

Physical activity, sedentary behaviour, and obesity

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Insufficient levels of daily physical activity play a potentially major role in contributing to the obesity epidemic that currently affects both developed and developing countries. Therefore, physical activity has become a vital part of public health strategies for prevention of weight gain, for weight loss, and for prevention of weight regain after weight loss. In fact, virtually all public health agencies and scientific organizations recommend physical activity as part of weight management, including but not limited to the World Health Organization (WHO), the United States Centers for Disease Control and Prevention (CDC), the National Heart, Lung, and Blood Institute, the American Heart Association, the American College of Sports Medicine (ACSM), and the World Obesity Federation, as well as several national and regional guidelines.

In 2001, the ACSM issued guidelines recommending at least 150 min-

utes per week of moderate-intensity physical activity for overweight or obese adults to improve their health, and 200–300 minutes per week for long-term weight loss [1]. Moderate-intensity activities are those that require 3–6 times as much energy as sitting quietly. In 2002, the Institute of Medicine of the National Academies recommended 60 minutes per day of moderate-intensity physical activity for prevention of unhealthful weight gain [2]. In 2003, the International Association for the Study of Obesity advocated 40–50 minutes per day of moderate-intensity physical activity for prevention of obesity, and 60–90 minutes per day for prevention of weight regain in formerly obese individuals [3].

Setting definitions for clinically significant weight loss has been challenging, in part because health gains related to weight maintenance or weight loss probably operate under a continuum and are not based on

a particular threshold. Despite this issue, some have operationalized the definition of weight maintenance as a change of ≤ 5 lb (≤ 2.3 kg) [4] or $< 3\%$ of body weight [5], with a weight change of $> 5\%$ considered to be clinically significant [5].

This chapter discusses whether physical activity is effective for prevention of weight gain, for weight loss, and for prevention of weight regain after weight loss. This chapter focuses primarily on adults.

Physical activity and prevention of weight gain

Primary prevention of obesity begins with weight maintenance, not weight reduction. Long-term observational studies of physical activity in relation to weight maintenance fairly consistently show a relationship between the two. For example, the prospective Harvard cohorts showed that women and men who reported

increasing their recreational activity levels by 23.2 metabolic equivalent (MET)-hours per week (top quintile) gained 1.76 lb less (0.8 kg less) within the next 4 years of follow-up than those who decreased their activity levels by 16.3 MET-hours per week (bottom quintile) [6]. One MET is defined as the ratio of the energy consumed during a specific activity to the energy consumed while sitting quietly ($3.5 \text{ mL O}_2 \text{ kg}^{-1} \text{ min}^{-1}$). Similarly, the 15-year Coronary Artery Risk Development in Young Adults (CARDIA) Study reported that each 0.5 hour per day of walking, the most popular type of recreational activity among adults, was associated with 0.15 kg/year less weight gain in men and 0.29 kg/year less weight gain in women, with stronger associations noted among those with a larger baseline weight [7]. Taken together, these long-term epidemiological investigations indicate that moderate-intensity physical activity is associated with prevention of weight gain. A 2009 position paper from the ACSM stated that 150–250 minutes per week of moderate-intensity physical activity is effective to prevent weight gain [8].

Physical activity and weight loss

A negative energy balance brought about by physical activity will lead to weight loss, with a greater negative energy balance resulting in a more pronounced weight loss. Directed research on the long-term effect of physical activity on weight loss has been sparse. A 12-month randomized controlled trial found a cumulative weight loss of 1.8 kg in men and 1.4 kg in women for those engaging in moderate to vigorous activity for 60 minutes per day, 6 days per week [9]. By comparison, sedentary controls gained 0.1 kg (men) and 0.7 kg (women) during that period. A recent systematic review and meta-analysis examined the available evidence on

the effect of isolated physical activity on weight loss among overweight and obese individuals from randomized clinical trials and reported that 120–240 minutes per week of aerobic exercise at intensities of 40–85% of maximum heart rate were related to weighted mean differences in weight of -1.6 kg (95% confidence interval [CI], $-1.64 \text{ to } -1.56 \text{ kg}$) for 6-month programmes and -1.7 kg (95% CI, $-2.29 \text{ to } -1.11 \text{ kg}$) for 12-month programmes. The authors concluded that isolated aerobic exercise is not an effective weight-loss therapy but may be effective in conjunction with diets [10].

