Increasing physical activity: alterations in body mass and composition

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ABSTRACT I provide an overview of the role of physical activity in the prevention of overweight and obesity and in the treatment of overweight and obese individuals. A secondary focus of this paper is on the potential mechanisms responsible for changes in body composition consequent to physical activity. The use of the term "physical activity" is preferred to the term "exercise" to better reflect a broader scope of movement, not limited to formal exercise regimes. A brief review of prospective studies that investigated alterations in body composition consequent to physical activity alone is presented, along with a discussion of the influence of genetics, macronutrients in the diet, and characteristics of exercise programs on the magnitude of change observed in these studies. This is followed by a review of the specific role of chronic physical activity on energy intake, resting metabolic rate, the thermic effect of feeding, and the thermic effect of activity. Finally, I discuss the role physical activity plays in preventing overweight and obesity and the most appropriate use of exercise in the management of overweight. Am J Clin Nutr 1996; 63(suppl):456S–605.

KEY WORDS Exercise, physical activity, overweight, obesity, prevention, treatment

INTRODUCTION

Scientists and clinicians are now acutely aware of the importance of physical activity in the regulation of body mass and composition. The energy expended by intentionally increasing amounts of physical activity can be substantial. Further, energy intake is also influenced by increasing activity levels, in that intake appears to be more closely regulated to the actual energy needs of the body. I review briefly the existing literature on the effect of increasing amounts of physical activity on altering body mass and composition, interpret the results of this review, and then discuss potential mechanisms by which physical activity might exert its effects on weight regulatory mechanisms. This is followed by a discussion of the most appropriate use of exercise in the prevention of overweight and obesity.

PHYSICAL ACTIVITY AND ALTERATIONS IN BODY MASS AND COMPOSITION

Several excellent review articles have been published within the past 15 y that closely investigated the existing literature on the role of physical activity in altering body mass and composition (1–4). Before summarizing these reviews, however, it is important to first discuss the great variation in results found in individual research studies.

Several studies have reported remarkable alterations in body mass and composition with physical activity intervention. For example, Hadjiofou et al (5) trained 32 obese women for 45 d with a variety of activities over a period of ~10 h/d. Diet was maintained "normocaloric." At the end of the 45 d, there was a mean loss of body mass of 12.4 kg (−1.93 kg/wk) and a mean loss of fat mass of 11.0 kg (−1.71 kg/wk). In addition, Lee et al (6) studied 197 obese male military recruits who had been placed on a 20-wk program of basic training (976 1-h training periods). No dietary restrictions were imposed. They reported a 12.5-kg loss in total body mass (−0.63 kg/wk) and an 11.9-kg loss in fat mass (−0.60 kg/wk).

In contrast, several studies reported little or no change in body mass or composition consequent to a formal program of physical activity. Hagan et al (7) compared the effects of aerobic conditioning (walking, running, or both for 30 min/d, 5 d/wk), diet restriction, or both on body mass and composition in overweight men and women. There were no significant changes over 12 wk in either body mass or composition in the free-eating, exercise group compared with the free-eating, non-exercise control group. Further, Hardman et al (8) studied 28 women enrolled in a 12-mo brisk-walking program, which started with 100 min/wk and increased to 175 min/wk at the end of the third month. They found no significant differences in body mass or composition changes between the brisk walkers and nonexercising control subjects. In fact, the brisk walkers actually gained both body mass and fat mass over the 12-mo program.

Understanding the extreme variability found between studies, we can now look at the results of several reviews that have attempted to synthesize the results of individual studies conducted through 1990. Epstein and Wing (1) conducted a meta-analysis of all the studies investigating aerobic exercise and body mass loss published up to 1980 that had met a set of

1 From The University of Texas at Austin, Department of Kinesiology and Health Education.
2 Portions of this review were adapted with permission from: Wilmore JH. Variation in physical activity habits and body composition. Int J Obes 1995;19(suppl 4):S107–17.
3 Supported by the National Institutes of Health (NHLBI/ROI HL47321–03).
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INCREASING PHYSICAL ACTIVITY

457S

inclusion criteria, for a total of 16 studies. Across all the studies reviewed, there was a mean body mass change of 0.02 kg/wk in the control groups and -0.09 kg/wk for the exercising groups. Relative body fat loss averaged 0.02%/wk in the control groups and -0.09%/wk in the exercising groups, with the heavier subjects having greater fat losses.

