ARTICLE

Improvement of Fitness, Body Composition, and Insulin Sensitivity in Overweight Children in a School-Based Exercise Program

A Randomized, Controlled Study

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Background: Obesity and poor physical fitness constitute a health problem affecting an increasing number of children. Causes include a pervasive "toxic" environment that facilitates increased caloric intake and reduced physical activity. An effective strategy for prevention and treatment of childhood obesity likely includes a collaborative effort in the school setting.

Objective: To determine whether a school-based fitness program can improve body composition, cardiovascular fitness level, and insulin sensitivity in overweight children.

Design: Fifty overweight middle school children with a body mass index (BMI) above the 95th percentile for age were randomized to lifestyle-focused, fitness-oriented gym classes (treatment group) or standard gym classes (control group) for 9 months. Children underwent evaluation of fasting insulin and glucose levels, body composition by means of dual energy absorptiometry, and maximum oxygen consumption ($\dot{V}O_2$max) treadmill testing at baseline (before the school year) and at end of the school year.

Settings: Rural middle school and an academic children's hospital.

Main Outcome Measures: Baseline test results for cardiovascular fitness, body composition, and fasting insulin and glucose levels.

Results: At baseline, there were no differences between groups before intervention (values for age, 12±0.5 years [all results, mean±SD]; BMI [calculated as weight in kilograms divided by the square of height in meters], 31.0±3.7; percentage of body fat, 36.5%±4.6%; lean body mass, 41.4±8.6 kg; and $\dot{V}O_2$max, 31.5±5.1 mL/kg per minute). Compared with the control group, the treatment group demonstrated a significantly greater loss of body fat (loss, −4.1%±3.4% vs −1.9%±2.3%; $P=.04$), greater increase in cardiovascular fitness ($\dot{V}O_2$max, 2.7±2.6 vs 0.4±3.3 mL/kg per minute; $P<.001$), and greater improvement in fasting insulin level (insulin level, −5.1±5.2 vs 3.0±14.3 μIU/mL [−35.4±36.1 vs 20.8±99.3 pmol/L]; $P=.02$).

Conclusions: Children enrolled in fitness-oriented gym classes showed greater loss of body fat, increase in cardiovascular fitness, and improvement in fasting insulin levels than control subjects. The modification to the school physical education curriculum demonstrates that small but consistent changes in the amount of physical activity has beneficial effects on body composition, fitness, and insulin levels in children. Partnering with school districts should be a part of a public health approach to improving the health of overweight children.

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Obesity and poor physical fitness constitute the health problem affecting an increasing number of youth. These factors are associated with future insulin resistance, type 2 diabetes mellitus (T2DM), blood lipid abnormalities, and hypertension.[1,2] Diverse causes of childhood obesity arise from a pervasive "toxic" environment that collectively facilitates increased caloric intake and reduced physical activity. An effective strategy for prevention and treatment of childhood obesity, therefore, must be pervasive and collaborative to alter children's environment. An attractive starting point for a collaborative effort is the school setting, where active and passive decisions regarding physical activity, food choices, and attendance can be reasonably controlled and programmatically altered.

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Obesity increases the risk of insulin resistance, T2DM, and other cardiovascu-

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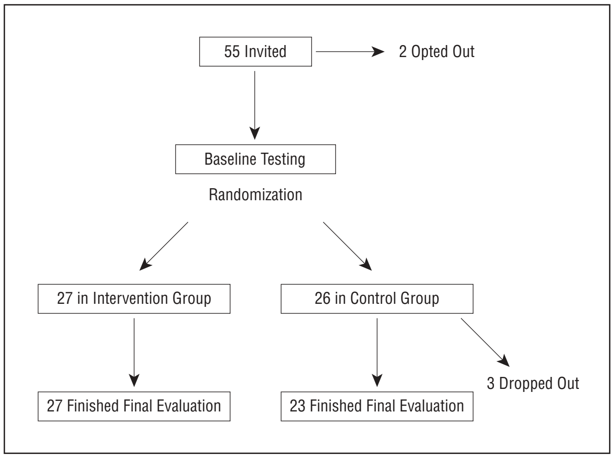

