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# Glycemic Control in a Type I Diabetic Athlete: Recommendations for Athletic Trainers in Management, Athlete Care, and Performance

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GLYCEMIC CONTROL IN A TYPE I DIABETIC ATHLETE: RECOMMENDATIONS FOR  
ATHLETIC TRAINERS IN MANAGEMENT, ATHLETE CARE, AND PERFORMANCE

by

Megan E. Whyte

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University of the Pacific  
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## DEDICATION

This manuscript is dedicated to my parents, Buck and Melanie, who have unconditionally supported me through this journey. Not only did you support my decision to move across the country, but you also decided to make the drive with me and the contents of my entire apartment. I will never be able to thank you enough for everything that you have done for me for the past 25 years. Of course, I can't forget about my Uncle Dorm, as he has supported me just as unconditionally as my parents.

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# GLYCEMIC CONTROL IN A TYPE I DIABETIC ATHLETE: RECOMMENDATIONS FOR ATHLETIC TRAINERS IN MANAGEMENT, ATHLETE CARE, AND PERFORMANCE

## Abstract

by Megan E. Whyte

University of the Pacific  
2019

Type I diabetes in athletes is a relatively rare condition and as a certified athletic trainer it is critical to know how to manage all aspects of this disease in an athlete. Current National Athletic Trainers' Association (NATA) guidelines exist for developing a basic plan for management and care of an athlete with Type I Diabetes, but there is room to improve current guidelines, using evidence-based practice. Purpose: to address: medical management of a type I diabetic athlete as a case study, obtain first person observations from the athlete's perspective, and provide additional evidence based practice recommendations to athletic trainers based on the findings. Methods: case study narrative with one subject, a 22-year-old male collegiate soccer player was performed. Data were collected via open-ended questionnaire, open-ended interview, and subject's submission of pertinent medical information and records. Results: The NATA Position Statement on Type I Diabetes and other peer review articles informed this study. While NATA guidelines created a good general baseline for how to approach providing diabetic athlete care; additional recommendations are suggested based on the findings of this case study. These recommendations include: Creating safe pre-participation blood glucose ranges to prevent hypoglycemia during exercise, establishing greater knowledge about the technology the patient uses, what medical supplies the patient should be responsible for versus the athletic trainer, developing a relationship with the patient's endocrinologist or primary care physician, and

administration of insulin by an athletic trainer. These additional suggested recommendations inform athletic trainers to attain a better understanding of how to manage and care for a patient with Type I Diabetes, and increase the likelihood of both streamlining patient care and preventing metabolic crisis.

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## **Chapter 1: Introduction**

### **Diabetes**

Type 1 diabetes, or insulin-dependent diabetes mellitus (IDDM), is caused by the inability of the pancreas to produce sufficient levels of the hormone insulin, which helps regulate blood glucose levels. Insulin is released by the beta cells of the pancreas into the blood stream when glucose levels go up, such as after eating. Insulin helps glucose enter the body's cells where glucose can be used for energy or stored for future use. With type I diabetes the beta cells of the pancreas do not or cannot respond normally to produce insulin when glucose is present. This pancreatic impairment results in an abnormal metabolism of carbohydrates, which leads to elevated levels of glucose in the blood. Thus, exogenous insulin therapy is necessary to prevent hyperglycemia, or high blood sugar. Insulin deficiency often becomes symptomatic in children between the ages of 9 and 16 and is a life-long disease with no known cure. Type 1 diabetes is less common than type 2, or non-insulin dependent diabetes mellitus (NIDDM), with only 5-10% of all diabetes cases being type 1. While the cause of the disease is not fully understood, one main factor involves an autoimmune destruction of the beta cells in the pancreas that result in the marked and progressive inability of the pancreas to secrete insulin. While there is no cure for type 1 diabetes, it is manageable with insulin therapy (Fahey, Stallkamp, & Kwatra, 1996).

### **Purpose of Study**

The current case study examines glycemic control, eating and exercise habits to provide more complete and specific recommendations for athletic trainers dealing with type I diabetic athletes based on current NATA recommendations.

**Limitations**

Limitations of this study include:

1. This was a case study based on one subject who is male; females may have additional gender specific concerns to consider/address.
2. The subject is a post-pubescent male.
3. This study involved a highly aerobic athlete and recommendations might differ for other types of athletes, based on primary mode of exercise/metabolic pathway used.
4. The data collected observes only one season and one off-season, thus no year to year comparison is possible.
5. This study was not trying to figure out how to attain glycemic control as the subject had already established good glycemic control.

**Delimitations**

Delimitations of the study include:

1. Limited period of time to collect data
2. Only one diabetic athlete in the university athlete population, during the limited time period to collect data.

## Chapter 2: Review of Literature

### History

**1900-1939.** Insulin was discovered in 1910 by Sir Edward Albert Sharpey-Schafer, an English physiologist who was studying the pancreas. Six years later, Elliot Joslin MD published the first edition of *The Treatment of Diabetes Mellitus*. In 1921 Frederick Banting, MD, and his student assistant Charles Best, MD, were able to successfully extract insulin from dog pancreases and inject it into dogs whose pancreases had been removed. Banting and Best observed a reduction in blood sugar levels in dogs without pancreases, making this the first successful insulin transplant experiment. This insulin extract was purified so it could be used in humans and two years later, in 1923, Eli Lilly and Co. began commercial production of insulin. Banting and J. J. R. Macleod were awarded the 1923 Nobel Prize in Physiology or Medicine, but the contributions of Best and James Collip have also been acknowledged as crucial in the discovery of insulin. Due to the work of Eli Lilly and Co. manufacturers were able to produce slower-acting insulins over the next few years, and in 1936 Novo Nordisk developed protamine insulin. This was monumental as slower acting insulin allows for a slower decrease in the blood sugar levels preventing the “crash” most experience after eating a high carbohydrate meal (Association, 2018).

