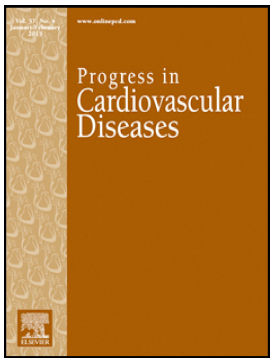

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The Effects of Exercise and Physical Activity on Weight Loss and Maintenance

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Abbreviations:

BMI: Body mass index

BP: Blood pressure

CRF: Cardiorespiratory fitness

CV: Cardiovascular

DM: Diabetes mellitus

ET: Exercise training

HDL: High density lipoprotein

LDL: Low density lipoprotein

LTPA: Leisure time physical activity

PA: Physical activity

TGs: Triglycerides

US: United States

VO_2 max: Maximal oxygen consumption

Abstract

Obesity represents a major health problem in the United States and is associated with increased prevalence of cardiovascular (CV) disease risk factors. Physical activity (PA) and exercise training (ET) are associated with reduced CV risk, improved cardiometabolic risk factors, and facilitated weight loss through creating a negative energy balance. Clinicians need to counsel overweight and obese patients on how much PA/ET is needed to promote weight loss and weight loss maintenance. This will help establish realistic expectations and maximize improvements in CV risk factors. Although the minimum guidelines for aerobic PA (150 minutes of moderate or 75 minutes of vigorous physical activity per week) can improve CV health, these levels are generally inadequate for clinically significant weight loss or weight maintenance without caloric restriction. The purpose of this review is to evaluate the role of ET to promote clinically significant weight loss and promote weight maintenance. In particular, we will evaluate the likelihood of weight loss from ET programs composed of aerobic training only, resistance training only and programs that combine diet and ET. We will also explore the role of PA in promoting short-term and long-term weight maintenance.

Obesity is associated with increased prevalence of major health conditions, including cardiovascular (CV) disease, diabetes mellitus (DM), and hypertension [1-4], as well as increased CV mortality [5] and incident DM risk [6-8]. Recent data suggest that 69.5% of the United States (US) population is overweight or obese [9]. Adults with obesity represent 36.4% of the total population in the US with 20.6% Class I, 8.8% Class II, and 6.9% Class III obesity [9]. The economic burden in the treatment of obesity is estimated to be $147 billion annually in the US, and the annual per capita health expenses are $1,809 greater for obese compared to non-obese adults [10, 11]. Therefore, reducing the prevalence of obesity has both clinical and economic implications.

Similar to obesity, lack of physical activity (PA) or exercise training (ET) is associated with the development of CV disease [12]. Data from the American Heart Association 2018 Heart and Stroke Statistics [13] indicate that 50.3% of adults in the US do not meet the aerobic component of the PA guidelines of 150 min/wk of moderate or 75 minutes of vigorous PA per week (or an equivalent combination of moderate and vigorous activities). In addition, 30.4% of adults in the US report no leisure time PA (LTPA). Importantly, the data above is based on questionnaire measures, which are subjective. Data from the National Health and Nutrition Examination Survey using accelerometry have estimated that only 9.6% of adults are performing the recommended levels of physical activity [14, 15]. Certainly, PA and ET can reduce obesity level by increasing total energy expenditure, thus promoting a negative energy balance when caloric intake is lower than energy expenditure. Independent of weight, adequate PA has been shown to reduce CV risk [16-19], DM risk [20-22] and improve many cardiometabolic risk factors [23, 24].

Clinicians need to council overweight and obese adults on appropriate PA programs for weight reduction and weight maintenance to optimally reduce CV risk. This will help patients have reasonable expectations for weight loss based on the amount and modality of their

selected PA/ET program. In the present review paper, we will report on the data evaluating the impact of PA on reducing weight and promoting weight maintenance. To assist readers, we have presented tables denoting expected weight loss based on PA level (Table 1) and the chance of clinically significant weight loss based on exercise modality (Table 2). In particular, we will evaluate the likelihood of weight loss from ET programs composed of aerobic training only, resistance training only and programs that combine diet and ET. We will also explore the role of ET/PA level in promoting short-term and long-term weight maintenance.

Rationale for Weight Loss in Overweight and Obese Individuals

Given the high prevalence of obesity, weight loss is recommended by various health organizations to promote improvements in CV health [25]. The 2013 Guidelines for the Management of Overweight and Obesity [25] recommend weight reduction for overweight (BMI 25-30 kg/m^2) individuals with one indicator of increased CV risk (e.g. dyslipidemia, pre-diabetes, hypertension, etc.) and obese individuals (BMI ≥30 kg/m^2). While improvements in CV risk factors can be seen with modest weight loss of 2-3% [26-28], the current guidelines recommend at least 5-10% (clinically significant weight loss) within 6 months due to the more profound improvements in major CV risk factors compared to modest weight loss [28]. Weight loss improves lipid profile (low density lipoprotein [LDL]: ~5 mg/dL, triglycerides [TGs]: ~15 mg/dL, high density lipoprotein [HDL] ~2-3 mg/dL) [25, 29, 30], and other clinically relevant cardiometabolic risk factors, such as insulin sensitivity [31, 32], arterial stiffness [33, 34], c-reactive protein [35, 36] and resting blood pressure (BP) [25, 30]. Thus, reducing weight in overweight and obese patients should result in beneficial effects on lowering CV risk.