Figure 1. Randomization scheme. After baseline testing, 53 overweight middle school children with a body mass index above the 95th percentile for age were randomized to lifestyle-focused, fitness-oriented gym classes (treatment group) or standard gym classes (control group) for 9 months, and 50 completed the final evaluation.

lar morbidities.[3,4] However, it has been recently demonstrated in adults that level of fitness is a more accurate predictor of cardiovascular and all-cause mortality than weight status.[5] Although it is presumed that the beneficial effect of fitness training on insulin sensitivity reflects the combined effects of increased lean body mass and reduced fat mass,[6] physical activity alters insulin sensitivity independent of changes in weight and body composition in adults[7] and in children.[8,9] Therefore, efforts to improve insulin sensitivity in children may be best focused on increasing physical activity rather than simply restricting calories to achieve weight control.[10]

Addressing obesity in children is problematic in health care and education environments. School personnel report a lack of training in intervention, whereas health care providers report ineffective office-based intervention strategies.[11] By better coordinating efforts in these environments, prevention and treatment of childhood obesity could be improved. Because most adults do not achieve the US Surgeon General's recommended 30 minutes of moderate physical activity on most days of the week,[12] childhood has been identified as a critical period for nurturing lifetime activity behavior,[13,14] and school physical education is a key opportunity to promote active lifestyles.

Behavioral interventions have had mixed results. The Diabetes Prevention Program demonstrated a reduction in the incidence of diabetes in high-risk adults with lifestyle intervention.[15] For children, encouraging additional exercise or promoting healthy nutritional changes can be obstructed (or promoted) in varying environments.[16-18] The most successful programs are those that incorporate these changes into the children's lifestyles, such as within the family or the school environment.[19-21] Gutin et al[19] have successfully designed school-based programs that promote physical activity and monitor changes in fitness and metabolic variables. A recent study by Jamner et al[22] demonstrated that a school-based intervention in adolescent girls can increase physical activity and prevent a decline in cardiovascular fitness. Some school-based nutrition and exercise interventions such as Planet Health have been successful at reducing body mass index (BMI) and triceps skinfold measurements among girls,[23,24] whereas others (eg, the Pathways project) have fallen short of their goals in Native American schools.[25] This study differs from those interventions by focusing on fitness and its effect on fasting insulin levels, in addition to BMI. Fasting insulin level may be a useful marker for insulin resistance, a main determinant for risk of T2DM.[26] In this report we use a controlled design to investigate whether a school-based fitness program makes a difference in fitness, fatness, and insulin sensitivity.

METHODS

Fifty-five children with a BMI above the 95th percentile for age were invited from a single school for participation in this study. Fifty-three chose to undergo evaluation for the baseline testing at the University of Wisconsin Exercise Science Laboratory, Madison (**Figure 1**). All testing was completed by the same investigators during a single visit after an overnight fast. The procedures were approved by the Human Subjects Committee, and informed written consent was obtained before initiating the testing protocol. Testing included a physical examination, blood work to determine fasting glucose and insulin levels, baseline body composition, and cardiovascular fitness assessment before beginning the program. Height was measured on a wall-mounted stadiometer to the nearest 0.5 cm. Weight was measured on a calibrated beam balance platform scale to the nearest 0.1 kg.

