Physical activity, total and regional obesity: dose-response considerations

ROBERT ROSS and IAN JANSSEN

School of Physical and Health Education, Queen's University, Ontario, CANADA

ABSTRACT

ROSS, R., and I. JANSSEN. Physical activity, total and regional obesity: dose-response considerations. *Med. Sci. Sports Exerc.,* Vol. 33, No. 6, Suppl., 2001, pp. S521–S527. **Purpose:** This review was undertaken to determine whether exercise-induced weight loss was associated with corresponding reductions in total, abdominal, and visceral fat in a dose-response manner. **Methods:** A literature search (MEDLINE, 1966–2000) was performed using appropriate keywords to identify studies that consider the influence of exercise-induced weight loss on total and/or abdominal fat. The reference lists of those studies identified were cross-referenced for additional studies. **Results:** *Total fat*. Review of available evidence suggested that studies evaluating the utility of physical activity as a means of obesity reduction could be subdivided into two categories based on study duration. Short-term studies (≤16 wk, $N = 20$) were characterized by exercise programs that increased energy expenditure by values double (2200 vs 1100 $kcal \cdot wk^{-1}$) that of long-term studies (≥26 wk, $N = 11$). Accordingly, short-term studies report reductions in body weight (−0.18 vs −0.06 $kg \cdot wk^{-1}$) and total fat (−0.21 vs −0.06 $kg \cdot wk^{-1}$) that are threefold higher than those reported in long-term studies. Moreover, with respect to dose-response issues, the evidence from short-term studies suggest that exercise-induced weight loss is positively related to reductions in total fat in a dose-response manner. No such relationship was observed when the results from long-term studies were examined. *Abdominal fat.* Limited evidence suggests that exercise-induced weight loss is associated with reductions in abdominal obesity as measured by waist circumference or imaging methods; however, at present there is insufficient evidence to determine a dose-response relationship between physical activity, and abdominal or visceral fat. **Conclusion:** In response to well-controlled, short-term trials, increasing physical activity expressed as energy expended per week is positively related to reductions in total adiposity in a dose-response manner. Although physical activity is associated with reduction in abdominal and visceral fat, there is insufficient evidence to determine a dose-response relationship. **Key Words:** PHYSICAL ACTIVITY, OBESITY, ABDOMINAL FAT, VISCERAL FAT, WEIGHT LOSS, DOSE-RESPONSE

It is generally accepted that a decrease in daily physical activity has contributed to the increased prevalence of obesity worldwide (13,18,31,47). Accordingly, limited evidence also suggests that an increase in physical activity (exercise) without caloric restriction is a useful strategy for reducing obesity, in particular, abdominal and visceral obesity (38,39,40,44). This review was undertaken to determine whether exercise-induced weight loss is associated with corresponding reductions in total, abdominal, and visceral fat in a dose-response manner.

The format of this review follows the guidelines set forth in the recent National Institutes of Health, National Heart, Lung, and Blood Institute (NHLBI) document (31). As such, Section A (Current Knowledge) consists of a series of Evidence Statements followed by a brief rationale. Following each Evidence Statement is an Evidence Category that is generally consistent with the criteria established by the Expert Panel (31).

To consider the influence of varying levels of physical activity on total and abdominal obesity, a MEDLINE search (1966–2000) was performed using "weight loss" and "exercise" as keywords. The reference lists of those studies identified were then reviewed for additional studies. Appropriate studies were identified using the following inclusion criteria:

1. The subjects participating in the exercise group either had to consume an isocaloric diet for the duration of the study, thereby ensuring that the negative energy balance observed (e.g., significant reduction in total and/or abdominal fat) was induced by the increase in physical activity or the subjects in the physical activity (exercise) group were instructed not to change their diet (eating) habits and thus, in theory, a negative energy balance would be induced by an increase in exercise.
2. The subjects were overweight or obese, and thus the mean BMI values had to be greater than 25.0 $kg \cdot m^{-2}$ (31). For studies not reporting BMI values, the mean percent body fat had to be greater than 20% in men and greater than 33% in women, values that correspond to a BMI of 25.0 $kg \cdot m^{-2}$ (15).
3. That measurements of whole-body or abdominal fat were obtained using established methods (e.g., underwater weighing, duel energy x-ray absorptiometry, computed tomographic scan, magnetic resonance imaging (MRI), and waist circumference).
4. That the authors reported the caloric expenditure of the exercise or provided the information required to permit estimation of oxygen cost and caloric expenditure

0195-9131/01/3306-0521/$3.00/0
MEDICINE & SCIENCE IN SPORTS & EXERCISE®

Submitted for publication January 2001.
Accepted for publication March 2001.
Proceedings for this symposium held October 11–15, 2000, Ontario, Canada.

(e.g., $\dot{V}O_{2max}$, exercise frequency, intensity, and duration).