I (2) reviewed 46 studies that investigated changes in body mass and composition with exercise training in adult populations. A total of 59 different training groups were represented in these 46 studies. The mean program duration was 16.3 wk. Relative body fat decreased by an average of only 1.6% (−0.10%/wk), total mass by 1.0 kg (−0.06 kg/wk), and absolute fat by 1.6 kg (−0.13 kg/wk).

Ballor and Keesey (3) reported the results of a meta-analysis of those factors affecting changes in total mass, fat mass, and fat-free mass consequent to exercise training. Of the ≈500 published studies reviewed up through 1990, only 53 studies met selection criteria for inclusion into the analysis. The analysis was broken down by sex and by activity, including walking and jogging, cycling, and weight training.

Table 1 summarizes the changes in body mass and composition for those individual studies and reviews presented in this section. From this table, it is apparent that there is reasonably close agreement across the three review articles as to the magnitude of weekly changes in body mass and composition despite the substantial extremes in results from the individual studies cited. From the results of the review articles cited in Table 1 it must be concluded that formal exercise training, in the absence of significant changes in diet, does not result in substantial changes in body weight and composition. On the basis of the mean changes shown for these three reviews, over the course of 1 y an individual would experience a loss of 3.2 kg body mass, 5.2 kg fat mass, and 5.8% relative fat, and a gain of 2.0 kg fat-free mass.

### TABLE 1

<table>
<thead>
<tr>
<th>Study</th>
<th>Mean change in body mass</th>
<th>Mean change in fat mass</th>
<th>Mean change in relative fat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hadjiolova et al (5), individual study</td>
<td>−1.93</td>
<td>−1.71</td>
<td>−1.17</td>
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<tr>
<td>Lee et al (6), individual study</td>
<td>−0.63</td>
<td>−0.60</td>
<td>−0.49</td>
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<tr>
<td>Hagan et al (7), individual study</td>
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<tr>
<td>Males</td>
<td>−0.03</td>
<td>−0.02</td>
<td>−0.01</td>
</tr>
<tr>
<td>Females</td>
<td>−0.05</td>
<td>−0.12</td>
<td>−0.12</td>
</tr>
<tr>
<td>Hardman et al (8), individual study</td>
<td>0.01</td>
<td>0.02</td>
<td>0.08</td>
</tr>
<tr>
<td>Epstein and Wing (1), review</td>
<td>−0.09</td>
<td>NR²</td>
<td>−0.09</td>
</tr>
<tr>
<td>Wilmore (2), review</td>
<td>−0.06</td>
<td>−0.13</td>
<td>−0.10</td>
</tr>
<tr>
<td>Ballor and Keesey (3), review</td>
<td></td>
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</tr>
<tr>
<td>Walking, jogging</td>
<td>−0.08</td>
<td>−0.10</td>
<td>−0.09</td>
</tr>
<tr>
<td>Males</td>
<td>−0.05</td>
<td>−0.10</td>
<td>−0.13</td>
</tr>
<tr>
<td>Females</td>
<td>−0.06</td>
<td>−0.11</td>
<td>−0.13</td>
</tr>
<tr>
<td>Cycling</td>
<td>−0.03</td>
<td>−0.05</td>
<td>−0.10</td>
</tr>
<tr>
<td>Males</td>
<td>−0.03</td>
<td>−0.10</td>
<td>−0.16</td>
</tr>
</tbody>
</table>

1 This table was adapted with permission from the International Journal of Obesity (9).

2 Not reported.

### POTENTIAL FACTORS AFFECTING CHANGES WITH TRAINING

Although there are many potential factors that could affect the responses of body mass and composition to exercise training, I focus briefly on several that could play a critical role.

#### Genetic limitations

It has been well established from previous research that there is considerable individual variability in the response to a given intervention. The genetic basis of this variability was recently shown by Bouchard et al (10). Seven pairs of young adult, male, identical twins exercised on a cycle ergometer twice a day, 9 of every 10 d, over a period of 93 d, at a work rate that was individually prescribed to produce a net energy deficit of 4.2 MJ/d (1000 kcal/d). Energy intake was fixed at pretraining, weight-maintenance levels. The total energy deficit over the course of the study was 244 ± 9.8 MJ (x ± SEM). The mean loss in body mass was 5.0 kg (0.38 kg/wk) and the mean loss in fat mass was 4.9 kg (0.37 kg/wk). Relative body fat decreased from 23.6% to 18.8%, a total loss of 4.8%, or 0.36%/wk. There was reasonably close agreement in the amount of body mass lost within a given twin pair, but there was about a fourfold difference between the twin pair that lost the most compared with the twin pair that lost the least. At the extremes, for the same energy deficit of 4.2 MJ/d, one subject lost ≈1 kg and another lost ≈8 kg. Thus, for an identical intervention the variation in response can be considerable.

