ARTICLE

Exercise and Weight Loss: No Sex Differences in Body Weight Response to Exercise

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CAUDWELL, P., C. GIBBONS, G. FINLAYSON, E. NÄSLUND, and J. BLUNDELL. Exercise and weight loss: no sex differences in body weight response to exercise. *Exerc. Sport Sci. Rev.*, Vol. 42, No. 3, pp. 92–101, 2014. *There is a view that exercise is less effective for weight loss in women compared with men. This systematic review examines the evidence for sex-based differences in the effect of exercise on body weight. We hypothesize that, when energy expenditure is equivalent, there will be no evidence for sex differences in body weight response to exercise.* **Key Words:** body composition, sex, energy expenditure, energy intake, appetite

INTRODUCTION

Exercise is recommended by many public health organizations as a method of weight control and improving health. There is now a wealth of evidence demonstrating the many health benefits of exercise, which are independent of weight loss (5,11,22,24). However, the efficacy of exercise to produce weight loss when not accompanied by a dietary intervention still is questioned (35). There also is a prevailing view that women lose less weight in response to exercise than men (2,13). The smaller amounts of weight allegedly lost reported for women usually are attributed to a stronger defense of body fat resulting in a stronger compensatory increase in energy intake (EI) to maintain energy balance (4). However, there are problems with interpreting the current literature for sex differences in exercise-induced weight loss. These problems mainly are caused by a number of common methodological issues and include poor/unknown exercise compliance, inaccurate/nonmeasurement of exercise-induced energy expenditure, differences in duration of study, and differences in participant characteristics. Furthermore, there are very few studies designed to include simultaneous assessment of energy expenditure, body composition, and EI. This creates a serious challenge for determining the impact of exercise on energy balance and for examining any sex-based differences in body weight response to exercise.

We have demonstrated on two separate occasions that when exercise energy expenditure (EE) is similar between men and women that there is no significant difference in body weight response to exercise. The 12-wk supervised aerobic exercise program produced significant reductions in body weight and body fat for both men and women (6,26). Therefore, the purpose of this systematic review was to examine the evidence for differences in weight loss in response to exercise between men and women. This review analyzed the literature to draw comparisons between short-, medium-, and long-term interventions, supervised and unsupervised exercise programs, and normal and overweight participants and also to examine the issue of exercise-induced energy expenditure and compensation. We hypothesize that when exercise-induced energy expenditure is similar; there is no effect of sex on body weight or any such related compensatory appetite response to exercise.

METHODS

This report has involved a systematic literature search using the following databases: Medline, Pubmed, and Sports Discus. The search was designed to include all articles published in English with the higher-order categories of Exercise OR Physical Activity AND Body Weight OR Body Composition. The search terms used are in Table 1. The resultant list was screened for studies that met the inclusion criteria. Inclusion criteria were human adults aged between 18 and 65 years

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TABLE 1. Keyword terms used for the database search.

Participants	Intervention	Manipulation	Outcome Variables	Exclusions
Adults	Exercise	Gender	"Body weight"	Animals
Obese	"Physical activity"	Sex	"Body mass"	Athletes
Lean	Running	"Men" AND "Women"	"Body composition"	Disease
"Normal weight"	Walking	"Male$" and "Female$"	"Fat mass"	Children
Overweight	Cycling		"Fat free mass"	Adolescents
	Rowing		"Lean mass"	Older adults
	Swimming		"Muscle mass"	Eating disorders
			"Energy intake"	Smoking
			"Food intake"	
			"Energy expenditure"	

enrolled in an exercise intervention. Studies were excluded if the research used animals, if men and women were not in the same exercise study, if body weight was not measured before and after the intervention, if there was any disease within the participant group, or if there was a dietary or pharmacological intervention added to the exercise. If body weight was not reported for men and women separately, the corresponding author was contacted and these data were requested. A comprehensive list of the studies reviewed is presented in Table 2.

RESULTS

The search generated 1184 results, 1117 of these were eliminated on the basis of titles and abstracts alone. The full text was retrieved for 67 articles. After examination of these articles, 21 articles were identified that met all the inclusion/exclusion criteria. Figure 1 shows the systematic review process. The final 21 studies included in the review are listed in Table 2. The duration of the interventions ranged from 8 days to 16 months. The sample size ranged from 12 to 557 participants, and the body mass index (BMI) ranged from 19.4 to 35.0 kg m^{-2}. Fourteen of the studies were carried out on overweight or obese participants, and seven studies used normal-weight individuals. Seventeen of the exercise interventions were carried out under supervision, and four studies were self-monitored interventions. These selected studies were classified into three groups based on the length of the intervention: short-term interventions, 1 to 14 days (n = 2); medium-term interventions, 2 to 16 wk (n = 8), and long-term interventions, longer than 16 wk (n = 11).

Short-term Exercise Interventions

From the 21 research articles included in the systematic review, two interventions were classified as short-term studies (28,37). These studies generally were well controlled, the exercise was monitored, and the exercise prescription was based on exercise-induced energy expenditure. In both interventions, participants were normal weight mainly, and the observed change in body weight was small in men (~0.6 kg) and women (~0.6 kg). Interestingly, in both studies, women lost more weight than men, but the differences were not significant (possibly because of the small sample size and low statistical power). From this limited available evidence, it seems that there is no sex-based difference in body weight response to short-term exercise. Normal-weight men and women both show small changes in body weight or composition after a short period of repeated exercise. However, for exercise to have a more substantial impact on body weight and body composition, a significant period of regular exercise where a substantial amount of energy is expended is required.

