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

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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·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·wk⁻¹) and total fat (−0.21 vs −0.06 kg·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·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·m⁻² (15).

3. That measurements of whole-body or abdominal fat were obtained using established methods (e.g., underwater weighing, dual 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.
(e.g., $V_O^{2max}$, 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 ($\leq$16 wk, $N$ = 5) are characterized by relatively high energy expenditures ($\sim$2200 kcal·wk$^{-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 ($\geq$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 ($\sim$0.18 vs $\sim$0.06 kg·wk$^{-1}$) and total fat ($\sim$0.21 vs $\sim$0.06 kg·wk$^{-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 ($\leq$16 wk) studies reveal that an increase in physical activity is positively associated with a reduction in total fat in a dose-response manner. This is not the case for long-term ($\geq$26 wk) studies.
2. Only three studies prescribed exercise for women of a magnitude greater than $\sim$1500 kcal·wk$^{-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.**

<table>
<thead>
<tr>
<th>Study Duration</th>
<th>Sex</th>
<th>BMI kg·m$^{-2}$</th>
<th>% Fat</th>
<th>Treatment</th>
<th>Study Duration (wk)</th>
<th>Energy Expenditure (kcal·wk$^{-1}$)</th>
<th>Exercise Duration (min·wk$^{-1}$)</th>
<th>Expected Weight Loss (kg·wk$^{-1}$)</th>
<th>Actual Body Weight Loss (kg·wk$^{-1}$)</th>
<th>Actual Body Fat Loss (kg·wk$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Studies $\leq$16 wk duration</td>
<td>81 older adults</td>
<td>28</td>
<td>Control</td>
<td>16</td>
<td>—</td>
<td>490</td>
<td>90</td>
<td>$-0.06$</td>
<td>0.03</td>
<td>$-0.03^c$</td>
</tr>
<tr>
<td>Posner et al., 1992 (35)$^a$</td>
<td>166 older adults</td>
<td>28</td>
<td>Exercise</td>
<td>8</td>
<td>—</td>
<td>112</td>
<td>$-0.19$</td>
<td>0.07</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maurier et al., 1997 (30)$^a$</td>
<td>11 diabetics</td>
<td>30</td>
<td>Control</td>
<td>15</td>
<td>—</td>
<td>119</td>
<td>0.11</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hinkleman and Neiman, 1993 (22)$^a$</td>
<td>10 diabetics</td>
<td>30</td>
<td>Exercise</td>
<td>34</td>
<td>—</td>
<td>965</td>
<td>225</td>
<td>$-0.13$</td>
<td>0.00$^a$</td>
<td>$-0.01^a$</td>
</tr>
<tr>
<td>Sopko et al., 1985 (44)</td>
<td>6 men</td>
<td>28</td>
<td>Control</td>
<td>12</td>
<td>—</td>
<td>3500</td>
<td>300</td>
<td>$-0.46$</td>
<td>$-0.52^c$</td>
<td>$-0.64^c$</td>
</tr>
<tr>
<td>Ross et al., 2000 (38)</td>
<td>8 men</td>
<td>31</td>
<td>Exercise</td>
<td>12</td>
<td>—</td>
<td>4900</td>
<td>455</td>
<td>$-0.63$</td>
<td>$-0.63^a$</td>
<td>$-0.51^a$</td>
</tr>
<tr>
<td></td>
<td>16 men</td>
<td>32</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Studies $\geq$26 wk duration</td>
<td>12 postmenopausal women</td>
<td>27</td>
<td>Control</td>
<td>39</td>
<td>—</td>
<td>735</td>
<td>147</td>
<td>$-0.09$</td>
<td>$-0.07^c$</td>
<td>$-0.08^c$</td>
</tr>
<tr>
<td>Kohrt et al., 1997 (23)</td>
<td>14 postmenopausal women</td>
<td>27</td>
<td>Exercise</td>
<td>48</td>
<td>—</td>
<td>980</td>
<td>140</td>
<td>$-0.13$</td>
<td>$-0.02^c$</td>
<td>$-0.05^c$</td>
</tr>
<tr>
<td>Binder et al., 1996 (24)$^a$</td>
<td>17 older women</td>
<td>25</td>
<td>Control</td>
<td>52</td>
<td>—</td>
<td>1330</td>
<td>133</td>
<td>$-0.17$</td>
<td>$-0.08^c$</td>
<td>$-0.09^c$</td>
</tr>
<tr>
<td>Wood et al., 1988 (48)$^a$</td>
<td>23 older women</td>
<td>25</td>
<td>Exercise</td>
<td>26</td>
<td>—</td>
<td>1500</td>
<td>266</td>
<td>$-0.20$</td>
<td>$-0.07^c$</td>
<td>$-0.05^c$</td>
</tr>
<tr>
<td>Ready et al., 1995 (36)</td>
<td>42 men</td>
<td>29</td>
<td>Control</td>
<td>52</td>
<td>—</td>
<td>1330</td>
<td>133</td>
<td>$-0.17$</td>
<td>$-0.08^c$</td>
<td>$-0.09^c$</td>
</tr>
<tr>
<td>Ready et al., 1995 (36)</td>
<td>47 men</td>
<td>32</td>
<td>Exercise</td>
<td>26</td>
<td>—</td>
<td>1500</td>
<td>266</td>
<td>$-0.20$</td>
<td>$-0.07^c$</td>
<td>$-0.05^c$</td>
</tr>
<tr>
<td>Ready et al., 1995 (36)</td>
<td>10 postmenopausal women</td>
<td>29</td>
<td>Control</td>
<td>26</td>
<td>—</td>
<td>1500</td>
<td>266</td>
<td>$-0.20$</td>
<td>$-0.07^c$</td>
<td>$-0.05^c$</td>
</tr>
<tr>
<td>Ready et al., 1995 (36)</td>
<td>15 postmenopausal women</td>
<td>29</td>
<td>Exercise</td>
<td>26</td>
<td>—</td>
<td>1500</td>
<td>266</td>
<td>$-0.20$</td>
<td>$-0.07^c$</td>
<td>$-0.05^c$</td>
</tr>
</tbody>
</table>