Percentages of body fat and fat-free body mass were measured by means of dual energy absorptiometry. Whole-body scans were performed using the Norland XR-36 whole-body bone densitometer (Norland Corporation, Fort Atkinson, Wis), and tissue masses were analyzed using software version 3.7.4/2.1.0 (Norland Corporation). The XR-36 x-ray tube operates at 100 kV and uses dynamic samarium filtration (K-edge at 46.8 keV) to produce energy peaks at maximums of 40 and 80 keV. The XR-36 uses dynamic filtration to minimize beam hardening. Dual NaI (sodium iodide) detectors measure the attenuated x-ray using a pixel size of 6.5 × 13.0 mm and a scan speed of 260 mm/s. Subjects removed metal objects or clothing containing metal components and wore only workout shorts and a T-shirt for the scan procedure, as described previously.[27] Each scan session was preceded by a calibration routine using multiple quality-control phantoms that simulate soft tissue and bone. Based on 18 scans of 6 subjects using the XR-36 whole-body procedures, the total body coefficients of variation are as follows: soft tissue mass, 0.2%; total body mass, 0.2%; lean body mass, 1.0%; fat mass, 2.5%; percentage of fat, 2.4%; and total bone mineral content, 0.9%.

Children underwent a 4-minute submaximal treadmill walk test at 5% grade and measurement of maximum oxygen consumption ($\dot{V}O_2max$) performed by open-circuit spirometry using a progressive treadmill walking protocol to volitional fatigue on a CPX-D treadmill (Medical Graphics Corp, St Paul, Minn). Requirements to ensure that subjects reached their $\dot{V}O_2max$ with this protocol included at least 2 of the following: (1) maximum heart rate of more than 200 beats/min; (2) respiratory exchange ratio (ratio of maximum carbon dioxide to $\dot{V}O_2$) of more than 1.0; and (3) a plateau in oxygen consumption. The subject's oxygen consumption at a heart rate of 170 beats/min was recorded in case the subject was not able to meet the criteria for a $\dot{V}O_2max$ test. All subjects reached their $\dot{V}O_2max$ according to these criteria.

A 10-mL fasting blood sample for insulin and glucose level measurement was obtained from an antecubital vein. Samples

Table. Patient Characteristics*

	Baseline		9-Month Evaluation		
	Intervention (n = 27)	Control (n = 23)	Intervention (n = 27)	Control (n = 23)	*P* Value†
Female, No. (%)	14 (52)	10 (43)	14 (52)	10 (43)	.43
Age, y	12.5 ± 0.5	12.5 ± 0.7			.69
BMI	32 ± 6	30 ± 4	33 ± 10	30 ± 5	.10
$\dot{V}O_2$max, mL/kg per minute	31.5 ± 5	31.8 ± 5	34.5 ± 6	32.5 ± 6	<.001
Body fat, %	36.5 ± 4.7	36.4 ± 4.6	32.6 ± 6.4	34.5 ± 5.8	.04
Fasting insulin level, μIU/mL	25.7 ± 15.7	22.9 ± 13.2	21.9 ± 14	25.8 ± 10	.02
Fasting glucose level, mg/dL	83 ± 4	86 ± 7	87 ± 5	93 ± 7	.07

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by the square of height in meters); NS, not significant; $\dot{V}O_2$max, maximum oxygen consumption.

SI conversion factors: To convert glucose to millimoles per liter, multiply by 0.0555; insulin to picomoles per liter, multiply by 6.945.

*Unless otherwise indicated, data are expressed as mean ± SD.

†Calculated as the difference in change from baseline between treatments (2-sided Wilcoxon rank sum test).

were separated by low-speed centrifugation at 4000*g* for 10 minutes. Fasting insulin concentration was determined using the chemiluminescent assay (Esoterix, Calabasas Hills, Calif), and glucose concentration was determined by an enzymatic method (Beckman Coulter Diagnostics, Fullerton, Calif).

Once baseline testing was completed, children were randomized and enrolled in lifestyle-focused, fitness-oriented gym classes (considered the treatment or intervention group) or standard gym classes (control group) for 9 months (the entire school year). Participants in the intervention group were in class sizes limited to 14 students to ensure adequate supervision and more direct time spent with each instructor. Classes were designed to make fitness and good nutrition fun and achievable and to maximize the amount of movement during the class period. Three subjects dropped out of this study (all in the control group), as 2 moved away during the school year and 1 stopped coming to school for nonmedical reasons. None of their data were included in these analyses, and none of these data were significantly different from those of the rest of the cohort at baseline.

