



# Effects of Physical Activity on Diabetes Management and Lowering Risk for Type 2 Diabetes

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## ABSTRACT

*Physical activity is a proven form of diabetes management and is considered a cornerstone in the prevention of diabetes. In children with diabetes, physical activity may improve insulin sensitivity and glucose uptake in skeletal muscle. Aerobic-based physical activity lasting 40-60 minutes daily for a minimum of four months is shown to enhance insulin sensitivity, and may reduce the risk for type 2 diabetes. An important adjunct to aerobic-based physical activity for diabetes prevention is resistance training. The American Academy of Pediatrics supports properly supervised strength/resistance training as a safe method for strength development in preadolescent children. Resistance training may increase skeletal muscle mass, therefore increasing whole-body glucose disposal capacity. In addition to immediate health benefits during childhood, increased physical activity in children and adolescents is likely to contribute to the establishment of healthy leisure habits over a lifetime and improved adult cardiovascular health. Large-scale intervention studies, however, are needed to determine the most effective physical activity strategies for prevention and management of type 2 diabetes in children and adolescents.*

*Tompkins CL, Soros A, Sothern MS, Vargas A. Effects of physical activity on diabetes management and lowering risk for type 2 diabetes. Am J Health Educ. 2009;40(5):286-290. This paper is part of a sponsored set of papers contributed through the National Institute of Diabetes and Digestive and Kidney Diseases, National Institutes of Health.*

## INTRODUCTION

Adiposity is a major determinant of type 2 diabetes in children and adolescents and is the most relevant modifiable diabetes risk factor in youth.<sup>1-3</sup> Lifestyle modifications are necessary to manage established diabetes successfully and to lower the risk for type 2 diabetes in high-risk youth. In addition to diet, physical activity is a proven form of diabetes management and is considered a cornerstone in the prevention of diabetes.<sup>1-3</sup> Participation in physical activity is shown to improve body composition and decrease resting heart rate and blood pressure in chil-

dren and adolescents. In children with diabetes, however, physical activity may provide additional advantages.<sup>4</sup> By improving both

insulin sensitivity and glucose uptake in skeletal muscle,<sup>2,3</sup> physical activity may have the potential to reduce the incidence of type

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2 diabetes in children and adolescents.<sup>3</sup>

Type 2 diabetes mellitus is associated with insulin resistance.<sup>5</sup> Studies performed in children and adolescents demonstrate a positive association between physical activity and insulin dynamics, with increased activity significantly related to lower fasting insulin and greater insulin sensitivity.<sup>3,6</sup> Physical activity may improve insulin sensitivity by enhancing glucose transport into muscle cells and increasing the production of muscle glycogen to replace the amount used during exercise.<sup>7</sup> Furthermore, the long-term improvements in insulin sensitivity that follow exercise training may be explained by an increase in fat-free mass; thereby increasing the volume of muscle tissue into which glucose can be transported. In addition, these outcomes may be further enhanced by a concomitant decrease in fat mass and a resulting decrease in inflammatory adipokines.<sup>3</sup>

Most randomized controlled trials in overweight children and adolescents have shown that physical activity enhances insulin sensitivity in childhood. Nassis et al.<sup>6</sup> examined the effects of an aerobic exercise training program on insulin sensitivity in overweight and obese 9-15 year olds. After 12 weeks of training, insulin sensitivity increased without changes in body weight or percent fat mass. Moreover, after the training, lower limb fat free mass increased by 6.2%, a change that was significantly associated with enhanced insulin sensitivity.<sup>6</sup> Kahle<sup>9</sup> also observed a significant decrease in fasting insulin in obese adolescent males after 15 weeks of mild intensity training.

Ferguson<sup>8</sup> observed significantly decreased fasting insulin in seventy-nine obese 7-11 year-old children after four months of exercise training. However, no significant changes in fasting glucose were observed. Unfortunately, eight months after the training program ceased, the beneficial effects of the exercise on fasting insulin were removed.

