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Effects of different training protocols on exercise performance during a short-term body weight reduction programme in severely obese patients

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ABSTRACT. *The effects on aerobic, anaerobic and strength performance of aerobic (A) or A and strength (AS) training, integrated with a 3-week body weight reduction programme involving an energy-restricted diet, nutritional education and psychological counselling, were evaluated in 52 grade II or III obese individuals (A: n=26; AS: n=26). After 3 weeks, both training programmes led to a similar and significant reduction (p<0.001) in body mass (A: 4.8%; AS: 4.4%) and an increase (p<0.05 - p<0.01) in maximal oxygen consumption (A: 16.8%; AS: 10.9%). A significant (p<0.05 - p<0.001) increase was found in absolute lower limb anaerobic power output evaluated by means of a jumping test (A: 13.7%; AS: 18.1%) and stair climbing test (A: 9.7%; AS: 4.3%), without any significant difference between A and AS. A comparable and significant (p<0.01) increase was also found in average horizontal velocity during a short sprint running test (A: 8.1%; AS: 7.1%), with a shorter time of foot-ground contact (A: 4.9%; AS: 6.6.%) and a higher step frequency (A: 4.0%; AS: 10.4%). The maximum strength increase after the body weight reduction programme determined by one maximal repetition test of lower and upper limb muscle groups was significantly greater (p<0.05 - p<0.001) in the AS group, ranging from 11.4% to 25.4% (A) and from 26.7% to 41.8% (AS). These results indicate that integrating a body weight reduction programme involving diet, nutritional education and psychological counselling with A or AS exercise has similar positive effects in lowering body mass and improving A and anaerobic performance. However, the addition of strength training to A conditioning increases maximum strength.*
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Key words:
Obesity, exercise, body weight reduction programme, aerobic performance, anaerobic performance, maximum strength.

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INTRODUCTION

The incidence of weight disturbances, such as overweight and obesity, has rapidly increased in the industrialised world, and the fact that this trend is likely to continue (1, 2) is a major concern because of the concomitant increase in the incidence of obesity-related medical conditions and the related death risk (3, 4). There is general agreement concerning the positive effect of physical activity, alone or in combination with dietary caloric restriction, in preventing (5) and treating obesity (6).

A number of studies have substantiated the favourable effects of caloric restriction and exercise conditioning on body weight reduction and body composition, their maintenance over time, and their effects on glucose tolerance, insulin sensitivity and serum leptin levels (7-11). The relatively smaller number of studies considering the improvement in physical fitness deriving from the combined use of caloric restriction and exercise have mainly evaluated changes in aerobic (A) capacity (12), anaerobic muscle performance (13) and maximum strength (14).

In general, these studies were designed to study overweight or moderately obese (grade I) patients in the long term and there is relatively little information concerning the effect of the combination of diet and exercise on the physical performance of the severely obese (grade II and III), especially in the short term.

Furthermore, given the beneficial effect of the combination of a weight-loss dietary regimen and physical training mainly aimed at preventing the loss of skeletal muscle mass due to dietary restriction alone (14), it seems to be important to further our understanding of the combined effects of strength and A training during a body weight reduction programme and compare them with those obtained using A exercise alone in combination with the same weight loss programme.

The aim of this study was to examine the effects of diet combined with A or AS training on A, anaerobic and strength performance during a short-term body weight reduction programme in severely obese patients.

MATERIALS AND METHODS

Subjects

Fifty-two obese subjects (14 males, 38 females) gave their informed consent to participate in the study, which was approved by the Ethics Committee of the Istituto Auxologico Italiano. All of them had been admitted to the Institute's 3rd Division of Metabolic Diseases in order to follow a 3-week multidisciplinary body weight reduction programme (DEP-AST) consisting of an energy-restricted diet, nutritional education, psychological counselling and physical (A or AS) training. The exclusion criteria were any signs or symptoms attributable to acute cardiovascular, orthopedic or neuromuscular diseases. None of the patients had previously engaged in systematic physical activity as assessed by specific questioning during the initial physical examination.

