG (decrease of 6% in FM) than in CLG and EG was probably due to the greater EPOC (excess post exercise oxygen consumption) in the hours following exercise. This increase of EPOC may explain the greater reduction of fat in the CH group, as a matter of fact, if fat loss was attribut-
able only to the training session, subjects had to expend about 28 Kcal*min⁻¹ in the 50 minute session. Actually, this calculation, does not consider the delayed effect of training (EPOC) that causes an increases of energy expenditure during the 36-48 h after training, thus well beyond the training session duration (for example Shuenke et al calculated an increase of about 400 Kcal per day).²² Metabolic rate remains elevated for 48 hours after an acute moderate- to high-intensity bout of resistance exercise likely due to protein turnover and tissue repair.²³, ²⁴

Our findings are similar to those of others authors that showed that Higher intensity session (i.e., 80% 1RM) produced higher EPOC than standard set exercise (12-15 reps),²⁵ moreover there are data demonstrating that repeated bouts of aerobic exercise can activate more effectively adipose tissue lipolysis than conventional aerobic training.²⁶

Moderate to high intensity, high-volume programmes using short rest periods (as rest pause) are known to cause greater acute GH (Growth Hormone) response compared with conventional strength or power training using high loads, low repetitions and long rest intervals in men.²⁷, ²⁸ Moreover, we observed previously²⁹ how RP (Rest Pause) technique is more efficient in improving body mass than other techniques in young trained subjects. The effect of GH on body fat and the induction of an increase in EPOC on the metabolism and on the consumption of fat with the metabolism at rest is, in fact, commonly known.

Therefore, in our view the greater reduction of body fat in CHG (decrease of 6% in FM) than in CLG and EG might be explained by:
- the greater EPOC in the hours following exercise produced by RP technique and the interval training compared to conventional resistance training and endurance training;
- the more effective adipose tissue lipolysis induced by repeated bout of interval training compared to conventional endurance training;
- the greater acute GH response derived from the greater lactacid aerobic work performed.

In men, the onset of aging (40 years and older) is generally associated with an increase in abdominal fat assessed by waist circumference and waist-to-hip ratio.³⁰ There is strong evidence that resistance training may reduce total body fat mass in human,³¹, ³² independent of dietary caloric restriction. It is well known that excessive abdominal fat (high waist circumference values) and especially visceral adipose tissue is correlated with the development of hyperlipidemia, hypertension, insulin resistance and glucose intolerance, diabetes and heart disease.³³ Therefore, it is clear that regional distribution of fat may be more important to health than the total amount of body fat; several studies have demonstrated decreases in visceral adipose tissue after resistance training programs.³¹, ³² CHG showed a significant decrease in waistline circumference in comparison to CG, however no significant differences were found when it was compared to EG and CLG.
Blood lactate

CHG showed greater reduction in blood lactate (produced at 100 W) than the other three groups, however, difference was statistically significant only when CHG was compared to CG.

Peak oxygen consumption has traditionally been used as an index of exercise capacity. However, some studies have shown that exercise capacity may be evaluated using submaximal and endurance protocols.33, 34

CHG performed a lactic acid-based work heavier than the other two training groups: therefore the high intensity training (Rest Pause Technique and Interval Training) could explain the greater decrease in blood lactate produced after 15 minute of 100 Watt rectangular test on the cycloergometer.

1 RM test

As expected the high intensity training has produced a dramatical increase in 6 RM performance compared to standard (15 reps) training both in leg press and in lat pulldown and also to Endurance training. Standard training improve strength better than endurance training only in lat pulldown exercise (obviously considering that EG did not training the upper part of the body) whilst there was no difference in legs strength between the two groups EG vs CLG. Both groups CHG and CLG in the current study demonstrated large increases in strength, which was not surprising considering that subjects had little or no previous training experience. It is plausible that, in view of the short duration of the study, the strength gains were likely due to neural adaptations rather muscular hypertrophy.35, 36 In this study the lack of significant differences between group CLG and EG in the leg press 6 RM test was somewhat surprising considering the different kind of training. A possible explanation for the lack of significant differences might be the muscular stimulus given by the Endurance training to the lower limbs. It’s possible to argue that a longer duration study may show significant differences between CLG and EG.

Conclusions

In conclusion, our results indicate that high-intensity resistance exercise performed with "rest pause" method and combined with endurance training (performed with "interval training") in the circuit training technique is more effective in improving some physiological parameters which can be important cardiovascular risk factors (body weight, body fat, waistline) and improving performance efficiency in overweight middle-age men compared to endurance training alone or low intensity circuit training. We can, therefore, recommend “Circuit High Intensity Training” to be used as a mean to promote health and weight loss. In addition further studies are needed to confirm the role of a “Circuit High Intensity Training” for the prevention of cardiovascular diseases in middle aged adults.

References