**1940-1947.** In 1940 The American Diabetes Association was founded to help combat the increasing amount of cases of diabetes and to address the comorbidities that develop due to the disease. In 1949 it was discovered that insulin works like a key to transport glucose into the cells when glucose levels in the blood are too high. Until 1959 there were no real classifications of diabetes, but radioimmunoassay technology uncovered that a percentage of the population with diabetes was still able to produce their own insulin. This led to the identification of IDDM and

NIDDM. In 1961, 38 years after commercializing production of insulin, Eli Lilly and Co. began producing glucagon, a hormone whose main function is to raise blood sugar levels, as a treatment for severely low blood sugar levels. Having a readily available form of glucagon via injection could potentially assist in reducing hospitalizations from hypoglycemia. As medical procedures continued to advance, the first successful pancreas transplant was performed at the University of Minnesota Hospital in 1966. Insulin receptors on the cell surface were discovered in 1971 but were not identified as GLUT-4 receptors until 1989. In 1972 the relationship between blood vessel disease and hyperglycemia is reported which established correlation between chronic hyperglycemia and comorbidities of diabetes. In the last few years of the 1970's, a test was developed to measure glycosylated hemoglobin (HbA1C) which became the gold standard for measuring long-term diabetes glycemic control, and the National Diabetes Data Group develops a new classification system. The new classifications were insulin-dependent, non-insulin dependent, gestational diabetes, and diabetes associated with other syndromes or conditions (Association, 2018).

**1980-PRESENT.** In 1983 a link was discovered between hypoglycemia and brain metabolism. Then in 1984 the insulin molecule was identified to be the target of the autoimmune response in individuals with type I diabetes. Along with the identification of insulin as a target of the immune system, the glutamate decarboxylase (GAD) protein was also later identified to trigger a progressive autoimmune response that leads to diabetes. In 1989 the American Diabetes Association published its first standards of care to help guide physicians through the treatment of diabetes. The early 1990's brought about significant changes to the way diabetes was managed. In 1993, the Diabetes Control and Complications Trial (DCCT) showed that regulating blood glucose levels, and keeping them within the normal ranges as much as

possible, resulted in a smaller likelihood of the onset and progression of eye, kidney, and nerve diseases caused by diabetes. The trial also helped show that any long-term normalization of blood glucose helps reduce the chance of the onset of the comorbidities, even if the patient has a history of poor glucose regulation. In 1997 the fasting glucose level for diagnosing diabetes was lowered from 140 mg/dL to 126 mg/dL which goes along with the results of the DCCT. In the early 2000's the American Diabetes Association created a definition for prediabetes using impaired fasting glucose (IFG) defined as fasting blood glucose of 100-125 mg/dL, and/or impaired glucose tolerance (IGT) defined as a glucose level of 140-199 mg/dL two hours after drinking a large bolus of glucose. Another marker added to inclusion for prediabetes was an HbA1C level of 5.7%-6.4% (Association, 2018).

### **Technology**

In 1949, Becton Dickinson and Co. also began production of standardized insulin syringes based on designs from the American Diabetes Association. The next big breakthrough in diabetes care came in 1953, when tablets and test strips for urine testing became widely available. This breakthrough was important as testing for glucose in the urine allowed for early identification of kidney damage, which often does not show symptoms until damage is significant and often irreversible. As technology progressed, testing strips not only became more readily available, but also in 1964 strips were introduced that allowed diabetic patients to test blood glucose levels by comparing the color spot on a blood glucose test strip with standardized color blocks. This helped patients understand glycemic control ranges more accurately (Association, 2018). Technology advanced again with the introduction of the first glucose meter by the Ames Company in 1970, called the Ames Reflectance Meter. This meter consisted of a needle that “indicated the intensity of blue light reflected from a paper strip.” The meter then

gave a number that correlated to the glucose levels in the blood the paper strip was exposed to. This first meter weighed about three pounds and was originally marketed to physicians and not patients (Aleppo, 2018). It wasn't until Richard Bernstein acquired a machine and used it to map out the daily fluctuations in his blood glucose levels that companies began to realize patients could use this technology to better monitor their own blood glucose levels. As glucose monitors continued to evolve, the Biostator was developed in 1974, creating the first closed loop insulin infusion, enabling the production of continuous glucose monitors (Association, 2018). The Biostator works by having a small amount of venous blood continuously flowing through the machine which can analyze the blood glucose concentration (Continuous Glucose Monitoring | NIDDK, 2018). The Biostator feedback system was also able to note the amount of insulin or dextrose required to normalize the blood glucose concentration. The Biostator system was a giant leap forward in allowing a patient to go about their normal daily routine while on the machine which allowed for better planning and creating individualized medical regimes for type I diabetics. Although the first insulin pump was technically created in 1963 by Dr. Arnold Kadish, these devices were incredibly large and were designed to be worn as a backpack which made them quite impractical. It wasn't until 1976 that a smaller, more wearable device was created, and in 1978 portable insulin pumps were introduced to the market. In 1980 the concept of basal-bolus insulin was introduced and allowed for "intensive insulin therapy" to be used in the clinic as a treatment for type I diabetes (Association, 2018).