CURRENT STATUS OF KNOWLEDGE

Evidence statement. Physical activity is associated with reductions in total fat in a dose-response manner within trials that are less than 4 months in duration (Evidence Category B).

Nine randomized, controlled trials (RCT) (Table 1) and 22 nonrandomized trials (Table 2) met the inclusion criteria. Before considering the relationship between varying levels of physical activity and obesity reduction, we examined the findings of all studies with respect to the utility of exercise to induce fat loss. In so doing, it was noted that the findings differed substantially depending on the duration of the study. Indeed, short-term RCT (≤16 wk, $N = 5$) are characterized by relatively high energy expenditures (~2200 kcal·wk^{-1}) that correspond to an average weight loss of 0.26 kg·wk^{-1} and fat loss of 0.25 kg·wk^{-1} (Table 1). By comparison, long-term RCT (≥26 wk, $N = 4$) are characterized by energy expenditures of about 1100 kcal·wk^{-1} that correspond to an average 0.06 kg·wk^{-1} reduction in both body weight and total fat. A similar pattern of observations was noted for the nonrandomized studies (Table 2). Short-term exercise studies ($N = 15$) generally report much greater reductions in body weight (−0.18 vs −0.06 kg·wk^{-1}) and total fat (−0.21 vs −0.06 kg·wk^{-1}) by comparison with long-term studies ($N = 7$). In addition, study duration (short-term vs long-term) also influenced the relationships observed between varying levels of physical activity and obesity reduction (e.g., dose-response).

To determine whether physical activity (exercise) was associated with reduction in total fat in a dose-response manner, we regressed the average weekly energy expenditure values (e.g., group means obtained from each study) with the corresponding reductions in total fat. For short-term studies (RCT and nonrandomized combined, $N = 20$), the reduction in total adiposity was positively related to energy expenditure (Fig. 1). In other words, the greater the energy expended by exercise, the greater the fat loss. No relationship was observed when the average increase in physical activity was regressed with the average reduction in total fat for the long-term studies (RCT and nonrandomized combined ($N = 12$), Fig. 1). In addition, independent of the magnitude of the exercise-induced energy deficit, for both RCT and nonrandomized studies combined, the reduction in body weight achieved within the short-term studies approached 85% of that expected (Fig. 1). This contrasts with observations in long-term studies wherein the achieved weight loss was about 30% of that expected.

From the studies in Tables 1 and 2 come the following summary observations:

1. Results from short-term (≤16 wk) studies reveal that an increase in physical activity is positively associated with a reduction in total fat in a dose-response manner. This is not the case for long-term (≥26 wk) studies.
2. Only three studies prescribed exercise for women of a magnitude greater than ~1500 kcal·wk^{-1}; thus, the dose-response relationship is determined in large measure on the basis of findings from studies using male subjects.
3. On average, the weight loss attained in short-term studies is approximately 85% of that expected, and is composed almost entirely of fat.
4. The influence of age, race, and gender on these observations is unknown.

TABLE 1. Influence of caloric expenditure on changes in body weight and total body fat: evidence from randomized, controlled trials.

Reference	Subjects	BMI		Treatment	Study Duration (wk)	Energy Expenditure (kcal·wk^{-1})	Exercise Duration (min·wk^{-1})	Expected Weight Loss (kg·wk^{-1})[b]	Actual Δ Weight (kg·wk^{-1})	Actual Δ Body Fat (kg·wk^{-1})
	Sex	kg·m^{-2}	% Fat							
Studies ≤16 wk duration										
Posner et al., 1992 (35)[a]	81 older adults		28	Control	16	—	—	—	−0.01	0.02
	166 older adults		28	Exercise		490	90	−0.06	0.03	−0.03[c]
Maurier et al., 1997 (30)[a]	11 diabetics	30		Control	8	—	—	—	−0.02	−0.15
	10 diabetics	30		Exercise		840	112	−0.11	−0.19	−0.07
Hinkleman and Neiman, 1993 (22)[a]	18 women		34	Control	15	—	—	—	0.11	0.06
	18 women		36	Exercise		965	225	−0.13	0.00[c]	−0.01[c]
Sopko et al., 1985 (44)	6 men		28	Control	12	—	—	—	NS	NS
	6 men		31	Exercise		3500	300	−0.46	−0.52[c]	−0.64[c]
Ross et al., 2000 (38)	8 men	31		Control	12	—	—	—	0.01	−0.6
	16 men	32		Exercise		4900	455	−0.63	−0.63[c]	−0.51[c]
Studies ≥26 wk duration										
Kohrt et al., 1997 (25)	12 postmenopausal women	27		Control	39	—	—	—	0.01	0.01
	14 postmenopausal women	27		Exercise		735	147	−0.09	−0.07[c]	−0.08[c]
Binder et al., 1996 (2)[a]	17 older women	25		Control	48	—	—	—	0.01	0.01
	23 older women	25		Exercise		980	140	−0.13	−0.02[c]	−0.05[c]
Wood et al., 1988 (48)[a]	42 men		29	Control	52	—	—	—	0.00	−0.01
	47 men		27	Exercise		1330	133	−0.17	−0.08[c]	−0.08[c]
Ready et al., 1995 (36)	10 postmenopausal women	32		Control	26	—	—	—	0.02	0.01
	15 postmenopausal women	29		Exercise		1500	266	−0.20	−0.07[c]	−0.05[c]

NS, nonsignificant change.