SCHOOL FITNESS CURRICULUM

Students randomized to fitness classes also received a small nutrition education component. This consisted of educational handouts to participants to develop healthier eating habits. The nutrition portion focuses on the Food Guide Pyramid, recommended servings of food, appropriate portion sizes, healthier food choices, and the benefits of those choices.

Students were randomly assigned to the intervention (smaller fitness-oriented class size of 12-14 children) or control (traditional classes) group. The frequency of fitness-oriented and standard physical education classes was 5 times every 2 weeks for a 45-minute class period.

INTERVENTION GROUP

Class size was limited to 14 students to allow for increased instructor attention, increased opportunity for motivation, and less time standing in line. The curriculum was personalized to match the student's skill levels and encourage student participation. Competitive games were de-emphasized, and lifestyle-focused activities (walking, cycling, and snowshoeing) were encouraged. A consistent warm-up plan brought students into movement participation as quickly as possible soon after they entered the gym. Typical movement time was 42 minutes of a 45-minute class period, as children did not change clothes for this class to increase activity time. Skills were taught with the class broken down into groups of 2 for promoting more movement and less time watching. The ethos of the class encouraged physical fitness, less self-conscious focus on appearance, and full group participation.

CONTROL GROUP

Control subjects participated in the traditional physical education classes of 35 to 40 students. After accounting for the time for changing clothes, taking attendance, and giving instructions, movement time averaged 25 minutes of the 45-minute period. The same class topics (eg, football, mile run/walk, kickball) were taught as in the intervention group, but in a different format, as typical issues in the traditional class were a greater range of skill levels, longer lines during skill development drills, and larger numbers of students on teams when games were played. These issues tended to result in less movement and a tendency for students to hold back and not enter into play.

STATISTICAL ANALYSES

The overall change between the 2 groups was analyzed using the 2-sided Wilcoxon rank sum test. Statistical significance was set at $P<.05$ for all tests, and SAS statistical software (SAS Institute, Cary, NC) was used. Unless otherwise indicated, data are expressed as mean±SD.

RESULTS

Patient characteristics and study results are presented in the **Table**. The mean lean body mass was 41.4±8.6 kg, and mean percentage fat was 36.5±4.6%.

ANTHROPOMETRICS AND BODY COMPOSITION

At baseline, the mean age of the study participants was 12±0.5 years, and 48% of the subjects were female (Table). The mean BMI (calculated as weight in kilograms divided by the square of height in meters) was 32±6 and 30.4±4 in the intervention and control groups, respectively. There were no differences in age, BMI, or sex distribution between groups at baseline (Table).

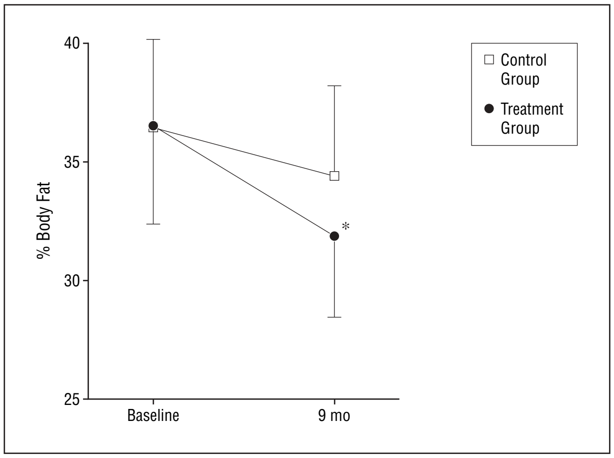

Figure 2. Mean±SD decrease in percentage of body fat as indicated by dual energy absorptiometry. After a 9-month school year, the decrease was greater in the treatment group compared with the control group. Asterisk indicates *P*=.04.