Does Aerobic ET Alone Result in Clinically Significant Weight Loss?

The vast majority of the studies investigating the effects of aerobic ET on weight loss suggests that programs consistent with the minimum levels of PA recommendations (~150

minutes of moderate intensity ET) without dietary restriction may induce modest weight loss (~2-3 kg), but in general are unlikely to result in clinically significant weight loss (≥5% weight loss) [26, 37-40]. This finding has been demonstrated by the mean weight loss of large supervised ET randomized controlled trials (RCTs) without a caloric restriction component. However, studies that have daily exercise (instead of only 3-4 times a week) have resulted in clinically significant weight loss [41, 42]. The American College of Sports Medicine currently recommends 225-420 min/wk of ET for individuals attempting to lose weight [26].

For this section, we have limited our discussion to supervised aerobic training studies without a dietary restriction component in study populations that were overweight or obese at baseline. Donnelly et al. [43] evaluated the impact of 18 months (3 times/wk, 30 min/session) of continuous versus intermittent ET (5 times/wk, 15 min/session) in overweight and obese participants. The authors observed small reductions in body weight (2.0%) in the continuous training group and no significant change in intermittent groups after the intervention. In the Dose Response to Exercise in postmenopausal Women (DREW) study (N=464), overweight and obese postmenopausal women were randomized to 50% (72.2 min/wk), 100% (135.8 min/wk) and 150% (191.7 min/wk) of PA guidelines at a heart rate associated with 50% of VO_2 max for 6 months [44]. The mean percent weight loss was approximately 0.5%, 2.5% and 0.7% in the 50%, 100%, and 150% groups, respectively (not significant between groups). Importantly, this study demonstrated that greater amounts of ET did not result in greater overall weight loss. In the Health Benefits of Aerobic and Resistance Training in individuals with type 2 diabetes (HART-D) study (N=262), Church et al. [37] observed no significant weight changes in adults with DM participating in the aerobic training group only (0.8%) compared to a control group (1.0% weight gain) for 9 months. In the Studies of a Targeted Risk Reduction Intervention through Defined Exercise (STRRIDE) study, Slentz et al. [45] reported minimal to modest weight loss after 8 months of low amount/moderate intensity (0.7%), low amount/vigorous intensity (0.9%) and high

amount/vigorous intensity (3.0%). A dose response was observed between miles walked per week and weight change. However, the percent weight loss in participants who walked 17 miles per week (the maximum in the study) was approximately 3.5%. Thus, in overweight and obesity adults with various clinical conditions, aerobic ET alone without dietary restriction does not result in clinically significant weight loss. However, even in aerobic training studies where clinically significant weight loss was not achieved, other indicators of body composition did improve, such as waist circumference (DREW, HART-D, STRRIDE) [37, 40, 44, 46] and body fat (STRRIDE) [46]. In patients that have been exercising regularly, but do not experience weight loss, waist circumference may be an additional measure that can be obtained in clinical visits to evaluate for change in adiposity with exercise training.

In contrast to the previous studies, clinically significant weight loss is possible when ET levels greatly exceed the minimum PA guidelines (e.g. daily exercise or 2,000 kcals/wk). In the first Midwest Exercise Trial (MET 1), Donnelly et al. [41] observed a clinically significant weight loss in response to 16 months of aerobic ET in men (-5.2 kg, 5.5% weight loss), but not women (0.6 kg, 0.7% weight gain). The duration of this study was longer than others previously mentioned (16 months vs. ≤9 months). In addition, the study included a younger population (~23 y) compared to other studies which have not observed clinically significant weight loss (>50 y) [37, 40, 44]. Importantly, the participants expended 400 kcals per session (~2,000 kcals per week) which is considerably higher than studies that did not observe clinically significant weight loss [26, 37-40]. Similarly, in the Midwest Exercise Trial 2 (MET 2), Donnelly et al. [42] compared the impact of 400 kcals/session vs. 600 kcals/session of aerobic ET in young adults. The authors observed modest weight loss with 10 months of aerobic ET in the 400 kcal group (-3.9 kg, 4.2% percent weight loss) and clinically significant weight loss in the 600 kcal group (-5.2 kg, 5.6% weight loss). No gender differences were observed in this study. Ross et al. [47] evaluated the effect of exercise-induced weight loss compared to diet-induced weight loss and exercise without weight

loss in overweight and obese men. After 12 weeks of daily ET (700 kcals/session), men in the exercise-induced weight loss group lost 7.3% of body weight compared to the control group (0.0%). In another study by Ross et al. [48] in premenopausal women with abdominal obesity, participants lost 6.7% of their body weight after 14 weeks of aerobic ET (500 kcals per session of daily exercise) compared to the control group (1.0% weight gain).

Aerobic ET levels that greatly exceed the minimum PA recommendations have a higher likelihood of resulting in clinically significant weight loss compared to lower levels. Engaging in moderate amounts of exercise without caloric restriction (~150 min/wk of moderate intensity) is not the optimal intervention to induce clinically significant weight loss. For the treatment of overweight and obese adults, caloric restriction in combination with exercise adherence is recommended. For patients who are unable to lose weight, but are able to maintain regular exercise habits, it is important for clinicians to emphasize that improvements in cardiometabolic risk factors have been observed independent of weight loss including improvements in adiposity [37, 40, 44, 46], insulin sensitivity [49, 50], arterial compliance [51-53], endothelial function [54], lipoprotein particle size [55] and cardiorespiratory fitness (CRF) [44, 56]. A strong rationale for clinicians to continue to promote PA/ET programs exists even in adults that are unable to achieve their weight loss goals. Specifically, greater CRF is associated with reductions in CV disease and all-cause mortality compared to unfit men and women [57-59].