[a] The exercise energy expenditure was not reported. The oxygen cost was estimated on the basis of the subjects' $\dot{V}O_{2max}$, exercise intensity, frequency, and duration. Energy expenditure was subsequently determined by multiplying the oxygen cost by 5 kcal·L^{-1}.

[b] Expected change in weight on the basis of weekly caloric expenditure. It was assumed that 7700 kcal = 1 kg.

[c] Reduction in exercise group significantly greater than reduction in control group ($P < 0.05$).

TABLE 2. Influence of caloric expenditure on changes in body weight and total body fat: evidence from nonrandomized trials.

	Subjects									
		BMI								
Reference	Sex	kg·m^{-2}	% Fat	Treatment	Study Duration (wk)	Energy Expenditure (kcal·wk^{-1})	Exercise Duration (min·wk^{-1})	Expected Weight Loss (kg·wk^{-1})[b]	Actual Δ Weight (kg·wk^{-1})	Actual Δ Body Fat (kg·wk^{-1})
Studies ≤16 wk duration										
Poehlman et al., 1994 (33)[a]	18 older adults	25		Exercise	8	665	154	−0.09	0	−0.05
Goran and Poehlman, 1992 (19)[a]	11 older adults		30	Exercise	8	665	91	−0.09	0	−0.11[d]
Weltman et al., 1980 (46)[a]	5 men		28	Control	10	—	—	—	−0.03	0.02
	11 men		23	Exercise		770	182	−0.1	−0.10	−0.10[c]
Reid et al., 1994 (37)[a]	7 adults	30		Exercise	12	945	119	−0.12	−0.04	−0.09
Grediagin et al., 1995 (17)	6 women	24		HI Ex	12	1190	140	−0.16	−0.06	−0.19
	6 women	26		LI Ex		1190	224	−0.16	−0.27[d]	−0.19
Gordon et al., 1997 (16)[a]	14 hypertensive adults	34		Exercise	12	1365	147	−0.17	−0.08	−0.07
Farrell and Barboriak, 1980 (12)[a]	7 men	28		Exercise	8	1505	105	−0.20	−0.25	−0.21[d]
	9 women	24		Exercise		840	105	−0.11	−0.06	−0.11[d]
Houmard et al., 1994 (23)[a]	13 men	30		Exercise	14	1505	154	−0.2	−0.14[d]	−0.20[d]
Kollias et al., 1973 (27)	5 young women	30		Exercise	15	1610	245	−0.21	−0.38[d]	−0.22[d]
Schwartz, 1987 (41)[a]	14 obese men		31	Exercise	12	1715	119	−0.22	−0.23[d]	−0.29[d]
Hagan et al., 1986 (21)[a]	12 men		25	Exercise	12	1785	147	−0.23	−0.02	−0.02
	12 women		35	Exercise		1130	147	−0.15	−0.05	−0.12
Keim et al., 1990 (24)[a]	5 women		35	Exercise	12	2380	245	−0.31	−0.42[d]	−0.37[d]
Boileau et al., 1971 (3)	8 young men	37		Exercise	9	2765	300	−0.36	−0.36[d]	−0.66[d]
Bouchard et al., 1994 (5)	14 young men		24	Exercise	13	4375	357	−0.57	−0.38[d]	−0.38[d]
Leon et al., 1979 (29)	6 young men	33		Exercise	16	5495	448	−0.71	−0.47[d]	−0.37[d]
Studies ≥20 wk duration										
Smutok et al., 1993 (43)[a]	10 men	29		Control	20	—	—	—	0.04	0.01
	13 men	28		Exercise		945	91	−0.12	−0.02	−0.07
Poirier et al., 1996 (34)[a]	11 diabetic men		27	Exercise	26	1225	154	−0.16	−0.03	−0.02
Frey-Hewitt et al., 1990 (14)[a]	44 men		27	Exercise	46	1470	182	−0.19	−0.09	−0.09[d]
Coggan et al., 1992 (6)[a]	12 older men		28	Exercise	43	1505	175	−0.20	−0.08[d]	−0.08[d]
	11 older women		36	Exercise		1505	175	−0.20	−0.05[d]	−0.06[d]
Kohrt et al., 1992 (26)	16 older men	25		Control	~45	—	—	—	0.00	−0.01
	47 older men	27		Exercise		1890	182	−0.24	−0.12[c]	−0.06[c]
	13 older women	24		Control		—	—	—	0.03	0.02
	46 older women	25		Exercise		1120	182	−0.14	−0.04[c]	−0.04[c]
Després et al., 1991 (8)[a]	13 women	34		Exercise	60	2450	406	−0.32	−0.06[d]	−0.08[d]
Lamarche et al., 1992 (28)[a]	31 women	34		Exercise	26	2450	406	−0.32	−0.03	−0.03

HI Ex, high-intensity exercise; LI Ex, low-intensity exercise.