Most recommendations from public health organizations and government agencies use both physical activity and dietary energy restriction for weight loss. Weight-loss programmes vary considerably with respect to the amount of physical activity used and the level of energy restriction imposed, with a greater energy deficit yielding a more pronounced weight loss. Evidence suggests that dietary energy restriction combined with physical activity results in greater weight loss than dietary energy restriction alone. For example, a Cochrane review involving 1049 subjects from 14 trials with follow-up of 3–12 months compared exercise plus diet versus diet alone and reported a weight loss of -1.1 kg (95% CI, $-1.5 \text{ to } -0.6 \text{ kg}$) in the exercise-plus-diet group versus the diet-only group [11]. Similarly, pooling the data from 452 subjects from five trials yielded a reduction in body mass index (BMI) of -0.4 kg/m^2 (95% CI, $-0.7 \text{ to } -0.1 \text{ kg/m}^2$) in the exercise-plus-diet group versus the diet-only group [11]. Physical activity and dietary energy restriction yield comparable weight loss if they offer similar amounts of negative energy balance. Importantly, energy restriction combined with exercise training is more effective than energy restriction alone for increasing loss of fat mass and preserving lean

body mass, and therefore it leads to a more desirable effect on overall body composition [12].

Moreover, physical activity of high intensity leads to more pronounced weight loss than physical activity of lower intensity. This is indicated by pooled data on a comparison of high-intensity versus low-intensity exercise without changes in diet during 3.5–12-month periods in 317 subjects from four trials, in which the high-intensity-exercise group showed a reduction in weight of -1.5 kg (95% CI, $-2.3 \text{ to } -0.7 \text{ kg}$) compared with the low-intensity-exercise group [11].

According to the 2009 ACSM position paper, physical activity demonstrates a dose–response relationship with weight loss, such that < 150 minutes per week of moderate-intensity physical activity yields minimal weight loss, > 150 minutes per week of moderate-intensity physical activity results in weight loss of 2–3 kg, and 225–420 minutes per week of moderate-intensity physical activity leads to weight loss of 5–7.5 kg [8]. In addition to the effect of physical activity on weight loss, regular exercise yields numerous health benefits independent of weight loss, such as improvements in insulin action, blood lipids, endothelial function, haemostatic factors, and blood pressure [13].

Physical activity and prevention of weight regain after weight loss

Most people are able to lose weight but have considerable difficulty maintaining weight loss. Physical activity is widely endorsed as being indispensable for long-term weight maintenance [1] and is frequently referred to as a stable predictor of weight maintenance after weight loss [14]. The evidence for maintenance of weight loss is far less abundant than that for initiation of weight loss.

A recent systematic review and meta-analysis of randomized controlled trials on long-term maintenance of weight loss reported that the combination of physical activity and dietary energy restriction resulted in a difference of -1.56 kg (95% CI, -2.27 to -0.86 kg) in weight regain compared with controls at 12 months [15]. There was no evidence of effectiveness for interventions involving physical activity only. An earlier systematic review that also included observational studies reported that individuals who engaged in physical activity experienced less weight regain than their sedentary counterparts, but confounding by a healthy lifestyle or reverse causation by better exercise adherence among those with less weight regain could not be ruled out [16]. Taken together, findings from observational studies and controlled trials show inconsistent results, and the volume of physical activity needed to prevent weight regain after weight loss remains poorly defined. Despite these uncertainties, the 2009 ACSM position paper suggested that weight maintenance after weight loss is improved with > 250 minutes of physical activity per week [8].

Resistance training

Resistance training has not been considered a major contributor to weight loss, because the energy expenditure associated with weight training is generally less than that associated with a typical aerobic exercise session of the same duration. In addition, resistance exercise increases fat-free mass, potentially leading to a net gain in body weight. However, resistance exercise is associated with acute stimulation of metabolic rate and fat oxidation, and it enhances total energy expenditure because of increased muscle mass; this provides some rationale for examining its relationship to weight loss [17].

