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The role of physical activity in producing and maintaining weight loss

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Summary

The majority of randomized, controlled trials (RCTs) show only modest weight loss with exercise intervention alone, and slight increases in weight loss when exercise intervention is added to dietary restriction. In most RCTs, the energy deficit produced by the prescribed exercise is far smaller than that usually produced by dietary restriction. In prospective studies that prescribed high levels of exercise, enrolled individuals achieved substantially greater weight loss—comparable to that obtained after similar energy deficits were produced by caloric restriction. High levels of exercise might, however, be difficult for overweight or obese adults to achieve and sustain. RCTs examining exercise and its effect on weight-loss maintenance demonstrated mixed results; however, weight maintenance interventions were usually of limited duration and long-term adherence to exercise was problematic. Epidemiologic, cross-sectional, and prospective correlation studies suggest an essential role for physical activity in weight-loss maintenance, and post hoc analysis of prospective trials shows a clear dose–response relationship between physical activity and weight maintenance. This article reviews the role of physical activity in producing and maintaining weight loss. We focus on prospective, RCTs lasting at least 4 months; however, other prospective trials, meta-analyses and large systematic reviews are included. Limitations in the current body of literature are discussed.

Keywords

exercise; obesity; reduced obesity; weight reduction; weight regain

Introduction

The majority of the adult population in the US is overweight or obese.[1] Consequently, effective interventions are needed that will help people achieve and maintain a healthier body weight. Addressing the issue of body weight should start with a basic understanding of energy balance. Negative energy balance is required for weight loss. People lose weight when energy expenditure exceeds energy intake for a defined period of time. Successful maintenance of weight loss occurs when expenditure and intake are matched at the reduced

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body weight for a continued period of time. Although these states of energy balance are clear, identifying the optimum strategies to achieve them is challenging. In particular, there is controversy about the relative importance of changes in diet versus changes in physical activity in body-weight management.

This article aims to review the published research that addresses the role of physical activity as a strategy in body-weight management, both when used as a single intervention and when used in combination with dietary restriction. We chose to focus on prospective, randomized, controlled trials (RCTs) of at least 4 months in duration; however, other prospective trials, meta-analyses and large systematic reviews are also included and discussed as appropriate. We first examine the role of physical activity as an intervention alone or in combination with dietary modification in producing weight loss. Next we discuss the role of physical activity in weight-loss maintenance. Finally, we identify the limitations of the current body of literature, and provide suggestions for future research.

The Role of Physical Activity in Producing Weight Loss

Physical activity alone

Sixteen RCTs[2–17] were identified that had compared weight loss in groups assigned physical activity alone with that in groups assigned no intervention. A summary of the findings of these RCTs is included in Table 1. Of note, we excluded from our analysis studies in which individuals were specifically counseled to maintain their baseline body weight during the course of the intervention, such as the STRRIDE (Studies of a Targeted Risk Reduction Intervention through Defined Exercise) study.[18] In almost all these studies the average BMI was between 25 and 30 kg/m^2. Thus, on the whole, overweight but not obese individuals were included. The duration of these studies ranged from 4 months to 16 months. In all studies except one[15] a trend towards some degree of weight loss or prevention of weight gain was seen with exercise compared with controls. Of the 16 RCTs, 11 found statistically significant improvements in weight loss with exercise compared with controls.[2,3,5–7,9–11,13,16,17]

The magnitude of the differences in weight outcomes between groups in these studies was small. Weight loss in the exercise group ranged from 0.1 kg to 5.2 kg, with most studies showing weight loss of only 1–3 kg. These findings are similar to those of previously published meta-analyses and reviews which concluded that exercise alone was associated with weight loss of 0.6–3.0 kg compared with controls.[19–22]

With few exceptions, the RCTs we reviewed suffered from notable limitations that might confound interpretation of the results. In the majority of these studies, energy expenditure resulting from physical activity was neither rigorously controlled nor accurately measured, and the negative energy balance induced by exercise was modest to the degree that one would not expect substantial weight loss. Frequently, the levels of exercise prescribed in weight-loss studies are derived from exercise standards intended to promote cardiovascular health or fitness, not weight loss. The majority of studies that we reviewed used exercise prescriptions of ~60–180 min per week.[2–4,6,8–10,12–15] Importantly, only four of these exercise studies considered change in body weight or composition as a primary outcome of the study.[5,7,10,11] The other studies addressed the effect of exercise on lipids, cardiovascular disease risk factors, glucose and insulin levels, BMD or diabetes.

Several uncontrolled studies and shorter-term RCTs have examined the effects of higher levels of exercise than prescribed in the RCTs we selected and have found correspondingly larger weight losses.[23,24] Lee *et al*.[23] studied the impact of 5 months of military training on the body weight of obese male recruits. The participants averaged 29 h per week of training, 57% of which was considered intense physical activity. In the 175 individuals who completed the training, the mean weight loss was 12.5 kg. Similarly, Hadjiolova *et al*.[24] evaluated the effect of a 45-day exercise program on the body weight of 32 obese women. Studied individuals averaged 10 h of activity daily (estimated energy expenditure 3,600–3,700 kcal per day) and lost an average of 12.5 kg. Despite the uncontrolled study design, the findings of these studies are important because they demonstrate that when the exercise prescription is of sufficient magnitude to produce an energy deficit of 500–1,000 kcal per day (a deficit usually produced by programs involving caloric restriction) substantial weight loss can occur.

This conclusion is supported by two short-term studies performed in women[25] and men,[26] which demonstrate that when energy balance induced by either caloric restriction or energy expenditure is carefully matched the effect of diet-induced and exercise-induced, weight loss is similar. Individuals in these trials were randomized to an identical daily energy deficit (500–700 kcal), created either by diet or by supervised daily exercise, for a 12-week period. In the exercise-only group, energy intake was closely controlled to baseline levels. Similar weight losses (approximately 6 kg in women and 8 kg in men) occurred in both the diet-only and exercise-only groups, which suggests that if a large negative energy balance is successfully created by exercise substantial weight loss can occur, provided that there is not a compensatory increase in energy intake.

Given the results above, higher levels of exercise than those prescribed in most of the RCTs we reviewed might be necessary to promote weight loss; however, as the exercise prescription increases in amount or length, adherence becomes a major challenge. In the Midwest Exercise Trial,[5] the longest study we reviewed, less than half the individuals in the exercise arm completed the 16-month study despite being compensated for their time.[27] Similarly, in the study by Ross *et al.*[25] only about 50% of individuals randomized to the activity arm completed the intervention.

Another factor that might confound the results of the RCTs we reviewed is that energy intake can increase when energy expenditure is increased long term, and this change might attenuate weight loss with exercise alone.[27] In most studies, it is difficult to verify that energy intake in the exercise-inter vention group did not increase above the level of the participants' baseline diet. Compensation can also occur in other components of energy balance, including resting metabolic rate (RMR) and nonexercise physical activity in response to high levels of exercise.