The enrolled subjects were divided into 2 age- and gender-matched groups, one of which underwent A training (n=26) and the other AS training (n=26); their baseline anthropometric data are shown in Table 1. The measurements for each patient, who were all thoroughly familiar with the experimental instruments and how to perform the different tests, were made during the course of one day before and at the end of the programme. All of the patients completed the 3-week programme.

TABLE 1
Average physical characteristics (± SD) of the subjects undergoing aerobic (A) or aerobic plus strength (AS) training. Ranges are indicated in parenthesis.

	A (n=26)	AS (n=26)
Age (yr)	29.1±6.6 (18-46)	29.8±7.9 (19-44)
Height (m)	1.66±0.10 (1.47-1.87)	1.65±0.09 (1.48-1.81)
Weight (kg)	115.8±20.6 (90.5-163.6)	112.5±15.5 (84.0-148.0)
Males/Females	7/19	7/19

DEP-AST programme

The programme combined an energy-restricted diet, nutritional education, psychological counselling and A or AS exercise training (5 days/week).

Diet

Caloric intake was restricted by means of a diet (1200-1800 kcal/day) containing 21% proteins, 53% carbohydrates and 26% lipids; the amount of energy to be supplied by the diet was calculated by subtracting approximately 500 kcal from the measurement of basal energy expenditure. The estimated water content of the food was 1000 ml water, 1560 mg Na, 3600 mg K and 900 mg Ca. A fluid intake of at least 2000 ml/day was encouraged. Dietary compliance was evaluated every day by a dietician.

Nutritional education

This consisted of lectures, demonstrations and group discussions (with or without a supervisor), which took place every day throughout the programme.

Psychological counselling

This consisted of 2-3 sessions/week conducted by clinical psychologists and based on individual or cognitive-behavioural strategies, including stimulus control procedures, problem solving training, stress management skills, goal setting, the development of healthy eating habits, assertiveness training, the facilitation of social supports, cognitive restructuring of negative maladaptive thoughts, and relapse prevention training.

Aerobic and strength training

The protocol was designed in accordance with the guidelines of the American College of Sport Medicine (ACSM) (15). All of the subjects were tested for maximal oxygen uptake ($\dot{V}O_2$max) using a graded submaximal test and cycle ergometer (Technogym, Gambettola, Italy) before and at the end of the programme. After a 6-min warm-up period at 50 W (50 rpm), the subjects performed three 4-min exercise periods at respectively 60, 70 and 80 W (60 rpm). The test was stopped if the subject reached 75% of predicted maximal heart rate (HR) calculated using the formula: 220 - age (yr). HR was recorded using a HR monitor (Polar, Finland) in order to monitor cardiac activity and subsequently calculate the average HR during the last minute of each step. The ACSM formula was used to estimate $\dot{V}O_2$max, and the rating of perceived exertion (RPE, Borg scale) was simultaneously recorded. Maximal force production (1 maximal repetition, 1MR) was tested before and at the end of the programme using the Brzycki formula (16) and 3 different isotonic machines: vertical traction, chest press and leg press (Technogym, Gambettola, Italy). After a warm-up of one set of 15 repetitions, the test consisted of a repeated set of 20 repetitions at progressive loads in order to achieve an RPE of 6-7.

The A exercise (group A) involved daily sessions (5 days/week) on a cycloergometer (10 min), treadmill (20 min) and armergometer (5 min) for a total duration of 35 min/day at an intensity corresponding to 50% of individual $\dot{V}O_2max$ for each exercise type during the 1st week of the programme and 60% during the following 2 weeks. The exercise protocol for this group entailed an average daily expenditure of 267 kcal ± 70 standard deviations (SD) during the 1st week, increasing to 331 kcal ± 79 SD in the 3rd week.