Medium-term Exercise Interventions

Nine medium-term interventions were included in the literature search. In three of these studies, it was demonstrated that men lost more weight in response to exercise compared with women. Hill and colleagues (17) reported that men lost 1 kg in response to a 10-wk exercise program, whereas women maintained their initial weight. Although the exercise was supervised, the exercise prescription was based on intensity and duration, whereas energy expended from these sessions was not recorded or verified. Evidence for a sex difference in change in body weight in response to low-intensity exercise was reported by Irving *et al.* (18). This study demonstrated that, in response to 16 wk of supervised exercise in which the energy expenditure was fixed at 400 kcal per session, obese men lost significantly more weight during low-intensity exercise than obese women (-4.4 vs -2.1 kg). This modest weight loss outcome in women suggested the possible existence of some form of compensation in response to the increase in energy expenditure. However, this study also incorporated a high-intensity training arm. In response to high-intensity exercise, there was no difference in body weight response between the sexes (-2.8 (men) vs -2.6 kg (women)) (18). This study draws attention to a possible effect of exercise intensity, which on the basis of these data would suggest that women respond similarly to high- and low-intensity exercise, whereas body weight in men is more responsive to a low-intensity regimen.

Another study that demonstrated a sex difference in response to medium-term exercise was reported by Andersson *et al.* (1). Men significantly reduced their body mass in response to 12 wk of supervised exercise (compared with baseline),

TABLE 2. Experiments that are included in the systematic review and have examined the impact of exercise on weight loss in men and women.

Authors	Participants	Exercise Intervention	Supervised/EE	Change BM (Preintervention to Postintervention)	Sex-Based Difference	Comment
Short-term interventions (1–13 days)						
McLaughlin *et al.* (28)	8 normal-weight and overweight men and 8 normal-weight women	4 exercise sessions for 8 days. Exercise duration designed to expended 2092 kJ per session	Supervised and fixed EE	BM: M: 0.0 W: -0.6 kg	Yes women lost more weight than men	
Whybrow *et al.* (37)	6 normal-weight men and 6 normal-weight women	13 days of moderate exercise (MEX 2.0 MJ d^{-1}) 13 days high-intensity exercise (HEX 4.0 MJ d^{-1})	Supervised and fixed EE measured with doubly labeled water	MEX BM M:-0.67 W: -0.96 kg HEX BM M: -0.63 W: -1.13 kg	No	There was a 30% partial compensation in EI for the EE in both men and women.
Medium-term interventions 2–16 wk						
Andersson *et al.* (1)	22 women and 9 men normal and overweight	3-month exercise intervention 3 times per week 60 min per session	Supervised by a physiotherapist. No measurement or estimation of EE	BM M: -2.0 kg W: -0.7 kg FM M: -2.9 kg W:-2.6 kg FFM M :0.8 W:1.9 kg	Yes men lost more body weight than women	There was no sex-based difference in fat mass
Caudwell *et al.* (6)	107 overweight and obese sedentary adults	3-month exercise intervention. 5 sessions per week expending 500 kcal per session at 70% HR_{max}	Supervised and EE measured	BM M: -3.0 W -2.4 kg FM M: - 3.1 W: -3.0 kg FFM M: 0.1 W: 0.6 kg	No	Men and women expended the same amount of energy
Devries *et al.* (10)	18 obese and normal-weight men and 23 normal-weight and obese women	3-month training cycle ergometer 3 60 min sessions per week at 65%–70% $\dot{V}O_{2peak}$	Supervised participants completed the same number of sessions. No measurement or estimation of EE	Obese participants: BM M: -1.0 W: -1.0 kg Normal-weight participants BM: M: -1.0 W:0.0 kg	No	Both men and women significant decrease in WC
Hill *et al.* (17)	Majority normal-weight men (n = 8) and women (n = 9) 1 overweight man and 1 overweight woman	10-wk exercise program 4 60-min sessions per week at 70% HR_{max}	Supervised. No measurement of EE but exercise designed to expend 1500–2000 kcal wk^{-1}	BM M: -1.0 W: 0.0 kg	Yes men lost more weight than women	FM and FFM measured but not reported
Irving *et al.* (18)	10 men and 24 women obese and sedentary	16-wk supervised exercise 5 sessions per week expending 400 kcal per session at either LIE or HIE	Supervised	LIET: BW: M:-4.4 kg W:-2.1 kg FM: M: -3.9 kg W: -1.3 kg FFM: M: -0.5 kg W: -0.8 kg HIET: BW: M: -2.8 kg W: -2.6 kg FM: M: -3.4 kg W: -2.1 kg FFM: M:0.5 kg W:-0.3 kg	Yes on the LIET men lost more body weight than women, No sex-based effect on the HIE condition	The control group for the men also lost 4.5 kg.
King *et al.* (20)	16 overweight/obese men and 16 overweight/obese women	16 wk 3 sessions per week of either resistance or circuit training	Each session supervised the participants recorded repetitions and weight lifted	Circuit training — BM M:-3.1 W:-2.62 kg FM M -2.64 W: -4.1 kg Resistance training BM M: -0.14 W:0.13 kg FM M: 2.35 W: -0.96 kg	No	

(Continued on next page)