Finally, the loss of adipose tissue that occurs when an individual's exercise level increases can be negated to some degree by a corresponding rise in lean muscle mass, which leads to difficulties in interpreting results when outcome is assessed solely by changes in body weight. Studies that involve body composition consistent ly show that exercise training improves body composition, often independent of weight loss,[28–30] and can preferentially reduce abdominal visceral fat[7,26,31] and improve cardio metabolic risk factors.[32] Thus, body weight might not be the optimum sole outcome measure to evaluate when examining the health benefits of an exercise intervention.

Physical activity and dietary restriction

Seventeen RCTs were identified that had compared weight loss by food restriction alone with food restriction plus physical activity for a duration of 4 months to 1 year (Table 2).[2,4,6,12,28,29,33–43] The average BMI of individuals enrolled in these studies ranged from 25 to 37 kg/m^2, with the majority of studies reporting an average BMI of over 30 kg/m^2. Thus, on the whole, individuals in the diet plus exercise studies were heavier than those in the exercise-alone studies. The findings of most of the studies suggest that adding physical activity to food restriction tends to produce greater weight loss than dietary restriction alone;[2,4,6,28,29,33,35–38,40–43] however, in only two of these studies[35,43] did the difference reach statistical significance.

Overall, the addition of exercise to food restriction produced an average increase in weight loss of about 1.5 kg. The exercise interventions were not generally intense and ranged from 60 min to 240 min per week; the exercise prescription exceeded 200 min per week in only four studies.[35,36,40,41] Seven studies[2,29,33,37,38,40,42] also included a resistance-training arm, but this intervention led to no greater difference in weight loss compared with control. All studies reported data for people who completed the treatment regimen only. Completion rates ranged from 63% to 100%; in the studies that reported data on adherence to exercise, rates ranged from 57% to 90%.[28,29,35,38] In over half of the studies body weight or body composition was the primary outcome.[28,29,33–38,40–42] The other studies addressed effects of diet and exercise on lipids, cardiovascular disease risk factors, or glucose and insulin levels and thus might not have been powered to detect differences in body weight.

The results of the 17 RCTs are consistent with those of an extensive 1997 meta-analysis by Miller *et al*.,[21] in which they reviewed 493 studies (not limited to RCTs) published between 1969 and 1994 and which reported comparisons of diet (224 studies), aerobic exercise (76 studies) or diet plus aerobic exercise (119 studies) for weight loss in healthy individuals. Diet alone (−10.7 kg) and diet plus exercise (−11 kg) were superior to exercise alone (−2.9 kg) in reducing weight; however, there was no significant difference between the diet and diet plus exercise groups.

Although most RCTs show trends towards a modest improvement in short-term weight loss with the addition of exercise to diet, this effect is rarely significant. Again, this result is not un expected given the low amount of physical activity generally prescribed. In most of these studies activity intervention was intended to expend roughly 1,000–1,500 kcal per week compared with a caloric deficit of 500–1,000 kcal per day with the dietary intervention; therefore, the contribution of physical activity towards negative energy balance was much less than the contribution of food restriction. In addition, both the level of adherence to the activity prescription and the short duration of these RCTs are important limitations. To be effective for weight management, it is likely that excercise needs to be prescribed and adhered to for longer durations to improve individuals' fitness to the point where they can perform enough work and expend sufficient energy to cause weight loss.

The Role of Physical Activity in Maintaining Weight Loss

Twelve RCTs were identified that had investigated weight regain after weight reduction.[44–55] For inclusion in this review, the RCTs had to compare an exercise-based weight-maintenance program with a control, and report a follow-up period of at least 1 year after weight reduction. The design of these studies varied considerably; they are presented in two distinct groups in Tables 3 and 4. The average BMI ranged from 30 to 38 kg/m^2, though the BMI was not explicitly reported in several studies.[47–51] The exercise interventions ranged from 60 min to 300 min per week.

Eight RCTs randomized individuals to diet versus diet plus exercise intervention (Table 3) with follow-up of greater than one year after completion of the intervention.[47,48,50–55] The duration of the weight-loss intervention was less than 1 year in all studies. In more than half of these studies[47,48,50,52,54] the initial weight reduction intervention was 20 weeks or less in length. Little or no supervised intervention was prescribed in the maintenance period.

Only a few studies evaluated the impact of a physical activity intervention during the weight-loss maintenance phase. We identified four RCTs that compared physical activity inter ventions with a sedentary control group after initial weight reduction (Table 4).[44–46,49] These studies began with a 12–26-week weight-loss intervention, after which individuals were randomly assigned either an exercise inter vention or control intervention for a 26–40-week weight-maintenance phase, with a subsequent minimally supervised follow-up period. In most of these studies, the individuals in both arms were given advice to continue some degree of dietary modification.

Overall, only four studies showed significantly less weight regain at follow-up in the group assigned to exercise either during the weight reduction intervention[47,50,54] or the weight maintenance intervention;[45] however, in the majority of studies [45,47,49–55] exercise produced a weight difference that favored the exercise group of, on average, –4.5 kg at longest follow-up.

Several meta-analyses and systematic reviews have addressed the role of exercise in weight-loss maintenance. Miller *et al*.[21] reviewed 152 studies (not limited to RCTs) that had evaluated diet, exercise, or diet plus exercise and reported at least 1 year of follow-up data. At 1-year post program, the mean amount of weight loss maintained (6.6 kg, 6.1 kg and 8.6 kg in the diet, exercise or diet plus exercise group, respectively) was greatest in the diet plus exercise group, though this result was not significant.

Curioni and Lourenco[56] reviewed RCTs “published through March 2003” comparing diet plus exercise interventions with diet alone, all with follow-up greater than 1 year after initial intervention. In the six studies they identified, programs that included both diet and exercise produced a 20% greater weight loss than diet alone by the end of the intervention period and at 1-year follow-up. Fogelholm and Kukkonen-Harjula[57] reviewed all research reports published between 1980 and early 2000 that had data on physical activity and weight gain or regain with follow-up of more than 1 year. Prospective observational studies (16), nonrandomized studies (19), and RCTs (11) were included. The results from observational studies, but not clinical trials, suggested that exercise leads to successful weight-loss maintenance.

A central issue in the effectiveness of a physical activity program is adherence; poor adherence to a given exercise protocol might be one of the main reasons why RCTs so often fail to find an association between physical activity and weight maintenance.[22] In many of the RCTs we reviewed substantial proportions of patients did not complete exercise interventions. The 1986 study by Perri *et al.*[48] reported that 42% of individuals assigned the exercise intervention reported no exercise at 18 months of follow-up. The remaining 58% of individuals reported an average of only 46 min per week.

