Physical Activity, Adiposity, and Obesity Among Adolescents

Oded Bar-Or and Tom Baranowski

This review examines the evidence that the level of physical activity (PA) or total energy expenditure during adolescence affects body adiposity in the obese and nonobese adolescent population. Several cross-sectional studies suggested that obese children were less physically active than their nonobese peers, but there was no consistent difference in the total energy expenditure. The likelihood that infants of obese mothers become obese at age 1 year is greater if their total energy expenditure (using the doubly labeled water technique) is lower at age 3 months. Many interventional studies in the general adolescent population show a small (1–3% body fat) reduction in adiposity as a result of physical training. It appears, though, that programs longer than one year are more efficacious than shorter programs. Lifestyle activities (e.g., walking to and from school) appear to have a more lasting effect than regimented activities (e.g., calisthenics or jogging).

This paper assessed the relationship of physical activity to two dependent variables, adiposity and obesity, among adolescents (11–21 year olds). Adiposity is the amount of body fat, presented either as mass (sometimes referred to as ‘‘weight’’) or as a percentage of total body mass. Obesity is a state above normal adiposity at which health problems are likely to occur. Ways to measure or assess adiposity include measurement of one or more skinfolds, bioimpedance analysis, underwater densitometry, and body scanning by x-rays or computerized tomography. Various criteria have been used to identify the level corresponding to obesity, based either on excess body mass (mass per age, per height, or per height$^2$ = body mass index [BMI]) or on excess adiposity. In the case of excess body mass, one should use the term overweight, rather than obesity. Although excessive body mass usually denotes excessive adiposity among adults, an overweight adolescent is not always obese. This distinction is important for assessing an intervention during growth, when participants may become leaner while gaining body mass. Some authors have focused on training-induced changes in lean body mass, or in fat-free mass. While such changes are important to an adult, they are harder to interpret in the growing adolescent, unless a well-matched control

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group is included. Another health-related adiposity index is fat distribution (or "fat patterning"). There are some reports on the effects of training on this index in adults, but none in adolescents, and, therefore, this index shall not be discussed further.

**Physical activity (PA)** refers to naturally occurring body movement. **Training** generally denotes a regimen in which subjects undergo a structured, usually supervised, set of exercises over weeks and months. **Enhanced PA**, on the other hand, merely denotes an increase in activity level. Although on the same continuum, a distinction between training and enhanced PA is warranted because one does not necessarily need to "train" to reverse the effects of a sedentary lifestyle (e.g., one can walk up stairs instead of using an elevator). For the sake of brevity and simplicity, however, we shall use "training" for both.

**Method of Review**

Preliminary Medline searches were conducted for exercise, physical activity, training and adiposity, obesity, overweight, coronary risk, and children or adolescents. In addition, personal files of the two authors were used, as well as references in major review papers. While we focused on 11- to 21-year-old adolescents, data on children were scanned as well.

Table 1 lists longitudinal and cross-sectional noninterventional studies that have assessed the relationship between the degree of adiposity (or obesity) and the level of PA (or total daily energy expenditure [EE]). Table 2 lists interventional studies in which training was either the only intervention, or part of a multicomponent program. Table 3 is a summary of the above findings. Since the relationship of PA with adiposity may differ between the general adolescent population and those who already are obese, these two groups of studies are presented separately in the Tables. Training is seldom the exclusive intervention in obesity, but is often part of a multicomponent intervention with low-calorie diet and lifestyle behavior modification. Table 2 includes an entry that specifies the intervention, accordingly.