The subjects performing AS exercises (group AS) underwent a session of aerobic training followed by a strength training workout (5 days/week) on each of the 3 isotonic machines. The A component consisted of a session on a cycloergometer (10 min) and treadmill (20 min) for a total of 30 min/day at an intensity corresponding to 50% of individual $\dot{V}O_2max$ during the 1st week of the programme and 60% during the following 2 weeks. The strength training consisted of a single series of 15 repetitions at 40% 1MR during the 1st week, 50% 1MR during the 2nd week, and 60% 1RM during the 3rd week on each machine. The AS exercise protocol entailed a total average daily expenditure of 227 kcal ± 55 SD during the 1st week, increasing to 284 kcal ± 61 SD in the 3rd week.

All of the training sessions were supervised by a certified trainer and a physician.

Measurements of anaerobic performance

<u>Jumping test</u>

The subjects performed a series of five consecutive jumps with maximal effort while keeping their hands on the hips and being careful to bend the knee to about 90-100° during the phase of contact with the ground between the jumps (17). An operator checked that the manoeuvre was appropriately performed and, in the case of failure, the test was repeated after an interval of about 10 min. The flight (Tf,j) and contact (Tc,j) times relating to each jump in the series were measured using a digital timer (± 0.001 s) connected to an optical acquisition system (Optojump, Microgate, Italy) consisting of two arrays of photocells mounted close to each other (0.02 m) on two 1 m bars placed frontally on the ground at a distance of about 1 m. All of the flight and contact times were acquired on a personal computer and displayed on-line while the subject performed the sequence of jumps. The total vertical displacement of the centre of gravity (ΔCG) during flight was obtained for every jump as:

$$\Delta CG = (g\ Tf,j^2) / 8$$

where g is the acceleration of gravity (9.81 m s^{-2}). Under these experimental conditions, the specific average mechanical power of the positive work phase of each jump, expressed per unit body mass (spec,j), was calculated using the following formula:

$$\dot{W}spec,j = g^2\ Tf,j\ (Tc,j + Tf,j) / (4\ Tc,j).$$

The absolute power ($\dot{W}j$) was then determined by multiplying spec,j by the subject's body mass. The best power result for each subject was selected within the series of 5 jumps.

<u>Running test</u>

The subjects performed a short indoor sprint (8 m) running at maximum speed in a measurement track obtained using 8 pairs of the same optical arrays as those used for the jumping test, arranged in a linear modular system (Optojump, Microgate, Italia). The subjects started the sprint about 2 m before the beginning of the measurement track and a further 4 m were available to slow down after the end of the track. The timing of the run within the effective measurement field was determined using two pairs of photocells aligned with the two sides of the track, at about 0.5 m from ground. While the subject performed the run, the time of foot contact with the ground (Tc,r) and flight off ground (Tf,r) relating to each step were acquired on a personal computer and displayed on-line, together with the instantaneous foot position along the track. These data were used to determine the average speed (v), step frequency (fs) and step length (Ls) for each subject.

<u>Stair climbing test</u>

All of the patients performed a stair climbing test (18) modified in order to meet the performance capabilities of critically obese individuals, as previously described by Sartorio et al. (13, 19). The subjects were invited to climb an ordinary flight of stairs one step at a time and at the highest possible speed. There were 13 steps of 15.3 cm each, thus covering a total vertical distance of 1.99 m. An operator measured the time required to complete the test using a digital stopwatch. The test was considered as starting at the moment the first foot was lifted and ending when the same foot came into contact with the last step. The vertical component of the speed (vv) was calculated from the vertical dimensions of the steps. Under these conditions, the average specific mechanical power ($\dot{W}spec,s$) is directly proportional to the vertical

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component of the speed since, whatever the speed, the subject raises every unit of his body mass by a height (in m) that is equivalent to his vertical speed (in m s^{-1}). It is given by:

$\dot{W}spec,s = (g\ h)/t$,

where h is the vertical distance covered during the test and t the climbing time. The average total power ($\dot{W}s$) was then determined by multiplying spec,s by the subject's body mass.

Statistical analysis

All of the data are given as mean values ± SD. Within-group differences before and after the DEP-AST program were tested using Student's t test for paired data, and the between-group differences using Student's t test for unpaired data. Regression line equations were calculated by means of the least-square method. The differences between the regression lines were tested using conventional regression equation comparisons (20). P values of less than 0.05 were considered statistically significant.

