###### Type 2 Diabetes and its Prevalence in the Youth Population

# Honors Thesis

###### Presented in Partial Fulfillment of the Requirements

###### For the Degree of Bachelor of Science in Sport and Movement Science

In the School of Sport and Movement Science

at Salem State University

By

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Commonwealth Honors Program

Salem State University

2019

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Acknowledgements

I would like to thank my thesis advisor Dr Heidi Fuller for making in impact on me during my Sophomore year in her Introduction to Health Education and Health Promotion course. You were a knowledgeable and passionate professor that helped me become a better student. I am grateful for your support, encouragement and patience with me throughout the writing process of my thesis. I would like to thank all my Sport and Movement Science professors as they helped guide me and lead me to find passions within the Health and Fitness Industry. Lastly, I would like to thank my parents for supporting me throughout the last four years and pushing me to stick with the Honors Program as well as being a sounding board for me through academic doubts I had along the way. You have been an amazing support system and I can never repay you for all you have done for me.

Abstract

There is a rise in cases of Type 2 Diabetes (T2D) in all populations especially adolescents. This paper provides a literature review of clinical studies and evidence that identified the dynamics around the rise in T2D in adolescents and determined that by introducing exercise programs, altered diet and emotional support, the incidence of adolescent T2D should decrease. The prevalence of adolescent obesity directly relates to the number of youths diagnosed with T2D, so targeting obesity and T2D issues concurrently should ensure improvements in T2D. The overall goal of this project was to determine whether there was an issue regarding T2D and adolescents, the extent of that issue, and how it could be addressed. The following literature review recognizes the phenomena associated with the changing nature of T2D in the adolescent population, explores the effectiveness of interventions, and establishes the need for additional research in this area.

 *Keywords:* Type 2 Diabetes, Adolescence, obesity, and minority groups

Introduction

The following literature review examines the incidence of Type 2 Diabetes (T2D) in adolescents. A special emphasis on young people in minority groups has been included. This project was initiated based on results from an initial literature review. A comprehensive literature review was then conducted using scholarly resources available through the Salem State University library databases including PubMed and WebMD. Key phrases included T2D, Adolescence and T2D interventions, T2D and obesity, and T2D and minority groups. A review of over 20 studies established that T2D is an issue due to the increasing rates in obesity as well as sedentary lifestyles and the unhealthy diets that currently exist. These issues are addressed in detail in the following sections.

**Increasing Prevalence in Type 2 Diabetes**

**History of Type 2 Diabetes**

Type 2 Diabetes (T2D) accounts for ∼90–95% of those with diabetes and primarily affects adults. It involves those with insulin resistance or who may also have relative insulin deficiency and usually have relative insulin deficiency. T2D has historically been referred to as non–insulin-dependent diabetes or adult-onset diabetes (American Diabetes Association, 2010; Danaei, Friedman, Oza, Murray, & Ezzati, 2009). T2D is not to be confused with type 1 diabetes, which is an auto immune condition. The demographic of people with T2D is not only increasing but it is changing. It is no longer a disease only seen in older individuals as it is now occurring in adolescents. Prior research on T2D in adolescents was limited due to this lower incidence.

The rise in obesity has paralleled obesity-related conditions such as hypertension, dyslipidemia, and T2D (Shaibi, Ryder, Kim, & Barraza, 2015). Although there are genetic predispositions to an individual developing T2D, there are many youths developing it with no genetic connections and an increasing number developing it at a younger age. There is a correlation between the increase in preventative diseases, especially T2D, and the climbing levels of inactivity. Diseases that were once considered adult diseases like T2D, fatty liver disease and metabolic syndrome are no longer only expected in adulthood as the prevalence of overweight and obese youth continues to rise (Lee et al., 2013). There are apparent reasons as to the increased incidence, both societally and biologically.

**Sedentary Lifestyle and Food Changes**

There are strong correlations that can be seen between obesity, Cardiovascular Disease (CVD) and T2D. Studies by Lacoppidan et al. (2015) and Tuomilehto et al. (2001) both emphasis that obesity, diet and lifestyle choices are all major factors when it comes to the development of T2D. An individual that may be categorized as overweight or obese based on their Body Mass Index (BMI), may not show classic symptoms due to other unhealthy factors which may be less prominent.