#### Macronutrients in the diet

The macronutrient composition of the diet consumed by subjects is also recognized as an important factor that could alter the magnitude of change in body mass and composition. Tremblay et al (11) studied nine healthy male subjects who exercised on a treadmill for 1 h at an intensity of 55–60% of their maximal oxygen uptake, which constituted a mean energy expenditure of...
~2.8 MJ, or ~2.2 MJ above what they would have expended had they not exercised. The energy intakes and expenditures of the subjects were then directly observed for 48 h after exercise. The subjects had free access to three different diets, one on each of three different occasions: low-fat, high-fat, and mixed.

Energy balances computed over the 48-h postexercise observation period were as follows: -6.4 MJ when subjects consumed the low-fat diet, -4.5 MJ when subjects consumed the mixed diet, and 0.9 MJ when subjects consumed the high-fat diet. This indicates the important interaction between exercise and diet. Exercise can induce a substantial energy deficit when a low-fat diet is consumed after exercise. However, the increase in energy intake associated with the high-fat diet was sufficient to fully compensate for the energy cost of the exercise and the excess postexercise energy expenditure.

Characteristics of the exercise program

The extent or magnitude of change in body mass and composition with exercise training can be greatly affected by the nature of the exercise intervention. The mode of activity is one possible source of variation in response. In recent unpublished observations from our laboratory, we observed greater decreases in fat mass and increases in fat-free mass consequent to resistance training compared with standard forms of aerobic training such as stationary cycling, walking, and running. It was also shown in one study that the changes in body mass and composition were not as great with swimming compared with walking and stationary cycling (12). However, Lieber et al (13) found comparable reductions in relative and absolute body fat in sedentary males assigned to an 11.5-wk program of either swimming or running.

The magnitude of change in body mass and composition is also highly dependent on the duration, frequency, and intensity of the training program. It is possible that there exists a threshold that must be exceeded before substantial alterations in body mass and composition can occur. Further, there has been speculation that low-intensity exercise produces greater losses in fat mass compared with high-intensity exercise as the result of a higher percentage of the substrate coming from fat. However, although the respiratory exchange ratio is significantly lower, indicating a greater rate of fat utilization, the rate of energy expenditure is also considerably lower, so the net effect on the total grams of fat utilized is negated. Thus, there is little or no difference in the total grams of fat utilized per unit of time (14). Further, there is potentially a substantially greater utilization of fat during the postexercise period with higher-intensity exercise (15, 16).

POTENTIAL MECHANISMS FOR ALTERING BODY MASS AND COMPOSITION

Over the past 15 y, there has been an increased interest in the potential mechanisms by which physical activity might alter body mass and composition. Theoretically, physical activity can affect both sides of the energy balance equation:

Energy intake = energy excreted

= resting metabolic rate (RMR)

+ thermic effect of feeding (TEF)

+ thermic effect of activity (TEA) (J)

Each of these will be briefly discussed.

Energy intake

Generally, with exercise of low to moderate intensity and/or duration there is little or no change in energy intake. With exercise of higher intensity and longer duration there is an increase in energy intake. Paradoxically, the energy intake of male rats appears to be reduced with increased levels of physical activity, whereas female rats tend to eat the same or slightly more (17). Although the evidence is not as strong in humans, mainly as the result of limitations in methodology, there is support for this same trend (18). The reason for this sexual dimorphism in response is unclear at this time. The pattern of response may differ between subjects of different percentages of body fat and with different patterns of body fat distribution.

Resting metabolic rate

There has been considerable interest over the past 10 y in the potential role of exercise training in increasing RMR. Because RMR represents between 60% and 70% of the total energy expended each day in an active individual who is not training, an increase in the RMR by only 1-2% could have a major effect on weight regulation over the long term. The RMR response to exercise training is still under investigation. Although several cross-sectional studies have shown higher RMR values expressed per kilogram of fat-free weight in aerobically trained and resistance-trained compared with untrained men and women (19), other studies have been unable to confirm this relation (20). Longitudinal studies look promising (21), but there is a need for additional longitudinal studies investigating both aerobic training and resistance training to determine the ability of either or both of these to increase RMR.