**Results**

**Associations Among Activity, Adiposity, and Obesity**

A problem in this area has been that some authors approach PA as a behavioral phenomenon, while others measure EE, the physiologic corollary of PA. Because body mass is a primary determinant of EE, an obese adolescent, with an observed low PA, can have a higher total EE than a leaner (lighter), somewhat more active peer. In determining its relationship to adiposity, PA should be expressed as body movement, not as EE. Alternatively, when data on EE are available, one should consider taking differences in body mass into account. While some authors have neglected this consideration, others have presented their data as the ratio between EE and kilograms of body mass, fat-free mass, or body surface area. Such an approach, while intuitively useful, violates principles of scaling by ratio and should be discouraged. There are several alternative scaling approaches based on physical and mathematical principles (1). An approach based on biological
<table>
<thead>
<tr>
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<th>Subjects</th>
<th>Design</th>
<th>Physical activity-type/ measure</th>
<th>Dependent variable</th>
<th>Effects</th>
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</thead>
<tbody>
<tr>
<td>Beunen et al. (16)</td>
<td>32 active boys, 32 inactive boys, 12–19 years from Leuven Growth Study</td>
<td>Prospective observ.</td>
<td>Self report of participation in sports over 3 yr (&gt; 5 hr/wk vs. ≤ 1.5 hr/wk)</td>
<td>Subscapula, suprailiac, triceps and calf skinfolds, calf circumference</td>
<td>No differences in body composition between active and inactive boys</td>
</tr>
<tr>
<td>Dotson &amp; Ross (38)</td>
<td>4,539 5th-12th grade boys, 4,261 5th-12th grade girls; national probability sample</td>
<td>Cross-sectional observ.</td>
<td>Questionnaire on types, frequency, duration of activities</td>
<td>Triceps &amp; subscapula skinfolds</td>
<td>Variety, number of cardiorespiratory activities and days of PE were related to lower skinfolds (no statement of strength of relationship)</td>
</tr>
<tr>
<td>Johnson (3)</td>
<td>5 day PE: 151 boys, 133 girls; 2 or 3 day PE: 220 boys, 239 girls (7th &amp; 8th grade students, urban, middle class)</td>
<td>Cross-sectional observ.</td>
<td>No days of PE (5 vs. 2 or 3)</td>
<td>Triceps &amp; skinfold</td>
<td>Sig 3.6 lb less fat for boys, but n.s. 2.1 lb less fat for girls</td>
</tr>
<tr>
<td>Sallis et al. (39)</td>
<td>148 boys (M age = 11.9 yr), 142 girls (M age = 11.8 yr); Mexican American and non-Hispanic whites</td>
<td>Cross-sectional observ.</td>
<td>7-day physical activity recall; rating of activity level</td>
<td>BMI (kg/m²)</td>
<td>Males: r = -.28 for activity rating and BMI, but not for females: no relationships</td>
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<tr>
<td>Sunnegardh et al. (40)</td>
<td>171 boys (M age = 13.6 yr), 172 girls (M age = 13.6 yr)</td>
<td>Cross-sectional observ.</td>
<td>Self-reported frequ. and duration of common activities weighted by energy cost estimates</td>
<td>Parizkova equations for est. % body fat using triceps &amp; subcapular skinfolds</td>
<td>No relationship detected</td>
</tr>
<tr>
<td>Watson &amp; O’Donovan (6)</td>
<td>85 boys, 17 or 18 yr in W. Ireland</td>
<td>Cross-sectional observ.</td>
<td>Activity questionnaire over past 7 d; subjects asked to generalize to past 4 wk</td>
<td>% fat from circumferences: upper arm, chest, thigh, calf</td>
<td>No relationship between % fat and physical activity</td>
</tr>
<tr>
<td>Study</td>
<td>Sample Description</td>
<td>Methodology</td>
<td>Findings</td>
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<tr>
<td>Bandini et al. (41)</td>
<td>33 obese and nonobese adolescent boys and girls, 12-18 yr</td>
<td>Cross-sectional observ.</td>
<td>Total daily energy expenditure using doubly labeled water. Groups labeled obese and nonobese. Obese: 3,282 ± 682 Kcal/d; nonobese: 2,777 ± 586 Kcal/d (not adjusted for weight or FFW).</td>
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<td>Bandini et al. (13)</td>
<td>14 nonobese boys (M age = 14.5 yr), 18 obese boys (M age = 14.4 yr), 14 nonobese girls (M age = 14.3 yr), 16 obese girls (M age = 15.2 yr)</td>
<td>Cross-sectional observ.</td>
<td>Total energy expenditure using doubly labeled water minus basal metabolic rate. Body fat from doubly labeled water. Obese had higher non-basal-energy expenditures, but correlations of body fat with non-basal-energy expenditure: males: r = -.47; females: r = -.58</td>
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<tr>
<td>Bradfield et al. (42)</td>
<td>4 obese girls (16.6 yr), 6 nonobese girls (16.9 yr)</td>
<td>Cross-sectional observ.</td>
<td>Energy expenditure (Kcal/min) from HR monitoring (for 3 to 6 d/S). Groups separated by triceps skinfold, arm circumference. No relationship</td>
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<td>Bullen et al. (2)</td>
<td>Summer camp attendees; camp with obese: 109 girls; camp with lean: 72 girls; 15.2 yr vs. 14.5 yr</td>
<td>Cross-sectional observ.</td>
<td>Motion pictures of activity during 3 sports: swimming, volleyball, tennis. Camp designation. Obese girls were less active in all activities.</td>
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<tr>
<td>Stunkard &amp; Pestka (43)</td>
<td>15 obese girls, 15 nonobese girls (median age = 12 yr in both groups); 2 wk at a summer camp and 1 wk at home</td>
<td>Cross-sectional observ.</td>
<td>Pedometers calibrated for stride, mileage walked; record at camp and at home; coef. of activity (distance walked × % overweight). Groups separated by median % overweight from tables. No difference in physical activity, obese girls expended substantially more energy, obese lost more or gained less than nonobese at camp</td>
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<tr>
<td>Waxman &amp; Stunkard (4)</td>
<td>4 obese boys, 4 nonobese male siblings at home, 4 nonobese peers at school</td>
<td>Cross-sectional observ.</td>
<td>Weekly nonparticipant observation (time sampling) for 4–5 months; at school: lunches and recess; at home: before, during, and after dinner (each from 1 to 3 hr). Weight recorded before each dinner. Obese boys were far less active inside the home (74% vs. 49% sitting), somewhat less active outside the home, and no difference outside; obese boys experienced equal energy expended inside and more outside</td>
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<tr>
<td>Wilkinson et al. (7)</td>
<td>Boys: 10 obese, 10 nonobese; girls: 10 obese, 10 nonobese; 12 yr of age</td>
<td>Cross-sectional observ.</td>
<td>Pedometers worn at waist for 24 hr. Groups separated by weight for height index; obese &gt; 90th percentile. No difference in physical activity.</td>
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</tbody>
</table>