TABLE 2. *Continued.*

Martins *et al.* (27)	Normal-weight PP: 11 men and 14 women	6 wk of exercise 30–45 min at 65-75% HR_{max} 4 times per week	Self report compliance with heart rate monitors	BM M: 0.3 kg W:0.3 kg, % FM M: -0.1%W: -0.9%	No	
Martins *et al.* (26)	Overweight and obese men (n = 7) and women (n = 8)	3-month exercise intervention. 5 sessions per week expending 500 kcal per session at 70% HR_{max}	Supervised and measured	BM M: -3.6 W -3.5 kg FM M: -2.88 W: -2.8 kg FFM M: 0.76 W: 0.47 kg	No	Men and women expended the same amount of energy
			Long-term interventions 16 wk–16 months			
Donnelly *et al.* (12)	74 participants overweight and obese men and women	16 months 45 min per session 2000 kcal wk^{-1}	Exercise intervention supervised and EE measured	BM M: -5.2 W: 0.6 kg FM M: -4.9 W: –0.2 kg FFM M: -0.2 W: 0.9 kg	Yes men lost more weight than women	Men expended 200 kcal per session more than women
Donnelly *et al.* (14)	46 women and 46 men overweight and obese	10 months 5 sessions per week. Each session expend 400 or 600 kcal at 70% HR_{max}	Supervised and EE measured	400 Kcal BM M:-3.8 W:-4.1 FM M:-3.6 W:-3.4 FFM M:0.0 W:0.1	No men and women lost equivalent amounts of body weight and body fat	
Després *et al.* (9)	7 women and 12 men young, lean, and sedentary	20-wk cycling program. 5 times per week 40–45 min per session at 80% HR_{max}.	Supervised and Heart rate recorded	BMM: -1.2 W: +0.8 kg %FM M:-1.7 W:-2.6%	Yes women lost more fat than men. Men lost more BM than women.	
Després *et al.* (8)	11 women and 11 men young, lean, and sedentary	20-wk cycling program. 5 times per week 40–45 min per session at 80% HR_{max}	Supervised and heart rate recorded	BMM: -2.9 kg W: -0.5 kg % FM M:-3.2 W:-3.1%	Yes men lost significant body mass and %FM women did not	Men increased lipolysis more than women 46% vs 66%
Juneau *et al.* (19)	60 men and 60 sedentary women	6-month exercise program. 65%–77% of peak heart rate 5 sessions per week	Self-monitored home-based intervention EE estimated – M: 345 kcal per session W: 235 kcal per session	BM M: -1.5 W 0.4 kg % BF M -1.5 W -1.5%	Yes	Decrease in BM in men only significant result compliance – M: >90% W: >75%
Lowndes *et al.* (25)	38 sedentary men (17) and women (21)	6 months supervised exercise 4 days wk^{-1} at 60%–85% HR_{max}	Supervised	BM M: -0.99 kg W: -0.86 kg FM M : +0.67 kg W: -2.59 kg	No	Women lost more fat than men
McTiernan *et al.* (29)	102 men and 100 women lean and overweight adults	12 months 6 days per wk 60 min per session moderate to vigorous	3 days wk^{-1} supervised and 3 days wk^{-1} unsupervised EE estimated	BM M: -1.8 W: -1.4 kg FM M: 3.0 W:-1.9 kg	No	Loss of fat was dependent on baseline levels and minutes per day of exercise
Pérusse *et al.* (30)	Sedentary men (n=51) and women (n=46) BMI of men 25 women 23	20-wk endurance exercise program. Started 30 min at 55% $\dot{V}O_{2max}$ and 50 min at 75% $\dot{V}O_{2max}$	Supervised EE estimated from power output	BM: M: -0.2 W: 0.3 kg FM M: -0.9 W -0.5 kg FFM M: 0.7 W: 0.8 Kg	Yes men lost more fat than women	Men are overweight and women are normal weight. The fat mass changes are similar

Slentz *et al.* (32)	120 sedentary men and women	9-month exercise program 3 exercise groups — HIE, MOD, and MILD HIE — 23 kcal kg^{-1} body weight wk^{-1} MOD and MILD groups 14 kcal kg^{-1} body weight wk^{-1}	Supervised and heart rate recorded	HIE BW–M -3.9 kg, W -2.9 kg FM M: -5.1 kg, W: -4.8 kg FFM M: 1.1 kg, W: +1.9 kg MOD BW M: -1.1, W:-1.1 kg FM M: -2.7 kg, W: -2.6 kg FFM M: 1.6, W:1.6 kg MILD BW M: -1.3 W: -1.2 kgFM: -2.8, W:-1.3 kg FFM M: 1.4 W: 0.15 kg	No	
Westerterp *et al.* (36)	11 normal-weight women and 12 normal-weight men	40 wk of exercise training. 4 sessions per wk 30 – 90 min running	Supervised, EE measured by doubly labeled water	BM M: -0.8 W:-0.3 kg FM: M: -4.2 W: -2.2 kg FFM: M 3.4 kg W: 1.9 kg.	Yes — men lost more fat	Men expended a much larger amount of energy than women
Wilmore *et al.* (38)	Normal-weight and overweight men (n = 258), women (n = 299)	20-wk endurance exercise program. Started 30 min at 55% $\dot{V}O_2max$ and 50 min at 75% $\dot{V}O_2max$	Supervised EE estimated from power output	BM M: -0.4 kg, W -0.1 kg. FM M: -0.9 kg, W:-0.5 kg FFM M:+0.5 kg, W:+0.4 kg	No	Would only assume a 1.3 kg FM loss because of the estimated EE

These studies are categorized as short-term (1–14 days), medium-term (2–16 wk), and long-term (longer than 16 wk).

BM indicates body mass; FM, fat mass; FFM, fat-free mass; %BF, percentage body fat; LIET, low-intensity exercise training; HIET, high-intensity exercise training; MEX, moderate exercise energy expenditure; HEX, high exercise energy expenditure; EE, energy expenditure; EI, energy intake; WC, weight change.

whereas women did not (-2.0 vs -0.7 kg). However, it should be noted that this was not a genuine sex difference because there was no statistically significant difference when the sexes were compared directly. Moreover, when body composition data were examined, the smaller weight loss observed in women was accounted for by a significant increase in fat-free mass. The reductions in fat mass on the other hand were comparable between men and women (-2.9 vs -2.6 kg). Therefore, although the authors reported a sex difference in body weight response to exercise, the consideration of body composition in the analysis modified the interpretation. This outcome draws attention to the importance of measuring body composition (at least fat mass and fat-free mass), which provides a greater understanding of the physiological response to exercise.