RESULTS

BMI significantly decreased after the DEP-AST programme in both groups (Table 2), with no statistically significant difference between them.

After the completion of the DEP-AST programme, absolute and per kg A performance (assessed by the indirect determination of $\dot{V}O_2max$) significantly and comparably increased in both groups (Fig. 1). Figure 2 shows RPE as a function of HR at the 4 levels of the test for $\dot{V}O_2max$ determination before and after the programme. Although there is a close linear correlation between RPE and HR both before and after the DEP-AST programme, there were significantly different regressions in the relationship after the programme, which lead to a different exercise impact.

Table 2 also summarises lower limb anaerobic performance during the jumping and stair climbing tests, and locomotor capabilities during the sprint test. After the DEP-AST programme, anaerobic performance and horizontal velocity during the sprint significantly and similarly increased in both groups. No systematic between-group difference was found in the improvements attained in these tests.

The maximal strength results obtained using the 3 isotonic machines before and after the DEP-AST programme are shown in Table 3. Although the 1MR value developed with all of the machines increased significantly in both

TABLE 2

Average body mass index (BMI) values (± SD) and the results of the jumping, sprinting and stair climbing tests before and after 3 weeks of the DEP-AST programme in the subjects undergoing aerobic (A) and aerobic plus strength (AS) training. The within-group differences (shown in the Table) were tested using a Student's t-test for paired data. No significant between-group difference was found.

	A (n=26)		AS (n=26)	
	Before	After	Before	After
BMI	41.7±5.3	39.7±4.8***	41.1±4.1	39.3±3.8***
Jumping test				
Tc, j (s)	0.487±0.110	0.430±0.120*	0.435±0.110	0.361±0.090**
Tf, j (s)	0.297±0.061	0.323±0.068***	0.300±0.069	0.323±0.059***
ΔCG (m)	0.113±0.049	0.133±0.043***	0.116±0.048	0.132± 0.047***
$\dot{W}$spec, j (W/kg)	11.99±4.01	14.12±4.09***	13.03±4.81	15.62±5.07***
$\dot{W}$j (W)	1368±550	1556±527**	1424±527	1682±610***
Short running test				
Tc,r (s)	0.244±0.035	0.232±0.044*	0.243±0.031	0.227±0.033***
v (m/s)	3.33±0.61	3.60±0.63**	3.53±0.59	3.78±0.65**
fs (steps/s)	3.23±0.45	3.36±0.49*	3.27±0.39	3.61±0.70*
Stair climbing test				
Wspec, s (W/kg)	5.30±1.10	5.61±0.91***	5.19±0.85	5.62±0.87**
Ws (W)	568±164	623±149**	587±147	612±156*