Lacoppidan et al. (2015) studied Danish men and women ages 50-64 years for a span of five years. The study examined the influence of a Nordic diet on the likelihood of developing T2D later. Their finding suggested that adhering to a regional diet is recommended for preventing T2D. Tuomilehto et al. (2001) also studied an adult population with modifications in diet and exercise. It was shown that changes in diet helped with weight reduction in turn helping with insulin resistance. After following up years later, both studies had a lesser number of participants with T2D and those individuals also remained more physically active than those in the control group, establishing that dietary changes are imperative for the control and prevention of T2D.

It is more effective to combat overweight and obesity in adolescents by focusing more on lifestyle modifications rather than emphasizing weight loss, even though it is a contributing factor. Positive health benefits can still occur through lifestyle modifications even if weight loss does not occur. If the individual remains overweight for their lifetime, implementing different health strategies can still improve upon other CVD risks like cholesterol levels, blood pressure, insulin resistance (Shaibi et al, 2012).

Colberg et al. (2010) reiterate that T2D is becoming more prevalent as physical activity levels have diminished. Further complicating the issue is that the diagnosis for T2D is often delayed, impacting interventions focused on exercise and nutrition. T2D can still be managed post diagnosis but would be much easier to control if addressed pre-onset rather than post diagnosis. Introducing exercise to any individual helps improve stroke volume and cardiac output, blood pressure, and cholesterol levels. These cardiac changes have been seen to correlate with changes in tissue metabolism and signaling which is beneficial for everyone including type 2 diabetics. (Nystoriak & Bhatnagar, 2018).

Through implementation of healthy diet regimes, exercise, excess weight loss and other self-care actions, many with T2D can control their blood glucose. Some individuals will still require insulin, but medications are not always necessary if these actions are put into place. If supplemental insulin remains necessary, it should be used in partnership with lifestyle improvements not in place of (Colberg et al., 2010). If medication is still necessary after implementing lifestyle changes, pharmaceutical strategies should be prepared to partner with lifestyle intervention and work together to solve the disease rather than treat the symptoms (Ommen et al., 2018).

**Change in Biological Advantages**

From an evolutionary standpoint, the increase in T2D makes sense as it is highly correlated with overweight or obese individuals. This is no longer an advantage to excess calorie consumption as a lack of food or foods with high fat are much less likely scenarios for human beings in industrialized countries. In a newly industrialized society, decreased levels of activity and access to energy-dense foods packed with fats, is detrimental rather than advantageous to human survival (Mccall & Raj, 2009). The human body is good at storing fat, it biologically wants to store fat when there is an abundance of it, because it is preparing for a time when fat is not readily available. Adipose tissue is beneficial because it provides energy, aids in immune and reproductive functions and sends and receives signals that coordinate energy allocation (Wells, 2012). Thought obesity is associated with many negative and harmful diseases, adipose tissue does have a purpose; just not in excessive amounts. Wells, (2012) supports Mccall & Raj, (2009) and how important it is to recognize that the increased rates of obesity and often coupling diseases are higher in industrialized populations due to increased fat intake and inactivity. Wells argues that as humans continue to take in fat at higher quantities, the body continues to store fat at high rates with no events like famine that will utilize the excess stores of fat (2012).

**Type 2 Diabetes in Adolescents and Adults**

**Adults Versus Adolescence Response to Interventions**

Research conducted using adult participants has helped pave the way for studies on mixed demographics and adolescents. There is an abundance of studies on adults with T2D or that are prediabetic, there are less on T2D in adolescence however it is now a growing field of study. Zeitler, Chou, Copeland and Geffner (2015) suggest that T2D in youth differs from adults and consequently, there is a need for more research and treatment options. Edelstein et al. (2018) posits that T2D in adolescence may be more severe and a more rapid progressive disorder than in adults. Hannon and Arslanian (2015) confirm this and add therapeutic failure rates in youth are significantly higher than in adults and decline in β cell function is much faster in youth.

