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Resistive exercise in conjunction with restricted caloric intake in controlling obesity

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Abstract

The present article reviews the current knowledge concerning caloric restriction in conjunction with either aerobic or anaerobic exercise for weight loss. Conflicting data exists on the effect aerobic exercise (with caloric restriction) has on resting metabolic rate and the increase or preservation of fat-free mass. Aerobic exercise that emphasizes long duration and low intensity (RQ=0.9 or less) has been the prescription clinicians use for inducing body mass loss. A wide range of studies, however, deem caloric restriction as opposed to exercise (either aerobic or anaerobic) as the more important variable regarding weight loss. With this in mind the role of exercise should seek to counteract the deleterious physiological and metabolic adaptations that occur as a result of dieting. This review of literature proposes that resistive exercise in conjunction with a moderate caloric restricted diet may be an alternative form of exercise in controlling obesity.

Resting metabolic rate, resistance training, fat-free mass, very low calorie dieting

Obesity is viewed as a health problem and is therefore a concern for the health care professional. Clearly, two methods are responsible for inducing body mass loss: creating a negative caloric balance through caloric restriction or through increased physical activity. Typically, a high rapid rate of weight loss achieved by dietary manipulation alone results in deleterious physiological and metabolic consequences--loss of fat-free mass (1,2) and decline in metabolic rate (3,4). Therefore, clinicians agree that a careful combination of the two weight loss methods yields the best results.

Aerobic exercise, used in conjunction with caloric restriction, has been the preferred mode of activity for weight reduction for several reasons: (a) aerobic exercise helps to prevent a decrease in fat-free mass (5,6); (b) aerobic exercise helps to prevent an attenuation in resting metabolic rate as a result of dieting (7,8); (c) aerobic exercise that is low in intensity (*RQ*= 0.9 or less) and long in duration (20 minutes or longer) yields a high energy cost and at the same time promotes the utilization of fats via beta-oxidation (9,10); and (d) low-intensity exercise can be performed with minimum risk and is a much safer way to exercise than strenuous anaerobic activity.

The above findings have inspired many clinicians to prescribe aerobic exercise during caloric restriction. In contrast, numerous investigators (11-14) question the role of aerobic exercise in weight loss.

Moderate aerobic exercise (5 d • wk^{-1}, 30-45 min walk/jog) when combined with a reducing diet does very little to enhance weight loss (11). Although it is true that the preferential fuel source during aerobic exercise is fat, dietary restriction provides a greater stimulus for weight loss than aerobic exercise alone (12,15). In addition, several studies do not support the notion that aerobic exercise counters the usual diet-induced decline in resting metabolic rate (11,13,14). Finally, aerobic exercise during a 1200-1500 kcal • d^{-1} diet showed little effect on offsetting the loss of fat-free mass (1,11,16).

Recently, there is emerging evidence suggesting that resistive exercise is helpful in maintaining fat-free mass during moderate caloric restriction (18). Although the caloric cost of resistive exercise is lower than aerobic exercise, maintenance or increases in fat-free mass may produce alterations in the resting metabolic rate favorable to long term weight control. The importance of resistance weight training in conjunction with a caloric-restricted diet for weight control has not been clearly established.

The purpose of this paper, therefore, is (a) to review the effects that aerobic and resistive exercise have on body composition; (b) to review the mechanisms involved that influence RMR; and (c) to review the limited literature on the effectiveness of resistive exercise as an alternate form of exercise for weight control during caloric restriction.

Body Composition

Diet or Exercise for Weight Loss? Very low calorie diets (VLCDs) are efficacious for inducing weight loss (30). In a review of literature by Bjorntorp and Brodoff (15), the researchers concluded that effective control of obesity is achieved more easily by diet than by exercise. While it has been found that exercise can often significantly aid an overweight person, diet is more effective in controlling obesity because it creates a greater negative energy balance. By dieting, according to Bjorntorp and Brodoff, an obese person can decrease energy intake by as much as 1,500 kcal • d^{-1}, compared to an exercise program which yields a much smaller energy loss, usually around a few hundred kcal • d^{-1}.

Similar conclusions were reported by Jequier (31), pointing towards dietary restriction as opposed to exercise as the more important variable regarding weight loss.

In a study by Ballor et al. (32), the intensity of exercise performed--high (85% of peak $V0_2$) or low (50% of peak $V0_2$), for 25 and 50 min/d respectively--had the same effect on body fat loss when combined with a reducing diet. It appears that caloric restriction may negate the expected effects of high vs. low intensity exercise (i.e., low-intensity exercise oxidizes more fat than high- intensity exercise). With this in mind the substrate used during exercise is irrelevant. Alternatively, the role of exercise should seek to restore metabolic function and provide a long- term solution to weight control.