The six remaining medium term exercise interventions did not report any significant differences in body weight response to exercise according to sex (6,10,15,20,26,27). However, in light of the above comment about body composition, it is worth noting that, in the studies undertaken by King *et al.* (20), Caudwell *et al.* (6), and Martins *et al.* (26), there were significant and similar reductions in both body weight and fat mass for men and women at the end of the exercise period (and no difference between the sexes). In all of these protocols, the exercise was supervised and the energy expenditure of the exercise sessions was controlled and measured.

In the remaining studies, no significant reductions in body mass or fat mass were observed. In two of these studies, the exercise intervention was prescribed but not measured or supervised, and, therefore, little can be concluded with certainty (15,27). The study undertaken by Devries *et al.* (10) had a mixed sample of normal and overweight participants, and the exercise intervention, although supervised, generated a low level of energy expenditure. Although no sex differences were reported, any expected weight change would be minimal.

The current evidence suggests that body weight and particularly body fat response to medium-term exercise are similar in men and women. Indeed, any change in body weight and body composition was usually small in both men and women, unless the exercise was supervised and the prescription for exercise-induced energy expenditure was substantial.

Long-term Exercise Interventions

The remaining 11 articles were classified as long-term exercise interventions (>16 wk). In six of these articles, a sex difference in response to exercise was observed (8,9,12,19,30,36), and four studies demonstrated no sex effect (25,29,32,38). However, some of these outcomes should be interpreted with caution. For example, the study undertaken by Juneau *et al.* (19) concluded that men reduced body weight more than women in response to a 6-month exercise program. However, compliance to the intervention was self-reported; the exercise program was based on intensity and duration, leading to different estimations of energy expenditures in men and women. Furthermore, the reductions in percentage body fat were similar between men and women, highlighting the importance of going beyond BMI and body weight. An additional example is the study by Pérusse *et al.* (30), although the men did lose more fat mass (-0.9 kg) than the women (-0.5 kg), the women were, on average, normal weight, whereas the men were overweight.

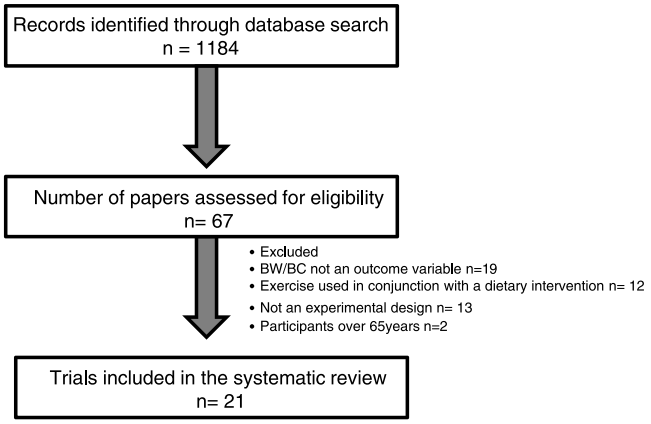

Figure 1. Flow diagram of the systematic review process.

The most convincing evidence demonstrating that women may compensate for exercise-induced energy expenditure more than men are data from the Mid West Trial. Donnelly *et al.* (12) reported that men lost 5.2 kg of body weight and 4.9 kg of fat mass after 16 months of supervised exercise, whereas women maintained body weight and fat mass. However, both men and women were found to significantly reduce visceral fat. The exercise intervention was under direct supervision of researchers and was prescribed at a set intensity and duration for men and women (45 min at 55%–70% of $\dot{V}O_{2max}$ 5 days wk^{-1}). Because of the larger body weight of the men, this prescription would have resulted in greater exercised-induced energy expenditure in men (667.7 ± 116.4 per session) compared with women (438.9 ± 88 kcal per session). This difference in energy expenditure, therefore, could be sufficient to account for any difference in weight loss between men and women. Nevertheless, even given the significantly larger amount of energy expended in the male participants, women did not lose any weight despite expending more than 400 kcal, which suggests some form of compensation for the increased energy expenditure. EI was assessed at baseline and at five other time points throughout the intervention. Participants ate in the University cafeteria for 2-wk periods, where food was photographed digitally before and after consumption and the type and amount of foods were quantified by research staff. Other food and snacks that were eaten out of the cafeteria were measured by multiple-pass 24-hour recall procedures. Even so, the researchers did not detect any increase in EI in response to the intervention for either men or women. However, recently, this group has reported the results of their second Mid West Trial. In this study, exercise-induced energy expenditure was matched between men and women at either 400 or 600 kcal per session, and the changes in body composition were not different between men and women (14).

Two further studies were reported by Després and colleagues. These studies used a similar methodology and similar participants but generated different outcomes. Després *et al.* (9) demonstrated a significant effect of sex, with women reducing percentage body fat (-2.6%) more than men (-1.7%) in response to exercise. In contrast, Després *et al.* (8) found that men demonstrated a statistically significant reduction in percentage body fat, whereas women did not. However, the changes in percentage body fat were almost identical; men, -3.2% versus women, -3.1%. Therefore, although there was a statistically significant decrease for the men and not the women, there was no clinically meaningful (or statistical) difference between the sexes. The authors suggested that individual variability in body fat change may have accounted for the discrepancy between the studies. In the latter study, there was large individual variability in body fat response to the training program in the women. Therefore, this could explain the lack of a significant reduction in fat mass observed in the women, considering that the mean change was almost identical to that of the men. Whereas in the former study, which had a smaller sample size and a smaller mean reduction in percentage fat mass (-2.7%), the changes in fat in women were more homogeneous, leading to a statistically significant reduction.