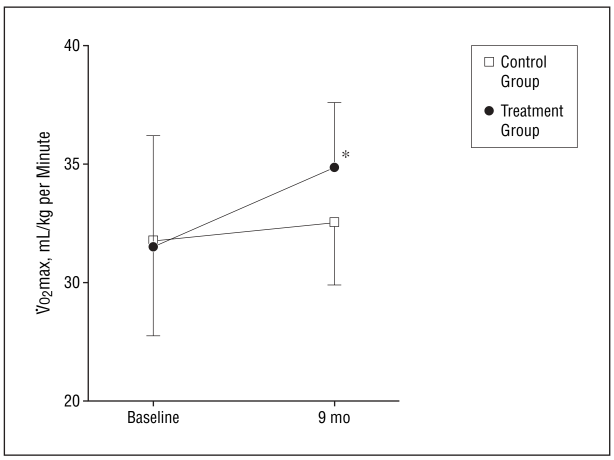

Figure 3. Mean±SD change in fitness levels as indicated by maximum oxygen consumption ($\dot{V}O_2$max) levels. After a 9-month school year, the change was greater in the treatment group compared with the control group. Asterisk indicates *P*<.001.

Figure 2 illustrates a significantly greater decrease in the percentage of body fat in the treatment group (−4.1%±3.4%) compared with the control group (−1.9%±2.3%; *P*=.04) after completion of the 9-month intervention, resulting in end-of-treatment percentage of mean body fat measures of 32.6%±6.4% and 34.5%±5.8%, respectively. The BMI was 33±10 and 30±5 at the end of the study in the treatment and control groups, respectively (*P*=.10 compared with baseline).

CARDIOVASCULAR FITNESS

There were no differences in cardiovascular fitness between groups before treatment. After 9 months, the intervention group showed significant improvements in cardiovascular fitness ($\dot{V}O_2$max) compared with their own baseline measurements (2.7±2.6 vs 0.39±3.3 mL/kg per minute; *P*<.001 (**Figure 3**) and compared with the control group (34.5±6 vs 32.5±6 mL/kg per minute). Significant changes were also seen in the oxygen consumption at a heart rate of 170 beats/min (1.9±3.3 mL/kg per minute for the treatment group vs −0.2±3.1 mL/kg per minute for the control group; *P*=.008).

INSULIN SENSITIVITY

At baseline, there were no differences between groups in measures of insulin sensitivity. The fasting insulin levels were 25.7±15.7 μIU/mL (178.5±104.2 pmol/L) and 22.9±13.2 μIU/mL (159.0±90.3 pmol/L) (reference range, 4.0-24.0 μIU/mL [27.8-166.7 pmol/L]) for the treatment and control groups, respectively.

After 9 months, the intervention group had significant improvements compared with baseline in fasting insulin levels (−5±5.2 vs 3±14 μIU/mL [−35.4±36.1 vs 20.8±99.3 pmol/L]; *P*=.02), 1/insulin ratio (0.02±0.04 vs −0.01±0.03; *P*=.01), and glucose-insulin ratio (1.7±3.5 vs −1.2±2.5; *P*=.02). The control group showed no change in measures of insulin sensitivity.

COMMENT

The current obesity epidemic affects school children, and thus a school-centered intervention may be a logical intervention. This study of 50 obese children (BMI >95th percentile) compared the effect of a school-based fitness program on body composition, cardiovascular fitness, and fasting insulin levels. Children who participated in small fitness-oriented classes showed significantly greater improvement in all of these measures compared with the children who participated in standard gym classes. These results demonstrate that measurable health benefits were achieved with modifications of the school physical education curriculum and suggest that a school curriculum could be effective in improving cardiovascular fitness, reducing body fat, and improving insulin sensitivity. In this study, even a small change in the amount of physical activity showed beneficial effects on body composition, fitness, and insulin levels in children. Similar benefits have been shown by lifestyle improvements in adults with known glucose intolerance.[28]

Although results from other school-based interventions have been equivocal, the most significant changes noted in our program, changes in cardiovascular fitness, have not typically been measured in most previous programs. Furthermore, we specifically did not use weight as a primary end point of this intervention. We acknowledge that there are many ways of evaluating health and fitness, including testing of $\dot{V}O_2$max, body composition, and insulin sensitivity. This project also focused mainly on increasing physical activity, with only a small component of nutrition education, and no dietary intervention or outcomes were measured. We have demonstrated changes in insulin sensitivity in the absence of change in BMI. It is possible that, as in adults, we may find physical activity and fitness to be just as important as fatness in children.