Several other studies demonstrated improved insulin sensitivity and glucose metabolism following aerobic training in overweight and obese children between the

ages of 9 and 16 years of age.<sup>3,6</sup> These improvements were observed without changes in body weight or fat, suggesting that the improvement in insulin sensitivity may be due to changes in the ability of the muscles to metabolize glucose. These findings support previous studies in adults that reported physical training-induced improvements in insulin sensitivity without changes in body fat.<sup>10</sup> Likewise, studies evaluating exercise and diet together resulted in a decrease in fasting blood glucose and HgbA1C levels in children. Conversely, similar evaluations of diet alone demonstrated no significant reductions in blood glucose concentrations.<sup>1,9,11</sup>

Schmitz et al.<sup>3</sup> observed the effect of physical activity on insulin resistance and other cardiovascular disease factors in 357 healthy weight children without diabetes (age range 10-16 years). Significant correlations were observed between self-reported physical activity and both fasting insulin and insulin sensitivity. Moreover, in the subset of children with higher systolic blood pressure<sup>3</sup>, the correlations were significantly stronger. Conversely, two other studies did not find significant differences in insulin after physical activity. Kang<sup>13</sup> reported no significant changes in fasting insulin after eight months of moderate to vigorous physical training in 80 obese youths. Additionally, no significant reductions in fasting insulin were observed by Treuth and colleagues<sup>14</sup> over five months of resistance training in twelve obese pre-pubertal girls.

Whereas physical activity is recommended to help increase insulin sensitivity, resistance training, specifically, may provide additional benefits. Compared to endurance training, resistance training may substantially increase skeletal muscle mass and strength and, thus, whole-body glucose disposal capacity.<sup>7,12</sup> Recent investigations report significant metabolic benefits of resistance training in children and adolescents. Shaibi and colleagues<sup>12</sup> examined the effects of a 16-week resistance training program in twenty-two overweight Latino adolescent males randomly assigned to two-times-per-week resistance training or a non-exercising control condition. Sig-

nificant increases in strength as measured by 1-rep max were observed in the resistance training group. More importantly, insulin sensitivity measured by the frequently sampled intravenous glucose tolerance test with minimal modeling was significantly improved (45.1+/-7.3% in the resistance training group versus -0.9+/-12.9% in the control group). Remarkably, these results remained significant after adjusting for fat and lean mass by DEXA. In another investigation, Benson and others<sup>15</sup> examined the relationship between upper body strength and insulin resistance in a large cohort (N=126) children, 10-15 years of age. Poor upper body strength was an independent predictor of insulin resistance. And, children in the highest and middle tertiles of absolute upper body strength were 98% less likely to have high insulin resistance than those with the lowest strength even after adjusting for maturation, central adiposity and body mass. Thus, resistance or strength training should be considered as a safe and effective modality of exercise in children at risk for developing type 2 diabetes. This coincides with recent recommendations by the U.S. Government Physical Activity Guidelines for American Children and Adolescents<sup>16</sup> which include bone- and muscle-strengthening activities for inclusion into each day's minimum of 60 minutes of physical activity.

## PHYSICAL ACTIVITY RECOMMENDATIONS

Reducing overweight and impaired glucose tolerance with increased physical activity and healthier eating habits may help prevent or delay development of type 2 diabetes in high-risk children and adolescents. Children with a BMI greater than the 85th percentile for age and sex should be counseled to increase physical activity and reduce weight gain while allowing for normal growth and development. With the decrease in physical activity and the increase in prevalence of type 2 diabetes in children and adolescents, educators, researchers and parents need to place a higher priority on increasing children's physical activity.<sup>2</sup>

Children and adolescents at metabolic



risk should partake in regular, moderate intensity physical activity. This activity should be performed for at least 30 minutes, but preferably 45-60 minutes, at least five days per week. An increase in physical exercise may accompany this recommendation as part of the child's daily lifestyle activities.<sup>17</sup> For prevention and management of type 2 diabetes in children and adolescents, aerobic-based exercise lasting 40-60 minutes daily for a minimum of four months is likely to enhance insulin sensitivity, and may reduce the risk for type 2 diabetes in children and adolescents.