The five remaining supervised long-term studies did not demonstrate a significant effect of sex on body weight (14,25,29,32,38). In the majority of these studies, there was a small and nonsignificant weight loss in response to supervised exercise in both men and women. The exceptions were the studies carried out by Slentz *et al.* (32) and Donnelly *et al.* (14), in which both men and women achieved a significant weight and fat loss. Here, the exercise interventions were supervised, a large exercise prescription (based on EE) was made, and the participants were overweight. These studies demonstrated a clear dose-response effect of the amount of exercise and body weight loss. In the remaining studies, one was unsupervised so it is unknown whether the participants completed the prescribed exercise. In the other studies, the exercise interventions were modest (see Table 2 for details of the interventions): for example, 30 min cycling 3 days wk^{-1} (38) creating a small increase in energy expenditure; in another study, the men and women participants were lean (25). These factors make further interpretation difficult.

In conclusion, the evidence for a sex effect on body weight response to short-, medium-, and long-term exercise is weak. The large majority of research indicates a similar body weight and fat mass response to exercise. In the minority of studies where men did demonstrate a larger decrease in weight and fat mass, it usually could be attributed to a larger exercise-induced energy expenditure in men compared with women. Therefore, these outcomes do not suggest that women respond poorly to exercise or that they are compensating selectively for the increased energy expenditure more than men. Research studies in which energy expenditure was controlled and measured consistently demonstrated equivalent changes in fat mass in men and women. A supervised intervention that generates a large exercise-induced energy expenditure seems to be the major factor that influences body composition changes in response to exercise and not sex.

When interpreting these data on exercise-induced weight loss in men and women, it is important to consider methodological issues and other factors that may influence the conclusions and outcomes of the research.

Factors Influencing the Interpretation of Studies

Normal and Overweight Participants

When examining the effect of exercise on weight loss, it is important that the research is conducted in a relevant population.

In the current review, a distinction was drawn between the sex-based effects in normal-weight and overweight participants. In normal-weight participants, 50% (5 of 10) of the research indicated that men lost more weight in response to exercise than women; 10% (1 of 10) demonstrated no differences; and 40% (4 of 10) observed that women lost more weight than men. These results suggest that there is very little or no evidence to support the belief that normal-weight women do not lose as much weight as normal-weight men in response to exercise.

Only 3 of the 11 studies (27%) on the overweight population included in this review demonstrated a larger weight loss in overweight men than overweight women (12,18). In the study described by Andersson *et al.* (1), although the changes in body mass were different between men and women, the reductions in fat mass were equivalent. Moreover, in the study undertaken by Irving *et al.* (18), this effect was demonstrated only under a low-intensity exercise regimen. In response to the high-intensity exercise, there was no effect of sex and both men and women experienced a significant weight and body fat loss. The remaining eight studies demonstrated an equal body weight response to exercise in overweight and obese men and women (73% of the studies in overweight and obese men and women demonstrated no main effect of sex on body weight changes in response to exercise). These outcomes suggest a marked equivalence in exercise-induced weight loss in overweight men and women. Moreover, in many studies, a focus on the average weight loss could lead to a false impression. The situation in normal-weight participants indicated a polarization of outcomes — some studies favoring men and others women. Rather than seek a common all-embracing statement concerning sex effects, it is more judicious to examine the particular characteristics of each study to seek underlying reasons for a particular outcome. Changes in total body mass obviously are captured from changes in body composition. Concerning weight loss, body mass and fat mass are the most prominent variables reported. However, when changes in body mass are not mirrored by changes in fat mass (*e.g.*, (1)), then it is plausible to support that the difference is accounted for by differences in fat-free mass. In studies on exercise, this is important. Under conditions of dietary restriction, reductions in both fat and fat-free mass are observed. For exercise regimens, the loss in fat-free mass is minimized and increases also occur. Indeed in one study (6) involving 12 wk of supervised exercise of equivalent intensity and energy expenditure (but not duration), women significantly increased fat-free mass but men did not. Such an increase in fat-free mass obviously would tend to reduce the observed changes in body mass if reductions in fat mass were equivalent. These considerations indicate the importance of measuring and reporting body composition in addition to body mass to attain a more complete understanding of any physiological and anthropometric adjustments to exercise.

Furthermore, it also is important to recognize the individual day-to-day fluctuations in body weight that occur. In a number of the studies, the average weight loss was very small and within the normal range of day-to-day fluctuations and the measurement error of the equipment. Therefore, making conclusions about any sex-based differences should be approached with caution.

Supervised Versus Unsupervised Exercise

In overweight and obese adults, a clear distinction in the efficacy of exercise was observed between supervised and unsupervised interventions. This is important because only in the case of supervised and monitored exercise was there proof that the exercise was carried out effectively. When exercise is prescribed but not supervised, there is no guarantee that the amount or intensity of exercise actually was completed. This lack of credibility of self-reported behavior is relevant also in studies involving dietary reporting. There were two studies that used a self-report method of physical activity levels (15,29). Both of these studies found very modest levels of weight loss in response to exercise alone. One study did not demonstrate any significant change in body composition in response to 12 wk of exercise training (15). In the other study, half of the intervention was supervised, whereas self-report data were used for the remaining sessions. After 12 months of exercise, a modest and nonsignificant weight loss of less than 2 kg was observed (29). In contrast, five studies in which exercise was supervised in overweight and obese adults all produced a significant weight loss, ranging from 2 to 5 kg (depending on the duration of the intervention). Therefore, for exercise to generate a meaningful weight loss, it is essential to ensure that the prescribed amount of exercise has been undertaken. The outcomes of studies using unsupervised and unmeasured exercise cannot be used to provide evidence for sex differences.