[a] The exercise energy expenditure was not reported. The oxygen cost was estimated on the basis of the subjects' $\dot{V}O_{2max}$, exercise intensity, frequency, and duration. Energy expenditure was subsequently determined by multiplying the oxygen cost by 5 kcal·L^{-1}.

[b] Expected change in weight on the basis of weekly caloric expenditure and duration of study. It was assumed that 7700 kcal = 1 kg.

[c] Reduction in exercise group significantly greater than reduction in control group ($P < 0.05$).

[d] Significant within-group reduction ($P < 0.05$).

Evidence statement. There is insufficient evidence to determine whether an increase in physical activity is associated with a corresponding reduction in abdominal obesity in a dose-response manner (Evidence Category C).

Four RCT considered the effects of exercise on abdominal obesity measured using waist circumference (Table 3). From these studies it is difficult, if not impossible, to determine the influence of varying levels of physical activity on abdominal fat. Indeed, within two studies the reduction in waist circumference in the exercise group was not significant by comparison with controls (Table 3). Moreover, with the exception of Ross et al.(38), all other studies that considered the influence of physical activity on abdominal fat are characterized by relatively low levels of physical activity (840–1890 kcal·wk^{-1}). Evidence from nonrandomized studies reinforce the observation that varying levels of physical activity, expressed as energy expended per week, are not related to concurrent reductions in waist circumference (Table 3).

Only three RCT and three nonrandomized studies meeting the inclusion criteria report whether physical activity is associated with reductions in visceral fat (Table 3). From

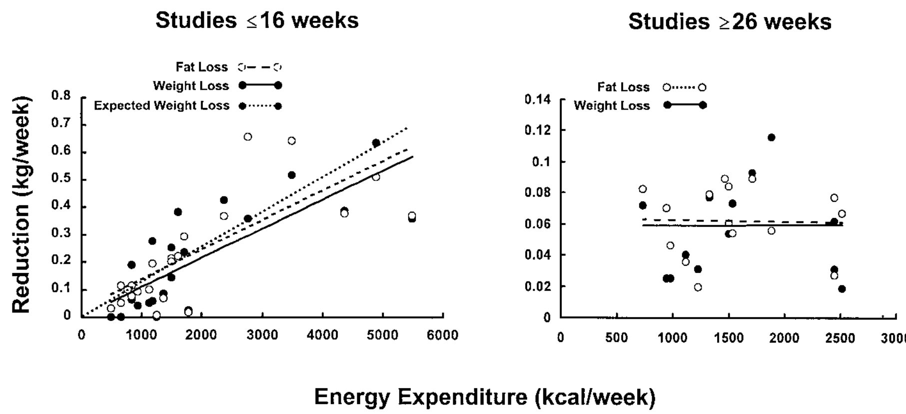

FIGURE 1—Illustration of the relationship between energy expenditure expressed as kcal per week, fat loss, weight loss, and expected weight loss expressed in kilograms lost per week. Studies with a duration of 16 wk or less are shown in the left panel, whereas the relationships for studies 26 wk or longer are shown in the right panel.

these studies, although it is generally reported that physical activity is associated with reductions in visceral fat, it is not possible to establish a dose-response relationship. The latter observation may be explained in part by the relatively low levels of visceral fat before treatment for several of the studies reviewed. For example, in three of the four studies that report only minor reduction in visceral fat in response to exercise (8,11,42; young men), initial visceral fat values were, in general, low by comparison with those studies that observed substantial reductions in visceral fat. Whether a threshold exists below which the mobilization of visceral fat in response is markedly reduced, is unknown.

From the studies in Table 3 come the following summary observations:

1) limited evidence suggests that an increase in physical activity is not related to a corresponding reduction in abdominal obesity as measured by either waist circumference or imaging methods in a dose-response manner; and

2) although physical activity is associated with reductions in visceral fat, there is insufficient evidence to establish a dose-response relationship.

Does an Increase in Physical Activity Prevent Weight Gain in a Dose-Response Manner?