$^a$ The exercise energy expenditure was not reported. The oxygen cost was estimated on the basis of the subjects’ $V_O^{2max}$, 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 ($P < 0.05$).
**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

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**Evidence from nonrandomized studies**

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

<table>
<thead>
<tr>
<th>Reference</th>
<th>Sex</th>
<th>BMI (kg·m⁻²)</th>
<th>% Fat</th>
<th>Treatment</th>
<th>Study Duration (wk)</th>
<th>Energy Expenditure (kcal·wk⁻¹)</th>
<th>Exercise Duration (min·wk⁻¹)</th>
<th>Expected Weight Loss (kg·wk⁻¹)</th>
<th>Actual Δ Weight (kg·wk⁻¹)</th>
<th>Actual Δ Body Fat (kg·wk⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smutok et al., 1993</td>
<td>10 men</td>
<td>29</td>
<td>25</td>
<td>Control</td>
<td>20</td>
<td>1715</td>
<td>119</td>
<td>-0.22</td>
<td>-0.23</td>
<td>-0.22</td>
</tr>
<tr>
<td>Poirier et al., 1996</td>
<td>14 obese men</td>
<td>31</td>
<td>12 men</td>
<td>Exercise</td>
<td>12</td>
<td>1715</td>
<td>119</td>
<td>-0.22</td>
<td>-0.23</td>
<td>-0.22</td>
</tr>
<tr>
<td>Keim et al., 1990</td>
<td>5 women</td>
<td>35</td>
<td>12 women</td>
<td>Exercise</td>
<td>12</td>
<td>1130</td>
<td>147</td>
<td>-0.15</td>
<td>-0.23</td>
<td>-0.12</td>
</tr>
<tr>
<td>Boileau et al., 1991</td>
<td>8 young men</td>
<td>37</td>
<td>14 young men</td>
<td>Exercise</td>
<td>9</td>
<td>2765</td>
<td>300</td>
<td>-0.36</td>
<td>-0.36</td>
<td>-0.36</td>
</tr>
<tr>
<td>Leon et al., 1979</td>
<td>6 young men</td>
<td>33</td>
<td>12 women</td>
<td>Exercise</td>
<td>16</td>
<td>5495</td>
<td>448</td>
<td>-0.71</td>
<td>-0.71</td>
<td>-0.71</td>
</tr>
<tr>
<td>Poehlman et al., 1992 (33)</td>
<td>11 older adults</td>
<td>30</td>
<td>8 men</td>
<td>Exercise</td>
<td>8</td>
<td>1505</td>
<td>105</td>
<td>-0.20</td>
<td>-0.20</td>
<td>-0.20</td>
</tr>
<tr>
<td>Horan et al., 1994 (17)</td>
<td>13 women</td>
<td>28</td>
<td>13 women</td>
<td>Exercise</td>
<td>60</td>
<td>1505</td>
<td>105</td>
<td>-0.20</td>
<td>-0.20</td>
<td>-0.20</td>
</tr>
<tr>
<td>Hagan et al., 1986</td>
<td>13 older women</td>
<td>840</td>
<td>14 older women</td>
<td>Exercise</td>
<td>14</td>
<td>1505</td>
<td>105</td>
<td>-0.11</td>
<td>-0.11</td>
<td>-0.11</td>
</tr>
<tr>
<td>Hagan et al., 1997 (10)</td>
<td>46 older women</td>
<td>182</td>
<td>46 older women</td>
<td>Exercise</td>
<td>11</td>
<td>2765</td>
<td>300</td>
<td>-0.15</td>
<td>-0.15</td>
<td>-0.15</td>
</tr>
<tr>
<td>Gredigian et al., 1995</td>
<td>14 hypertensive adults</td>
<td>1365</td>
<td>14 hypertensive adults</td>
<td>Exercise</td>
<td>12</td>
<td>1190</td>
<td>147</td>
<td>-0.17</td>
<td>-0.17</td>
<td>-0.17</td>
</tr>
<tr>
<td>Frey-Hewitt et al., 1990 (14)</td>
<td>44 men</td>
<td>1470</td>
<td>44 men</td>
<td>Exercise</td>
<td>46</td>
<td>1715</td>
<td>119</td>
<td>-0.22</td>
<td>-0.22</td>
<td>-0.22</td>
</tr>
<tr>
<td>Coggan et al., 1992 (61)</td>
<td>12 older men</td>
<td>1470</td>
<td>12 older men</td>
<td>Exercise</td>
<td>46</td>
<td>1715</td>
<td>119</td>
<td>-0.22</td>
<td>-0.22</td>
<td>-0.22</td>
</tr>
<tr>
<td>Kohrt et al., 1992 (26)</td>
<td>47 older men</td>
<td>1470</td>
<td>47 older men</td>
<td>Exercise</td>
<td>11</td>
<td>1715</td>
<td>119</td>
<td>-0.22</td>
<td>-0.22</td>
<td>-0.22</td>
</tr>
<tr>
<td>Després et al., 1991 (8)</td>
<td>13 women</td>
<td>1600</td>
<td>13 women</td>
<td>Exercise</td>
<td>11</td>
<td>1715</td>
<td>119</td>
<td>-0.22</td>
<td>-0.22</td>
<td>-0.22</td>
</tr>
<tr>
<td>Lamarche et al., 1992 (28)</td>
<td>60</td>
<td>2765</td>
<td>300</td>
<td>Exercise</td>
<td>9</td>
<td>1715</td>
<td>119</td>
<td>-0.22</td>
<td>-0.22</td>
<td>-0.22</td>
</tr>
</tbody>
</table>