Prevalence of Clinically Significant Weight Loss with Aerobic ET

While much of the data evaluating whether ET induces clinically significant weight loss from the mean change in weight, few studies have reported the prevalence of clinically significant weight loss following aerobic ET. In the MET 2 study, Donnelly et al. [42] observed a 45.9% and 62.2% prevalence of clinically significant weight loss in young adults exercising at 400 and 600 kcals per session (5 days/wk, 10-month intervention), respectively. In a secondary analysis from the DREW study, Swift et al. [28] observed that <20% of postmenopausal

overweight and obese women experienced clinically significant weight loss in response to moderate intensity aerobic ET (50% of VO_2 max) at PA guidelines. Only 10.3% of women who exercised at half of PA guidelines (72.2 min/wk) achieved clinically significant weight loss. Interestingly, women that exercised at 150% of PA guidelines (191.7 min/wk) had a lower prevalence of clinically significant weight loss (14.6%) compared to women who exercised at PA guidelines (20%, 135.8 min/wk) [28]. This may suggest that postmenopausal women have compensation for weight loss (perhaps increased dietary or deceased non-exercise PA) with increased levels of aerobic training [28, 60]. In terms of exercise intensity, Swift et al. [27] observed a low prevalence of clinically significant weight loss in overweight and obese adults who participated in 8 months of aerobic ET in an ancillary report from the STRRIDE study. The authors observed that the prevalence of clinically significant weight loss was 7.6%, 9.3%, and 14.3% in the low amount/moderate intensity, low amount/high intensity, and high amount/high intensity training, respectively.

In summary, the available evidence suggest that the prevalence of clinically significant weight loss is low (<20%) in participants that do not perform daily exercise and exercise less than 2,000 kcals per week of ET. These observations reiterate the need of dietary restriction or high exercise levels in programs designed to promote clinically significant weight loss.

Cardiometabolic Health Benefits for Weight Loss and Exercise Training

While the attainment of clinically significant weight loss is an important health metric, the cardiometabolic benefits accrued from weight loss are particularly important in the treatment of overweight and obese patients. An examination of participants in prospective studies that were able to achieve mean levels of weight loss of at least 5% suggests that improvements in several cardiometabolic risk factors (e.g. body fat, visceral fat, lipids, and insulin sensitivity) are observed for aerobic ET in combination with weight loss compared to aerobic training alone [28, 42, 47]. However, it is important to emphasize that modest weight loss as little as 2-3% is

associated with CV benefits [26, 28, 61-63], which may be more achievable for some overweight and obese patients.

In the MET 1 study, Donnelly et al. [41] observed that 400 kcals per session for 16 weeks resulted in clinically significant weight loss in men, but not women. Male exercisers had greater reductions in body fat (-3.9%) compared to male controls (0.8), but change in visceral fat was similar between groups. In the MET 2 study, Donnelly et al. [42] observed a clinically significant mean weight loss (5.7%) with 600 kcals per session of aerobic ET for 16 weeks. This group had greater reductions in body fat (-4.3%) and fat mass (-5.2 kg) compared to the control group (body fat: -0.6%, body mass: 0.2 kg). Ross et al. [47] compared the impact of 12 weeks of exercise-induced weight loss compared to exercisers without weight loss. Participants in the exercise without weight loss group compensated for exercise calorie expenditure with increased energy intake. The authors observed greater reductions in body fat, visceral fat, 2-hour oral glucose tolerance and increased glucose disposal in the exercise-induced weight loss group compared to the exercise with no weight loss group.

Two retrospective studies have evaluated changes in CV risk factors in participants who have achieved a specified weight loss criterion (e.g. >5% weight loss) with aerobic ET compared to those that did not [27, 28]. Swift et al. [28] evaluated the effect of aerobic training on clinically significant weight loss (>5%), modest weight loss (3 to 5%) and a group that did not achieve either (<3% weight loss) on CV risk factors in postmenopausal women in the DREW study. Both the clinically significant weight loss and modest weight loss groups had a significant increase in insulin sensitivity (assessed via HOMA-IR) compared to the no weight loss group (Figure 1). The authors found that the clinically significant weight loss group had greater reductions in fasting insulin and waist circumference compared to the no weight loss group. Importantly, no differences between groups were observed for lipids, BP, glucose or CRF (VO_2 peak). Similarly, using data from the STRRIDE study, Swift et al. [27] evaluated the

cardiometabolic adaptations in participants that achieved at least modest weight loss (≥3%) compared to participants that did not (<3%). The authors observed that aerobic training without weight loss improved insulin sensitivity (assessed via an intravenous glucose tolerance test), but a more robust improvement was observed in participants that achieved at least modest weight loss. Larger changes were also observed for other health indicators such as waist circumference, TGs, non-HDL cholesterol, LDL particle size, total LDL particles and HDL particle size in participants who achieved at least modest weight loss compared to aerobic training without weight loss.

Weight loss with exercise is an important and understandable health metric to promote changes in cardiometabolic risk factors. Weight loss may be particularly important to maximize the improvements in insulin sensitivity and some lipid adaptations when combined with aerobic ET. Importantly, even modest weight loss (~3%) appears to be effective in improving insulin sensitivity measures with aerobic ET [27, 28].