*Note. Minimum dose for dose–response was not applicable to any of the studies.*
<table>
<thead>
<tr>
<th>Citation</th>
<th>Subjects</th>
<th>Intervention</th>
<th>Dependent variable</th>
<th>Effects</th>
<th>Min. dose Dose-res.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jetté et al. (18)</td>
<td>Males: 14-16 yr; 11 E: $M = 32%$ fat; 10 C: $M = 33%$ fat</td>
<td>Lacrosse: 45 min, 2/wk, 5 months</td>
<td>% fat</td>
<td>E: 10.9% fat; C: 2.3% fat</td>
<td>n.a.</td>
</tr>
<tr>
<td>Moody et al. (20)</td>
<td>Females: 14-17 yr; 28 E: &gt; 30% fat; 12 C: &lt; 30% fat</td>
<td>Jogging: 50–60 min, 4/wk, 15 wk</td>
<td>Body density, sum 12 skinfolds, sum 7 girth measurements</td>
<td>E: 2.5% fat, 1.1 kg LBM, 52.5 mm skinfold</td>
<td>See below</td>
</tr>
<tr>
<td>Moody et al. (20) (cont.)</td>
<td>Females: 14-17 yr, from 15-wk grp. above; 19 E: &gt; 30% fat initially</td>
<td>Jogging: 50–60 min, 4/wk, 29 wk</td>
<td>Same as above</td>
<td>E: 3.14% fat, 1.15 kg LBM, 61.1 mm skinfold, 9.5 cm girth</td>
<td>Changes greater than after 15 wk</td>
</tr>
<tr>
<td>Sasaki et al. (21)</td>
<td>Japanese; 11 yr initially; E: 21 males obese, 20 females, 20% excess of average wt; C: nonobese sex-matched</td>
<td>Running: pace-blood lactate threshold, 20 min, 7/wk, 2 yr</td>
<td>LBM &amp; fat mass (from skinfolds); “obesity index”</td>
<td>Fat mass: males = 40%, females = 31%; LBM: males = 29%, females = 37%; “obesity index”: males = 55%, females = 48%</td>
<td>n.a.</td>
</tr>
<tr>
<td>Epstein et al. (24)</td>
<td>8-12 yr; 20-80% over ideal wt for ht, age, sex; tricep skinfold &gt; 85%ile</td>
<td>Group 1: $n = 18$, diet, 15 sessions over 35 wk; Group 2: $n = 18$, diet &amp; exercise, 15 sessions over 35 wk; exercise: lifestyle change caloric expenditure from 1,400 Kcal/d–2,800 Kcal/d gradually; Group 3: $n = 17$, control, no treatment</td>
<td>% overweight, BMI</td>
<td>6 mo: significant weight loss in Groups 1 &amp; 2 vs. Group 3, who gained wt; 1 yr: % overst. similar for Groups 1 &amp; 2</td>
<td></td>
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</tbody>
</table>
Epstein et al. (33) 8-12 yr; 21 females, 14
males; > 20% ideal wt for ht