A detailed consideration of the role of physical activity in the prevention of weight gain is beyond the scope of this review. However, the role that physical activity plays in attenuating the normal age-related weight gain has recently been reviewed by DiPietro (9) and those interested in this important topic are encouraged to review this work. Within the context of this review, a notable study is that of DiPietro and colleagues (10), who examined the association between changes in body weight and cardiorespiratory fitness (determined by treadmill test) over an average of 7.5 yr in 4599 men. The authors observed a dose-response relationship between change in treadmill time (e.g., change in cardiorespiratory fitness) and body weight. Whereas men who decreased treadmill time (decrease in fitness) gained over 2 kg of body weight, the men without change in treadmill time (maintained fitness) had an increase in body weight of 0.6 kg, whereas the men who increased treadmill time by 1 min (increased fitness) had no change in body weight, and the men who increased treadmill time by 3 min actually decreased body weight by 1.2 kg (10). To interpret a dose-response relationship between physical activity and the prevention of weight gain from the data of DiPietro and colleagues (10), one assumes that the observed increase in treadmill time (fitness) is a consequence of an increase in physical activity. In support of this assumption is the observation that cardiovascular fitness is determined in large measure by physical activity patterns, with heritability accounting for about 25% of the variance in maximal aerobic power (4). To our knowledge, there are no longitudinal studies that report whether physical activity can attenuate the normal increase in total and abdominal fat that occurs with advancing age.

RESEARCH PRIORITIES

Absent from the literature are studies that systematically consider the influence of various levels of physical activity on the reduction of total or abdominal obesity. As a consequence, our consideration of whether a dose-response relationship existed between physical activity and obesity reduction required that we perform a regression analysis inherent to which were several assumptions. First, because the majority of studies reviewed required that we estimate energy expenditure on the basis of mean values for $\dot{V}O_{2max}$, exercise intensity, duration, and frequency (Tables 1 and 2), our regression analysis was dependent on estimates of exercise-induced energy expenditure. Second, although the average exercise-induced energy expenditure values in the studies examined ranged from 500 to 5500 kcal·wk^{-1}, in 75% of the studies energy expended by exercise fell below 1800 kcal·wk^{-1} (Fig. 1 and Tables 1 to 3). Finally, unlike a meta-analysis, we made no attempt to weigh the studies on the basis of, for example, the number of participants in each study. Together, these limitations suggest that the dose-response relationship observed between exercise and obesity reduction be interpreted with caution.

The conclusions of this review are derived in large measure from studies that use middle-aged male, Caucasian subjects; as such, the influence of age and race is unknown. With respect to gender, although 19 of the 31 studies incorporated female subjects, inspection of Tables

TABLE 3. Influence of aerobic exercise on changes in abdominal fat: evidence from randomized, controlled trials and nonrandomized trials.

Reference	Subjects: Sex	BMI: kg·m^{-2}	% Fat	Treatment	Study Duration (wk)	Energy Expenditure (kcal·wk^{-1})	Exercise Duration (min·wk^{-1})	Δ Waist Girth (mm·wk^{-1})	Δ VAT (cm^2·wk^{-1}) [%·wk^{-1}]	Δ ASAT (cm^2·wk^{-1}) [%·wk^{-1}]	Δ TAAT (cm^2·wk^{-1}) [%·wk^{-1}]
Randomized, Controlled Trials											
Maurier et al., 1997 (30)[a]	11 diabetics	30		Control	8	—	—	0.0	–0.5 [0.4]	–1.1 [0.4]	–1.7 [0.4]
	10 diabetics	30		Exercise		840	112	–1.25	–9.5 [6.1][b]	–5.1 [2.2][b]	–14.5 [3.8]
DiPietro et al., 1998 (11)[a]	7 older adults	27		Control	16	—	—	–1.37	–0.5 [0.6]	+0.7 [0.4]	+0.1 [0.0]
	9 older adults	27		Exercise		910	175	–1.94	–2.0 [0.8]	+1.2 [0.5]	+0.1 [0.0]
Binder et al., 1996 (2)[a]	17 older women	25		Control	48	—	—	0.08	NR	NR	NR
	23 older women	25		Exercise		980	140	–0.60[b]			
Ross et al., 2000 (38)	8 men	31		Control	12	—	—	–0.08	0 [0]	[0.2]	[0.1]
	16 men	32		Exercise		4900	455	–5.42[b]	–4.3 [2.3][b]	[1.5][b]	[1.9][b]
Nonrandomized Trials											
Grediagin et al., 1995 (17)	6 women	24		HI Ex	12	1190	140	~–2.5[c]	NR	NR	NR
	6 women	26		LI Ex		1190	224	~–0.80			
Houmard et al., 1994 (23)[a]	13 men	30		Exercise	14	1505	154	–3.07[c]	NR	NR	NR
Kohrt et al., 1992 (26)	16 older men	25		Control	~45	—	—	0.08	NR	NR	NR
	47 older men	27		Exercise		1890	182	–0.78[b]			
	13 older women	24		Control		—	—	0.13			
	46 older women	25		Exercise		1120	182	–0.76[b]			
Schwartz et al., 1991 (42)[a]	13 young men	26		Exercise	27	2520	182	–0.67	–0.4 [0.7][c]	–0.8 [0.4][c]	–1.2 [0.4]
	15 older men	26		Exercise		1715	196	–1.19[c]	–1.3 [0.9][c]	–1.3 [0.7][c]	–2.6 [0.8]
Després et al., 1991 (8)[a]	13 women	34		Exercise	60	2450	406	NR	–0.1 [1]	–1.0 [0.2][c]	–1.1 [0.2]
Bouchard et al., 1994 (5)[a]	14 young men		24	Exercise	13	3500	357	NR	–2.2 [2.8][c]	–5.2 [2.1][c]	–7.4 [2.3]

Δ, change; VAT, visceral adipose tissue; ASAT, abdominal subcutaneous adipose tissue; TAAT, total abdominal adipose tissue (visceral + subcutaneous); HI Ex, high-intensity exercise; LI Ex, low-intensity exercise; NR, not reported.