Van Dale *et al.*[52] reported that 72% of individuals discontinued the exercise training after completing the initial 12–14-week treatment phase. Wadden *et al.*[53] reported that participants in his study attended only 57% of exercise sessions during weeks 25–40 of the exercise intervention. The 1998 study by Wing *et al.*[55] reported that attendance at group exercise sessions during the initial 6 months was 56– 70%; however, attendance dropped to 16–37% in months 6–12. A poor relationship between exercise interventions and prevention of weight regain in RCTs is, therefore, not surprising.

Observational and cross-sectional studies provide more consistent results concerning the role of physical activity in weight-loss maintenance.[58–60] For example, data from the National Weight Control Registry (NWCR) support the idea that high levels of physical activity are critical to weight-loss success. The NWCR is a registry of over 6,000 individuals who have maintained a minimum 13.6 kg weight loss for at least 1 year; the average weight loss is 30.4 kg maintained for a mean duration of 5.5 years. NWCR members report expending an average of 2,682 kcal per week by means of physical activity, and nearly 90% report regular exercise.[60]

Using the gold-standard doubly labeled water method to obtain activity levels, Schoeller *et al.*[61] and Weinsier *et al.*[62] found that 77–80 min per day of moderate intensity activity added to a sedentary lifestyle was needed to prevent weight regain in the year after weight loss.

Long-term follow-up data from non randomized, prospective, interventional studies also suggest a critical role for physical activity in weight-loss maintenance. Fogelholm and Kukkonen-Harjula[57] reviewed 13 non randomized, weight-reduction studies that had a prospective follow-up of more than 1 year and found that most results were consistent: 12 of 13 studies reported that a large amount of physical activity at follow-up was associated with less weight regain after weight reduction.

Several of the RCTs we reviewed also show a strong retrospective relationship between amount of exercise performed at follow-up and maintenance of weight loss. Wadden *et al.*[53] found that the greater the number of minutes participants walked in the 4 months before follow-up, the less weight they regained (co efficient of correlation –0.44, P <0.05). Fogelholm *et al.*[45] reported that daily physical activity, as indicated by a higher number of daily steps, was a positive and independent predictor of weight maintenance after a very-low-calorie diet. Wing *et al.*[54] compared individuals reporting low (using 168–616 kcal per week), medium (700–1,200 kcal per week) and high (1,372–4,116 kcal per week) levels of exercise at 1 year follow-up and found weight losses of –2.3, –5.9 and –9.1 kg respectively (P <0.01).

Other prospective studies have also found that when data were examined on the basis of how much exercise was actually performed, greater levels of exercise were associated with improved weight loss maintenance at follow-up.[63,64] Jakicic *et al.*[64] studied 201 overweight or obese sedentary women enrolled in a 12-month behavioral weight-loss intervention. Enrolled women were randomly assigned one of four exercise regimens involving different estimated energy expenditures and exercise intensities. No significant effect of either exercise intensity or duration on the changes in body weight between groups was reported; however, when data were analyzed in a post hoc analysis on the basis of how much exercise was actually performed, weight loss at 12 months was significantly greater in the group with >200 min per week of exercise (11.6 kg) compared with the group with less than 150 min per week of exercise (3.8 kg). In addition, women averaging approximately 280 min of exercise per week showed no weight regain from 6 months to 18 months of treatment.

A prospective study published in 2003 by Jeffery *et al*.[65] provides direct evidence for a relationship between the amount of exercise performed and long-term weight-loss maintenance. Overweight men and women in a behavioral therapy program were randomized to standard behavioral therapy (energy expenditure goal of 1,000 kcal per week) or a high level of physical activity group (energy expenditure goal 2,500 kcal per week). At 18 months, the standard behavioral therapy group averaged 1,629 kcal per week whereas the high physical activity group averaged 2,317 kcal per week. Energy intake (self-reported) was the same in both groups. Mean weight loss at 6 months was no different between the groups, but weight loss was significantly greater in the high physical activity group than in the standard behavioral therapy group at 12 months (−8.5 ± 7.9 kg versus −6.1 ± 8.8 kg [mean ± SD]) and at 18 months (−6.7 ± 8.1 kg versus −4.1 ± 8.3 kg).

Despite the mixed results of the RCTs presented in Tables 3 and 4, cross-sectional and prospective correlation studies strongly support the important role of physical activity in weight-loss maintenance. Retrospective analyses demonstrate that when high levels of physical activity are actually performed a very strong relationship between activity and weight-loss maintenance is consistently observed.

Gaps in Our Knowledge of Physical Activity and Weight Loss

What impact does increased physical activity have on energy balance?

In several studies we reviewed, the expected weight loss (as calculated from the energy expenditure of the exercise prescribed) was significantly greater than that which is actually observed, even when the exercise intervention was supervised. For example, at the end of the Midwest Exercise Trial[5], women who exercised were expending approximately 2,200 kcal per week if exercise was supervised and had increased 24 h energy expenditure by 209 ± 555 kcal (mean ± SD) over baseline as assessed by doubly labeled water, yet had lost no

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weight. Although energy intake was measured periodically and not found to be increased, some compensatory change in calorie intake must have occurred for body weight to remain stable. This study was, however, performed at a time of high risk for weight gain (many participants were college students) as indicated by the 2.9 kg weight gain in the control group shown in Table 1.

Exercise can also affect other components of energy expenditure, including RMR and spontaneous physical activity. Although RMR decreases during energy restriction, there is evidence that RMR is preserved when weight loss is caused by exercise[66], and recent data suggest that RMR is greater in adults who perform regular aerobic exercise than their sedentary peers.[67–72]

Compensatory changes can also occur in levels of spontaneous physical activity outside the exercise period of the study. Donnelly and Smith[27] have reported anecdotal observations which suggest that when an exercise program is initiated, spontaneous physical activity might temporarily decline because of fatigue, but returns to baseline levels at some time point and might eventually increase to above baseline levels as fitness increases. In the Midwest Exercise Trial[5], however, the increase in 24 h energy expenditure at the end of the study, as measured by doubly labeled water (209 kcal per day) was less then expected given the measured energy expenditure of exercise (2,200 kcal per week). This finding suggests that a compensatory decrease in spontaneous physical activity can persist long term. An important area for future research is the impact of exercise on other components of the energy-balance equation, including energy intake, RMR, and spontaneous physical activity during times when exercise is not being undertaken.

Why might physical activity be critical to maintain long-term weight-loss?

Although data suggest that high levels of physical activity are associated with successful weight-loss maintenance, it is not clear why this relation is the case. One possibility is that the primary impact of physical activity on weight-loss maintenance is mediated through its effect on total energy expenditure. The increase in physical activity energy expenditure that occurs with exercise might compensate for the reduction in total energy expenditure that otherwise occurs with weight loss and might raise total energy expenditure to the point where the caloric restriction required to match energy expenditure is feasible for people to maintain. Exercise might also augment RMR in the long term, as discussed above; this change would help to compensate for the expected decrease in RMR that occurs with weight loss.