Issue of Exercise-Induced Energy Expenditure

The evidence suggesting that women respond less well to exercise in terms of weight loss most frequently arises from studies in which the exercise program is prescribed but not supervised, and, therefore, the energy expenditure of the exercise is not monitored or recorded. Consequently, any observed differences in weight loss could be attributed to compliance with the exercise prescription. The most plausible assumption is that the capacity of exercise to produce weight loss is based on the energy expended and the energy deficit created. Randomized controlled trials have demonstrated a clear dose-dependent relationship between the amount of exercise performed and the amount of fat lost (32). Moreover, a recent review concluded that the small magnitude of weight loss observed with exercise primarily is caused by low doses of exercise-induced energy expenditure (34). This issue of the dose of exercise administered, and energy expended, is relevant to an understanding of the sex response to exercise. However, investigation of this issue often is hindered by energy expenditure not being measured directly but rather inferred or estimated from intensity and duration.

Usually, intensity is defined as a percentage of $\dot{V}O_{2max}$ or a proportion of maximum heart rate. When the intervention is based on both intensity and duration, larger individuals will generate a greater energy expenditure for the given workload. This means that men normally will expend more energy than women. For example, Westerterp *et al.* (36) reported that, during supervised training sessions of similar duration and intensity, men increased their daily energy expenditure by 2.6 MJ d^{-1} and women 1.8 MJ d^{-1} (measured by doubly labeled water). Therefore, men expended 224 MJ more than women

through exercise during the 40-wk supervised training period for similar intensity and duration of exercise. Furthermore, the meta-analysis carried out by Ballor and Keesey (2) calculated that the energy expenditure for males was approximately twice that of females per session (435 vs 210 kcal). The males were heavier and tended to have more body fat. This discrepancy between exercise-induced energy expenditure in men and women may contribute to the observed differences in body weight loss in response to exercise. In fact, our experiments have demonstrated in two separate studies that, when exercise-induced energy expenditure is similar in men and women, then there are no significant differences in the body weight or body fat response to exercise. The 12-wk supervised aerobic exercise program produced significant reductions in body weight and body fat for both men and women (6,26). We have replicated this finding after a 16-wk exercise intervention, in which both men and women demonstrated significant decreases in body weight and body fat (20). This finding also has been replicated by an independent research group. A 10-month supervised exercise program reduced body weight and body fat significantly and equally for men and women (14). Consequently, it seems that, when the exercise expenditure is controlled, measured, and is the same for men and women, then similar changes in body weight and body fat can be expected and observed.

Compensation for Exercise-Induced Energy Expenditure

The reason often cited for the larger weight loss in men compared with women (although there is little evidence of this) is that women are better at defending body weight and therefore, in response to exercise, they will increase food intake to maintain energy balance. In contrast, it is reported that, in men, exercise does not induce compensatory eating. There have been two recent reviews examining the impact of acute exercise on food intake in men and women with differing conclusions. One review concluded that motivation and food intake in response to acute exercise are modulated by sex; men demonstrating no increase in food intake and women compensating for the acute negative energy balance (4). This conclusion was based on a very small number of studies undertaken where men and women were not in the same exercise protocol. In contrast, a recent meta-analysis revealed that sex did not moderate the compensatory eating response to acute exercise (31). Furthermore, in agreement with previous research indicating that when energy expenditure was matched between men and women, no sex differences were observed in body composition response to exercise (31). Hagobian *et al.* (16) demonstrated that an acute bout of exercise where men and women expended similar amounts of energy (30% of total daily EE) did not produce any effect on subjective appetite, appetite hormones, or EI in either men or women, highlighting the fact that acute exercise suppressed relative EI regardless of sex (16).

There are very few studies where simultaneous, robust, and objective measurements of body composition, appetite, and food intake have been measured in response to a long-term exercise regimen. The studies that are available demonstrate that there is no significant difference between sexes in EI response to medium- or long-term regular exercise (6,12). Figure 2 describes two formulations that can account for deductions arising from experimental studies.

The lack of any convincing evidence that there are sex-based differences in response to exercise does not imply that each individual responds in an identical manner to exercise training. A large individual variability in body weight response to exercise is well documented (3,6,7,23,33). This large variability occurs within sex; both men and women display a range of body composition changes in response to the same dose of exercise (6). This variability has been shown to be accounted for partly by appetite responses to exercise. Those individuals who did not lose as much weight as predicted experienced an increase in both hunger levels across the day and objectively measured food intake. In contrast, those individuals who lost the predicted amount of weight did not demonstrate a change in hunger levels or food intake (6,7,21,23). It should be noted, however, that even those individuals who achieved lower than anticipated changes in body composition and body weight still demonstrated significant and meaningful health benefits, including reductions in waist circumference, blood pressure, and resting heart rate and improvements in cardiovascular fitness (22).

Summary of main findings

This review has highlighted some important issues that must be stated:

1. When energy expenditure is equal, weight loss is likely to be equal regardless of sex.
2. Examination of body composition is critically important.
3. Exercise does produce individual variability in weight loss, this individual variability is driven by differences in appetite; however, this is independent of sex.
4. Exercise produces substantial health benefits independent of weight loss.

CONCLUSIONS

Exercise alone has been demonstrated to generate significant weight loss, as long as the exercise is supervised, and if the energy expended is large enough to create a meaningful negative energy balance. There is some evidence (although not overwhelming) to suggest that lean women do not lose as much weight in response to exercise as lean men. However, in overweight participants, if there are occasions in which men perform better, the effect usually can be attributed to greater exercise-induced energy expenditure rather than an increase in compensatory eating in women. However, in the majority of research and especially when EE is matched between men and women, there is no evidence for sex differences in body weight response to exercise. Furthermore, there does not seem to be any robust evidence to demonstrate that women compensate for exercise-induced energy expenditure to a greater degree than men.