## **Management**

Management of type 1 diabetes is possible through administering insulin shots, using an insulin pump, checking blood glucose levels often throughout the day, following a healthy and balanced diet, and exercising regularly (Fahey, Stallkamp, & Kwatra, 1996). As technology



advances, it is becoming increasingly more common to see a type 1 diabetic use an insulin pump to control the flow of insulin. An insulin pump is a machine that will deliver insulin to the wearer as it is programmed with variable potential settings depending on the method of delivery desired. Insulin can be delivered via a “drip feed” which is a continuous injection throughout the day, but the pump can also deliver a large dose or bolus, when needed (Aleppo, 2018). Along with an insulin pump, most type 1 diabetics will also have some form of continuous glucose monitor that can be included as a component of an insulin pump or may be a completely separate device. A continuous glucose monitor is a small device attached to the abdomen or upper arm that measures then wirelessly sends the glucose readings to a monitor, which can be as simple as an app on your smartphone (Continuous Glucose Monitoring | NIDDK, 2018). The clear goal of managing diabetes in an athlete is avoiding hypo- and hyperglycemic episodes during and after activity. It is imperative that the athletic trainer discuss a management plan with their athlete, and check in with this athlete before and after each practice; including but not limited to weight lifting, practice, games, and conditioning. Although the American Diabetes Association recommends an ideal range for blood glucose levels, it is important to speak with the individual athlete and determine the ideal range that their endocrinologist has provided them (Brooks, Fahey, White, & Baldwin, 2000).

### **Exercise and Diabetes**

Exercise is a healthy part of management of type 1 diabetes; however, exercise affects insulin levels and it increases the risk of hypoglycemia. Skeletal muscle helps with glycemic control and metabolic homeostasis and is where glucose is predominantly stored when insulin is active. Non-insulin dependent glucose uptake (NIDGU) is the main way skeletal muscle helps with glycemic control and is the uptake of glucose by cells when insulin is not present, primarily

when muscle contracts. Muscles utilize glucose as the main source of fuel during the beginning stages of exercise. Exercise increases the ability of GLUT-4 receptors to translocate to the cell surface allowing glucose to flow into the cell. This increased translocation continues even after exercise has ended, and exercise also increases the number of GLUT-4 receptors that are present in the skeletal muscle cells. Exercise additionally increases the amount of skeletal muscle. An increased presence of GLUT-4 receptors and their activity due to the aforementioned effects of exercise allows for better uptake of glucose by the cells, thus reducing the amount of insulin required. Given that there is a high rate of ATP turnover during muscle contraction, exercise increases AMPK phosphorylation and enzymatic activity in an intensity-dependent manner. As soccer is a relatively high intensity activity, glucose is the main source of fuel and will be derived from hepatic glucose production or muscle glycogenolysis. In skeletal muscle, acute AMPK activation suppresses glycogen and protein synthesis but promotes glucose transport and lipid metabolism. As muscle glycogen is depleted, a balance develops between glucose production and glucose uptake by exercising muscle. This causes insulin secretion to decrease as muscle glucose uptake increases due to exercise stimulating (rather than insulin stimulating) the translocation of GLUT-4 receptors to the cell surface. A slight increase in catecholamines combined with the decrease of insulin promotes lipolysis in exercise, permitting the use of free fatty acids as fuel and later gluconeogenesis. Once exercise stops, insulin levels rapidly increase in response to high blood glucose levels and removal of circulating catecholamines. This results in hyperglycemia and hyperinsulinemia combining to create ideal homeostatic metabolic conditions for the replenishment of muscle glycogen (Brooks, Fahey, White, & Baldwin, 2000).

## **Glycemic Disorders**

The increase in glucose uptake during exercise creates an issue for an athletic trainer providing care for a type 1 diabetic athlete. When athletes exercise, the physical activity lowers blood glucose levels as the muscles are using stores of glycogen as fuel. As the glycogen stores are depleted blood glucose will naturally drop, meaning the athlete will need to increase their glucose levels before or potentially even during exercise, so that they don't fall into a hypoglycemic state. If blood glucose falls below 70 mg/dL the person is considered hypoglycemic. When blood glucose levels get this low, signs and symptoms such as tachycardia, sweating, palpitations, hunger, nervousness, headache, trembling, and dizziness can occur. If blood glucose levels continue to fall and get below 54 mg/dL, immediate medical intervention is required. At this level signs and symptoms will include blurred vision, fatigue, difficulty thinking, loss of motor control, aggressive behavior, seizures, convulsions and loss of consciousness which can eventually lead to a diabetic coma. Glycemic control during exercise is more problematic for a diabetic athlete as they are out on a playing field and do not always have access to high glycolytic sources to keep their glucose levels stable (Kirk, 2009). On the opposite side of the spectrum, though it is rare, if an athlete's blood glucose levels are too high before beginning exercise, there is a potential that an even higher spike may occur, leading to hyperglycemia (Jimenez, et al., 2007). If one is in a state of hyperglycemia for an extended period of time, negative side effects such as: cardiovascular disease, nerve damage, kidney damage, eye damage, and skin conditions can occur. A person is considered hyperglycemic when blood glucose levels reach 250 mg/dL or higher. If blood glucose levels continue to rise and get above 300 mg/dL ketoacidosis begins to occur. The patient can experience excessive thirst, frequent urination, nausea and vomiting, abdominal pain, weakness or fatigue, shortness of

breath, fruity-scented breath, and confusion. Consequently, a majority of the symptoms of ketoacidosis are what is used to make the diagnosis of diabetes. The patient will most likely present to the emergency room with many of these symptoms leading practitioners to test blood glucose levels as well as take a urine sample to test for high ketone levels in the urine. The normal ranges for blood glucose levels range from 90 to 140mg/dL, but this range will vary from person to person depending on a multitude of factors including age, gender, activity level, and any comorbidities they may have (Medicine, 2001).