A study conducted by Edelstein et al. (2018), compared 66 youth and 355 adults with IGT or who were recently diagnosed with T2D, and tested their oral glucose tolerance test (OGTT) glucose, C-peptide, and insulin responses and insulin sensitivity. Two-hour glucose fasting was similar in both adults and youth, with youth having ∼50% lower 1hr/fasting. Two-hour C-peptide and insulin concentrations were all higher in youth. Insulin sensitivity and β-cell responses had differing results between youth and adults with IGT or those recently diagnosed with T2D. Youth displayed greater C-peptide and insulin responses that exceeded what is needed to compensate for their lower insulin sensitivity. Edelstein suggests that the greater response in C-peptide and insulin response may contribute to a more rapid decline in β-cell function in youth and an acceleration of T2D in youth more than adults (2018). It was notable that an acceleration of T2D was found more in youth than adults. This indicates an even higher risk for adolescents that show prediabetic symptoms because it is more challenging to reverse than for adults. Adults and adolescents may not respond in the exact same way, however improvements in symptoms/risk factors improve in both groups with interventions.

**Type 2 Diabetes in Adolescents**

**Increasing Rates of Childhood Obesity**

The increase in T2D among youth has increased along with the number of overweight and obese adolescents. According to Davis et al. (2012) a third of elementary-age children are overweight or obese. Other than genetic factors, obesity is a huge link for development of T2D, as its prevalence has doubled over the past 20 years and will continue to do so without preventative measures (Copeland, Becker, Gottschalk, & Hale, 2005). Pediatric obesity has reached epidemic proportions in youth coupled with many other diseases and these patients are being treated with drug therapies. Although there is proven success with these therapies, they also come with side effects that do not partner with a training therapy. Adiposity accounts for 55% of the variance in insulin sensitivity in children and 80–90% of children and adults with T2D are obese (Rosenbaum et al., 2007).

Until public health trends shift in order to combat childhood obesity, health care professionals remain the personnel to treat their condition which often means drug treatment rather than being able to implement new routines (Shaibi et al., 2012). A study aimed to discover whether training in a hypoxic environment could affect training on glucose metabolism and insulin sensitivity. Fourteen obese adolescents were subjected to six weeks of either hypoxic or normoxic training, three times a week. Pre and post testing results showed that hypoxic training had a positive effect on improving glucose tolerance and decreased insulin levels during an OGTT. Other markers for obesity were also improved upon after training in both the hypoxic and normoxic groups (De Groote et al. 2018). From this study it is assumed that hypoxic training is what improved the markers from pre to post test results, however it is not necessarily determined that it was the hypoxic training that is necessary or simply any type of exercise training. Either way, improvements in insulin levels, glucose tolerance and other markers were evident.

A clinical trial conducted by Lee et al. (2013), studied 44 obese adolescent girls to determine whether aerobic exercise or resistance training was more beneficial in reducing intrahepatic lipid content and visceral fat as well as improving insulin sensitivity. Significant reduction in percent body fat was seen in both the aerobic exercise and resistance exercise groups but not in the control. This study concluded that implementation of exercise every week works on improving the weight of overweight and obese female youth as well as improving insulin sensitivity, drawing a correlation between weight and diabetic symptoms.

Another project conducted by Rosenbaum (2007), studied 73 students from New York City schools who were primarily Hispanic. They were separated into an intervention group and a control group who received the intervention after the first group had been previously studied twice in order to observe a difference in length of participation. Prior to initial testing, students and their families were reminded that the students should not eat or drink anything in the morning. Base levels of fasting glucose and insulin were measured along with other factors. Subjects were then fed breakfast and went to class. The same test was administered four months later. Interventions included classroom sessions that were 45 mins long, one day a week that talked about T2D, nutrition and diet modifications, and exercise sessions consisting of dance/non-contact kickboxing that was offered three times per week. Slight improvements were seen in both the intervention group and control group including improved BMI, % body fat, insulin and glucose levels. This study was not limited to obese adolescents because it wanted to show that improvements and health benefits could be seen in all related disease markers even if the child was at a normal weight.