Another possible hypothesis for the association between high levels of physical activity and weight loss is that physiologic regulation of energy intake and maintenance of energy balance becomes facilitated. This idea was initially developed by Mayer in the 1950s. He observed that energy intake was better matched to energy expenditure when people were physically active. The matching was less precise when people were very inactive.[73] High levels of energy expenditure might create an environment in which body-weight-regulation systems function optimally match energy intake and expenditure. At lower levels of energy throughput the physiological adjustments for intake and expenditure might be less well matched.

Finally, high levels of physical activity could simply be a marker of adherence to dietary restriction. Although a number of studies appear to support the conclusion that physical activity is a key behavior for improving long-term weight loss, many studies fail to examine whether these individuals maintain changes in eating behaviors that ultimately would also contribute to improved long-term weight loss. Some short-term studies have suggested that physical activity programs can improve adherence to an energy-restricted diet.[74] An important consideration, therefore, is that exercise does not act in isolation to improve long-term maintenance of weight loss and might act in concert with other important behaviors to contribute to successful maintenance of weight loss.[75]

Is the amount of activity needed for weight-loss maintenance really ‘one size fits all’?

Several major organizations recommend moderate physical activity in the range of 60– 90 min per day for weight-loss maintenance.[76,77] Individual specific factors such as age, sex, amount of weight lost, current body weight, ethnicity, and genetic differences might, however, impact the amount of activity required for weight-loss maintenance, and some individuals might require more physical activity to maintain a weight loss than others. Successful weight-loss maintainers in the NWCR report engaging in physical activity that used 2,621 ± 2,252 kcal (mean ± SD) per week.[60] The high SD associated with the amount of activity reported suggests wide variability within this group.

One major source of variability might be sex. Women have lower BMI than men and thus need more exercise of the same intensity to burn the same number of calories. Few studies have, however, provided different exercise prescriptions on the basis of sex or analyzed data separately for men and women, and comparative data on sex, physical activity and weight maintenance are scarce. In addition, no prospective studies have performed subgroup analysis to evaluate the impact of age, current body weight, amount of weight loss maintained, and degree of concurrent dietary restriction. These factors are all important and might affect the amount of activity required to achieve energy balance at a reduced body weight.

Conclusions

Evidence from existing RCTs is relatively consistent with regard to the role of exercise in producing weight loss, either when used alone or in combination with dietary modification. Although the majority of RCTs show only modest weight loss with exercise alone, in most of these studies the level of exercise prescribed was relatively low and would have produced an energy deficit far smaller than that usually recommended for weight loss by caloric restriction. The resulting weight-loss findings from these studies are, therefore, consistent with the amount of exercise prescribed. Although other studies demonstrate that it is possible to achieve significant weight loss with high levels of physical activity alone (when the volume of exercise prescribed is equivalent to the energy deficit usually recommended for weight loss by caloric restriction and energy intake is held constant), producing the amount of activity needed is challenging given the difficulty of getting sedentary people to achieve and consistently adhere to increased physical activity.

Although adding physical activity to dietary modification increases initial weight loss, only a small advantage was gained in most of the RCTs. The daily energy deficit produced by short-term food restriction usually greatly exceeds that produced by physical activity and thus the contribution of additional physical activity (in the levels prescribed in many of these studies) to negative energy balance was minimal.

RCTs that have investigated the role of physical activity in weight-loss maintenance have reported mixed findings; however, limitations in existing RCTs include poor adherence to the physical activity prescribed, notable variability in the amount of exercise prescribed, and the limited duration of the exercise interventions. Few RCTs truly address the role of activity in weight-loss maintenance by providing a long term, sustained-activity intervention and there is a need for well-designed, prospective, randomized trials to assess such regimens. Studies in which activity is measured by observation or retrospective analysis illustrate a strong relation ship between physical activity and success in weight-loss maintenance. Future research should focus on the impact of physical activity on other components of energy balance, why physical activity appears to be so critical for successful weight maintenance, individual specific deter minants of how much activity is required for weight-loss maintenance, and how to motivate people to achieve and sustain the levels of activity that seem to be required for weight loss and weight-loss maintenance.

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References

1. Ogden CL, et al. Prevalence of overweight and obesity in the United States, 1999–2004. JAMA. 2006; 295:1549–1555. [PubMed: 16595758]
2. Anderssen S, et al. Diet and exercise intervention have favourable effects on blood pressure in mild hypertensives: the Oslo Diet and Exercise Study (ODES). Blood Press. 1995; 4:343–349. [PubMed: 8746601]
3. Binder EF, et al. Effects of endurance exercise and hormone replacement therapy on serum lipids in older women. J Am Geriatr Soc. 1996; 44:231–236. [PubMed: 8600189]
4. Cox KL, et al. Independent and additive effects of energy restriction and exercise on glucose and insulin concentrations in sedentary overweight men. Am J Clin Nutr. 2004; 80:308–316. [PubMed: 15277150]
5. Donnelly JE, et al. Effects of a 16-month randomized controlled exercise trial on body weight and composition in young, overweight men and women: the Midwest Exercise Trial. Arch Intern Med. 2003; 163:1343–1350. [PubMed: 12796071]
6. Hellenius ML, et al. Diet and exercise are equally effective in reducing risk for cardiovascular disease. Results of a randomized controlled study in men with slightly to moderately raised cardiovascular risk factors. Atherosclerosis. 1993; 103:81–91. [PubMed: 8280188]
7. Irwin ML, et al. Effect of exercise on total and intra-abdominal body fat in postmenopausal women: a randomized controlled trial. JAMA. 2003; 289:323–330. [PubMed: 12525233]
8. King AC, et al. Group- vs home-based exercise training in healthy older men and women. A community-based clinical trial. JAMA. 1991; 266:1535–1542. [PubMed: 1880885]
9. Kohrt WM, et al. Effects of exercise involving predominantly either joint-reaction or ground-reaction forces on bone mineral density in older women. J Bone Miner Res. 1997; 12:1253–1261. [PubMed: 9258756]