### **Why Is This Important?**

There are some questions that athletic trainers may not even know to ask their diabetic athlete. Outside of using resources such as the “National Athletic Trainers’ Association Position Statement: Management of the Athlete With Type 1 Diabetes Mellitus” it is still important to know how pancreas function is impaired, how blood glucose levels change with exercise and factors such as illness, fatigue, sleep disturbances, stress, etc., questions to discuss with the athlete, and ways to help limit episodes of hypo- and hyperglycemia.

### Chapter 3: Methodology

The methods of this study were approved by the institutional review board of The University of the Pacific. Prior to participation, the subject completed and signed an informed consent form. The sample population of this study was an undergraduate male soccer player with type I diabetes. Participant was selected based on the criteria of being a collegiate athlete with type I diabetes.

Data were collected through interviews with the participant where his journey with diabetes was discussed and daily normative values were reviewed. All data provided by the subject were blinded of all identifying information and kept in a locked cabinet behind a locked door, and/or in a password protected computer.

The subject was selected out of convenience. There was a pre-established professional relationship between the lead researcher and the subject. The lead researcher was the certified athletic trainer for the subject and therefore developed a professional medical relationship with the subject. Information was gathered through a semi-structured interview with medical follow-up. Primarily an interview was conducted, but medical information in collaboration with the subject was also gathered. Pertinent information also included output data from his CGM and any pertinent laboratory data such as HbA1C.

All information gathered through the interview and any accompanying medical information aided in getting a full history of the patient, his condition, and his journey through life with diabetes. The researcher was also interested in his experiences and his personal management techniques and evaluated how successful he has been based on his glucose levels and HbA1C. This information was combined with current literature to create guidelines for athletic trainers to use when they encounter an athlete with type I diabetes.

The following interview questions were asked of the subject to help guide the discussion:

1. When did you find out you have diabetes?
2. How did you find out?
3. How did you learn how to manage your diabetes? (did someone teach you or give you techniques, did you learn to read your body's signals, etc.)
  - a. How long have you had your insulin pump?
  - b. How long have you been using a continuous glucose monitor?
4. How long have you been an athlete?
5. Tell me about your dietary habits.
6. How do you stay physically active when not playing soccer?
7. Any other pertinent medical information?
  - a. History of any severe illness?
8. What is your perspective on being a *person* with diabetes?
9. What is your perspective on being an *athlete* with diabetes?

## Chapter 4: Results

### Subject Demographics

A 22-year-old male, type I diabetic, collegiate soccer player who was 72 inches tall and weighed 175 pounds participate in the case study. His HgA1C was 6.1 at the time of the study, body composition of 9.08% body fat using both hydrostatic weighing and skinfold calipers, and a  $VO_2$ max of 58mL/kg/min. With the results from his  $VO_2$ max testing, the subject falls into the category of “good”. There is only one category above this, that being “excellent” (Medicine, 2001). This result is to be expected of a high-level athlete and helps show the level of physical fitness of the subject. The subject has been playing soccer since he was a child and began playing competitively in the fourth grade. When not playing soccer, he remains physically active by going to the gym for cardio and weightlifting. He states that maintaining a relatively consistent exercise schedule is helpful for maintaining glycemic control, and missing as little as three days of exercise means he will have to adjust his basal insulin rates and carb-to-insulin ratios (Personal Interview with Subject, 2019).

### Subject History

The subject was diagnosed at age 12 in seventh grade, about ten years ago. Subject states that he felt constantly thirsty, became very lethargic and was always tired although he did not have any severe illnesses before his diagnosis. He began to have a burning sensation in the back of his throat which he now attributes to being in ketoacidosis. He began to lose a lot of weight and this is when his family began to notice the changes. His uncle is a type I diabetic, and his grandfather is a physician, and they both noticed the symptoms and decided to test his blood glucose levels. The machine couldn't read his actual blood sugar and just came back with a result of “600+”, and when his sugar was tested again in the hospital it read over 800 mg/dL. He was hospitalized for a week after his diagnosis where his blood glucose was brought down into

the normal range of about 120 mg/dL and his ketones and diabetic ketoacidosis symptoms were eliminated. During this time, he was also educated on what exactly diabetes is, how to count carbs, warning signs of hypo- and hyperglycemia, how blood glucose levels may vary with exercise and many more topics. He was also taught how management of diabetes varies from person to person and will take time, experience, and practice to get better.