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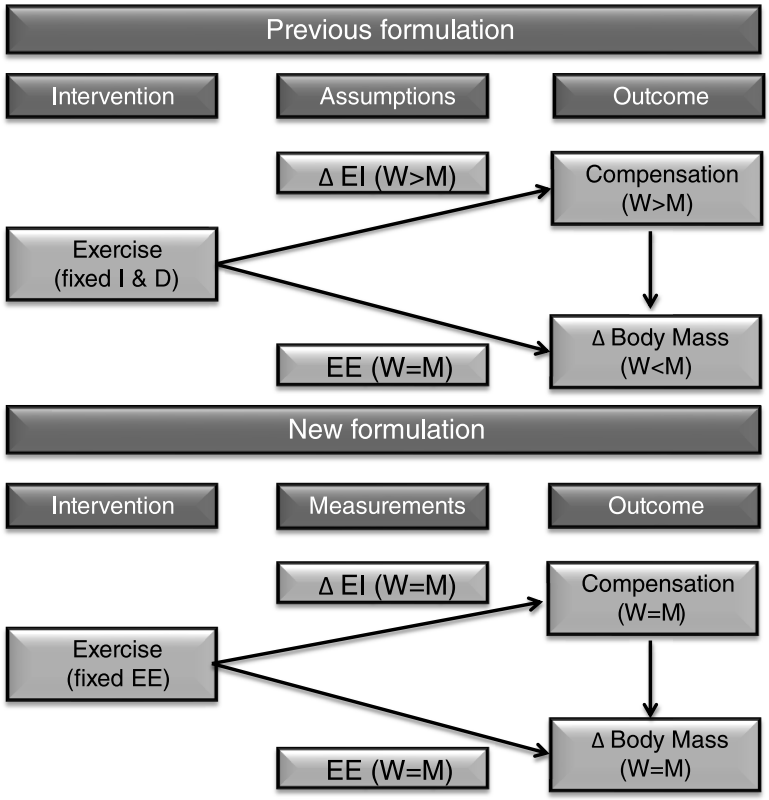

Figure 2. Formulations outlining exercise-induced weight loss in men and women. This figure contains two formulations, which can be used to describe the main issue of this review. The *top section* of the model demonstrates the old model of sex-mediated body weight responses to exercise. Previous research was carried out when the dose of exercise was prescribed in terms of intensity (I) and duration (D). Researchers assumed that this exercise generated the same energy expenditure (EE) in men and women and that the smaller reductions in body weight were caused by an assumed increase in energy intake (EI) in women that is not demonstrated in men. The *lower section* demonstrates the new formulation of exercise induced weight loss in men and women. This suggests that, although exercise will induce compensatory eating in some individuals, this is not mediated by sex. When men and women expend equivalent amounts of energy through exercise (accounting for body composition), changes in objectively measured EI also are equivalent; therefore, changes in body weight and body fat also are similar. To determine the existence of sex-related responses to exercise, it is important to measure objectively both energy expenditure and EI and to consider adjustments in body composition in addition to body weight.

References

1. Andersson B, Xu X, Rebuffe-Scrive M, Terning K, Krotkiewski M, Björntorp P. The effects of exercise, training on body composition and metabolism in men and women. *Int. J. Obes.* 1991; 15(1):75.
2. Ballor D, 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(11):717.
3. Barwell N, Malkova D, Leggate M, Gill J. Individual responsiveness to exercise-induced fat loss is associated with change in resting substrate utilization. *Metabolism.* 2009; 58(9):1320–8.
4. Bilski J, Teległów A, Zahradnik-Bilska J, Dembiński A, Warzecha Z. Effects of exercise on appetite and food intake regulation. *Medicina Sportiva.* 2009; 13(2):82–94.
5. Blair SN, Kampert JB, Kohl HW, Barlow CE, Macera CA, Paffenbarger RS, Gibbons LW. Influences of cardiorespiratory fitness and other precursors on cardiovascular disease and all-cause mortality in men and women. *JAMA.* 1996; 276(3):205–10.
6. Caudwell P, Gibbons C, Hopkins M, King N, Finlayson G, Blundell J. No sex difference in body fat in response to supervised and measured exercise. *Med. Sci. Sports Exerc.* 2013; 45(2):351–8.
7. Caudwell P, Hopkins M, King N, Stubbs R, Blundell J. Exercise alone is not enough: weight loss also needs a healthy (Mediterranean) diet? *Public Health Nutr.* 2009; 12(9A):1663–6.
8. Després J, Bouchard C, Savard R, Tremblay A, Marcotte M, Theriault G. The effect of a 20-week endurance training program on adipose-tissue morphology and lipolysis in men and women. *Metabolism.* 1984; 33(3):235–9.
9. Després J, Bouchard C, Savard R, Tremblay A, Marcotte M, Theriault G. Effects of exercise-training and detraining on fat cell lipolysis in men and women. *Eur. J. Appl. Physiol.* 1984; 53(1):25–30.
10. Devries MC, Samjoo IA, Hamadeh MJ, Tarnopolsky MA. Effect of endurance exercise on hepatic lipid content, enzymes, and adiposity in men and women. *Obesity.* 2008; 16(10):2281–8.
11. Do Lee C, Blair SN, Jackson AS. Cardiorespiratory fitness, body composition, and all-cause and cardiovascular disease mortality in men. *Am. J. Clin. Nutr.* 1999; 69(3):373–80.
12. Donnelly J, Hill J, Jacobsen D, *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(11):1343–50.
13. Donnelly J, Smith B. Is exercise effective for weight loss with ad libitum diet? Energy balance, compensation, and gender differences. *Exerc. Sport Sci. Rev.* 2005; 33(4):169–74.
14. Donnelly JE, Honas JJ, Smith BK, *et al.* Aerobic exercise alone results in clinically significant weight loss for men and women: Midwest exercise trial 2. *Obesity.* 2013; 21(3):E219–E28.
15. Hagan R, Upton S, Duncan J, Gettman L. Marathon performance in relation to maximal aerobic power and training indices in female distance runners. *Br. J. Sports Med.* 1987; 21(1):3–7.
16. Hagobian TA, Yamashiro M, Hinkel-Lipsker J, Streder K, Evero N, Hackney T. Effects of acute exercise on appetite hormones and ad libitum energy intake in men and women. *Appl. Physiol. Nutr. Metab.* 2013; 38(1):66–72.
17. Hill JO, Thiel J, Heller PA, Markon C, Fletcher G, DiGirolamo M. Differences in effects of aerobic exercise training on blood lipids in men and women. *Am. J. Cardiol.* 1989; 63(3):254–6.