**Other Related Disease Markers**

Obesity, poor diet, and physical inactivity are all issues associated with T2D, and all of which can be altered for youth and adults to decrease risk factors. According to Danaei, Friedman, Oza, Murray and Ezzati, (2009) sleep apnea is associated with visceral adiposity, reduced insulin sensitivity, cardiometabolic and T2D and by treating these factors it may decrease risk for T2D. These diseases can also be referred to as “lifestyle related diseases” because they are often treatable using similar methods (Ommen et al., 2018). There are already a few known tools that can be useful and inexpensive ways to screen people for their risk for developing T2D.

High BMI and waist circumference are known predictors of T2D and are easy to assess (Feller, Boeing, & Pischon, 2010). Kolahdooz et al. (2018). They examined youth between the ages of 11 and 23 to look at their T2D risk factors. Participants were given a questionnaire of which all answers were assigned a point value. Using the questionnaire, the participants were categorized into three groups: having two or more risk factors, being low risk, moderate, and high risk. There was no direct correlation with the likelihood of developing T2D, but all the other risk factors were highly prevalent.

When related diseases such as heart disease, high BP, high cholesterol etc. are present this does not mean the individual will automatically develop T2D; however, that individual is at much higher risk to develop the disease in the future. According to Martín-Timón, Sevillano-Collantes, Segura-Galindo, and Javier del Cañizo-Gómez (2014), patients with T2D are at much higher risk for cardiovascular morbidity and are excessively affected by CVD. This increased risk often results from factors like hypertension, dyslipidemia and obesity in these patients. Another way to avoid these related diseases or becoming diabetic is to ensure an individual has a support system to facilitate the necessary changes.

**Support from Others**

Barlow (2007), studied recommendations and prevention strategies for obese and overweight children and adolescents. After examining genetic factors, success of adherence to exercise programs, and following healthy nutrition guidelines, it was apparent that other factors were necessary to reduce health risks. Grey et. al. (2004) found that the role of the family is imperative to helping a child learn and practice healthy habits.

Grey et al.’s study focused on determining if a school could successfully implement a program to prevent T2D in at risk children. Programs were implemented at two inner-city schools for 16 weeks. Programs included and encouraged both guardians and youth to participate in the study. Two groups were studied, both groups were given nutritional and exercise education. The experimental group also received telephone support on a weekly basis. BMI, insulin resistance, dietary intake (24-Hour Food Recall), self-efficacy, activity, and parents' health promoting behaviors were used for data collection. The experimental group trended slightly lower in HbA1c and trended higher in income. Participants in the experimental group demonstrated lower glucose and insulin levels at 120 minutes and central adiposity after 12 months. HbA1c, weight, and BMI increased in both groups, but at a lower rate in the experimental group. More positive healthy choices and behavior in the experimental group were recorded, aligning with greater improvement. Coping Skills Training was also conducted which consisted of social problem solving, communication skills training, social skills training, cognitive behavior modification, and conflict resolution. This was the only differing factor between both groups and was thought to be an explanation as to why the experimental group had more improvements. Not only did the adolescents results improve, but many of the experimental groups’ parents that were involved with the study reported weight loss for themselves (Grey et al., 2004).

Soltero et al. (2018) focused on interventions that included nutrition and exercise, but the most significant factor was the involvement of families of the youth participants. An abundance of emotional support was offered, and behavior change strategies were monitored as a family as well as with monthly goals. Class sessions focused on giving the participants information as well as tools for coping strategies and developing positive body image. These coping skills were also shared with the families so that they could encourage participations positivity in the home. After a three-month intervention, youth in the intervention group exhibited significant increases in insulin sensitivity as well as reductions in BMI%, waist circumference, and percent body fat compared with controls that did not receive the same emotional support.