10. Pritchard JE, et al. A worksite program for overweight middle-aged men achieves lesser weight loss with exercise than with dietary change. J Am Diet Assoc. 1997; 97:37–42. [PubMed: 8990415]
11. Ready AE, et al. Walking program reduces elevated cholesterol in women postmenopause. Can J Cardiol. 1995; 11:905–912. [PubMed: 7489529]
12. Stefanick ML, et al. Effects of diet and exercise in men and postmenopausal women with low levels of HDL cholesterol and high levels of LDL cholesterol. N Engl J Med. 1998; 339:12–20. [PubMed: 9647874]
13. Stewart KJ, et al. Exercise and risk factors associated with metabolic syndrome in older adults. Am J Prev Med. 2005; 28:9–18. [PubMed: 15626550]
14. Tessier D, et al. Effects of aerobic physical exercise in the elderly with type 2 diabetes mellitus. Arch Gerontol Geriatr. 2000; 31:121–132. [PubMed: 11090907]
15. Verity LS, Ismail AH. Effects of exercise on cardiovascular disease risk in women with NIDDM. Diabetes Res Clin Pract. 1989; 6:27–35. [PubMed: 2649339]
16. Wood PD, et al. Increased exercise level and plasma lipoprotein concentrations: a one-year, randomized, controlled study in sedentary, middle-aged men. Metabolism. 1983; 32:31–39. [PubMed: 6848894]
17. Wood PD, et al. Changes in plasma lipids and lipoproteins in overweight men during weight loss through dieting as compared with exercise. N Engl J Med. 1988; 319:1173–1179. [PubMed: 3173455]
18. Slentz CA, et al. Effects of the amount of exercise on body weight, body composition, and measures of central obesity: STRRIDE—a randomized controlled study. Arch Intern Med. 2004; 164:31–39. [PubMed: 14718319]
19. Ballor DL, Keesey RE. A meta-analysis of the factors affecting exercise-induced changes in body mass, fat mass and fat-free mass in males and females. Int J Obes. 1991; 15:717–726. [PubMed: 1838100]
20. Garrow JS, Summerbell CD. Meta-analysis: effect of exercise, with or without dieting, on the body composition of overweight subjects. Eur J Clin Nutr. 1995; 49:1–10. [PubMed: 7713045]
21. Miller WC, et al. A meta-analysis of the past 25 years of weight loss research using diet, exercise or diet plus exercise intervention. Int J Obes Relat Metab Disord. 1997; 21:941–947. [PubMed: 9347414]
22. Wing RR. Physical activity in the treatment of the adulthood overweight and obesity: current evidence and research issues. Med Sci Sports Exerc. 1999; 31:S547–S552. [PubMed: 10593526]
23. Lee L, et al. The impact of five-month basic military training on the body weight and body fat of 197 moderately to severely obese Singaporean males aged 17 to 19 years. Int J Obes Relat Metab Disord. 1994; 18:105–109. [PubMed: 8148923]
24. Hadjiolova I, et al. Physical working capacity in obese women after an exercise programme for body weight reduction. Int J Obes. 1982; 6:405–410. [PubMed: 7129752]
25. Ross R, et al. Exercise-induced reduction in obesity and insulin resistance in women: a randomized controlled trial. Obes Res. 2004; 12:789–798. [PubMed: 15166299]
26. Ross R, et al. Reduction in obesity and related comorbid conditions after diet-induced weight loss or exercise-induced weight loss in men. A randomized, controlled trial. Ann Intern Med. 2000; 133:92–103. [PubMed: 10896648]
27. Donnelly JE, Smith BK. Is exercise effective for weight loss with ad libitum diet? Energy balance, compensation, and gender differences. Exerc Sport Sci Rev. 2005; 33:169–174. [PubMed: 16239833]
28. Ross R, et al. Effects of energy restriction and exercise on skeletal muscle and adipose tissue in women as measured by magnetic resonance imaging. Am J Clin Nutr. 1995; 61:1179–1185. [PubMed: 7762515]
29. Ross R, et al. Influence of diet and exercise on skeletal muscle and visceral adipose tissue in men. J Appl Physiol. 1996; 81:2445–2455. [PubMed: 9018491]
30. Kohrt WM, et al. Exercise training improves fat distribution patterns in 60- to 70-year-old men and women. J Gerontol. 1992; 47:M99–M105. [PubMed: 1624697]

31. Schwartz RS, et al. The effect of intensive endurance exercise training on body fat distribution in young and older men. Metabolism. 1991; 40:545–551. [PubMed: 2023542]
32. Katzmarzyk PT, et al. Targeting the metabolic syndrome with exercise: evidence from the HERITAGE Family Study. Med Sci Sports and Exerc. 2003; 35:1703–1709. [PubMed: 14523308]
33. Ashutosh K, et al. Effects of sustained weight loss and exercise on aerobic fitness in obese women. J Sports Med Phys Fitness. 1997; 37:252–257. [PubMed: 9509823]
34. Bertram SR, et al. Weight loss in obese women—exercise v. dietary education. S Afr Med J. 1990; 78:15–18. [PubMed: 2363076]
35. Hammer RL, et al. Calorie-restricted low-fat diet and exercise in obese women. Am J Clin Nutr. 1989; 49:77–85. [PubMed: 2912014]
36. Layman DK, et al. Dietary protein and exercise have additive effects on body composition during weight loss in adult women. J Nutr. 2005; 135:1903–1910. [PubMed: 16046715]
37. Lemons AD, et al. Selection of appropriate exercise regimens for weight reduction during VLCD and maintenance. Int J Obes. 1989; 13(Suppl 2):119–123. [PubMed: 2613406]
38. Marks BL, et al. Fat-free mass is maintained in women following a moderate diet and exercise program. Med Sci Sports Exerc. 1995; 27:1243–1251. [PubMed: 8531622]
39. Nicklas BJ, et al. Exercise blunts declines in lipolysis and fat oxidation after dietary-induced weight loss in obese older women. Am J Physiol. 1997; 273:E149–E155. [PubMed: 9252491]
40. Sweeney ME, et al. Severe vs moderate energy restriction with and without exercise in the treatment of obesity: efficiency of weight loss. Am J Clin Nutr. 1993; 57:127–134. [PubMed: 8424379]
41. Van Aggel-Leijssen DP, et al. Long-term effects of low-intensity exercise training on fat metabolism in weight-reduced obese men. Metabolism. 2002; 51:1003–1010. [PubMed: 12145773]
42. Wadden TA, et al. Exercise in the treatment of obesity: effects of four interventions on body composition, resting energy expenditure, appetite, and mood. J Consult Clin Psychol. 1997; 65:269–277. [PubMed: 9086690]
43. Wood PD, et al. The effects on plasma lipoproteins of a prudent weight-reducing diet, with or without exercise, in overweight men and women. N Engl J Med. 1991; 325:461–466. [PubMed: 1852180]
44. Borg P, et al. Effects of walking or resistance training on weight loss maintenance in obese, middle-aged men: a randomized trial. Int J Obes Relat Metab Disord. 2002; 26:676–683. [PubMed: 12032753]
45. Fogelholm M, et al. Effects of walking training on weight maintenance after a very-low-energy diet in premenopausal obese women: a randomized controlled trial. Arch Intern Med. 2000; 160:2177–2184. [PubMed: 10904461]
46. Leermakers EA, et al. Effects of exercise-focused versus weight-focused maintenance programs on the management of obesity. Addict Behav. 1999; 24:219–227. [PubMed: 10336103]
47. Pavlou KN, et al. Exercise as an adjunct to weight loss and maintenance in moderately obese subjects. Am J Clin Nutr. 1989; 49:1115–1123. [PubMed: 2655416]
48. Perri MG, et al. Enhancing the efficacy of behavior therapy for obesity: effects of aerobic exercise and a multicomponent maintenance program. J Consult Clin Psychol. 1986; 54:670–675. [PubMed: 3771884]
49. Perri MG, et al. Effects of four maintenance programs on the long-term management of obesity. J Consult Clin Psychol. 1988; 56:529–534. [PubMed: 2848874]
50. Sikand G, et al. Two-year follow-up of patients treated with a very-low-calorie diet and exercise training. J Am Diet Assoc. 1988; 88:487–488. [PubMed: 3351170]
51. Skender ML, et al. Comparison of 2-year weight loss trends in behavioral treatments of obesity: diet, exercise, and combination interventions. J Am Diet Assoc. 1996; 96:342–346. [PubMed: 8598434]
52. van Dale D, et al. Weight maintenance and resting metabolic rate 18-40 months after a diet/exercise treatment. Int J Obes. 1990; 14:347–359. [PubMed: 2361812]