*p <0.05; **p<0.01; ***p<0.001

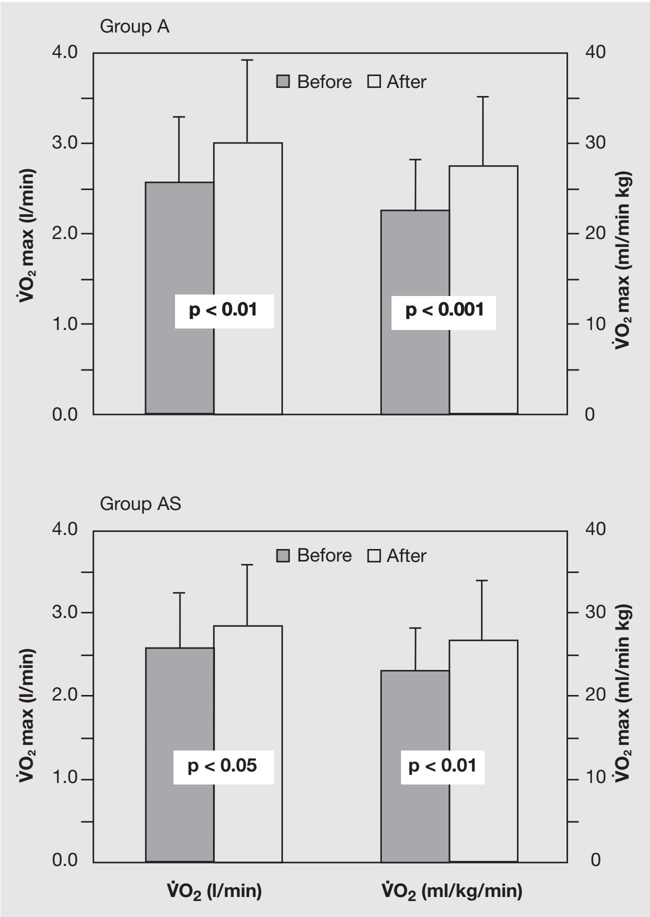

FIGURE 1
Average (± SD) maximal oxygen consumption ($\dot{V}O_2$max) in absolute terms (l/min) and per unit of body mass (ml/min/kg) before (dark bars) and after (light bars) the DEP-AST programme in the subjects undergoing aerobic (Group A, top panel) or aerobic plus strength training (Group AS, bottom panel). The within-group differences (shown in the table) were tested using a Student's t-test for paired data. No significant between-group difference was found.

groups, the improvements were significantly greater in the AS group (Fig. 3).

DISCUSSION

The results of the present study show that a short-term body weight reduction programme involving a moderate amount of aerobic exercise training makes it possible to attain a significant reduction in BMI, and significant improvements in A capacity and physical performance mainly based on lower limb alactic power output. If moderate strength training is added, a further significant improvement in the involved muscle groups can be reached.

Although there are only a few published studies of the effects of exercise on physical performance during body weight reduction programmes in morbid obesity, the results obtained using a short-term personalised and strictly quantified amount of A exercise in both of our groups confirm those previously obtained using aspecific exercise protocols in extremely obese (13, 19) and overweight individuals (14) not only in terms of A performance, but also anaerobic power output.

Although physical training can be expected to induce a number of metabolic adaptations improving the functional capacities relating to oxygen transport and use, the improvement in $\dot{V}O_2$max seems to be relatively high for such a moderately intense training programme. However, this may have been partially due to the notably poor degree of physical fitness in our subjects before the start of the protocol. It has been previously shown that the magnitude of improvement in A performance after a training programme is inversely related to the initial level of fitness (21), and that these improvements are mainly reached during the first 3 weeks of training (22). Since both exercise and weight loss synergistically increase parasympathetic activity, it is possible that exercise is particularly effective in obese patients during a body weight reduction programme. Obesity per se is associated with the decreased parasympathetic activity (23, 24) inherent in weight gain, as has also been demonstrated in overfed normal subjects (25) and animals (26, 27), and so obese patients may be particularly susceptible to the combined effects of exercise and weight loss. Changes in the balance

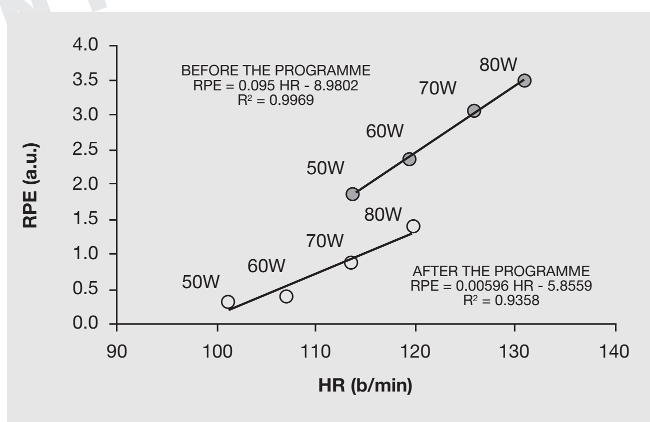

FIGURE 2
Average rate of perceived exertion (RPE), expressed in arbitrary units according to the Borg scale, plotted as a function of average heart rate (HR) in all subjects at the four levels (50, 60, 70 and 80 W) of the incremental test for $\dot{V}O_2$max determination before (dark circles) and after (open circles) the programme.