18. Irving BA, Weltman J, Patrie JT, *et al.* Effects of exercise training intensity on nocturnal growth hormone secretion in obese adults with the metabolic syndrome. *J. Clin. Endocrinol. Metab.* 2009; 94(6):1979.
19. Juneau M, Rogers F, De Santos V, *et al.* Effectiveness of self-monitored, home-based, moderate-intensity exercise training in middle-aged men and women. *Am. J. Cardiol.* 1987; 60(1):66–70.
20. King N, Byrne NM, Hunt A, Hills A. Comparing exercise prescribed with exercise completed: Effects of gender and mode of exercise. *J. Sports Sci.* 2010; 28(6):633–40.
21. King N, Caudwell P, Hopkins M, Stubbs J, Naslund E, Blundell J. Dual-process action of exercise on appetite control: increase in orexigenic drive but improvement in meal-induced satiety. *Am. J. Clin. Nutr.* 2009; 90(4):921–7.
22. King N, Hopkins M, Caudwell P, Stubbs R, Blundell J. Beneficial effects of exercise: shifting the focus from body weight to other markers of health. *Br. J. Sports Med.* 2009; 43(12):924.
23. King N, Hopkins M, Caudwell P, Stubbs R, Blundell J. Individual variability following 12 weeks of supervised exercise: identification and characterization of compensation for exercise-induced weight loss. *Int. J. Obes.* 2007; 32(1):177–84.
24. Blair SN, Kohl HW, Paffenbarger RS Jr, Gibbons LW and Macera CA (1995). Changes in physical fitness and all cause mortality a prospective study of healthy and unhealthy men. *JAMA* 273:1093–8.
25. Lowndes J, Zoeller R, Caplan J, *et al.* Leptin responses to long-term cardiorespiratory exercise training without concomitant weight loss: a prospective study. *J. Sports Med. Phys. Fitness* 2008; 48(3):391–7.
26. Martins C, Kulseng B, King N, Holst J, Blundell J. The effects of exercise-induced weight loss on appetite-related peptides and motivation to eat. *J. Clin. Endocrinol. Metab.* 2010; 95(4):1609–16.
27. Martins C, Truby H, Morgan L. Short-term appetite control in response to a 6-week exercise programme in sedentary volunteers. *Br. J. Nutr.* 2007; 98(04):834–42.
28. McLaughlin R, Malkova D, Nimmo M. Spontaneous activity responses to exercise in males and females. *Eur. J. Clin. Nutr.* 2006; 60(9):1055–61.
29. McTiernan A, Sorensen B, Irwin ML, *et al.* Exercise effect on weight and body fat in men and women. *Obesity.* 2007; 15(6):1496–512.
30. Pérusse L, Collier G, Gagnon J, *et al.* Acute and chronic effects of exercise on leptin levels in humans. *J. Appl. Physiol.* 1997; 83(1):5.
31. Schubert MM, Desbrow B, Sabapathy S, Leveritt M. Acute exercise and subsquent energy intake. A meta-analysis. *Appetite.* 2013; 63:92–104.
32. Slentz CA, Duscha BD, Johnson JL, *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(1):31.
33. Snyder K, Donnelly J, Jabobsen D, Hertner G, Jakicic J. The effects of long-term, moderate intensity, intermittent exercise on aerobic capacity, body composition, blood lipids, insulin and glucose in overweight females. *Int. J. Obes.* 1997; 21(12):1180–9.
34. Thomas D, Bouchard C, Church T, *et al.* Why do individuals not lose more weight from an exercise intervention at a defined dose? An energy balance analysis. *Obes. Rev.* 2012; 13(10):835–47.
35. Thorogood A, Mottillo S, Shimony A, *et al.* Isolated aerobic exercise and weight loss: a systematic review and meta-analysis of randomized controlled trials. *Am. J. Med.* 2011; 124(8):747–55.
36. Westerterp KR, Meijer G, Janssen E, Saris W, Ten Hoor F. Long-term effect of physical activity on energy balance and body composition. *Br. J. Nutr.* 1992; 68(1):21–30.
37. Whybrow S, Hughes D, Ritz P, *et al.* The effect of an incremental increase in exercise on appetite, eating behaviour and energy balance in lean men and women feeding ad libitum. *Br. J. Nutr.* 2008; 100(05):1109–15.
38. Wilmore JH, Després JP, Stanforth PR, *et al.* Alterations in body weight and composition consequent to 20 wk of endurance training: the HERITAGE Family Study. *Am. J. Clin. Nutr.* 1999; 70(3):346–52.