### **Patient Introduction to Management**

After the first year of learning to manage his carbohydrate intake and insulin usage, the subject was given an insulin pump. He was told to wait at least a year because his doctor preferred he not rely too heavily on a pump and learn to manage diabetes first and the pump second. In the early years of a diagnosis it is important for the patients to understand their own insulin to carbohydrate ratios and how they may need to adjust throughout the course of a day. The subject also admitted being “a little scared” of the pump in the beginning “because having something like a little needle attached to me all the time seemed a little intimidating” (Personal Interview with Subject, 2019). However, after he made the switch from the insulin pens to the pump, he states he liked the pump more even though it took some time to adjust. Five years prior to this case study, the subject got his first continuous glucose monitor (CGM) and admits he was intimidated by the CGM at first too. He states there was a large adjustment period, although he does not remember the exact amount of time, as the CGM was uncomfortable, fell off a lot, and it was not as accurate as he would have liked so he ultimately stopped using it for about a year. After the CGM was redesigned and a new model was introduced, he tried it again and has continually used one.

### **Patient Perspective**

When asked about how he views himself as a person with type I diabetes the subject stated,



“My diabetes is something that I have completely accepted and embrace about myself. I credit it with teaching me to push myself and not let anything stop me from what I want to accomplish. This I learned from persevering and continuing to play sports and even making it to the D1 level despite being a type one diabetic. I am very outward about having diabetes and even identify myself with the caduceus symbol since I wear the T1D alert bracelet on my wrist and carry that sign with me everywhere I go” (Personal Interview with Subject, 2019).

When asked about how he views himself as an athlete with type I diabetes the subject stated,

“I see myself as an opportunity to be a sort of inspiration to people. I know that while I see diabetes as a huge learning opportunity, others see it as an impassible obstacle. I want to show others that although diabetes is a challenge that one will have to carry with them for every second of the rest of their lives, they can still accomplish whatever they want to. There are many people that struggle with T1D; whether it be shortly following a diagnosis, years after it, or intermittently throughout life, I think T1D is something that people need help and support with” (Personal Interview with Subject, 2019).

### **Data Collection**

Output data were collected from the subjects CGM and insulin pump over a 10-day period in season, and another 10-day period during the off-season. The data included blood glucose levels measured every five minutes over a 24-hour period, manual finger sticks taken throughout the day, carbohydrates entered into the insulin pump, and any insulin boluses given. The CGM automatically generates a graph of the blood glucose levels, and the manual finger sticks were recorded and also used to create a graph. The implications for output data and graphs are discussed below, and the graphs are in Appendix A.

## Chapter 5: Discussion

### Blood Glucose

After reviewing the subject's output data from his continuous glucose monitor, insulin pump, and daily finger sticks, daily trends in blood glucose levels were readily identifiable. According to the subject, his endocrinologist wanted his blood glucose levels to remain in the range of 70-120mg/dL, and his HbA1C to fall between 6.0 and 6.5. A normal range for HgA1C is 4.0-5.6, with 5.7-6.4 showing a higher chance of getting diabetes, and finally 6.5 and higher showing the patient has diabetes (Brooks, Fahey, White, & Baldwin, 2000). The subject has a low HbA1C for a patient with diabetes, at only 6.1, which goes to show how well he manages his disease.

While in season, the subject consistently had an average blood glucose level that fell in the range of 80-150mg/dL according to the manual blood glucose readings he took each day. However, when looking at his continuous glucose monitor output, it is observed that he had multiple times where he fell below 70mg/dL, even getting as low as 40 mg/dL. He also consistently had high blood glucose levels, between 150mg/dL and 250 mg/dL, around seven a.m., two p.m., and ten p.m. These spikes are not unexpected as they occurred after he had eaten and administered his insulin but was still waiting for the insulin to take effect. His multiple 8-15 daily manual blood glucose finger sticks showed very widespread and inconsistent values because these data points present only a partial picture of what his levels are throughout the course of a day. The finger stick data, unlike CGM data, do not tell you if the blood glucose value is rising or falling, which is an important piece of information relevant to appropriate medical management of the diabetic.

During the off-season he consistently had blood glucose levels in the range of 80-130mg/dL. He consistently had high blood glucose levels around seven AM and nine PM which

occur after he has eaten breakfast or dinner. Although his finger sticks showed more regularity and consistency throughout the day, as compared to finger stick data from the in-season collection period, this is the opposite of what the data from his continuous glucose monitor showed. There are multiple days where his blood glucose levels were above 300 mg/dL, even exceeding 400 mg/dL at one point, which was not demonstrated by the finger sticks. There were also multiple days where his blood glucose levels fall below 60 mg/dL, even reaching as low as 40 mg/dL. The outputs generated by the continuous glucose monitor are important to have, understand, and utilize, as they show the complete and timely picture of what the diabetic goes through during the course of a day. The use of the CGM also allows for the identification of circadian trends, which will vary patient to patient. Without the information available from the CGM, the data suggests that the subject has more consistent glycemic control out of season than in-season, however this is backwards (see Appendix A). The graphs generated from the CGM data are important for the athletic trainer to utilize and understand as they give a complete picture of how an athlete is truly managing their glucose levels. Rather than just assessing average glucose values at designated times, or looking at a scatter plot of isolated glucose values, seeing all of the peaks and valleys on the graph provides context and vastly more useful and actionable data for the athletic trainer. Additionally, providing the slopes of the increases and decreases in blood glucose values demonstrates the rate of the glucose shifts for the athlete, which is a critical safety factor for the athlete. Appropriate use and understanding of the CGM data lets the athletic trainer understand what the normal for their athlete is and allows the athletic trainer to identify why their patient may be having an issue one day, based on objective data as opposed to a guess. If an athlete comes to the athletic trainer stating s/he is feeling sick or lethargic, the athletic trainer can use the CGM graph to help make an appropriate differential diagnosis determining if

the athlete is acutely ill, having an acute glycemic issue, is tired from the amount of school work and athletic activity they have been doing, or any combination thereof.