Intervention studies have consistently found no effect of resistance exercise on reducing body weight [8] or visceral adipose tissue [18]. The combination of resistance and aerobic exercise may enhance loss of fat mass compared with resistance exercise alone. A recent meta-analysis of 15 trials with 741 participants compared the effect of 2.5–6 months of aerobic training and resistance training on weight loss in overweight and obese subjects and reported that compared with resistance training, aerobic training produced greater decreases in body weight (mean difference [MD], -1.15 kg; 95% CI, -2.23 to -0.07 kg), waist circumference (MD, -1.10 cm; 95% CI, -1.85 to -0.36 cm), and fat mass (MD, -1.14 kg; 95% CI, -1.83 to -1.45 kg) [19]. However, resistance training was more effective than aerobic training in increasing lean body mass (MD, 1.26 kg; 95% CI, 0.71 to 1.81 kg). Moreover, compared with resistance training alone, the combination of aerobic and resistance training yielded more pronounced reductions in body weight (MD, -2.03 kg; 95% CI, -2.94 to -1.12 kg), waist circumference (MD, -1.57 cm; 95% CI, -2.38 to -0.75 cm), and fat mass (MD, -1.88 kg; 95% CI, -2.67 to -1.08 kg), whereas the combination of aerobic and resistance training generated a greater increase in lean body mass (MD, 0.90 kg; 95% CI, 0.31 to 1.48 kg) than aerobic training alone [19]. These pooled findings on the combination of aerobic and resistance training need to be interpreted with caution, because the total volume of exercise prescribed in some of the combination training groups was greater than the respective volumes in the aerobic training and resistance training groups. Notwithstanding the potential confounding effects of training volume, these data suggest that the combination of aerobic and resistance training may be the most efficacious exercise training modality for weight loss.

Few studies have examined the effects of resistance exercise on prevention of weight gain. One randomized trial assessed the efficacy of a 2-year strength programme in 164 overweight and obese premenopausal women and reported decreased percentage of body fat (2-year change of $-3.68\% \pm 0.99\%$ vs $-0.14\% \pm 1.04\%$ in controls) and attenuated intra-abdominal fat (2-year change of $7.05\% \pm 5.07\%$ vs $21.36\% \pm 5.34\%$ in controls) [20]. These results are relevant to obesity prevention programmes because most weight gain in adults is assumed to be fat, including abdominal fat.

Data about the influence of resistance training on prevention of weight regain after weight loss are also sparse. One trial assigned 90 middle-aged, obese, physically inactive men to a 2-month very-low-energy diet followed by randomization into 6 months of resistance training, walking, or no exercise [21]. The results showed that resistance training initially attenuated the regain of fat mass during the exercise programme. However, there were no differences in weight regain between the groups after 23 months of follow-up, which was explained by poor long-term adherence to the prescribed exercise programme [21].

Sedentary behaviour

In recent years, physical activity research has expanded its focus to include the potentially detrimental effects of sedentary behaviour on energy balance. The prevalence of sedentary behaviour has increased markedly in recent years, with objectively assessed measures showing that adults spend 50–60% of their day sedentary [22]. Sedentary behaviour occurs in various domains of life, including television or video viewing, computer use, reading, or sitting at a desk, at a counter, or in

a bus, car, or train. Prolonged time spent sedentary decreases energy expenditure and displaces light-intensity physical activities, potentially leading to weight gain over time. Although sedentary behaviour shows an inverse relationship with light-intensity physical activity, it can be conceptualized as a lifestyle factor that can coexist with moderate to vigorous physical activity [23]. Current public health programmes to reduce obesity have focused largely on decreasing dietary energy intake and increasing physical activity but have paid little attention to decreasing time spent sedentary.