**Intervention Methods for Type 2 Diabetes**

**Dietary Interventions**

Creating an exercise-induced energy deficit influences insulin sensitivity. Gaitan, Weltman and Malin, (2017) state that when a caloric deficit of 6.5 kcal/kg body weight follows an acute bout of exercise, during an OGTT, a 22% lower post meal insulin incremental area under the curve (AUC) was observed, compared to an 11% decrease when expended calories were replenished. Alternating food intake to meet the needs of exercise is proven to be a beneficial way to affect insulin sensitivity. A study conducted by Gow, Baur, Johnson, Cowell, and Garnett (2016) examined eight participants who were obese and had T2D, aged 7-16. They followed a very low energy diet for eight weeks. Three of the participants were on insulin prior to start of the study. Post testing results showed 2hr glucose and HbA1c had decreased as well as liver fat. The three participants that used insulin therapy were able to stop use due to the positive impact of the very low energy diet. The population size for the study was quite small and would be more informative had it had more participants, but it still had significant findings. Rosenbaum et al. (2007) also included nutrition education in sessions 3-8 encouraging modifications that lowered dietary fat (especially saturated fat), sweetened sodas and juices, and fast food.

Ommen et al. (2018) examined multiple dietary interventions supporting caloric restriction as well as intermittent fasting. In both diabetic and non-diabetic patients, fasting along with caloric restriction has been effective in improving insulin resistance weight loss and decreased CVD. There are different types of fasting regimes, ex. 24hr or daily intermittent, however it is likely a much harder task to fulfill, even more so than creating daily caloric deficit. Ommen concluded that at minimum, limiting sugars and starches from the diet may reduce and sometimes eliminate the need for glucose control medication (2018).

Larson- Meyer et al. (2006) studied 48 overweight individuals and placed them into four groups; the control, 25% calorie restriction (CR), 12.5% calorie restriction +12.5% energy expenditure through structured exercise (CREX), and 15% weight loss by a low-calorie diet (LCD). The study aimed to determine the effect of calorie restriction on insulin sensitivity, β-cell function, fat cell size, and ectopic lipid in overweight subjects with or without exercise. It is significant to note that insulin sensitivity improved in all groups except for the control. The most significant change was seen in the CREX and LCD groups. The authors concluded that ensuring proper caloric intake daily is important in maintaining and controlling factors that influence and promote T2D, especially to ensure a balance between intake and output.

**Benefits of Cardio Respiratory Exercise**

Exercise is a vital treatment for dealing with T2D. During exercise muscles use the glucose in the blood and insulin is not needed to complete this process. Danaei, Friedman, Oza, Murray, and Ezzati (2009) state that “cardiorespiratory fitness is directly associated with insulin sensitivity, and supervised exercise intervention in obese nondiabetic youth improves insulin sensitivity, even in the absence of weight loss.” Another study established that most, if not all, processes involved in insulin resistance are reversible if the right interventions are put in place. Introducing resistance training and by maintaining a low-glycemic index diet, muscle insulin resistance can be treated (Ommen et al., 2018).

As stated by Ommen et al. (2018) the causes for T2D can be placed into the following categories: “wrong diet, too little physical exercise, disrupted sleep, and too much stress”. All of which have nothing to do with needing a prescription to cure them. An experimental training program can show positive results toward improving insulin resistance and many other variables, but the programs needs to be able to be maintained. If programs are not maintained, long-term test results will be unlikely to have anyt health benefits. The best way to combat T2D is combining tools of exercise along with stress management and sleeping habits. Ommen et al. (2018) established that T2D is a reversible disease if diet and physical activity are adjusted and there is a better understanding of the disease itself.

Davis et. al. (2012) conducted a randomized clinical trial showed that monitored aerobic exercise training reduced diabetes risk (i.e., insulin resistance) and other CVD risks in children that were sedentary, overweight and obese, including 28% of those who were prediabetic. Davis et al. (2012) observed 222 overweight/obese sedentary children who were randomly selected from schools in Georgia. Out of these 222 participants, 85% were obese and 28% prediabetic. Children were put into three different groups, low-dose (20 min/d), high-dose (40 min/d) aerobic training or the control group, which was usual physical activity, all for 10-15 weeks. Intensity of exercise was the same, only the duration of exercise differed. All families involved in the study were given health education classes focusing on physical activity, healthy diets and stress management. A reduction in insulin AUC was larger in the high-dose group than the low-dose group and more than the control group. The improvements were relatively consistent throughout race or sex. Beta cell function only seemed to improve with higher duration exercise, even though the level of insulin resistance was relatively similar between the high and low dose. Oral Glucose Tolerance Test was used to attain baseline and posttest measurements. There was a greater change between baseline and posttest in results for the high-dose group. There was not a lot of difference between high and lowdose groups, but both were significantly higher than the control. Implementing an exercise program is one intervention proven to aid an individual’s health, but there are other strategies and ways to measure a person’s health (Davis et al., 2012). An appropriate BMI is typically equated with being healthy; which is accurate for the most part, however, a person’s health can improve drastically through exercise even if their weight does not change much.