[a] The exercise energy expenditure was not reported. The oxygen cost was estimated on the basis of the subjects $\dot{V}O_{2max}$, exercise intensity, frequency, and duration. Energy expenditure was subsequently determined by multiplying the oxygen cost by 5 kcal·L^{-1}.

[b] Reduction in exercise group significantly greater than reduction in control group ($P < 0.05$).

[c] Significant within-group reduction ($P < 0.05$).

1 and 2 reveals that only three nonrandomized trials prescribed exercise for women of a magnitude greater than ~1500 kcal·wk^{-1}. A rationale that would support the exclusion of women in studies wherein exercise is performed for longer durations is unknown. To the contrary, there is evidence to support the notion that women may be at an advantage when it comes to performing submaximal exercise. Indeed, during moderate-intensity long-duration exercise, females demonstrate a greater lipid and lower carbohydrate oxidation compared with men (7,45). A greater reliance on lipid as a fuel during submaximal exercise would spare muscle glycogen and thus, in theory, delay time to fatigue. Theses observations support the view that women are capable of performing moderate-intensity exercise of a sufficient duration and frequency to induce substantial weight loss.

As stated above, it is clear from Figure 1 that the weekly exercise-induced energy expenditure in the majority of studies reviewed in this analysis was low (e.g., <1500 kcal·wk^{-1}). Indeed, for short-term studies the exercise programs prescribed resulted in an weekly energy expenditure that approximated 1850 kcal. Accordingly, the weekly weight loss averaged 0.2 kg for a total weight loss of 2.3 kg over 12 wk. This observation is consistent with the recent evidence-based review wherein it is concluded that physical activity alone in overweight and obese men and women reduces total (~2 kg) and abdominal fat (~2 cm) only modestly or not at all (31). From a clinical perspective, weight loss of this magnitude would be considered inconsequential by many and would do little to maintain motivation and adherence to a weight loss strategy that uses exercise alone. On the other hand, it is also clear from this review that overweight and obese persons (at least men) can sustain a weekly energy expenditure that is associated with a far more meaningful weight loss. Thus, if the goal is to use exercise alone as a strategy for obesity reduction, it is suggested that clinicians and practitioners prescribe exercise programs wherein the energy expended approximates a minimum of 3000–3500 kcal·wk^{-1}. On the basis of data from our laboratory, this would require approximately 45–60 min of purposeful walking performed at a moderate intensity (~60% of peak $\dot{V}O_{2max}$ or 70% of maximum heart rate) on most days of the week (38). A program of this nature is not only consistent with recommendations related to the amount of physical activity required to improve cardiovascular health (32), but would result in substantial fat loss concurrent with the preservation of skeletal muscle and improvement in cardiovascular fitness (38).

Address for correspondence: Robert Ross, Ph.D., School of Physical and Health Education, Queen's University, Kingston, Ontario, Canada K7L 3N6; E-mail: rossr@post.queensu.ca.