Combined Exercise and Dietary Programs

The optimal strategy for promoting weight loss is the combination of caloric restriction and adherence to adequate aerobic PA/ET. RCTs and meta-analyses that have examined the impact of weight loss programs composed of both exercise and dietary caloric restriction have shown greater weight loss compared to programs composed of exercise only [64-67]. Similarly, diet only programs produce larger weight loss than exercise only programs [64-67].

In the Nutrition and Exercise in Women study, Foster-Schubert et al. [64] compared the impact of 12 months of a low-calorie diet (1,200-2,000 kcals/day, <30% fat), moderate intensity ET (5 days per week, 225 min/wk) or the combination of both programs on body composition in overweight and obese postmenopausal women. The group that did a combination of diet and exercise had a larger weight loss (10.8%) compared to the diet only (8.5%) or the exercise only

groups (0.8%) (Figure 2). Participants with higher attendance at nutrition study sessions and exercise adherence (≥196 min/wk) had greater weight loss than participants with low levels. In addition, participants in the diet and exercise group had greater reductions in body fat percentage (12.4%) compared to the exercise only (3.3%) or the diet only group (8.9%). Messier et al. [66] compared the impact of 18 months of diet only (800-1,000 kcals per day), exercise (3 days per week, strength training [20 minutes] and walking [15 minutes]) or a combination of both interventions in older overweight and obese adults. Participants in the diet only (9.5%) and the combination (11.3%) programs had greater weight loss compared to the exercise only group (2.0%). The authors also observed greater fat mass loss in both diet groups (diet only: -4.8 kg, diet+exercise: -6.5 kg) compared to the exercise only group (-0.4 kg). Similarly, a meta-analysis by Johns et al. [65] observed a 5.3 kg greater weight loss in combined diet and ET programs compared to diet alone for interventions that were 3-6 months long. For interventions that were 12-18 months, the authors observed a 6.3 kg greater weight loss with combined diet and exercise programs compared to diet only programs.

The notion of whether exercise augments the weight loss of diet only programs have observed mixed results with a RCT in support [64] and others that did not support these results [68-70]. However, the results of 2 meta-analyses suggest that the combination of exercise and diet results in greater weight loss compared to diet alone [65, 67]. In a meta-analysis of 6 studies, Curioni et al. [67] observed greater weight loss with diet and exercise (-13.0 kg) programs compared to diet only (-9.9 kg) in overweight and obese adults. The authors observed a difference of 1.24 kg greater pooled weight loss across studies for the diet and exercise group compared to the diet only group. Similarly Johns et al. [65], in a meta-analysis of 11 studies, observed that diet and exercise resulted in larger weight loss at 12-18 months compared to diet only groups (1.72 kg pooled mean difference). Importantly, in a separate analysis, differences between diet only and combined programs were not significant for shorter intervention periods

(3-6 months). This may suggest that differences in weight loss between combined and diet only programs are not discernable immediately and may require longer than 6 months to become apparent.

In summary, patients that use dietary or combination (diet and ET) weight loss programs generally experience greater weight loss than those who utilize ET only programs. While a diet only approach can produce clinically significant weight loss, patients should be counseled that exercise has independent health benefits [28, 71]. Importantly, both PA and CRF are independent predictors for CV disease [18, 72-74]. Some data suggest that adding exercise to a diet program can enhance weight loss [64, 65, 67]. Clinicians should encourage overweight and obese participants to pursue both dietary modification and regular exercise to promote weight loss and maximize the improvement in CV risk factors.

Resistance Training and Weight Loss

Resistance training alone is unlikely to produce a sufficient negative energy balance to result in clinically significant weight loss compared to aerobic training. Aerobic training sessions generally have a higher total energy expenditure compared to resistance training. In addition, potential gains in lean mass from resistance training can attenuate weight loss [75, 76]. Therefore, patients attempting to lose weight using resistance training only should be encouraged to perform an aerobic training program (with dietary caloric restriction) or add aerobic training to their resistance training program. Resistance training could be supportive of a negative energy balance by increasing lean mass, resting metabolic rate, and fat oxidation [26]. When used in combination with other weight loss intervention strategies, resistance training may have the potential to assist with weight loss or maintenance. Independent of weight loss, resistance training has been shown to promote reductions in adiposity in some studies [37, 75, 77] (but not all [76, 78]) and improvements in other CV risk factors [79-81]. Due to potential increases in lean mass with resistance training, recording body weight alone in clinical settings may obscure potential

improvements in body composition. Therefore, measuring waist circumference in addition to body weight at clinical visits may be necessary to capture changes in central adiposity in participants performing resistance training.

The fact that clinically significant weight loss is unlikely from resistance training alone is supported by the results of several RCTs [37, 75-78]. Olson et al. [76] observed no significant weight change (2.8% weight gain) in overweight women after 1 year of resistance training compared to a control group (1.0% weight loss). However, increases in lean mass were observed in the resistance training group. Schmitz et al. [77] observed no weight change in overweight and obese adults participating in a 2 year resistance training program compared to a control group, but the resistance training group had improvements in intrabdominal fat and percentage body fat. In the HART-D study, Church et al. [37] observed no weight change in adults with DM participating in resistance (0.3% weight loss) or a combination program (aerobic and resistance training) (1.5% weight loss) compared to a control condition for 9 months. The resistance training group lost more fat mass (-1.3 kg) compared to the control group (0.1 kg), but no changes were observed for lean mass. Similarly, Sigal et al. [78] observed no weight loss with 6 months of resistance training (1.1% weight loss) or a combination program (2.5% weight loss). No changes were observed in body fat or lean mass between the resistance and control groups.