During the out-of-season assessment period, when the subject's blood glucose exceeded 400mg/dL, he admitted that he had been drinking alcohol that night and clearly did not manage his blood glucose as well as he usually does. However, events like this are not uncommon with a type I diabetic and can be attributed to factors like: eating cake, ice cream, or cake and ice cream, or acute illness or stresses. Diabetics are people too, and sometimes being responsible about glycemic management takes a back seat to living in the moment and enjoying one's life. While in-season the subject was stricter with his diet and the team as a whole observes a "dry season" policy where no alcohol may be consumed. He states that he was completely compliant with dry season but he allowed himself to "be a college student in the off season" (Personal Interview with Subject, 2019).

### **Additional Recommendations**

Current guidelines for athletic trainers are established but are general, and they typically require the athletic trainer to do extensive additional research and planning on their own. Accepted management currently includes developing a diabetes care plan for practices and games with the athlete. This can include but is not limited to, monitoring blood glucose levels, insulin therapy guidelines, a list of any and all other medications taken, guidelines for hypoglycemia recognition and treatment, guidelines for hyperglycemia recognition and treatment, and emergency contact information. Noticeably absent from the guidelines are recommendations to: discuss with the endocrinologist or primary physician the treatment plan of care, learning the method of insulin delivery including both hardware and software, if the patient uses a pump, and other co-morbidities and health challenges. When monitoring blood glucose

levels, it is important to determine frequency of testing, and appropriate pre-exercise levels and values and what to do if the athlete is outside of those ranges. The guidelines do not give recommendations on the number of blood glucose checks per day, so this must be established with the athlete at the beginning of the season. The subject in this study was exceedingly compliant and performed manual checks between eight and fifteen times per day and this still gave an incomplete picture of how his blood glucose was managed.

The insulin therapy guidelines created need to include the type of insulin used, dosages for your athlete, any adjustment strategies for planned activity types, and insulin correction dosages for high blood glucose levels. What the current guidelines don't include is what an inappropriate blood glucose level pre-exercise is, and what to do to combat an abnormal value when it does occur. It should be recommended that the athlete not be allowed to participate if their blood glucose remains below 100 mg/dL 30 minutes before participation despite food intake, unless demonstrated that blood glucose is rising according to CGM data. As blood glucose levels fall during the initial stages of exercise, the athlete's blood glucose may fall too low and s/he will need to eat or drink a high glycolytic item and remove themselves from play for the day. It is important to note here, that a majority of the current research recommends athletic trainers not provide an athlete with insulin; it should only be administered by the athlete or a medical doctor who has training to deal with diabetic patients. However, if the athletic trainer has met with the athlete's endocrinologist, and is trained on how to properly administer insulin in an emergency scenario, then it should be recommended that the athletic trainer have the ability to administer insulin in an emergency situation when the athlete is unable to administer it themselves. This will entail the athletic trainer knowing how to check data on a pump if the athlete uses a pump, manually testing the blood glucose through finger stick if there

is no pump, learning how to measure out units of insulin if manually injecting, where to administer that insulin, or learning how to administer a bolus of insulin on a pump, and determining the correct bolus to administer if it has to be calculated (an insulin pump will typically recommend a specific bolus to deliver, but it needs to be calculated for a patient that isn't utilizing a pump). Having the athletic trainer deliver the medically necessary insulin in times of hyperglycemic crisis will reduce the amount of time the athlete spends in the hyperglycemic episode, instead of waiting for emergency medical services to arrive, transport the patient to an emergency department, triage, and finally administer insulin treatment. Working with the athlete's endocrinologist while determining the appropriate plan of care allows for safe execution of insulin administration in an effort to quickly lower the blood glucose while minimizing the risk of sending the athlete into a hypoglycemic episode.

Guidelines for recognition and treatment of hypo- and hyperglycemia must include prevention, signs and symptoms, treatment, use of glucagon for hypoglycemia, and treatment for ketosis with hyperglycemia. These guidelines should be thorough, but simple enough for anyone to understand in an emergency. Emergency contact information should include parent/guardian phone numbers and a copy of written consent for medical treatment if required when dealing with minors. It is also crucial that the athlete ensure they have a medical alert tag on their person at all times. Along with the diabetes care plan, it is important for the athletic trainer to know what to pack in their kit. At minimum it is recommended that the athletic trainer pack: A copy of the diabetes care plan, blood glucose monitoring equipment and supplies, glucagon injection kit, supplies for urine or blood ketone testing, a small sharps container, spare batteries, spare infusion sets and reservoirs for insulin pumps if applicable. While guidelines state the athletic trainer should carry these last items, they are prescription and expensive and it should be, and is more

pragmatic that it is the responsibility of the athlete to carry these items. Note, that no mention of additional insulin is addressed in current guidelines, and spare infusion sets and insulin reservoirs, without insulin are useless. Most diabetics do not carry additional insulin as it has to be refrigerated while stored. So, if the current recommendation to carry these items remains, the issue of additional insulin should be addressed. It is important to establish in the care plan if the athlete is going to carry a kit on them at all times where they can hold all of the supplies they need. If this is the case, this strategy will reduce cost for the athlete, and s/he will not need to provide extra supplies to their athletic trainer and can just keep one kit. A logical strategy could be that the athletic trainer keeps the athlete's kit on the sidelines with the athletic trainer during practices and games and returns it to the athlete at the completion of activities for the day. High glucose containing foods and/or drinks with a high glycemic index should also be carried by the athletic trainer. Some appropriate examples of high glycemic index foods include fruit snacks, glucose tablets, sugar packets, and fruit purees. Examples of high glycemic index fluids include orange juice, fruit punch, and non-diet soda. It is also important to know the timing of administration of the high glycemic item, whether it is before a practice versus before a game. It would be inadvisable to give an athlete a carbonated beverage right before they participate in a practice or game due to potential gastrointestinal distress, so fruit juice or a fruit puree would be the better choice. However, if the athlete has at least three to four hours before their athletic event, a carbonated beverage would be fine.