Evidence-based recommendations for physical activity in school-age youth include participation in 60 minutes or more of moderate to vigorous activity. This activity should be enjoyable, developmentally appropriate and involve a variety of activities.<sup>18</sup> The following evidence-based recommendations for physical activity in school-age youth are broken down by type and modality:<sup>18</sup>

*Preschool years:* General movement activities (jumping, throwing, running, climbing)

*Pre-pubertal (6-9 years):* More specialized and complex movements, anaerobic (tag, games, recreational sports)

*Puberty (10-14 years):* Organized sports, skill development

*Adolescence (15-18 years):* More structured health and fitness activities, refinement of skills

Physically inactive children and adolescents should take an incremental approach to reach the 60 minutes per day recommendation, increasing overall physical activity by 10% each week.<sup>18</sup> Tables 1, 2, and 3 provide recommendations for frequency, duration, and activity.<sup>19,20</sup>

Additionally, resistance training should be considered an important adjunct to aerobic-based physical activity for diabetes prevention programs in high-risk youth, independent of changes in body composition.<sup>21</sup> The prepubescent child, in particular, is at an increased risk of injury due to a reduction in joint flexibility caused by rapid growth in the long bones. Young children should

**Table 1. Moderate Intensity Progressive Exercise Prescribed Duration of Exercise (minutes per session)<sup>19</sup>**

	Week 1	Week 5	Week 10
Overweight	30	45	60
Obese	25	40	55
Severely Obese	20	35	50

**Table 2. Moderate Intensity Progressive Exercise Prescribed Frequency of Exercise (days per week).<sup>19</sup>**

	Week 1	Week 5	Week 10
Overweight	3	4.5	6
Obese	2	4	5.5
Severely Obese	1	3	5

**Table 3. Initial\* Activity Recommendations According to Body Mass Index (BMI) for Overweight, Obese, and Severely Obese Children and Adolescents.<sup>20</sup>**

Overweight Children (>85th-95th BMI), 7-18 Years	<ul style="list-style-type: none"> <li>▪ Limited access to TV, video games, computer</li> <li>▪ Recommended aerobic activities: Weight-bearing such as brisk walking, treadmill, field sports, roller blading, hiking, racquetball, tennis, martial arts, skiing, jump rope, indoor/outdoor tag games</li> <li>▪ Parent training and fitness education</li> <li>▪ Pacing skills</li> </ul>
Obese Children (>95th-99th BMI), 7-18 Years	<ul style="list-style-type: none"> <li>▪ Limited access to TV, video games, computer</li> <li>▪ Recommended aerobic activities: Non-weight bearing such as swimming, cycling, strength/aerobic circuit training, arm ergometer (crank), recline bike, and interval walking (walking with frequent rests, as necessary)</li> <li>▪ Parent training and fitness education</li> </ul>
Severely Obese Children (>99th BMI), 7-18 Years	<ul style="list-style-type: none"> <li>▪ Limited access to TV, video games, computer</li> <li>▪ Recommended aerobic activities: Non-weight bearing such as swimming, recline bike, arm ergometer (crank), seated (chair) aerobics, and seated or lying circuit training</li> <li>▪ Parent training and fitness education</li> <li>▪ Other emotional and dietary concerns addressed during treatment</li> </ul>

\* Recommendations should be adjusted every 10-12 weeks based on individual progress.



be provided safe opportunities to climb, run and jump to encourage development of muscular strength and endurance.<sup>20</sup>

Strength training suggestions for prepubescent children include the following:<sup>20</sup>

- Climbing trees
- Swinging on monkey bars
- Supervised jumping activities
- Swinging on a swing set
- Skipping rope
- Playing hopscotch
- Climbing into and out of a swimming pool
- Participating in gymnastics
- Dancing
- Learning a martial art