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TABLE 3

Average maximal force (± SD) obtained using three different isotonic machines before and after the DEP-AST programme in the subjects undergoing aerobic (A) and aerobic plus strength (AS) training. The within-group differences (shown in the table) were tested using a Student's t-test for paired data. No significant between-group difference was found.

	A (n=26)		AS (n=26)	
	Before	After	Before	After
Leg press (kg)	259.9±91.5	326.0±108.7***	244.8±73.7	347.1±99.7***
Chest press (kg)	32.1±16.9	37.4±17.3**	30.9±13.8	42.1±18.4***
Vertical traction (kg)	72.6±21.3	80.9±22.1***	70.1±15.7	88.8±21.2***

**p<0.01; ***p<0.001

between parasympathetic and sympathetic activity have also been invoked by Sartorio et al. (13) as the basis of the decrease in resting systolic and diastolic arterial pressure and HR, as well as exercise HR, observed after an aspecific training programme in extremely obese patients. These effects also suggest a trend toward an increase in cardiac stroke volume at rest and during exercise, which is possibly mediated by the changes in left ventricular load that have been shown to be closely related to weight loss in obese patents (28). Furthermore, Figure 2 shows that there was a linear correlation between the average rate of perceived exertion and average HR during the incremental cycloergometer tests in all ofour subjects, but significantly different regressions fit the data obtained before and after the DEP-AST programmes. It therefore seems that not only changes in HR for a given work load are responsible for subjective sensations during exercise, but an improvement in breathlessness and general fatigue may contribute toward decreasing RPE, and a possible role may also be played by a different rate of lactic acid output.

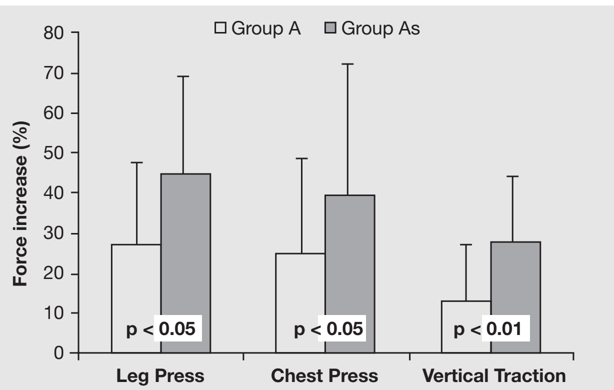

FIGURE 3

Average force increase (± SD) using the three isotonic machines after the DEP-AST programme in the subjects undergoing aerobic (Group A, light bars) or aerobic plus strength training (Group AS, dark bars). The between-group differences were tested using a Student's t-test for unpaired data.

A significant improvement in the performance based mainly on lower limb anaerobic alactic power was also observed in both groups, but the increase in maximal force was significantly greater in the AS group despite the fact that there was no significant between-group difference in performing the anaerobic power-related tests (Table 3), although a number of variables were numerically higher in the AS group. This finding is not completely surprising, because force generation on isotonic machines and jumping tests imply very different speeds and durations of action: the longer duration of the muscular contraction during isotonic machine exercise may not correspond to the optimal velocity of shortening for maximal power production during jumping or reaching maximal gait velocity during sprinting or stair climbing.

The changes in absolute anaerobic power observed after the weight reduction programme can be considered as being independent of the increase in specific power output (i.e. power per unit body mass) reached as a consequence of the weight loss. The average changes in lower limb specific power observed during the jumping test (+19%) do not match the decrease in body mass attained after the DEP-AT programme (-5%), and so a part of the improvement may also have been due to other factors.

One of these might be related to the positive effect of even moderate A exercise on the maintenance of fat-free mass during weight reduction, as has previously been observed in moderately obese or overweight individuals of both genders (8), and similar results have also been reported after a combination of A and AS training (14). A relative increase in muscle mass may therefore partially contribute to the improvement in anaerobic performance described in the present study especially as a response to strength training; however, detailed measurements of lower limb mass are required to assess the importance of this factor quantitatively.