Reduced physical activity and obesity place American children at increased risk for insulin resistance.[1-3] Although it has been shown that aerobic exercise is useful as a treatment strategy for insulin resistance,[28] questions have arisen whether or not a change in fitness levels would be expected for children. In a longitudinal study of fitness in girls aged 8 to 10 years, data suggest that fitness levels tend to remain constant during this period without formal intervention, but that children with obese parents tend to have less physical activity and lower fitness levels.[29,30] In children and adolescents, percentage of body fat and visceral adipose tissue are also positively correlated with insulin resistance,[31] which is an independent predictor of the development of stroke, cancer, coronary artery disease, hypertension, and T2DM in adulthood.[6,32] Although fasting insulin levels may not be as diagnostic for insulin resistance as frequently sampled testing, the utility of body fat measurement and fasting insulin levels was found to have greater precision than homeostasis model assessment alone in some studies.[33]

Puberty normally is associated with mild increases in insulin resistance, and in susceptible children it is a high-risk developmental period for obesity and T2DM. If puberty was likely to influence the results of this study, because groups were comparable in sex distribution and age, one might assume that 9 months after starting this intervention insulin resistance would have increased as the children matured. Although puberty is a time of known insulin resistance, which makes interpretation of this cohort slightly more difficult, insulin sensitivity improved as a result of increasing physical activity, despite advancing age. Physical education classes have the potential to provide 97% of children in the United States with regular physical activity.[34] For example, the SPARK (Sports, Play, and Active Recreation for Kids) program increased physical activity during school physical education, but not outside of school. It also demonstrated that physical education supplied only 18 of the recommended 150 minutes per week at school.[21]

A major limitation of this study is that it is not possible to show precisely what aspect of the class (ie, curriculum vs instructor-student ratio) promoted greater movement. The answer still needs to be resolved as to whether the best approach is to alter the curriculum or to change the class size. In this era of increased emphasis on academic testing and cuts in school physical education time and funding, it is important to pinpoint the most effective aspects of these interventions.

Because childhood obesity is predictive of adult obesity,[4] it is important to develop and evaluate interventions designed to start in childhood. The feasibility, demonstrated by this study, of producing changes in fitness levels, percentage of body fat, and fasting insulin levels (an indirect assessment of insulin sensitivity) is important to primary care physicians and school personnel. These findings should help to encourage the development of physical education programs that are effective in providing children with substantial amounts of physical activity. Clearly, however, an effective public health approach must promote increased physical activity inside and outside of school, as physical activity recommendations cannot be met through physical education alone.

In conclusion, school-based fitness programs can significantly improve cardiovascular fitness levels, fasting insulin levels, and body composition in obese children in the absence of detectable changes in BMI. These findings suggest that school curricula may be an effective vehicle for increasing physical activity and improving cardiovascular health for children, and further study is warranted.

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Poetry in Pediatrics

Simple Swordplay

For Dr Mindy Cohen

Errol Flynn, every Zorro since,
made it seem so elegant:
a morning duel, an afternoon rescue,
a quiet tea and a brandy after,
his sword, his horse, his comforts
distancing him from fear and fiction.
You have done the same with cancer,
carving your Z, having your tea, and
when the threat returns, carving again
without the benefit of a flowing cape,
wearing your mask lower, converting
your dusty arena into a sterile room
where you can stand upright
fighting disease, praying that more
than equal skill will cure your own,
and everyone else's worry will vanish
in the expected, well-rehearsed victory
before we empty the theater.

Stan Cohen, MD