Group 1: n = 13, diet &
aerobic ex., 60-70% max
HR, set distance 3 ×/wk;
Group 2: n = 12, diet &
lifestyle ex., isocaloris to
Group 1; Group 3: n = 10,
diet & calisthenics, 6
exercises, 3 ×/wk; all
groups: diet 1,200 Kcal/d, 8
weekly sessions,
measurement at 12 & 24 mo.

% overweight, BMI

% overweight; Year 1:
Group 1 = 16.3%; Group
2 = 16.1%; Group 3: 17.5%;
Year 2: sig. intergroup
difference; Group 1 = 9.5%,
Group 2 = 1.9%, Group 3 =
10.3%

Reybrouck et al. (23) 3.9–16.4 yr; 15 females, 10
males; 24-104% overwt.
related to ht

Group 1: n = 11, diet 800-
1,000 Kcal/day; Group 2:
n = 14, diet & exercise,
same diet as Group 1,
aerobic exercise 250 Kcal/
session daily, 4 mo.

% overweight

Group 1: n.s. 15.8 ± 10.5%
overwt., Group 2: sign. 25.5
± 13.5% overwt.

Rocchini et al. E: 34 males 10-17 yr, 38
females, > 75%ile tricep &
subscapular skinfolds; C: 10
nonobese, 10-14 yr

Group 1: n = 26, diet &
behavior change; Group 2:
n = 25, diet & behavior
change & exercise, aerobic
exercise, 60 min. 3/wk;
Group 3: n = 22, control, no
wt loss program; all groups:
20 wk

Body weight, % fat

Group 1: 2.5 kg wt, 4% fat;
Group 2: 2.4 kg wt, 6% fat;
Group 3: no signif. change

Note. All study designs were controlled trials. E = experimental group; C = control group; LBM = lean body mass; BMI = body mass index.
<table>
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<tr>
<th>Group</th>
<th>Evidence</th>
<th>Strength of association</th>
<th>Amount of dose–response data</th>
<th>Basis for recommendations</th>
<th>Recommendations</th>
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<tbody>
<tr>
<td>General adolescent population</td>
<td>No. studies</td>
<td>Level of quality</td>
<td>Association</td>
<td></td>
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</tr>
<tr>
<td>&gt; 10</td>
<td>I</td>
<td>↑</td>
<td>Scant</td>
<td>100% adolescents</td>
<td>None at present</td>
</tr>
<tr>
<td>&lt; 5</td>
<td>IIA</td>
<td>→</td>
<td>None</td>
<td>100% adolescents</td>
<td></td>
</tr>
<tr>
<td>&gt; 10</td>
<td>IIB</td>
<td>↑</td>
<td>None</td>
<td>100% adolescents</td>
<td></td>
</tr>
<tr>
<td>Obese adolescents</td>
<td>5-10</td>
<td>↑↑</td>
<td>Duration may be important</td>
<td>100% adolescents</td>
<td>Increase daily EE by ≥ 10%, combined with nutrition and behavior modification; de-emphasize exercise intensity</td>
</tr>
<tr>
<td>&gt; 10</td>
<td>IIB</td>
<td>↑↑ for PA</td>
<td>None</td>
<td>100% adolescents</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>→ for EE</td>
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</tbody>
</table>

*Note.* I = controlled trial; IIA = prospective observational; IIB = cross-sectional observational; → = no evidence for association; ↑ = some evidence; ↑↑ = good evidence.
reasoning is to present activity-related EE as the difference between total daily EE and the sum of resting metabolic and diet-induced EE.