Furthermore, it cannot be excluded that the acquisition of a certain degree of motor skill due to the training effect of the exercise programme may also have contributed to the results observed during anaerobic testing because, in general, the subjects were highly sedentary at the beginning of the programme and their movements were possibly limited by their unfamiliarity with physical exercise. In line with present findings, Sartorio et al. (19) have recently found that aspecific and mainly A exercise conditioning in morbidly obese subjects significantly increases motor co-ordination in balance tests as well as anaerobic tasks.

Finally, a post-programme improvement in general well-being and self-esteem leading to greater motivation during the motor task should be considered. Rippe et al. (29) and Nieman et al. (30) have recently demonstrated that the exercise component in weight loss programmes leads to an improvement in general psychological well-being, but other exercise-independent factors cannot be ruled out.

In conclusion, the results of the present study demonstrate that a short-term body weight reduction programme involving simple exercise conditioning of moderate intensity significantly improves the performance of motor tasks based on both A and anaerobic capabilities in severely (grade II and III) obese patients. The addition of strength training to systematic A conditioning also improves the force generation in such patients. Given the considerable degree of deconditioning and poor physical fitness of the patients at the beginning of the study, it is likely that the motor changes attained using the programme contribute toward enhancing their quality of life by improving their ability to perform everyday tasks related to albeit simple motor performances.

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REFERENCES

1. Flegal K.M.: The obesity epidemic in children and adults: current evidence and research issues. Med. Sci. Sports Exerc., 31, S509-S514, 1999.
2. Mokdad A.H., Serdula M.K., Dietz W.H., Bowman B.A., Marks J.S., Koplan J.P.: The continuing epidemic of obesity in the United States. J.A.M.A., 284, 1650-1651, 2000.
3. Must A., Spadano J., Coakley E.H., Field A.E., Colditz G., Dietz W.H.: The disease burden associated with overweight and obesity. J.A.M.A., 282, 1523-1529, 1999.
4. Allison D.B., Fontaine K.R., Manson J.E., Stevens J., Vanltallie T.B.: Annual deaths attributable to obesity in the United States. J.A.M.A., 282, 1530-1538, 1999
5. Di Pietro L.: Physical activity in the prevention of obesity: current evidence and research issues. Med. Sci. Sports Exerc., 31, S542-S546, 1999.
6. Wing R.R.: Physical activity in the treatment of adulthood overweight and obesity: current evidence and research issues. Med. Sci. Sports Exerc., 31, S547-S552, 1999.
7. Skender M.L., Goodrick G.K., Del Junco D.J., Reeves R.S., Darnell L., Gotto A.M., Foreyt J.P.: Comparison of 2-year weight loss trends in behavioral treatment of obesity: diet, exercise, and combination interventions. J. Am. Diet. Assoc., 96, 342-346, 1996.
8. Ross R., Rissanen J., Padwell H., Cliffort J., Shragge P.: Influence of diet and exercise on skeletal muscle and adipose tissue in man. J. Appl. Physiol., 81, 2445-2455, 1996.
9. Arciero P.J., Vukovich M.D., Holloszy J.O., Racetta S.B., Kohrt W.M.: Comparison of short-term diet and exercise on insulin action in individuals with abnormal glucose tolerance. J. Appl. Physiol., 86, 1930-1935, 1999.
10. Pasman W.J., Westerterp-Plantega M.S., Saris W.H.: The effect of exercise training on leptin levels in obese males. Am. J. Physiol., 274, E280-E286, 1998.
11. Weinstock R.S., Dai H., Wadden T.A.: Diet and exercise in the treatment of obesity: effects of 3 interventions on insulin resistance. Arch. Intern. Med., 158, 2477-2483, 1998.
12. Ashutosh K., Methrotra K., Fragale-Jackson J.: Effects of sustained weight loss and exercise on aerobic fitness in obese women. J. Sports Med. Phys. Fitness, 37, 252-257, 1997.
13. Sartorio A., Narici M.V., Fumagalli E., Faglia G., Lafortuna C.L.: Aerobic and anaerobic performance before and after a short-term body weight reduction program in obese subjects. Diab. Nutr. Metab., 14, 51-57, 2001.
14. Kraemer W.J., Volek J.S., Clark K.L., Gordon S.E., Puhl S.M., Koziris L.P., McBride J.M., Triplett-McBride N.T., Putukian M., Newton R.U., Hakkinen K., Bush J.A., Sebastianelli W.J.: Influence of exercise training on physiological and performance changes with weight loss in men. Med. Sci. Sports Exerc., 31, 1320-1329, 1999.
15. ACSM's Resource Manual for Guidelines for Exercise Testing and Prescription, ed 6. Baltimore, Lippincott, Williams & Wilkins, 2000.
16. Mayhew J.L., Prinster J.L., Ware J.S., Zimmer