53. Wadden TA, et al. Exercise and the maintenance of weight loss: 1-year follow-up of a controlled clinical trial. J Consult Clin Psychol. 1998; 66:429–433. [PubMed: 9583346]

54. Wing RR, et al. Exercise in a behavioural weight control programme for obese patients with Type 2 (non-insulin-dependent) diabetes. Diabetologia. 1988; 31:902–909. [PubMed: 3071485]

55. Wing RR, et al. Lifestyle intervention in overweight individuals with a family history of diabetes. Diabetes Care. 1998; 21:350–359. [PubMed: 9540015]

56. Curioni CC, Lourenco PM. Long-term weight loss after diet and exercise: a systematic review. Int J Obes. 2005; 29:1168–1174.

57. Fogelholm M, Kukkonen-Harjula K. Does physical activity prevent weight gain—a systematic review. Obes Rev. 2000; 1:95–111. [PubMed: 12119991]

58. Kayman S, et al. Maintenance and relapse after weight loss in women: behavioral aspects. Am J Clin Nutr. 1990; 52:800–807. [PubMed: 2239754]

59. Hartman WM, et al. Long-term maintenance of weight loss following supplemented fasting. Int J Eat Disord. 1993; 14:87–93. [PubMed: 8339104]

60. Klem ML, et al. A descriptive study of individuals successful at long-term maintenance of substantial weight loss. Am J Clin Nutr. 1997; 66:239–246. [PubMed: 9250100]

61. Schoeller DA, et al. How much physical activity is needed to minimize weight gain in previously obese women? Am J Clin Nutr. 1997; 66:551–556. [PubMed: 9280172]

62. Weinsier RL, et al. Free-living activity energy expenditure in women successful and unsuccessful at maintaining a normal body weight. Am J Clin Nutr. 2002; 75:499–504. [PubMed: 11864855]

63. Jakicic JM, et al. Effects of intermittent exercise and use of home exercise equipment on adherence, weight loss, and fitness in overweight women: a randomized trial. JAMA. 1999; 282:1554–1560. [PubMed: 10546695]

64. Jakicic JM, et al. Effect of exercise duration and intensity on weight loss in overweight, sedentary women: a randomized trial. JAMA. 2003; 290:1323–1330. [PubMed: 12966123]

65. Jeffery RW, et al. Physical activity and weight loss: does prescribing higher physical activity goals improve outcome? Am J Clin Nutr. 2003; 78:684–689. [PubMed: 14522725]

66. Wilmore JH, et al. Alterations in resting metabolic rate as a consequence of 20 wk of endurance training: the HERITAGE Family Study. Am J Clin Nutr. 1998; 68:66–71. [PubMed: 9665098]

67. Bell C, et al. High energy flux mediates the tonically augmented β-adrenergic support of resting metabolic rate in habitually exercising older adults. J Clin Endocrinol Metab. 2004; 89:3573–3578. [PubMed: 15240648]

68. Van Pelt RE, et al. Regular exercise and the age-related decline in resting metabolic rate in women. J Clin Endocrinol Metab. 1997; 82:3208–3212. [PubMed: 9329340]

69. Bell C, et al. Influence of adiposity on tonic sympathetic support of resting metabolism in healthy adults. Int J Obes Relat Metab Disord. 2003; 27:1315–1318. [PubMed: 14574340]

70. Bell C, et al. Tonic sympathetic support of metabolic rate is attenuated with age, sedentary lifestyle, and female sex in healthy adults. J Clin Endocrinol Metab. 2001; 86:4440–4444. [PubMed: 11549689]

71. Poehlman ET, et al. Influence of aerobic capacity, body composition, and thyroid hormones on the age-related decline in resting metabolic rate. Metabolism. 1992; 41:915–921. [PubMed: 1640872]

72. Poehlman ET, et al. Relation of age and physical exercise status on metabolic rate in younger and older healthy men. J Gerontol. 1991; 46:B54–B58. [PubMed: 1997564]

73. Mayer J, et al. Relation between caloric intake, body weight, and physical work: studies in an industrial male population in West Bengal. Am J Clin Nutr. 1956; 4:169–175. [PubMed: 13302165]

74. Kempen KP, et al. Energy balance during an 8-wk energy-restricted diet with and without exercise in obese women. Am J Clin Nutr. 1995; 62:722–729. [PubMed: 7572699]

75. Jakicic JM, et al. Relationship of physical activity to eating behaviors and weight loss in women. Med Sci Sports Exerc. 2002; 34:1653–1659. [PubMed: 12370568]

76. Saris WH, et al. How much physical activity is enough to prevent unhealthy weight gain? Outcome of the IASO 1st Stock Conference and consensus statement. Obes Rev. 2003; 4:101–114. [PubMed: 12760445]

77. Jakicic JM, et al. American College of Sports Medicine position stand. Appropriate intervention strategies for weight loss and prevention of weight regain for adults. Med Sci Sports Exerc. 2001; 33:2145–215678. [PubMed: 11740312]

Review Criteria

We searched PubMed with terms “exercise” or “physical activity” with “weight loss”, “weight reduction”, “weight-loss maintenance”, “weight management”, or “weight regain” for articles evaluating the role of physical activity alone or in combination with diet in short-term weight loss (<1 year) or weight-loss maintenance (follow up ≥1 year after weight reduction). The search was limited to English-language, randomized, controlled trials with an intervention of ≥4 months, published since 1997. Relevant articles published prior to 1997 were identified from the 1998 Obesity Education Initiative Expert Panel clinical guidelines which performed a literature review on this topic using similar search criteria. We also manually searched references in meta-analyses, reviews and position statements related to this topic.

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Learning objectives

Upon completion of this activity, participants should be able to:

1. Describe the magnitude and range of weight loss accomplished by exercise in 16 selected randomized trials.
2. Describe the effect of exercise intensity on weight loss.
3. List factors affecting the effect of exercise on weight loss.
4. Describe patterns of adherence to exercise in patients on weight management programs.
5. Identify the role of exercise in preventing weight regain after weight loss.