Thermic effect of feeding

It is reasonably clear that a single bout of exercise, either before, during, or after a meal, increases the thermic effect of that meal. The response does differ between lean and obese subjects, with obese subjects generally having an attenuated response (22). Less clear is the role of exercise training on modifying this response (22).

Thermic effect of activity

Increasing physical activity by formal exercise training can substantially increase the TEA. However, there are several factors that must be considered. First, there is the potential for a substantial expenditure of energy postexercise because metabolic rate can remain elevated above resting levels for several minutes up to ~24 h. This postexercise response has been referred to as the excess postexercise oxygen consumption (EPOC). There has been increasing interest in the importance of the EPOC in general weight regulation because it could have a major effect on total TEA (19, 23).

Increasing energy expenditure with a formal exercise program may result in a spontaneous reduction of normal daily activity throughout the remainder of the waking day. However, Meyer et al (24) reported either no change or an increase in physical activity the rest of the day as a result of training. These results have been replicated in lean and obese women, obese boys, and lean men. Goran and Poehlman (25), however, in a
INCREASING PHYSICAL ACTIVITY

study of healthy elderly subjects, found no increase in TEA with physical training. This was due to a compensatory decline in physical activity during the remainder of the day equal to the increase with training.

PREVENTION OF OVERWEIGHT

Physical activity and formal exercise training might be more important in the prevention of overweight and obesity than in their treatment. Although this has not yet been well-researched, several studies suggest that those who are active weigh less and have a lower fat mass than do those who are inactive. In their review of the data from the first National Health and Nutrition Examination Survey Epidemiologic Follow-up Study [1971-1975 (baseline) to 1982-1984 (follow-up)], Williamson et al (26) reported that recreational activity was inversely related to body weight at both baseline and at follow-up. Low recreational activity reported at follow-up was strongly related to a major weight gain (> 13 kg) that occurred over the preceding 10 y. The estimated relative risk of major weight gain for those in the low activity level group at follow-up compared with those in the high activity level group was 3.1 for men and 3.8 for women.

In the analysis of the initial baseline and follow-up data from the participants in the Multiple Risk Factor Intervention Trial (MRFIT), Blair (27) found that high baseline physical activity status and an increase in physical activity during the trial were both inversely associated with weight gain. In other words, those who were physically active at baseline, or who became active during the follow-up period, were the least likely to experience significant weight gain. Thus, physical activity might have its most significant effect in preventing, rather than in treating, overweight and obesity.

SUMMARY AND CONCLUSIONS

From the vast research literature available, it can be concluded that formal physical activity in the form of exercise training results in relatively small changes in body mass and composition over short periods of days or weeks. This is inconsistent with expectations because physical activity constitutes a major source of daily energy expenditure. The body, however, seems to partially compensate for the energy deficit created by exercise training by increasing energy intake, decreasing energy expenditure outside the formal exercise time, or both. However, when viewed over longer periods, such as months or years, increasing levels of physical activity can promote moderate changes in body mass and composition. Although this would be adequate for an individual who is moderately overweight or obese, it would make only a modest contribution to the substantial weight loss needed by an individual who is morbidly obese. It is also important to recognize that there is substantial individual variability in the response to a given intervention.

In almost all cases, weight loss is best achieved by combining dietary intervention with increased amounts of physical activity. The most effective strategy for weight loss in either moderately obese or morbidly obese individuals appears to be a hypoenergetic, low-fat diet combined with a moderate-intensity, moderate-duration resistance or aerobic exercise training program (4, 14). Exercise coupled with a hypoenergetic diet can accentuate losses of body mass and fat mass and preserve fat-free mass and RMR. However, there is a point at which the total energy deficit will exceed a certain critical value that will then lead to substantial reductions in fat-free mass and RMR, both highly undesirable changes (4, 19).

Increasing amounts of physical activity or maintaining high levels of physical activity for purposes of weight control might be most important in preventing the increases in weight known to occur with aging, from the early 20s through the late 60s. Although much less research has been conducted in this area of prevention in humans, the limited research to date is promising, and the animal research is very clear that animals that exercise weigh less and have lower absolute and relative body fat levels than do their sedentary counterparts. This preventive aspect must be an area of priority for future research attempting to better understand the role of physical activity in weight regulation.

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REFERENCES