Resistance training alone as an intervention does not induce clinically significant weight loss and should not be advocated as the primary method of weight reduction. However, for overweight and obese patients that will only participate in resistance training, it may produce some favorable changes in body composition [37, 75, 77] and some other health benefits [79-81].

Physical Activity Level and Weight Maintenance

Although obtaining significant weight loss is readily achievable, 80% of individuals are not able to maintain the weight loss [82]. The high rate of unsuccessful weight loss has public

health importance given that even mild weight regain (2-6%) [83] has been associated with regression in major CV risk factors, such as total cholesterol [84, 85], LDL cholesterol [85, 86], TGs [84, 87, 88], BP [87-89], glucose [84, 85, 90] and insulin levels [86, 89]. Successful weight loss maintenance has been associated with reduced CV disease and DM risk [91]. The promotion of strategies aimed at improving weight maintenance after significant weight loss is integral to promote improvements in CV health. Potential rationales for the high prevalence of weight regain after weight loss include increases in appetite hormones (e.g. ghrelin), decreases in anorexigenic hormones (e.g. leptin, glucagon-like peptide-1), reductions in compliance with self-monitoring/weighing habits, and decreases in resting metabolic rate with weight loss [92]. The most recent position stand by the American College of Sports Medicine recommends that adults need to obtain at least 200-300 minutes of moderate PA per week to promote weight maintenance after weight loss, which has been translated to 60 minutes of daily walking for public health purposes [26].

Overall, higher overall amounts of PA have been shown to promote greater weight maintenance [93-95]. Jakicic et al. [94] randomized obese women to vigorous intensity/high duration, moderate intensity/high duration, moderate intensity/moderate duration, or vigorous intensity/moderate duration exercise for 24 months. Participants also reduced caloric intake in the range of 1,200 to 1,500 kcals per day. The moderate and high intensities were defined as 60-65% and 70-85% of age predicted heart rate max, respectively. The energy expenditure for the moderate and high duration were 1,000 and 2,000 kcals per week, respectively. Retrospective analyses from this study show that participants that maintained the greatest amount of weight loss at 24 months (based on LTPA questionnaires) had greater PA energy expenditure (≥2000 kcals per day [~11% weight loss] vs. <1000 kcals/wk [~3% weight loss]) and amount of ET time per week (≥300 min/wk [11% weight loss] compared to <150 min/wk [3% weight loss]).

A different study by Jakicic et al. [96] evaluated the impact of intermittent home-based exercise on weight maintenance in sedentary overweight and obese women. Participants were assigned to a long bout (5 days per week, ~40 minutes), short bout (5 days per week, ~40 minutes divided into 10-minute bouts) or short bout plus home exercise equipment group (treadmill provided for home use). The initial weight loss at 6 months was ~7-10 kg without significant differences between groups. Retrospective analyses evaluating weight maintenance at 18 months showed that when all groups were combined, participants who exercised ≥220 min/wk (determined by questionnaire) had the most sustained weight maintenance (~-14 kg) compared to those that exercised less than 150 minutes a week (~-4 kg). Similarly, Andersen et al. [97] evaluated the impact of LTPA compared to structured ET in obese women for 16 weeks and participants were then followed-up after 12 months. The women were also asked to reduce caloric consumption to approximately 1,200 kcals per day. The weight loss in both the aerobic and lifestyle groups were approximately 8 kg at 16 weeks. In retrospective analyses for weight maintenance at 12 months, the authors classified participants into tertiles based on PA questionnaire data. Weight maintenance was greater in participants classified as most active (-2.0 kg) and moderately active (0.3 kg) compared to the least active group (4.9 kg). Thus, the evidence from retrospective analyses of weight loss interventions suggests that PA level is associated with improved weight maintenance.

Prospective studies that have specifically examined ET level on weight maintenance have limitations, including design issues, low adherence rates to exercise, and unsupervised ET/PA (or lack of objectively captured PA) [26]. Similar to retrospective studies, evidence from prospective studies suggest that PA levels less than 150 min/wk are not adequate for weight maintenance. Borg et al. [98] evaluated the impact of moderate walking (135 min/wk week, 60-70% $VO_{2\,max}$) or resistance training on weight maintenance (135 min per week, 60-80% of 1-repetition maximum) in obese men. During the initial weight loss phase (2 months), participants

consumed 500 kcals/day or 1,200 kcal/day (dependent on the week in the study), which elicited a mean 14.3 kg reduction in weight (~13.5% weight loss). Participants were subsequently randomized to a walking (45 minutes, 3 times per week), resistance training (45 minutes, 3 times per week), or a control group (did not perform any ET) following the initial weight loss phase. The authors observed no significant differences in weight between the control group and the two ET groups at 8 months or 31 months. The authors did observe that total energy expenditure (prescribed and non-prescribed PA) was negatively associated with weight gain from 2-8 months ($r = -0.32$, $p<0.001$) when all groups were combined. Jeffery et al. [99] compared the impact of a physical activity program of exercise level on weight maintenance. In the initial weight loss phase, participants were instructed to reduce caloric intake to 1,000-1,500 kcals/day (depending on baseline body weight) and fat intake to <20%. After weight loss, participants were randomized to a standard behavior therapy group (1,000 kcals per week, ~30 min /day) or a high PA treatment group (2,500 kcals per week, ~75 min/day). Differences in weight maintenance between the standard behavior therapy and high PA treatment groups were observed at 12 months (~-6 kg vs. ~-8.5 kg) and 18 months (~-4 kg vs. ~-6.5 kg). Importantly the prevalence of adherence to the high dose of exercise was <50% at 6 months and ~40% at months 12 and 18 despite having behavioral support, exercise coaches and exercise partners. This may suggest that intervention strategies need to target these time periods after weight loss to improve weight loss maintenance.

