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The Role of Exercise Training on Insulin Sensitivity in Overweight and Obese Adolescents

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Mini Review

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Abstract

The increase in childhood obesity prevalence over the past 30 years has become a public health concern for children and adolescents. Obese children have an increased risk for developing a myriad of chronic metabolic diseases and other health complications. While the effect of obesity on development of insulin resistance has been well documented, the purpose of this mini-review is to examine the role of exercise training on insulin sensitivity in overweight and obese adolescents. Previous studies have investigated the effects of different exercise training modalities on insulin resistance and cardio metabolic health in obese adolescents. Results from these studies demonstrate significant improvements in insulin sensitivity, but specific exercise modalities revealing the most benefit differ depending on sex of the adolescent. Study results recommend that exercise training should be included as an integral component of type 2 diabetes management in youth. While the American Diabetes Association and the American College of Sports Medicine include broad physical activity guidelines, recommendations regarding differences in exercise modality by age or sex are not specified. Further investigations are needed to provide a clear consensus on the independent effects of exercise on insulin resistance by sex and exercise modality.

Keywords: Exercise Training; Insulin sensitivity; Youth; Obesity

Introduction

Childhood obesity in the United States has become a major public health concern over the past30 years. There has been an increase of 12% in childhood obesity prevalence from 1974 to 2012 [1]. Recent data reported that 16.9% of all youth aged 2-19 years old are obese (defined as body mass index (BMI) ≥95th percentile for age) [2]. When the obesity prevalence was explored by age, 8.4% of 2 to 5 year olds, 17.7% of 6 to 11 year olds, and 20.5% of 12 to 19 year olds had a BMI ≥95th percentile. Obese children have an elevated risk for developing a myriad of chronic metabolic diseases such as type 2 diabetes, certain types of cancer, sleep apnea, hypertension, arthritis, gallstones, and have an increased risk of maintaining their obesity throughout adulthood [3-6]. Although the effect of obesity on the development of insulin resistance has been well discussed, the role of exercise independent of weight loss on insulin resistance is less clear. The purpose of this mini-review is to examine the role of exercise training on insulin sensitivity in overweight and obese adolescents.

Background

Glucose homeostasis, characterized by the balance of glucose intake with insulin secretion from the β beta cells in the pancreas and glucose uptake in the skeletal muscle, can be detrimentally altered through the presence of obesity and a lifestyle of sedentary behaviors and nutritional excess [7]. These lifestyle factors have a significant effect on glucose uptake by the skeletal muscle and are associated with the skeletal muscle becoming resistant to insulin [8]. As the skeletal muscles become increasingly insulin resistant through time, the β cells are no longer capable of secreting enough insulin to maintain a balanced glucose homeostasis. This leads to impaired glucose tolerance and eventually to the development of type 2 diabetes.

Although type 2 diabetes has historically been characterized as an adult chronic disease, prevalence of type 2 diabetes in youth increased by approximately 30% from 2001 to 2009 [9]. Among U.S adolescents (12 to 19 years old), the prevalence of impaired fasting glucose was 13.1%, impaired glucose tolerance was 3.4%, and pre-diabetes was 16.1%, with overweight adolescents having a 2.6 times higher rate of these insulin resistance markers compared to normal weight adolescents [7, 10].

Exercise and Insulin Sensitivity

Although weight loss through dietary changes and increased physical activity are generally recommended as the first lines of approach for obese adolescents with insulin resistance [11,12] recent research has shown that physical activity (without dietary changes) may have beneficial effects [11-13]. While exercise alone may not impact body weight reduction, exercise does appear to provide benefits to youth beyond weight loss. These benefits include increased insulin sensitivity, improved body composition, and improved markers for non-alcoholic fatty liver disease. Three recent randomized, controlled studies have investigated the effects of different modalities of exercise training on insulin resistance and cardio metabolic health in obese adolescents.