Key Points

- Substantial weight loss can be achieved with physical activity alone when the appropriate volume of exercise is prescribed and energy intake is held constant but for many overweight or obese individuals this strategy is not sufficient as the volume of exercise required is difficult to achieve and sustain
- Dietary restriction and increased physical activity in combination have generally been found to modestly improve weight loss compared with diet alone; however, overweight and obese individuals can lose large amounts of weight with dietary restriction alone
- The addition of physical activity (60–90 min) to a dietary intervention substantially increases the odds of successful long-term weight-loss maintenance and might be essential for most overweight and obese individuals to maintain weight loss

Table 1

Randomized, controlled trials for weight loss in exercise alone versus no-treatment control.

Reference	Duration (months)	Total *n* (completed regimen)	Study design	Weight change in control groups	Weight change in exercise groups	Significance[a]
Anderssen *et al*. (1995)[2]	12	219 M and F (210)	C vs D vs E vs D + E	C +1.1 kg	E –0.9 kg	*P* <0.05
Binder *et al*. (1996)[3]	11	71 F (71)	C vs E vs HRT vs HRT + E[b]	C or HRT +0.4 kg	E or HRT + E –1.1 kg	*P* <0.05
Cox *et al*. (2004)[4]	4	60 M (51)	C vs D vs E vs D + E	C –0.44 kg	E –1.55 kg	NS
Donnelly *et al*. (2003)[5]	16	131 M and F (74)	C vs E	C M –0.5 kg C F +2.9 kg	E M –5.2 kg E F +0.6 kg	*P* <0.05 *P* <0.05
Hellenius *et al*. (1993)[6]	6	158 M (157)	C vs D vs E vs D + E	C +0.3 BMI	E –0.3 BMI	*P* <0.05
Irwin *et al*. (2003)[7]	12	173 F (168)	C vs E	C +0.1 kg	E –1.3 kg	*P* <0.05
King *et al*. (1991)[8]	12	357 M and F (300)	C vs E1 vs E2 vs E3c	C M +0.1 BMI C F +0.0 BMI	E1, E2 or E3 M –0.2 to –0.9 BMI E1, E2 or E3 F –0.6 to +0.4 BMI	NS NS
Kohrt *et al*. (1997)[9]	11	48 F (39)	C vs AE vs RE	C +0.3 kg	AE –2.8 kg RE –0.7 kg	*P* <0.05 NS
Pritchard *et al*. (1997)[10]	12	64 M (58)	C vs D vs E	C 0.0 kg	E –2.6 kg	*P* <0.05
Ready *et al*. (1995)[11]	6	40 F (25)	C vs E	C +0.6 kg	E –1.9 kg	*P* <0.05
Stefanick *et al*. (1998)[12]	12	377 M and F (367)	C vs D vs E vs D + E	C M +0.5 kg C F +0.8 kg	E M –0.6 kg E F –0.4 kg	NS NS
Stewart *et al*. (2005)[13]	6	115 M and F (104)	C vs E	C –0.5 kg	E –2.3 kg	*P* <0.05
Tessier *et al*. (2000)[14]	4	45 M and F (39)	C vs E	C +0.1 kg	E –0.1 kg	NS
Verity and Ismail (1989)[15]	4	10 F (10)	C vs E	C –2.9 kg	E –2.1 kg	NS
Wood *et al*. (1983)[16]	12	81 M (78)	C vs E	C +0.6 kg	E –1.9 kg	*P* <0.05
Wood *et al*. (1988)[17]	12	155 M (131)	C vs D vs E	C +0.6 kg	E –4.0 kg	*P* <0.05

[a] *P* <0.05 considered significant for difference in weight loss for exercise versus control.

[b] Compared effects of exercise with and without HRT.

[c] Compared three exercise groups (E1, high intensity group-based; E2, high intensity home-based; E3, lower intensity home-based).

Abbreviations: AE, aerobic exercise; C, control; D, diet; E, exercise; F, female; HRT, hormone replacement therapy; M, male; NS, not significant; RE, resistance exercise.

Table 2

Randomized, controlled trials for weight loss in diet alone versus diet and exercise.

Reference	Duration (months)	Total *n* (completed regimen)	Study design	Weight change in diet-only groups	Weight change in diet + exercise groups	Significance[a]
Anderssen *et al*. (1995)[2]	12	219 M and F (209)	C vs D vs E vs D + E	D –4 kg	D + E –5.6 kg	NS
Ashutosh *et al.* (1997)[33]	12	37 F (31)	D vs D + AE vs D + RE vs D + AE + RE	D –14.5 kg	D + AE –15.0 kg D + RE –15.1 kg D + AE + RE –17.3 kg	NS NS NS
Bertram *et al.* (1990)[34]	4	45 F (36)	D vs D + E vs D + BT	D –9.3 kg D+BT –8.1 kg	D + E –7 kg	NS NS
Cox *et al*. (2004)[4]	4	60 M (51)	C vs D vs E vs D + E	D –10.88 kg	D + E –11.66 kg	NS
Hammer *et al.* (1989)[35]	4	36 F (26)	D1 vs D2 vs D1 + E vs D2 + E[b]	D1–5.8 kg D2 –9.5 kg	D1 + E –6.7 kg D2 + E –12.9 kg	$P < 0.05$ NS
Hellenius *et al.* (1993)[6]	6	158 M (157)	C vs D vs E vs D + E	D –0.3 BMI	D + E –0.6 BMI	NS
Layman *et al.* (2005)[36]	4	48 F (48)	D1 vs D2 vs D1 + E vs D2 + Ec	D1 –8.7 kg D2 –7.8 kg	D1 + E –9.8 kg D2 + E –6.7 kg	NS
Lemons *et al.* (1989)[37]	4	60 F (60)	D vs AE vs RE vs D + AE vs D + RE vs D + AE or RE[d]	D –12.8 kg	D + AE –12.2 D + RE –11.3 D + AE or RE –13.1	NS
Marks *et al*. (1995)[38]	5	67 F (44)	C vs D vs D + AE vs D + RE vs D + AE + RE	D –3.7 kg	D + AE –4.5 kg D + RE –3.5 kg D + AE + RE –5.4 kg	NS NS NS
Nicklas *et al.* (1997)[39]	6	28 F (20)	D vs D + E	D –9.8 kg	D + E –6.6 kg	NS
Ross *et al*. (1995)[28]	4	33 F (24)	D vs D + E	D –10 kg	D + E –11.7 kg	NS
Ross *et al*. (1996)[29]	4	33 M (33)	D vs D + AE vs D + RE	D –11.9 kg	D + AE –11.6 kg D + RE –13.2 kg	NS NS
Stefanick *et al.* (1998)[12]	12	377 M and F (367)	C vs D vs E vs D + E	D F –2.7 kg D M –2.8 kg	D + E F –3.1 kg D + E M –4.2 kg	NS NS
Sweeney *et al.* (1993)[40]	6	47 F (30)	D1 vs D2 vs D1 + AE vs D1 + AE + RE vs D2 + AE vs D2 + AE + RE[e]	D –13.5 kg	D1 or D2 + AE –14.5 kg D1 or D2 + AE + RE –11.5 kg	NS
Van Aggel-Leijssen *et al*. (2002)[41]	12	37 M (29)	D vs D + E	D –7.1 kg	D + E –8.9 kg	NS
Wadden *et al.* (1997)[42]	11	128 F (99)	D vs D + AE vs D + RE vs D + AE + RE	D –15.3 kg	D + AE –13.5 kg D + RE –17.3 kg	NS