PA Level and Weight Maintenance Beyond 18 Months

While much of the aforementioned studies focused on short-term weight maintenance (<2 years), a few prospective studies have looked at PA level in long-term maintenance. Data from the Diabetes Prevention Program (DPP) [100] evaluated 12 months and 3 year weight loss in adults with high risk for DM. DPP participants had a goal of obtaining 7% weight loss and participating in at least 150 min/wk of moderate intensity PA as part of a lifestyle modification

program. At year 1 and year 3, participants in the intensive lifestyle intervention reported that they exercised 224 and 247 min/wk, respectively. Participants were more likely to meet PA goals at 12 months if they were older, male, and monitored their fat intake. Predictors for meeting PA goals (at least 150 min/wk) were similar at 3 years. Weight loss goals were achieved (>7%) in 49% and 37% of participants at 12 months and 3 years, respectively. Predictors for weight loss maintenance at 12 months and 3 years included meeting exercise goals and monitoring fat intake.

The Action for Health for Diabetes (Look AHEAD) study randomized 5,145 men and women with DM to a usual care condition or an intensive lifestyle condition in which weight loss was evaluated at years 1 and 4. In brief, the intensive lifestyle condition included a PA goal of 175 min/wk (moderate to vigorous intensity), caloric restriction (1,200-1,500 kcals per day for participants <114 kg; 1,500-1,800 kcals per day for participants ≥114 kg) and meal replacement. Using data from Look AHEAD, Wadden et al. [101] showed that weight loss after year 1 was associated with higher self-reported PA. Participants in the highest quartile of minutes of PA (287.1 min/wk,11.9% weight loss) lost more weight than those in the lowest quartile (25.9 min/wk, 4.4%). Importantly, the odds of reaching 10% weight loss was 9.4 times greater in participants in the highest tertile compared to the lowest tertile. Other intervention factors that were associated with weight loss after year 1 were attending more sessions associated with the study and higher use of meal replacement [25]. After year 1, participants had individual goals for caloric intake (depending if the participant wanted to lose more weight, maintain weight loss, or counteract previous weight gain), replace one meal with replacement, and exercise (175 min/wk). About 25% of the participants who achieved a 10% weight loss at year 1 were able to maintain the loss at year 4. Similar to the year 1 outcomes, higher amount of treatment contacts and energy expenditure per week were associated with maintaining a 10% weight loss (Figure 3). After year 8, participants who maintained ≥10% weight loss had higher PA (1471.9 vs. 799.9

kcals/wk), greater number of weeks in the intervention with reduced caloric intake (20.4 vs. 11.9 weeks), lower fat intake (24.2 vs. 15.6 weeks), and had a higher prevalence of weighing themselves weekly (82.4% vs. 69.8%) compared to those that had body weights that were above their baseline weight.

A major limitation of the PA literature with regard to weight maintenance is the lack of objective measurement for PA; much of the data was derived from PA questionnaires. To address this, Unick et al. [102] evaluated the impact of PA level on weight maintenance in a sub-set from the Look AHEAD study (n=2,622) in which accelerometry was performed in years 1 and 4. Higher amounts of moderate to vigorous PA (150 to 250 min/wk, ~12% weight loss; 250 min/wk, ~13% weight loss) were associated with greater weight maintenance compared to <50 min/wk (~7% weight loss) at year 1. At year 4, individuals that participated in ≥250 min/wk of moderate to vigorous PA had greater weight maintenance (8.3%, CI: 6.1 to 10.4) compared to those who had 50-150 min/wk (5.5%, CI: 3.7 to 7.4) or <50 min/wk (5.8%, CI: 4.0 to 7.6). Major predictors of greater weight maintenance at year 4 included the weight change at year 1 (β= 0.638, $p<0.001$) and amount of year 4 moderate to vigorous PA (β=-0.003, $p=0.006$).

Similar to short-term studies, trials that have evaluated weight maintenance longer than 2 years observe that high amounts of PA are associated with greater weight maintenance compared to lower levels. Evidence from these studies suggest that clinicians should encourage their patients to engage in a high level of PA (200-300 minutes) and continue to self-monitor diet (particularly maintaining lower caloric intake/fat intake) to improve weight maintenance.