According to Sénéchal et al. (2015) regular physical activity is the foundation in preventing T2D in adults and youth. Chronic endurance training works as a protection against T2D due to promoting a reduction in adiposity. Their study considered whether changes in cardiorespiratory fitness were linked to metabolic response to endurance training in at risk adolescents. Over the course of a six-month intervention, 73 overweight and obese adolescents took part in an endurance exercise program. Participants were able to choose their modality of exercise during their three-sessions per week which lasted 30-45 minutes at a moderate or vigorous intensity. Exercise duration was adjusted in order to meet 350kcal expenditure per session. Reductions in BMI, visceral adiposity and hepatic triglyceride content were seen in all groups, especially those working at a higher intensity. The decrease in hepatic triglycerides is a benefit in relation to diabetes and other disease like fatty liver disease because there is typically a large production of hepatic triglycerides in type 2 diabetics while insulin fails to suppress blood sugar production.

Jhingan (2017), looked at young adults, ages 18-40, with T2D over the course of six months and tested glycosylated hemoglobin (HbA1c), blood pressure (BP) and weight prior to intervention and post intervention. Participants were told to cycle 25km/day at least five days a week. HbAlc% at baseline was 9.14±0.27 and after the program was 7.96±0.19, weight also decreased significantly. The groups were divided into two with one being ages 18-35 and the other ages 35-40. There was improvement in both groups, with significant findings related to the impact and correlation cycling training had on HbAlc along with BP and weight.

As indicated in the previous study by Lee et al. (2013) in which he observed three groups; aerobic exercise, resistance training and a control which was no exercise over a three-month trial of 180min of exercise per week, he found no significant changes in fasting glucose production and hepatic insulin sensitivity as compared with controls, however peripheral insulin sensitivity improved dramatically in the aerobic exercise group. A significant finding, because this is often a precursor to development of T2D.

**Conclusion**

In recent years, clinical studies have emphasized the increased prevalence of T2D. There are strong indications as to why the number of cases and the demographics of who T2D affects has changed; these include increased sedentary lifestyles, poor nutrition and increased rates of childhood obesity.

There are multiple interventions that can be put in place to correct these issues. Improvements in insulin sensitivity, beta cell function, glycosylated hemoglobin, weight and glucose levels are all important factors to assess in order to determine whether a program positively or negatively impacts body function. Programs aimed at reducing risks focus on “lifestyle interventions” including diet, exercise or the combination of the two.

 There is evidence that suggests that both the duration of the intervention as well as intensity of exercise are important in reducing T2D risk. Additionally, the longer a program is monitored, the more likely the adherence to the lifestyle. Any intervention element that aids in creating a caloric deficit and maintaining a diet that has less fat than calories being burned is an important tool in controlling adiposity and glucose levels.

As a result of this review it is apparent that adjustments in lifestyle are key to creating physiological changes, and that these interventions should be put into place at a young age to positively improve upon the risks associated with the development of T2D.

**Implications**

More research into prevalence of T2D in the youth population needs to exist. Although there is substantial literature related to adults, more studies need to be conducted which focus on adolescents, as young people do not respond to treatments in the same way adults do. Adolescent T2D, especially among minorities, will continue to be an issue so long as obesity rates and levels of inactivity do not improve. Based on this literature review there is evidence that interventions work. Without interventions more people will suffer from T2D which will put a strain on health care, the economy, and general quality of life. Additional research focused on adolescents, especially minorities, and the risks associated with obesity and T2D needs to be conducted and interventions known to be effective should be implemented.

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