Lee and colleagues investigated the effects of exercise without caloric restriction on abdominal fat, intrahepatic lipid, and insulin sensitivity in obese adolescent males [11,12,14] Forty-three obese adolescent males (mean age 14.8 years old) completed an intensive supervised aerobic training, resistance training, or non-exercise control program. Exercise training took place over 3-months, with 3 sessions per week for 60 minutes per session (180 minutes/week). Participants were encouraged to maintain weight and current dietary habits throughout the intervention period. Insulin sensitivity was measured through 3-hour hyperinsulinemic-euglycemic clamp procedure, body composition was measured with full-body MRI analysis, and intrahepatic lipid was measured with proton magnetic resonance spectroscopy. Although there was no weight loss observed in the exercising groups, the results showed significant improvements in insulin sensitivity in the resistance training group compared to the control group (no difference between the control group and aerobic training group). Significant reductions in abdominal subcutaneous, visceral fat, and intrahepatic lipid percent in both the aerobic and resistance training group compared to controls were observed. These results suggest that resistance training, independent of changes in diet or body weight, may be the most effective exercise modality to improve insulin sensitivity in obese adolescent males [14].

As a follow-up study, Lee and colleagues investigated the effects of aerobic and resistance training on insulin sensitivity and body composition in obese adolescent females (mean age 14.8 years old) [11]. Similar to the study in boys, subjects participated in an intensive 3-month supervised exercise program with approximately 180 minutes per week of aerobic or resistance training exercise. Subject insulin sensitivity was measured through 3-hour hyperinsulinemic-euglycemic clamp, and body composition was measured with full-body MRI analysis. The results showed significant improvements in insulin sensitivity in the aerobic training group compared to non-exercise controls (no significant difference between the resistance training and control group). Furthermore, there were significant reductions in visceral fat in the aerobic training group but not in the resistance training group. The authors suggest that, contrary to the study in males, aerobic exercise training may be the most effective exercise modality to improve insulin sensitivity in obese adolescent females [11]. These results are supported by Treuth et al who found no significant changes in fasting glucose and insulin after a 5-month strength training program in prepubertal girls [13]. Also, unlike the male study, Lee et al found no significant increases in lean muscle mass in response to the resistance training. The authors suggest that the presence of anabolic hormone in adolescent males, and gender specific physical activity preference may explain the difference in results between males and females [11].

Lastly, Sigal and colleagues investigated the effects of exercise on cardio metabolic risk markers in obese adolescent males and females [12]. Three-hundred and

four adolescents (mean age 15.6 years) were randomized to either aerobic exercise, resistance exercise, combined aerobic and resistance exercise, or non-exercise control group. The exercise intervention lasted 22 weeks, with 4 supervised exercise sessions per week. Results showed that body weight and waist circumference decreased significantly in the aerobic and resistance training group compared to controls and waist circumference decreased significantly more in the combined exercise modality group compared to the aerobic group. Although treadmill test time increased in all three groups, this study found no significant differences in levels of fasting insulin, fasting 2-hour glucose, or blood lipid levels [12]. The more favorable cardio metabolic results were found in patients who were most compliant to the exercise training protocol.

Conclusion

Exercise training, even without changes in diet or reduction in body weight, may have significant and beneficial effects on body composition and insulin sensitivity in obese adolescents [11-17]. This is in agreement with a 2014 meta-analysis investigating the quantitative effectiveness of exercise training on fasting insulin and insulin resistance in children and adolescents [17]. The meta-analytic review found that exercise is most effective in improving insulin status in children and adolescents with a high BMI, with the greatest effect in adolescents [17]. Although only a small to moderate effect was found between exercise without dietary changes and insulin resistance, the authors recommend including physical activity as an integral component of type 2 diabetes management in youth [17].

Studies suggest sex specific differences in insulin resistance by exercise modality in youth [11, 14-16]. The American Diabetes Association with the American College of Sports Medicine currently recommend of 150 minutes per week of moderate intensity aerobic physical activity, or vigorous activity for 90 minutes per week in addition to muscle strengthening exercises, at a frequency of 3 days per week without more than 2 consecutive days without physical activity [8, 18, 19]. These are broad physical activity guidelines that do not specify differences in exercise modality or recommendations by age or sex. Future studies are needed to further investigate the independent effects of exercise on insulin resistance by sex and exercise modality. Without a clear consensus, general physical activity as well as moderate to vigorous intensity exercise should be recommended for all youth, especially those at risk for developing insulin resistance or diabetes.

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