In order to safely monitor their glucose levels, the athlete may have to remove themselves from play, test their blood glucose, consume a high glycolytic food or drink or take insulin if they are hyperglycemic. Then a decision will need to be made on whether or not the athlete can return to play depending on how quickly their blood glucose levels normalize. As previously

discussed, this entails the athlete bring an onsite kit with all necessary equipment to assess blood sugar that is available at both practices and games. There are other potential complications of being an athlete with type 1 diabetes such as metabolic demands for carbohydrate and fat that must be met to maximize training effects and maintain both athletic performance and health. Also, additional calories and fluids may be required for diabetic athletes and will vary based on a myriad of factors such as: exercise intensity, total energy expenditure, type of exercise/training program, duration of exercise, gender, dehydration, and environmental factors

### **Future Directions and Other Considerations**

If this research were to be replicated, I would advise gathering more data over a longer period of time. If possible, include more subjects to provide more information and determine a greater number of, and more broadly-based recommendations. However, there is merit to thoroughly researching one subject rather than performing mediocre research on numerous subjects. All results and recommendations are derived and based on current peer reviewed literature, the data collected on the individual subject, and my first-hand experience of clinically managing a Division I NCAA athlete with type I diabetes. The fact that the subject in this case study had tight glycemic control and was very self-sufficient in his personal management of his type I diabetes, may limit the application of this data to a less well managed diabetic athlete population. It is my sincere hope that this project has shed more awareness of the needs of type I diabetics and will help athletic trainers will become better educated in the area of managing a type I diabetic athlete.



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APPENDIX A: BLOOD GLUCOSE GRAPHS

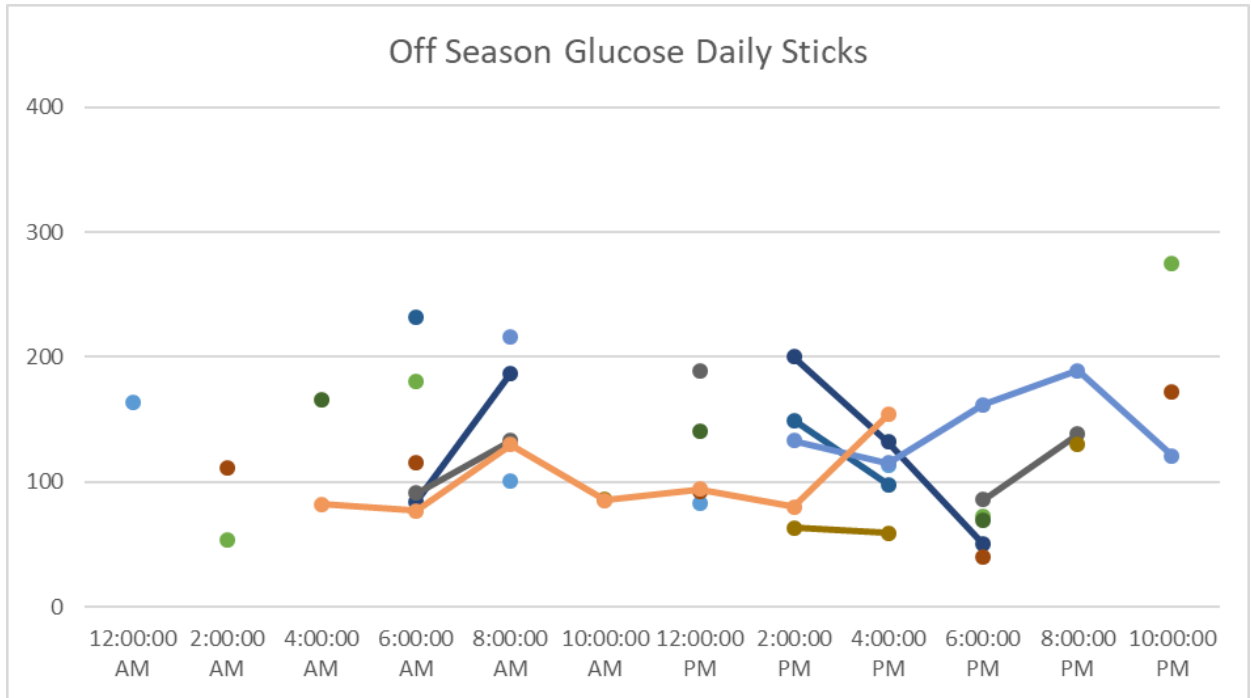


Figure 1: Off Season Glucose Daily Sticks. This is the graph of all the manual finger sticks the subject performed over 24 hours during a 10-day period of the off-season. Each day is represented by a different color, and the horizontal axis represents time, and the vertical axis represents mg/dL of blood glucose.