Conclusions

A strong rationale exists for the promotion of PA/ET and weight loss to reduce CV risk in overweight and obese patients. ET programs consistent with the minimum PA guidelines (150 min/wk of moderate intensity PA or 75 min/wk of vigorous intensity PA) are associated with CV health benefits. Patients seeking to lose weight without changing their dietary habits need to be

counseled that high PA levels (225-420 min/wk of exercise) are necessary to achieve clinically significant weight loss. When achievable, clinically significant weight loss with aerobic exercise training leads to larger improvements in insulin sensitivity and lipid variables compared to exercising with no weight loss. For those that are unable to obtain clinically significant weight loss, improvements in cardiometabolic health have been observed in participants who have achieved modest weight loss (~3%) and even independent of weight loss. For patients seeking to maintain weight loss, high levels of PA (200-300 min/wk of moderate intensity PA) have been associated with improved weight maintenance compared to lower levels (<150 min/wk). In addition, improved weight maintenance has also been associated with adherence to dietary plans, regular weighing and engagement in weight maintenance support groups.

Conflict of interest: None.

Table 1. Aerobic physical activity amount and expected weight loss. Adapted from the American College of Sports Medicine position stands, "*Appropriate physical activity intervention strategies for weight loss and prevention of weight regain for adults* " [26]

Aerobic physical activity amount	**Weight loss amount**
<150 min per week	No weight loss or minimal weight loss
150-225 min per week	Weight loss of 2 to 3 kg
225-420 min per week	Weight loss of 5 to 7.5 kg
200-300 min per week	Weight maintenance after weight loss

Table 2. Expected initial weight loss and possibly of clinically significant weight loss from different types of exercise training programs

Exercise type	Range of Expected Weight Loss	Chance of clinically significant weight loss
Aerobic exercise training only	0 to 3%	Possible, but only with high exercise volumes
Resistance training only	0 to 1%	Very unlikely
Aerobic and resistance training	0 to 3%	Possible, but only with high volumes of aerobic exercise training
Caloric restriction combined with aerobic exercise training	5 to 15%	Possible

Figure 1. Changes in insulin sensitivity in exercisers achieving clinically significant weight loss (>5%), modest weight loss (3-4.9%) and no weight loss (3%). Adapted from Swift et al. [28]

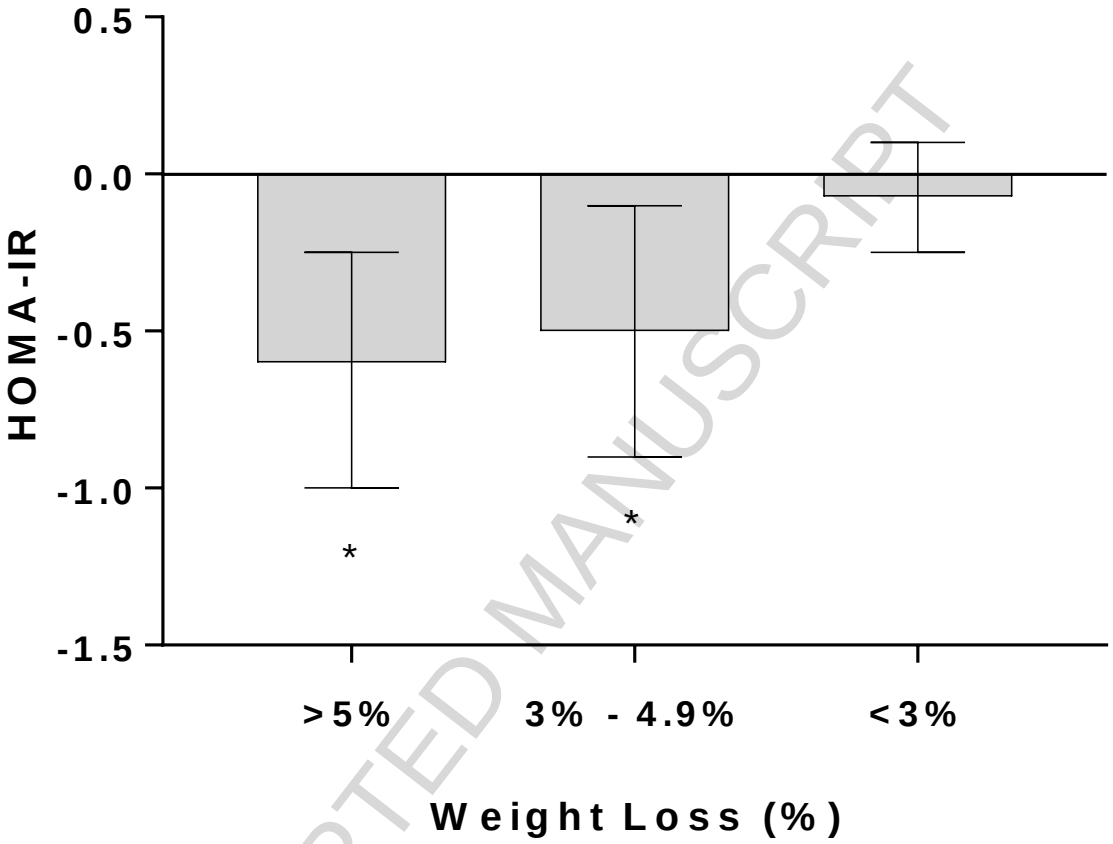


Figure 2. Changes in weight in response to 12 months of diet only, exercise only and the combination of diet and exercise * denotes significant difference compared to the diet+exercise arm. Adapted from Foster-Schubert et al. [103]