**Cross-Sectional Studies.** When comparing obese and nonobese groups, several studies (e.g., 2, 3, 4) have demonstrated lower PA in obese adolescents, particularly during nonstructured activities, or an inverse relationship between PA and adiposity. Others (e.g., 5, 6, 7) did not confirm such a relationship. One reason for such a discrepancy is that EE has often been presented in absolute energy units, without correction for the large body mass of the obese. Other reasons are small sample sizes, weak assessments of PA, and flawed designs. An example of the latter is the often-cited study by Bullen et al. (2), in which obese and nonobese girls participated in separate summer camps, which may have created counselors’ or other environmental biases. Another possible confounding factor is physical location. Waxman and Stunkard (4) observed obese boys to be substantially less active at home and somewhat less active outside the home, but equally active at the playground, when compared with their nonobese siblings. The existing studies may not be sensitive to these location differences in activity.

Data from large-scale surveys (8, 9) suggest a significant relationship between the prevalence of obesity and the extent of TV viewing. Other studies (10, 11) did not confirm such a relationship. Nor was a relationship detected between TV viewing and subsequent changes in BMI or adiposity of adolescent girls over a 2-year period (10). While the time spent watching TV takes away from the time available for PA, watching TV may also be associated with undesirable eating habits (12) and a reduced resting EE (13).

On balance, obese adolescents appear to be less active than their leaner peers, but the total EE of obese adolescents may be equal or higher. For example, Waxman and Stunkard (4) found lower PA (directly observed) among obese boys than among nonobese siblings, but Waxman and Stunkard found no intergroup difference in EE. Even when corrected for body size, EE may not necessarily be lower in obese adolescents (13).

The above studies were all conducted after the subjects had become obese, and, thus, could not address whether hypoactivity is part of the etiology of obesity or simply reflects less activity induced by more weight. One study (14) found that skinfold thickness at 1 year of age was greater in infants whose total EE (from the doubly labeled water technique) at age 3 months was lower. This pattern was not confirmed in a recent study (15), in which infants were followed until age 2 years.

**Longitudinal Observations.** The study by Beunen et al. (16) is important because it controlled for several possibly confounding variables (e.g., maturation, skeletal age) in matched groups of active and less active Belgian adolescents, who were followed for 3 years. This study revealed no relationship between separate skinfold thicknesses (or girths) and self-reported participation in sports. Limitations of this study included not measuring PA in school, in transit to and from school, or in activities other than sports. It is possible that summing the four skinfolds (thereby obtaining a more reliable index of total adiposity) would have yielded results different from those obtained from analyzing each variable separately.

**Training as a Single Intervention**

Numerous studies have shown that aerobic training can induce a reduction in adiposity and, to a lesser extent, an increase in fat-free mass. Wilmore (17)
summarized 55 such studies with obese and nonobese adolescents and adults. The overall effect in these studies was minimal: The average loss of percent body fat, following 6 to 104 weeks of training, was only 1.6%. The reduction was somewhat greater in obese adolescents (18, 19, 20) than in nonobese adolescents.

Sasaki et al. (21) reported a long-duration (2 years) intervention in which 11-year-old obese Japanese girls and boys were involved in a school-based running program, 7 days per week, 20 min each session. The intervention resulted in a continuous decrease in excess body mass throughout the program. A weakness of their design, however, was that the controls were nonobese children, rather than obese children who did not train.

**Training Within a Multidisciplinary Intervention**

The studies analyzed in this review include one subgroup that participated in a low-calorie diet intervention (with or without behavior modification) and another that had the same intervention plus physical training. We have not included the studies that compared effects of training to training plus diet, because such designs do not allow inferences on the effects of training. For the same reason we are not presenting the numerous studies in which the only intervention was multidisciplinary.