Aerobic Exercise Induced Body-Mass Alterations. In spite of the effectiveness of rapid weight loss using very low calorie diets, this treatment alone has been discouraged due to the deleterious metabolic consequences that can occur (3,4). It is widely accepted that dietary restriction combined with increased energy expenditure can offset these detrimental effects of dieting. The theory is that aerobic exercise training (during caloric restriction) spares body protein as it mobilizes fat stores, provided that the body-mass loss is not too great and not too fast (9). For example, in a 16-week investigation, moderate caloric restriction combined with aerobic exercise or aerobic exercise alone was found to minimize losses of fat-free mass and enhance body-fat loss relative to diet alone (6,24). Hagan et al. (1) reported similar findings in that the subjects who engaged in aerobic exercise (5 d • wk^{-1} for 30 min for 12 weeks) while consuming 1200 kcal•d^{-1} resulted in a greater decrease in body weight and fat weight when compared to diet alone (although the diet/exercise group did not spare fat-free mass). Pavlou's (5) obese male subjects demonstrated a sparing effect of FFM while engaging in aerobic exercise on a variety of hypocaloric diets.

These findings, however, are not conclusive. Nieman et al (11) report that moderate aerobic exercise, 2-7 hours per week and 60% of VO_{2max}, in conjunction with a reducing diet (1300 kcal • d^{-1}) does very little to enhance weight loss. This supports research conducted by Warwick and Garrow (25). Epstein and Wing (26) report that aerobic exercise alone provides little in terms of increases in fat-free mass. And as stated above, Hagan et al. (1) reported no sparing effect on fat-free mass in relation to those subjects undergoing only caloric restriction (1200 kcal•d^{-1}).

Research conducted by Hemsfield et al. (14) found that aerobically exercised women (while on a 900 kcal•d^{-1}) did not display any significant difference in weight loss or improvements in nitrogen balance when compared to sedentary controls. Additionally, aerobic exercise alone without dietary intervention has been shown to be ineffective in promoting weight loss (1,27,28). One suggestion to the disparity in the literature regarding body-mass alterations (and aerobic exercise) may be due to the magnitude of caloric restriction. For example, Zuti and Golding's (6) subjects reduced dietary intake only 250 kcal•d^{-1} (and added exercise to achieve a net caloric deficit of 500 kcal•d^{-1}), resulting in a slight increase in fat-free mass (although not statistically significant). Lewis et al. (24) also witnessed a sparing effect on FFM while on a *unmonitored* dietary plan, whereas Hagan et al. reduced their subjects' caloric intake by approximately 1020 kcal•d^{-1} (men) and 535 kcal•d^{-1} (women), which may have accounted for the absence of a sparing effect on FFM. A possible explanation as to why aerobic exercise (combined with a reducing diet) did not significantly contribute to weight loss (11,14,25) may be the *glycogen-water phenomenon* hypothesized by Warrick and Garrow (25). Aerobic exercise is known to increase glycogen stores; when stored, glycogen retains 3-4 times its weight in water, which would undermine the contribution of aerobic exercise to weight loss.

Although it is possible to achieve nitrogen balance and thus spare fat-free mass on a semistarvation diet (375 kcal•d^{-1}) during exercise (29) Heymsfield et al. (14) report that "the fluid compartment" of fat-free mass, not the protein mass, is the portion maintained in their investigation. At the present time there are no specific or concrete explanations as to what dictates nitrogen balance during underfeeding. In addition, as good as these explanations sound in theory there is no consensus that currently exists regarding the proper caloric restriction and the optimal exercise prescription that will promote effective body-mass alterations (i.e., maintain or increase fat-free mass and decrease bodyfat).

Incidentally, Tremblay et al. (49) reported that subjects who regularly participated in vigorous activities (>9 METS), their subcutaneous fat was generally lower than that of those participating in low intensity activity. It appears that the intensity of any given exercise dictates the degree of body composition alterations.

Resistance training and body-mass alterations. Resistance training has not been extensively investigated in terms of a weight loss tool in conjunction with dietary restriction. To date, a limited amount of data can be found regarding the effects that resistance training (in conjunction with dietary restriction) has on body fat, fat-free mass preservation, and RMR. Although there is some research on this topic (17,18), no consensus has been established. To highlight this topic, a hypothetical model is presented offering an alternative approach to weight control using resistance training.

Resistance training has been regarded as an inferior mode of exercise in terms of weight loss for several reasons: (a) the modest caloric deficit it creates as compared to aerobics (18), and (b) the metabolic fuel utilized during the exercise bout--mainly anaerobic pathways that rely on ATP, CP, and stored glycogen (33).