The Nurses' Health Study examined the association between sedentary behaviours, in particular television viewing, and risk of obesity [24]. The findings showed that time spent watching television was positively related to risk of obesity. Specifically, each increment of 2 hours per day in television watching was associated with a 23% (95% CI, 17–30%) increase in obesity after adjusting for age, smoking, diet, and physical activity. Also, each increment of 2 hours per day in sitting at work was associated with a statistically non-significant 5% (95% CI, 0–10%) increase in obesity. These results highlight the potential value of decreasing prolonged television watching and other sedentary behaviours for preventing obesity in adults.

Computer gaming and use of social media are additional important sources of time spent sedentary, particularly among young adults. A prospective cohort study of 2593 young adults aged 20–24 years in Sweden examined the association between leisure-time computer use for gaming/emailing/chatting and overweight development during

5 years of follow-up [25]. Compared with those who reported no computer gaming, women with a high volume of computer gaming (> 2 hours per day) had an odds ratio of developing overweight of 3.0 (95% CI, 1.29–6.83) after adjustment for age, occupation, social support, physical activity, sleep, and total computer use. No statistically significant association was noted among men (odds ratio, 1.4; 95% CI, 0.77–2.66). In addition, no statistically significant relationships emerged between leisure-time emailing/chatting and overweight in either women or men. The findings from this small cohort study suggest that sedentary behaviour that occurs during computer gaming is a potential risk factor for overweight, but further research is needed.

Sedentary behaviour is also an independent risk factor for obesity in children and adolescents. In fact, preventing childhood obesity has been described as the most favourable approach to reversing the global obesity epidemic. A recent meta-analysis of 25 studies compared three types of interventions with regard to their potential of reducing BMI in children: (i) interventions aimed at decreasing sedentary behaviours, (ii) interventions aimed at decreasing sedentary behaviours in combination with promoting physical activity, and (iii) interventions aimed at decreasing sedentary behaviours in combination with promoting physical activity and improving dietary habits [26]. The results indicated that interventions aimed at decreasing sedentary behaviours had a significant effect on reducing BMI, and that effect sizes of multicomponent interventions did not differ significantly from those of the single-component interventions.

Physical activity and appetite regulation

At habitually high levels of energy expenditure, energy intake appears to be matched to energy expenditure, resulting in maintenance of energy balance. However, at low levels of energy expenditure, homeostatic regulation of appetite control is lost and fails to restrain appetite to the low levels required to maintain energy balance. There is evidence that enhanced appetite control with high levels of energy expenditure operates through a mechanism involving augmented insulin and leptin sensitivity brought about by decreased fat mass [27].

Conclusions

Moderate-intensity physical activity performed for 150–250 minutes per week appears to prevent weight gain and may produce modest weight loss in adults. Greater amounts of moderate-intensity physical activity (> 250 minutes per week) are required for weight maintenance after weight loss. Resistance exercise does not appear to decrease body weight or body fat, but it promotes gain of lean body mass, and the combination of resistance exercise and aerobic exercise seems to be optimal for weight loss. Increased physical activity decreases levels of risk factors for chronic diseases, independent of its impact on regulating body weight. Moreover, sedentary behaviour is an independent risk factor for the development of overweight and obesity.

Key points

- Insufficient physical activity is a potentially relevant determinant of the global obesity epidemic.
- Moderate-intensity physical activity performed for 150–250 minutes per week appears to prevent weight gain and may produce modest weight loss in adults.
- Greater volumes of moderate-intensity physical activity (> 250 minutes per week) are required for weight maintenance after weight loss.
- Resistance exercise alone has little effect on reducing body weight or adipose tissue.
- The combination of resistance exercise and aerobic exercise appears to be optimal for weight loss.
- Physical activity has important health benefits independent of its effects on regulating body weight.
- Time spent sedentary is a potentially significant risk factor for obesity.

Research needs

- There is a need for observational research using objectively assessed energy intake and energy expenditure in relation to long-term prevention of weight gain in free-living populations.
- Intervention studies on the long-term effect of physical activity on weight loss are needed.
- Research is needed on the amounts and intensities of physical activity required for prevention of weight regain after weight loss.
- The efficacy of combined aerobic and resistance physical activity modalities for weight control should be examined.
- The potential of decreased time spent sedentary for preventing obesity should be evaluated.
- The combined effects of physical activity and body composition on appetite regulation should be investigated.

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