Rocchini et al. (22) administered a 20-week diet plus behavior modification program to 10- to 17-year-old obese girls and boys. Half of the subjects also took part in a 3-per-week, 1-hour-per-session exercise program (walking, jogging, swimming, dance, and games). Even though the exercise group had a greater reduction in percent fat than did the nonexercise group (6% vs. 4%), the difference was not significant. Reybrouck et al. (23) reported that the addition of exercise to a low-calorie diet induced a significantly greater weight loss in obese children and adolescents. Epstein et al. (24) found that the addition of lifestyle exercise to a diet program increased the 1-year effect on body weight in parents, but not in their obese children.

In addition to its effect on weight control, training induced a reduction in resting systolic and diastolic blood pressures (22) and in multiple coronary risk (25) among the obese. Another potentially important effect, shown for adults (26), is the reversal of nitrogen loss that is induced by a very-low-calorie diet. Such a loss occurs mostly, but not exclusively, during the first few weeks of dieting (27). Suskind et al. (28) reported an increase in fat-free mass in 17 out of 37 highly obese children and adolescents who underwent a 10-week exercise plus protein-sparing very low calorie diet. The study did not include controls, nor did the authors report the fat-free mass of the other 20 members of the cohort. Even if exercise reverses the nitrogen loss, very low calorie regimens may induce side effects (e.g., ketosis and long-range growth retardation) and should therefore be used selectively under strict medical control. An interesting possibility, as shown for adults (29), is that strength training, through its anabolic effect, will help to preserve fat-free mass, when done in conjunction with restrictive diets. In conclusion, the addition of exercise to a weight control program appears to improve the control of adiposity, as well as other physiologic variables, but not extensively or consistently.
Adiposity and Obesity

Recommendations

The General Adolescent Population

A major constraint in assessing the association between adiposity and enhanced PA, or the effects of training, is the lack of standardized assessment of adiposity, PA, and energy expenditure. This shortcoming limits the possibility of providing a conclusive summary of generalizable findings. "Gold standards" must be established for these measurements, against which other methods can be validated (30).

Training can induce a reduction in percent body fat and a small increase in the fat-free mass of healthy adolescents. Based on available evidence, it is hard to recommend a "minimal dose" (in intensity, calorie equivalents, frequency of sessions, or the total duration of the program) that will be effective in maintaining a reasonable body composition. However, the increase in adiposity of North American adolescents in the 1970s and 1980s suggests that current levels of activity are insufficient.

Obese Adolescents

The low level of motivation of obese adolescents to adhere to a training program is a major challenge to physicians, therapists, and educators. To improve the adherence of a patient, client, or student, one must understand the specific reasons for the client's reluctance to be physically active. These should be addressed before an activity program is prescribed. Even though training, by itself, has a beneficial effect, the resulting changes in adiposity are small. Modification of eating pattern (reduction of snacking, portion size, and calorie content) is therefore recommended. Some evidence suggests that behavior modification of the parents and of the child/adolescent, in separate groups, must be incorporated to achieve long-range effects (31, 32).

There are too few data to provide a recommendation about dose-response between training and weight control, nor is it clear whether there is a minimal dosage needed for an effect. The studies by Moody et al. (20) and Sasaki et al. (21) indicated the value of continuing a program for more than a year. The work of Epstein et al. (33) demonstrated the advantage of encouraging lifestyle activities over regimented activities. Furthermore, recreational and "fun" activities will increase adherence. Many North American schools include a large pool of at-risk adolescents, readily available sports facilities, and experts in nutrition, physical education, and health education. These conditions allow for large-scale interventions. Indeed, several school-based interventions, which combined training and nutritional education, have been effective (34, 35, 36). Further research is indicated to optimize such programs and assess their cost-effectiveness.

Some obese adolescents remain refractory to any intervention, even if they attempt behavioral changes. Evidence is emerging for the heritability of responsiveness of obese adults to training (37). More information is needed about this effect in children and adolescents. The ability to identify a priori individuals who are "responders" or "nonresponders" is of immense clinical importance.
References