If one looks at the immediate or acute physiological consequences of resistance training, the above explanations are justified. Of equal importance, are the chronic adaptations that occur as a result of resistive exercise. In the absence of dieting, resistance weight training has been shown to *increase* fat-free mass (18,34) with minimum effects on total body fat (18,34,36). Mayhew and Gross (35) also substantiate the above findings in that after a 9-week resistance weight training program (with no dietary intervention), subjects gained significant increases in fat-free mass and insignificant reductions in subcutaneous fat. (In reference to the insignificant alterations in fat mass, it has been suggested (37) that research studies lasting only 8-10 weeks, are not of sufficient duration to influence profound changes in body composition). Additionally, when weight training was combined with caloric restriction, a 4.32 kg reduction in fat weight and maintenance of fat-free weight were achieved in 8 weeks in a study conducted by Ballor (18). On the other hand, an experimental study conducted by Donnelly et al. (16) found that obese subjects revealed no advantage of adding an exercise regimen (aerobics or weight training) with a VLCD for weight loss or body composition changes. Differences in the two studies exist, however. In the Ballor study the subjects were neither as heavy nor as fat, and caloric restriction was moderate (1200-1500 kcal•d^{-1}) as compared to the Donnelly study (under 1,000 kcal•d^{-1}). Also, subjects in the Ballor study performed twice the number of strength exercises at a higher intensity than in the Donnelly study.

It appears that during very low calorie dieting the incidence of glyconeogenesis (without proper protein supplementation) increases and in response causes a negative nitrogen balance which negates any sparing effect of fat-free mass. Factors that govern whether or not the above phenomenon occurs include protein consumption, the duration of the diet and the level of activity performed (38).

In a more recent study conducted by Donnelly et al. (50), subjects who participated in a weight training program (vs. sedentary controls) during severe energy restriction (800 kcal•d^{-1}) witnessed a statistically significant increase in fast twitch cross sectional fiber area, concurrent with a decrease in bodyweight and FFM. The exact mechanism responsible for this occurrence is unknown. Some suggestions have been discussed elsewhere (51). The clinical significance of the above findings depends upon a more extensive investigation, the researchers concluded.

In summary, the limited research performed on the effect resistance training has on body composition makes it difficult to give definitive answers; however, the studies reviewed in this paper can draw the following conclusions: Weight training added to a moderate caloric-restricted diet (1200-1500 kcal•d^{-1}) results in maintenance of fat-free mass as well as a reduction in fat mass [4.3 kg•8 wk^{-1}] (18). Activity performed, endurance or strength training, during a VLCD results in a loss of fat weight with concomitant losses in fat-free mass (16), unless "proper" protein supplementation is administered (39,40). When weight training is the sole means of inducing a negative caloric balance, an increase in fat-free mass is likely to occur (18,34,35).

Aerobic versus resistive exercise and their influence on RMR. An abundance of research has been performed regarding exercise and its influence on resting metabolic rate. Depending upon which study you review, the metabolic adaptations that occur as a result of physical activity vary. In other words, it appears that the magnitude of the caloric restriction governs the effect exercise has on RMR. In terms of the factors regulating RMR, Bogardus et al. (20) studied 130 nondiabetic adults and found that 83% of the variance in resting metabolic rate was attributable to fat-free mass, age, and sex, with fat-free mass being the most important factor. Ravussin, Burnand, Schutz, and Jequier (23) had similar findings.

Broeder et al. (17) studied the effects of 12 weeks of either high-intensity endurance or resistance training on the metabolic rate on non-dieting adults. Results demonstrated (in both groups) that RMR did not significantly change. This data does suggest that endurance or resistance training may help to prevent attenuation of RMR. An interesting finding that is relevant to this discussion is that only the resistance exercise group showed a significant decrease in percent fat and subsequent increase in fat free mass. Surprisingly, when RMR is expressed in kj/min, there was an approximate 3% increase in the resistance exercise group. Thus "resistance training may offer an important role in maintaining or increasing metabolic rate when an individual is in a negative energy balance."

While it is true that other studies (11,19) demonstrate an increase in RMR of exercise subjects during caloric restriction in spite of a decrease in fat-free mass it is widely accepted that FFM is the chief determinant for the increase, provided that caloric restriction is moderate (20-23).

Lennon et al. (41) studied the effects that intensity of exercise has on RMR. A daily self-selected aerobic activity group (D) which participated in brisk walking, bicycling or any other sporting activity was compared to a prescribed exercise training group (P) which consisted of training every other day on a walk/jog program at speeds varying from 5 to 8.6 mph (dependant on max MET level achieved on the Bruce protocol). Additionally, all groups were on a restricted caloric diet (1200-1800 kcal•d^{-1}). Results revealed that the (P) group showed significant increases in RMR (when compared to controls) while the (D) group didn't, suggesting that training intensity is proportional to the increase in RMR.