Reference	Duration (months)	Total *n* (completed regimen)	Study design	Weight change in diet-only groups	Weight change in diet + exercise groups	Significance[a]
					D + AE + RE –16.6 kg	
Wood *et al.* (1991)[43]	12	264 M and F (227)	C vs D vs D + E	D M –5.1 kg D F –4.1 kg	D + E M –8.7 kg D + E F –5.1 kg	*P* <0.05 NS

[a] *P* <0.05 considered significant for difference in weight loss for exercise versus control.

[b] Compared interaction of two diets (D1 low fat *ad libitum* diet vs D 2,800 kcal low fat) with exercise in 2 × 2 factorial design.

[c] Compared interaction of two diets (D1 high protein vs D2 high carbohydrate) with exercise in a 2 × 2 factorial design.

[d] Compared diet alone to diet plus AE, diet + RE, diet + 8 weeks AE followed by 8 weeks RE, AE only, and RE only.

[e] Compared two diets (D1 severe energy restriction vs D2 moderate energy restriction) with no exercise, AE only, or AE and RE in 2 × 3 factorial design.

Abbreviations: AE, aerobic exercise; BT, behavioral therapy; C, control; D, diet; E, exercise; F, female; M, male; NS, not significant; RE, resistance exercise.

Table 3

Randomized, controlled trials for weight-loss maintenance with minimal supervision after exercise intervention for weight loss.

Reference	Weight-loss intervention duration	Minimally supervised follow-up duration	Total *n* (completed regimen)	Study design	Weight change for diet only	Weight change for diet + exercise	Significance[a]
Pavlou *et al.* (1989)[47]	8 weeks	18 months, unsupervised	160 (110)	VLCD vs VLCD + E	VLCD –3 kg	VLCD + E –11 kg	*P* <0.05
Perri *et al.* (1986)[48]	20 weeks	18 months, randomized to no contact vs 12 months maintenance program[b]	90 M and F (67)	BT vs BT + E	BT regain 4.9 kg	BT + E regain 5.1 kg	NS
Sikand *et al.* (1988)[50]	20 weeks	2 years, unsupervised	30 (15)	D vs D + E	D –0.8 kg	D + E –9.1 kg	NS
Skender *et al.* (1996)[51]	1 year	1 year, unsupervised	127 M and F (61)	D vs E vs D + E	D 1 year –6.8 kg D 2 years +0.9 kg	D + E 1 year –8.9 kg D + E years –2.2 kg	NS NS
van Dale *et al.* (1990)[52]	12–14 weeks	18–42 months, unsupervised	54 M and F (36)	D vs D + E	D –7.7 kg	D + E –14.4 kg	*P* <0.05
Wadden *et al.* (1998)[53]	48 weeks	12 months, unsupervised	99 F (77)	D + BT vs D + AE, D + RE, or D + AE + RE	100 weeks D + BT –6.9 kg	100 weeks D + AE –8.5 kg D + RE –10.1 kg D + AE + RE –8.6 kg	NS NS NS
Wing *et al.* (1988)[54]	10 weeks 10 weeks	1 year (monthly visits for initial 6 months) 1 year (weekly visits for 10 weeks then monthly)	25 M and F (19) 30 M and F (28)	Study 1: D vs D + E Study 2: D vs D + E	D –4.0 kg D –3.8 kg	D + E –7.8 kg D + E –7.9 kg	NS *P* <0.05
Wing *et al*. (1998)[55]	1 year	1 year (two 6-week refresher courses)	154 M and F (129)	C vs D vs E vs D + E	D 1 year –5.5 kg D 2 year –2.1 kg	D + E 1 year –7.4 kg D + E 2 years –2.5 kg	NS NS

[a] *P* <0.05 considered significant for difference in weight loss for exercise vs control.

[b] Multicomponent maintenance program included peer self-help groups, mail and telephone therapist contact for 1 year; therapist support was tailored to the individual client's initial treatment condition.

Abbreviations: AE, aerobic exercise; BT, behavioral therapy; C, control; D, diet, E, exercise; F, female; M, male; NS, not significant; RE, resistance exercise; VLCD, very-low-calorie diet.

Table 4

Randomized, controlled trials for weight-loss maintenance with maintenance intervention then no supervision after exercise intervention for weight loss.

Reference	Weight loss intervention duration	Weight maintenance intervention duration	Unsupervised follow-up duration	Total *n* (completers)	Weight regain for diet-only controls	Weight regain for diet + exercise	Significance[a]
Borg *et al*. (2002)[44] [b]	2 months	6 months	23 months	90 M (68)	8 months +1.6 kg	8 months AE +1.8 kg RE +0.3 kg	NS NS
					31 months +8.4 kg	31 months AE +10.1 kg RE +9.1 kg	NS NS
Fogelholm *et al.* (2000)[45] [c]	12 weeks	40 weeks	2 years	82 F (74)	1 year +2 kg 3 years +9.7 kg	Walk 1[f] 1 year –0.7 kg 3 years +6.2 kg	NS *P* <0.05
						Walk 2[g] 1 year –0.6 kg 3 years +9.5 kg	NS NS
Leermakers *et al.* (1999)[46] [d]	6 months	6 months	6 months	67 M and F (48)	18 months +0.8 kg	18 months +4.4 kg	*P* <0.05
Perri *et al.* (1988)[49] [e]	20 weeks	6 months	12 months	123 M and F (91)	BT-only improved weight maintenance compared with controls	Exercise did not alter results compared with BT-only; all exercise conditions improved weight maintenance compared with control	NS

[a] *P* <0.05 considered significant for difference in weight regain for diet and exercise versus diet control. Intervention involved:

[b] VLCD then randomized to control, walking (AE) or resistance training (RE) for maintenance;

[c] VLCD then randomized to control vs Walk 1 or Walk 2 interventions for maintenance;

[d] Weight loss then randomized to biweekly exercise focused or weight focused maintenance;

[e] BT randomized to five arms for maintenance.

[f] Walk 1 was 2-3 h per week;

[g] Walk 2 was 4-6 h per week.

Abbreviations: AE, aerobic exercise; BT, behavioral therapy; F, female; M, male; NS, not significant; RE, resistance exercise; VLCD, very-low-calorie diet.