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’ V̇O₂max, 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).
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 VO2max, 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
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 the laboratory, this would require approximately 45–60 min of purposeful walking performed at a moderate intensity (~60% of peak V˙O₂max 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).

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 V˙O₂max 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).

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

<table>
<thead>
<tr>
<th>Reference</th>
<th>Sex (n)</th>
<th>BMI (kg·m⁻²)</th>
<th>% Fat</th>
<th>Treatment</th>
<th>Study Duration (wk)</th>
<th>Energy Expenditure (kcal·wk⁻¹)</th>
<th>Exercise Duration (min·wk⁻¹)</th>
<th>Δ Waist Girth (mm·wk⁻¹)</th>
<th>Δ VAT (cm²·wk⁻¹)</th>
<th>Δ ASAT (cm²·wk⁻¹)</th>
<th>Δ TAAT (cm²·wk⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maurier et al., 1997 (30)*</td>
<td>11 diabetics</td>
<td>30</td>
<td>Control</td>
<td>8</td>
<td>—</td>
<td>0.0</td>
<td>−0.5 [0.4]</td>
<td>−1.1 [0.4]</td>
<td>−1.7 [0.4]</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>10 diabetics</td>
<td>30</td>
<td>Exercise</td>
<td>840</td>
<td>112</td>
<td>−1.25</td>
<td>−9.5 [6.1]*</td>
<td>−5.1 [2.2]*</td>
<td>−14.5 [3.8]</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>DiPietro et al., 1998 (11)*</td>
<td>7 older adults</td>
<td>27</td>
<td>Control</td>
<td>16</td>
<td>—</td>
<td>−1.37</td>
<td>−0.5 [0.6]</td>
<td>0.7 [0.4]</td>
<td>−0.1 [0.0]</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>9 older adults</td>
<td>27</td>
<td>Exercise</td>
<td>910</td>
<td>175</td>
<td>−1.94</td>
<td>−2.0 [0.8]</td>
<td>+1.2 [0.5]</td>
<td>+0.1 [0.0]</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Binder et al., 1996 (2)*</td>
<td>17 older women</td>
<td>25</td>
<td>Control</td>
<td>48</td>
<td>—</td>
<td>0.08</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>23 older women</td>
<td>25</td>
<td>Exercise</td>
<td>980</td>
<td>140</td>
<td>−0.60*</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Ross et al., 2000 (38)</td>
<td>8 men</td>
<td>31</td>
<td>Control</td>
<td>12</td>
<td>—</td>
<td>−0.08</td>
<td>0 [0]</td>
<td>+0.2 [0.1]</td>
<td>+0.1 [0.1]</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>16 men</td>
<td>32</td>
<td>Exercise</td>
<td>4900</td>
<td>455</td>
<td>−5.42*</td>
<td>−4.3 [2.3]*</td>
<td>+1.5*</td>
<td>+1.9*</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
</tbody>
</table>

*Significant within-group reduction (P < 0.05).

**The exercise energy expenditure was subsequently determined by multiplying the oxygen cost by 5 kcal·L⁻¹·min⁻¹.**

**The oxygen cost was estimated on the basis of the subjects’ V˙O₂max, exercise intensity, frequency, and duration. Energy expenditure was subsequently determined by multiplying the oxygen cost by 5 kcal·L⁻¹·min⁻¹.**

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**EXERCISE AND OBESITY REDUCTION**

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