Also relevant to this discussion, Poehlman, Melby, Badylak, and Calles (42) found that subjects who engage in heavy exercise and achieve very high maximal aerobic fitness (~70 ml•kg^{-1}•min^{-1}) are more likely to potentiate RMR. Data obtained in a study by Tremblay, Fontaine, and Nadeau (43) suggests that at any given level of fat-free mass, RMR is higher in very active individuals as compared to untrained subjects. The ramification is that the increases in RMR as a result of achieving high aerobic fitness levels are independent of any increase in fat-free mass and are instead due to an increase in the rate of activity per kilogram of tissue (44). This means that there may be different mechanisms governing the exercise-induced increase in RMR (i.e., resistance training increases RMR via an increase in fat-free mass, whereas aerobic training increases RMR without an increase in fat-free mass, but increasing tissue activity per kilogram of fat-free mass). The question remains unanswered, however, as to which mechanism for increasing RMR is superior.

Although the above studies reveal positive effects on the RMR it appears that the greater the magnitude of caloric restriction, the less likely an attenuation will occur (45,46,47).

Another factor that must be considered is the relationship between the genotype of the individual and its effect on the resting metabolic rate. In a study by Bouchard et al. (48) the genotype of the individual can account for as much as 40%.

In summary, it appears that the resting metabolic rate (when influenced by exercise) is regulated by a variety of mechanisms. Limited research has been done on the effect that resistance training has on RMR during energy restriction thus making a definitive conclusion on this topic difficult.

The studies reviewed in this paper draw the following conclusions: Many studies deem fat-free mass as the main contributor to RMR (20,23). Another factor is the intensity of the exercise--athletes who engage in heavy exercise, and as a result achieve a very high aerobic capacity can potentiate RMR independent of increases in fat-free mass (42-44). The degree of caloric restriction may directly be related to the positive effect exercise has on RMR.

This ambiguity regarding the effects exercise has on RMR epitomizes the current understanding of energy metabolism. More well-controlled studies especially regarding the measurement of RMR (most studies do not perform repeat measures), are needed to be conducted for longer periods of time (6 months to a year) to fully understand the effects that resistance training has on RMR.

Conclusion. Clearly, two methods are needed to induce weight loss—diet and exercise. Research is pointing toward control of calories as the more powerful of the two (15,31). Since dietary restriction is the discipline most responsible for weight loss, the exercise selection (whether aerobic or resistance training) may be left to the discretion of the dieter or health professional.

The role then of exercise should seek to counteract the deleterious physiological and metabolic adaptations that occur as a result of dieting. In terms of weight control, it seems that the formula energy output >energy input is not as simple as once thought. According to the studies reviewed, it appears that the extent to which exercise is beneficial to inducing favorable body composition alterations and attenuation of RMR depends chiefly on the magnitude of the caloric restriction. A VLCD combined with an aerobic or resistance training program will result in a reduction in metabolic rate as well as a decrease in fat-free tissue (16). On the other hand, when caloric restriction is moderate (1200-1500 $kcal \cdot d^{-1}$), high-intensity resistance exercise can maintain fat-free tissue (18), which has been shown, to be a powerful influence on an individuals RMR. If this is indeed true, the possession of fat-free mass should be a primary goal for the patient striving for permanent weight control. In contrast, individuals who achieve very high aerobic fitness levels (~70 $ml \cdot kg^{-1} \cdot min^{-1}$) tend to potentiate RMR (42), independent of increases in fat-free mass (44). In addition, individuals who participate in high-intensity exercise (>9 METS) tend to have lower body fat levels than those who participate in low-intensity exercise (49).

This adds a new perspective to the common belief among health professionals that a low-intensity, long-duration activity is the optimal method for weight control. From the literature, it's obviously more complicated than simply prescibing exclusively the above formula for weight reduction. Granted the acute benefits of low-intensity aerobic exercise yield a higher proportion of lipids used when compared to resistance exercise or high intensity aerobic exercise.

The chronic adaptations that occur due to high-intensity exercise (aerobic or resistance exercise), however, should demand consideration for long-term weight control.

The author would like to emphasize that although the literature supports high-intensity exercise for maximizing favorable body composition alterations, it is not practical for the unconditioned obese patient. Therefore, the goal should be to progressively increase the intensity of exercise so that energy expenditure is improved as well as promotion of fat-free mass. A low-intensity aerobic exercise would be advisable in the beginning, because it offers cardiovascular benefits, it's safer and it's more sensible.

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