REFERENCES

1. American College of Sports Medicine. *ACSM's Guidelines for Exercise Testing and Prescription*, 5th Ed. Baltimore, MD: Williams & Wilkins, 1995, pp. 275–283.
2. Binder, E. F., S. J. Birge, and W. M. Kohrt. Effects of endurance exercise and hormone replacement therapy on serum lipids in older women. *J. Am. Geriatr. Soc.* 44:231–236, 1996.
3. Boileau, R. A., E. R. Buskirk, D. H. Horstman, J. Mendez, and W. C. Nicholas. Body composition changes in obese and lean men during physical conditioning. *Med. Sci. Sports Exerc.* 3:183–189, 1971.
4. Bouchard, C., F. T. Dionne, J.-A. Simoneau, and M. R Boulay. Genetics of aerobic and anaerobic performance. *Exerc. Sport Sci. Rev.* 20:27–58, 1992.
5. Bouchard, C., A. Tremblay, J.-P. Despres, et al. The response to exercise with constant energy intake in identical twins. *Obes. Res.* 2:400–410, 1994.
6. Coggan, A. R., R. J. Spina, D. S. King, et al. Skeletal muscle adaptations to endurance training in 60- to 70-yr-old men and women. *J. Appl. Physiol.* 72:1780–1786, 1992.
7. Davis, S. N., P. Galassetti, D. H. Wasserman, and D. Tate. Effects of gender on neuroendocrine and metabolic counterregulatory responses to exercise in normal man. *J. Clin. Endocrinol. Metab.* 85:224–230, 2000.
8. Despres, J.-P., M.-C. Pouliot, S. Moorjani, et al. Loss of abdominal fat and metabolic response to exercise training in obese women. *Am. J. Physiol.* 261:E159–E167, 1991.
9. Dipietro, L. Physical activity in the prevention of obesity: current evidence and research issues. *Med. Sci. Sports Exerc.* 31:S542–S546, 1999.
10. Dipietro, L., H. W. Kohl III, C. E. Barlow, and S. N. Blair. Improvements in cardiorespiratory fitness attenuate age-related weight gain in healthy men and women: the aerobics center longitudinal study. *Int. J. Obes.* 22:55–62, 1998.
11. Dipietro, L., T. E. Seeman, N. S. Stachenfeld, L. D. Katz, and E. R. Nadel. Moderate-intensity aerobic training improves glucose tolerance in aging independent of abdominal adiposity. *J. Am. Geriatr. Soc.* 46:875–879, 1998.
12. Farrell, P. A., and J. Barboriak. The time course of alterations in plasma lipid and lipoprotein concentrations during eight weeks of endurance training. *Atherosclerosis* 37:231–238, 1980.
13. French, S. A., R. W. Jeffrey, J. L. Foster, P. G. Mcgovern, S. H. Kelder, and J. E. Baxter. Predictors of weight change over two years among a population of working adults: the Healthy Work Project. *Int. J. Obes.* 18:145–154, 1994.
14. Frey-Hewitt, B., K. M. Vranizan, D. M. Dreon, and P. D. Wood. The effect of weight loss by dieting or exercise on resting metabolic rate (RMR) in overweight men. *Int. J. Obes.* 14:327–334, 1990.
15. Gallagher, D., S. B. Heymsfield, M. Heo, S. A. Jebb, P. R. Murgatroyd, and Y. Sakamoto. Healthy percentage body fat ranges: an approach for developing guidelines based on body mass index. *Am. J. Clin. Nutr.* 72:694–701, 2000.
16. Gordon, N. F., C. B. Scott, and B. D. Levine. Comparison of single versus multiple lifestyle interventions: are antihypertensive effects of exercise training and diet-induced weight loss additive? *Am. J. Cardiol.* 79:763–767, 1997.
17. Gredigan, M. A., M. Cody, J. Rupp, D. Denardot, and R. Shern. Exercise intensity does not effect body composition change in untrained, moderately overfat women. *J. Am. Diet. Assoc.* 95:661–665, 1995.
18. Grundy, S. M., G. Blackburn, M. Higgins, R. Lauer, M. G. Perri, and D. Ryan. Roundtable consensus statement: physical activity in the prevention and treatment of obesity and its comorbidities. *Med. Sci. Sports Exerc.* 31:S502–S508, 1999.
19. Goran, M. I., and E. T. Poehlman. Endurance training does not enhance total energy expenditure in healthy elderly persons. *Am. J. Physiol.* 263:E950–E957, 1992.
20. Gordon, N. F., C. B. Scott, and B. D. Levine. Comparison of single versus multiple lifestyle interventions: are the antihypertensive effects of exercise training and diet-induced weight loss additive? *Am. J. Cardiol.* 79:763–767, 1997.
21. Hagan, R. D., S. J. Upton, L. Wong, and J. Whittam. The effects of aerobic conditioning and/or caloric restriction in overweight men and women. *Med. Sci. Sports Exerc.* 18:87–94, 1986.
22. Hinkleman, L., and D. C. Nieman. The effects of a walking program on body composition and serum lipids and lipoproteins in overweight women. *J. Sports Med. Phys. Fitness* 33:49–58, 1993.
23. Houmard, J. A., C. McCulley, L. K. Roy, R. K. Bruner, M. R. McCammon, and R. G. Israel. Effects of exercise training on absolute and relative measurements of regional adiposity. *Int. J. Obes.* 18:243–248, 1994.
24. Keim, N. L., T. F. Barbieri, M. D. Vanloan, and B. L. Anderson. Energy expenditure and physical performance in overweight women: response to training with and without caloric restriction. *Metabolism* 39:651–658, 1990.
25. Kohrt, W. M., A. A. Ehsani, and S. J. Birge Jr. Effects of exercise involving predominantly either joint-reaction or ground-reaction forces on bone mineral density (BMD) in women. *J. Bone Miner. Res.* 12:1253–1261, 1997.
26. Kohrt, W. M., K. A. Obert, and J. O. Holloszy. Exercise training improves fat distribution patterns in 60- to 70-year-old men and women. *J. Gerontol. Med. Sci.* 47:M99–M105, 1992.
27. Kollias, J., J. S. Skinner, H. L. Barlett, B. S. Bergstiinova, and E. R. Buskirk. Cardiorespiratory responses to young and overweight women to ergometry following modest weight reduction. *Arch. Environ. Health* 27:61–64, 1973.
28. Lamarche, B., J.-P. Despres, M.-C. Pouliot, et al. Is body fat loss a determinant factor in the improvement in carbohydrate and lipid metabolism following aerobic exercise training in obese women? *Metabolism* 41:1249–1256, 1992.
29. Leon, A. S., J. Conrad, D. B. Hunninghake, and R. Serfass. Effects of a vigorous walking program on body composition, and carbohydrate and lipid metabolism of obese young men. *Am. J. Clin. Nutr.* 33:1776–1787, 1979.
30. Mourier, A., J. F. Gautier, E. De Kerviler, et al. Mobilization of visceral adipose tissue related to the improvement in insulin sensitivity in response to physical training in NIDDM. *Diabetes Care* 20:385–391, 1997.
31. National Institutes of Health; National Heart, Lung, and Blood Institute. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults: the evidence report. *Obes. Res.* 6(Suppl. 2):51S–210S, 1998.
32. Pate, R. R., M. Pratt, S. N. Blair, et al. Physical activity and public health: a recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. *JAMA* 273:402–407, 1995.
33. Poehlman, E. T., A. W. Gardner, P. J. Archiero, M. I. Goran, and J. Calles-Escandon. Effects of endurance training on total fat oxidation in elderly persons. *J. Appl. Physiol.* 76:2281–2287, 1994.
34. Poirier, P., C. Catillier, A. Tremblay, and A. Nadeau. Role of body fat loss in the exercise-induced improvement of the plasma lipid profile in non-insulin-dependent diabetes mellitus. *Metabolism* 45:1383–1387, 1996.
35. Posner, J. D., K. M. Gorman, L. W. Windsor-Landsberg, et al. Low to moderate intensity endurance training in healthy older adults: physiological responses after four months. *J. Am. Geriatr. Soc.* 40:1–7, 1992.
36. Ready, A. E., D. T. Drinkwater, J. Ducas, D. W. Fitzpatrick, D. G. Brereton, and S. C. Oades. Walking program reduces elevated cholesterol in women postmenopause. *Can. J. Cardiol.* 11:905–912, 1995.
37. Reid, C. M., A. M. Dart, E. M. Dewar, and G. L. Jennings. Interactions between the effects of exercise and weight loss on risk factors, cardiovascular haemodynamics and left ventricular structure in overweight subjects. *J. Hypertens.* 12:291–301, 1994.
38. Ross, R., D. Dagnone, P. H. J. Jones, et al. Reduction in obesity and related comorbid conditions after diet-induced weight loss or exercise-induced weight loss in men: a randomized controlled trail. *Ann. Intern. Med.* 133:92–103, 2000.