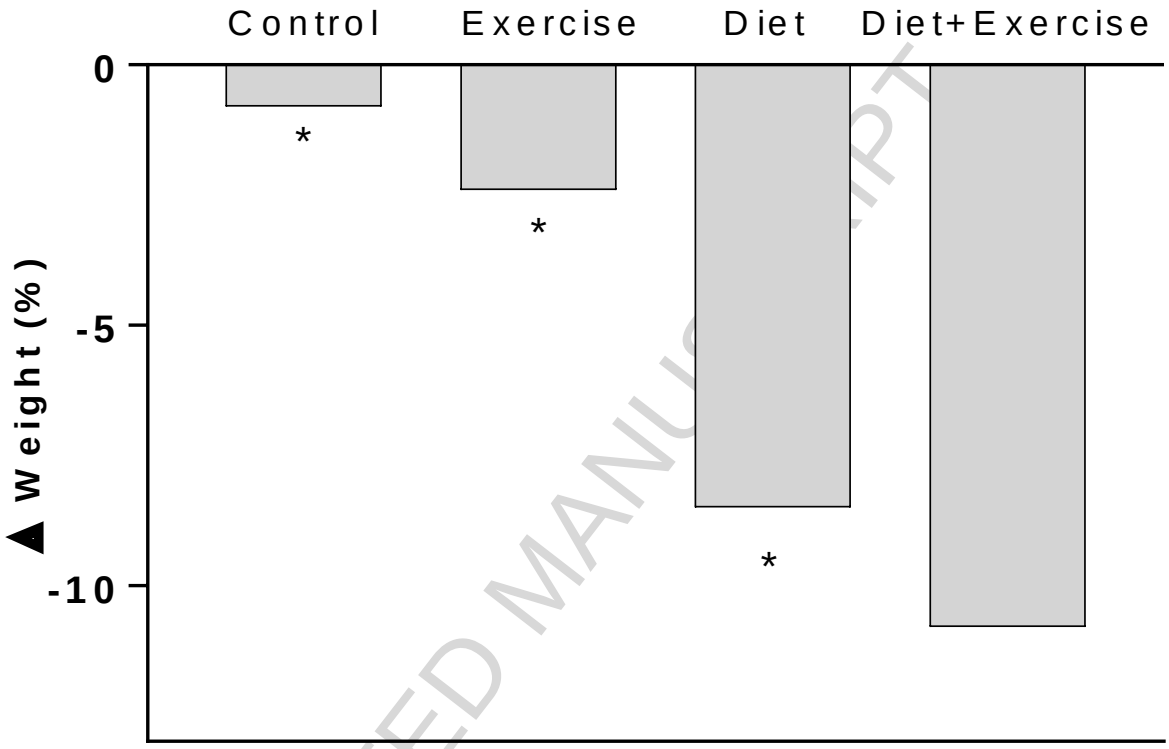
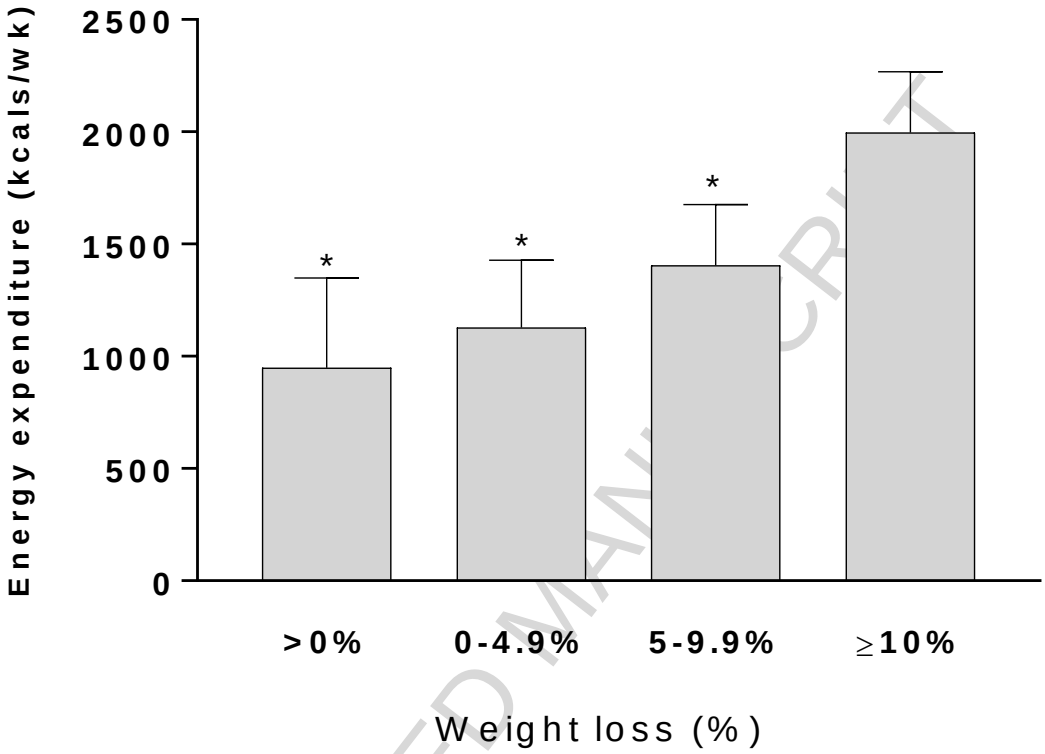


Figure 3. Weight maintenance at 4 years based on energy expenditure in the Look AHEAD study. *Denotes significant difference between compared to ≥10% group. Adapted from Wadden et al. [104]



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