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D.L., Arabas J.R., Bemben M.G.: Muscular endurance repetitions to predict bench press strength in men of different training levels. J. Sports Med. Phys. Fitness, 35, 108-113, 1995.

17. Bosco C., Luhtanen P., Komi P.V.: A simple method for measurement of mechanical power in jumping. Eur. J. Appl. Physiol., 50, 273-282, 1983.
18. Margaria R., Aghemo P., Rovelli E.: Measurement of muscular power (anaerobic) in man. J. Appl. Physiol., 21, 1662-1664, 1966.
19. Sartorio A., Lafortuna C.L., Conte G., Faglia G., Narici M.V.: Changes in motor control and muscle performance after a short-term body mass reduction program in obese subjects. J. Endocrinol. Invest., 24, 393-398, 2001.
20. Zar J.H.: Biostatistical analysis, ed. 2. Englewood Cliffs, NJ, Prentice-Hall, 1984, pp. 292-305.
21. Pollok M.L.: The quantification of endurance training programs. In: Wilmore J.H. (Ed.), Exercise and sport science reviews, vol. I. New York, Academic Press, 1973, pp. 155-188.
22. Hickson R.C., Hagberg J.M., Ehsani A.A., Holloszy J.O.: Time course of the adaptive responses of aerobic power and heart rate to training. Med. Sci. Sports Exerc., 13, 17-20, 1981.
23. Peterson H.R, Rothschild M., Weinberg C.R., Fell R.D., McLeish K.R., Pfeifer M.A.: Body fat and the activity of the autonomic nervous system. N. Engl. J. Med., 318, 1077-1083, 1988.
24. Aronne L.J., Mackintosh R., Rosenbaum M., Liebel R.L., Hirsch J.: Cardiac autonomic nervous system activity in obese and never-obese young men. Obes. Res., 5, 354-359, 1997.
25. Hirsch J., Leibel R.L., Mackintosh R., Aguirre A.: Heart rate variability as a measure of autonomic function during weight change in humans. Am. J. Physiol., 261, R1418-1423, 1991.
26. Van Vliet B.N., Hall J.E., Mizelle H.L., Montani J.P., Smith M.J. Jr.: Reduced parasympathetic control of heart rate in obese dogs. Am. J. Physiol., 269, H629-637, 1995.
27. Truett A.A., Borne A.T., Poincot M.A., West D.B.: Autonomic control of blood pressure and heart rate in obese hypertensive dogs. Am. J. Physiol., 270, R541-549, 1996.
28. Alpert M.A., Terry B.E., Lambert C.R., Kelly D.L., Panayiotou H., Mukerji V., Massey C.V., Cohen M.V.: Factors influencing left ventricular systolic function in nonhypertensive morbidly obese patients, and effect of weight loss induced by gastroplasty. Am. J. Cardiol., 71, 733-737, 1993.
29. Rippe J.M., Price J.M., Hess S.A., Kline G., DeMers K.A., Damitz S., Kreidieh I., Freedson P.: Improved psychological well-being, quality of life, and health practices in moderately overweight women participating in a 12-week structured weight loss program. Obes. Res., 6, 208-218, 1998.
30. Nieman D.C., Custer W.F., Butterworth D.E., Utter A.C., Henson D.A.: Psychological response to exercise training and/or energy restriction in obese women. J. Psychosom. Res., 48, 23-29, 2000.