39. Ross R., J. A. Freeman, and I. Janssen. Exercise alone is an effective strategy for reducing obesity and related comorbidities. *Exerc. Sport Sci. Rev.* 28:65–70, 2000.
40. Ross, R., and I. Janssen. Is abdominal fat preferentially reduced in response to exercise-induced weight loss? *Med. Sci. Sports Exerc.* 31:S568–S572, 1999.
41. Schwartz, R. S. The independent effects of dietary weight loss and aerobic training on high density lipoprotein (HDL) and apolipoprotein A-I concentrations in obese men. *Metabolism* 36:165–171, 1987.
42. Schwartz, R. S., W. P. Shuman, V. Larson, et al. The effect of intensive endurance exercise training on body fat distribution in young and older men. *Metabolism* 40:545–551, 1991.
43. Smutok, M. A., C. Reece, P. F. Kokkinos, et al. Aerobic versus strength training for risk factor intervention in middle-aged men at risk for coronary heart disease (CHD). *Metabolism* 42:177–184, 1993.
44. Sopko, G., A. S. Leon, D. R. Jacobs, et al. The effects of exercise and weight loss on plasma lipids in young obese men. *Metabolism* 34:227–236, 1985.
45. Tarnopolsky, L. J., J. D. MacDougall, S. A. Atkinson, M. A. Tarnopolsky, and J. R. Sutton. Gender differences in substrate for endurance exercise. *J. Appl. Physiol.* 68:302–308, 1990.
46. Weltman, A., S. Matter, and B. A. Stamford. Caloric restriction and/or mild exercise: effects on serum lipids and body composition. *Am. J. Clin. Nutr.* 33:1002–1009, 1980.
47. Williamson, D. F., J. Madans, R. F. Anda, J. C. Kleinman, H. Kahn, and T. Byers. Recreational physical activity and ten-year weight change in a US national cohort. *Int. J. Obes.* 17:279–286, 1993.
48. Wood, P. D., M. L. Stefanick, D. M. Dreon, et al. Changes in plasma lipids and lipoproteins in overweight men during weight loss through dieting as compared with exercise. *N. Engl. J. Med.* 319:1173–1179, 1988.