Strength training also reduces the incidence of overuse injury in the prepubescent child.<sup>21</sup> Inclusion of regular resistance training in a program to prevent and treat pediatric obesity in preadolescent children is not only feasible, but also safe, and may contribute to retention at one year.<sup>21,22</sup> Recently, a meta-analysis examined thirty childhood obesity treatment studies that included an exercise intervention.<sup>23</sup> Significant improvements in body composition were associated with programs that included high-repetition strength training in conjunction with moderate intensity aerobic exercise. Thus, the combination of high-repetition resistance training, moderate aerobic exercise and behavioral modification may be most efficacious for reducing body fat variables in overweight children. However, pediatric health care providers should be careful when recommending strength training to obese children and to children with diabetes.<sup>19</sup>

The American Academy of Pediatrics separates the terms resistance training and strength training from the terms weight lifting, power lifting, and body building<sup>24</sup> and supports properly supervised strength/resistance training programs as safe methods for strength development in preadolescent children and adolescents. The following strength training guidelines for children and adolescents should be adhered to:<sup>20,21</sup>

- Begin the program using weight at about 60% of what you can lift in one try (this baseline is called the one repetition maximum or your “1 rep max”).

- Lift the same amount of weight at each workout until you can perform 12 repetitions in perfect form, with little effort.

- When you are able to do a strength exercise perfectly 12 times, increase the weight by one to two pounds.

- Use a 2-4 second count to lift and lower the weight.

- Begin doing strength exercises once per week, gradually working up to twice per week. Never do strength exercises more than three times per week. *Always rest at least one day between strength workouts.*

- Rest one to two minutes after each set of 8 to 12 repetitions. One set of each strength exercise is recommended for children under age 14. One or two sets are recommended for older children.

- Isolate and focus on the muscles you are working by keeping all the other parts of the body stationary and relaxed (abdominals should always be pulled in, also glutes for standing exercises).

- Fully extend and contract the muscles without locking the joints when you are performing each strength exercise.

- Grip the weight handles lightly to prevent an increase in blood pressure.

- Breathe normally throughout the exercises.

Flexibility training, or stretching, is just as important as aerobic and strength training. Inflexible joints and muscles can inhibit children from participating in activities to their fullest potential. Inflexibility also can lead to chronic muscle and joint disorders. Stretching should be performed after aerobic or strengthening exercises to help prevent soreness and possible injury.<sup>20</sup>

With childhood obesity more prevalent now than in past generations, treatment programs that produce lasting results are sorely needed. *Trim Kids*, a clinic-based, interdisciplinary and multilevel weight management program, incorporates short-term goal

setting, regular feedback and motivational techniques to improve health behaviors.<sup>20</sup> Evaluations indicate that *Trim Kids* is effective in helping children lose weight and maintain weight loss at one-year follow-up.<sup>25</sup> To help combat childhood obesity, the *Trim Kids* program was implemented in YMCA centers across Southeast Louisiana. The Louisiana State University Health Sciences Center (LSUHSC), School of Public Health provided a two-day training session for staff members at the YMCA centers. Intervention programs were launched in seven locations with YMCA staff providing the nutrition and physical activity interventions and staff from LSUHSC providing the behavioral component. *Trim Kids* was recognized by the National Cancer Institute as a Research Tested Intervention Program and recently was acknowledged by the U.S. Surgeon General for its community dissemination in YMCA centers in Louisiana.<sup>26</sup>

In addition to immediate health benefits during childhood, increased physical activity in children and adolescents is likely to contribute to the establishment of healthy leisure habits over a lifetime and improved adult cardiovascular health.<sup>3</sup> Large-scale intervention studies are needed to determine the most effective physical activity strategies for prevention and management of type 2 diabetes in children and adolescents.<sup>2</sup> Physical activity should be sustained, however, throughout adolescence as improvements in insulin sensitivity are reversed following cessation of exercise.<sup>2</sup>

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