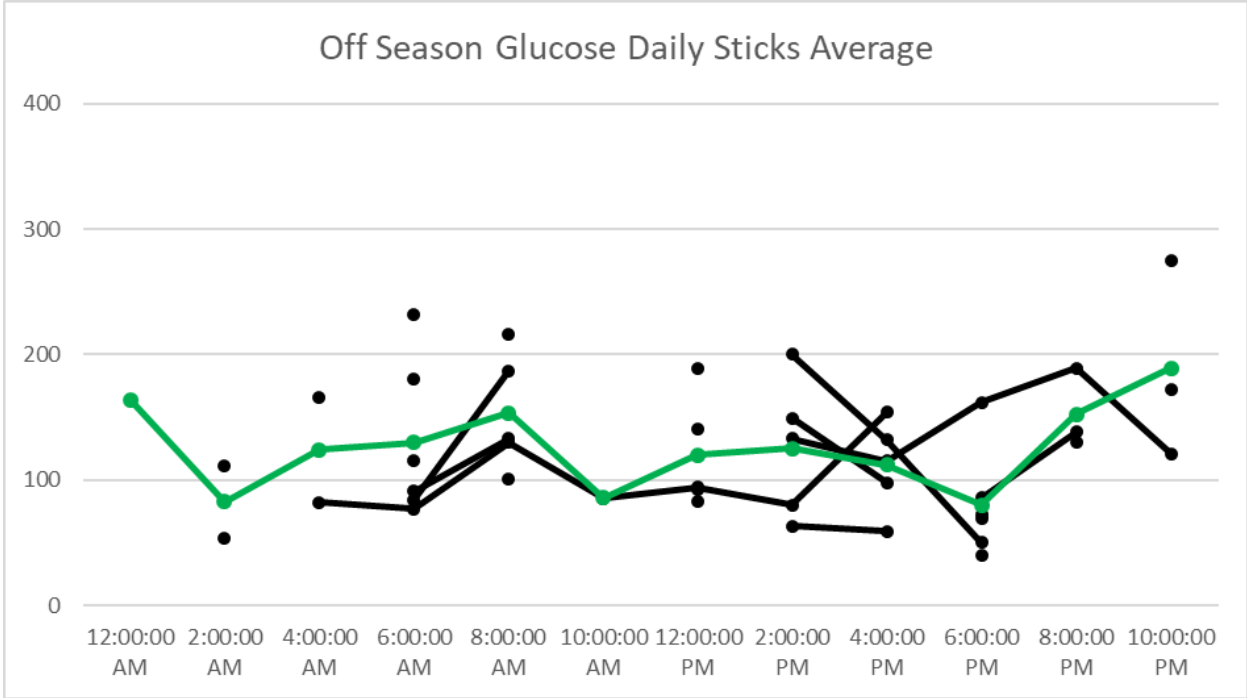


Figure 2: Off Season Glucose Daily Sticks Average. This is the graph of the daily finger sticks again, however the green line showcases the average blood glucose levels over the 10-day period.

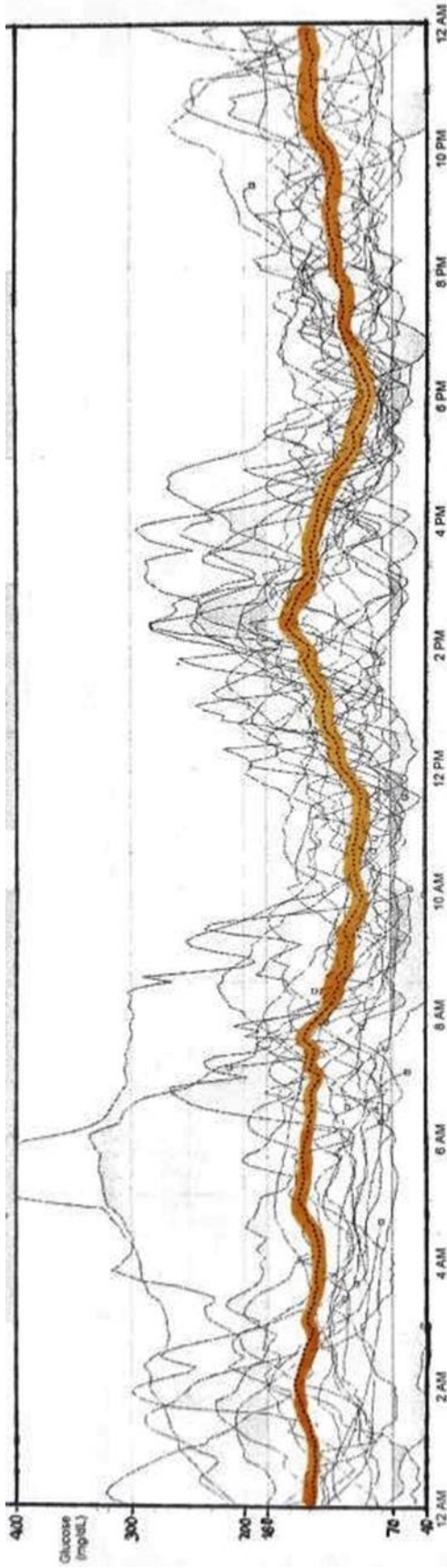


Figure 3: Off Season Continuous Glucose Monitor Output. This graph was collected from the subject's CGM. It shows blood glucose readings every five minutes for 24 hours over a 10-day period during the off-season. The orange line is the average over the 10-day period. This view shows a much more complete view of how the subject's blood glucose trends throughout the day.

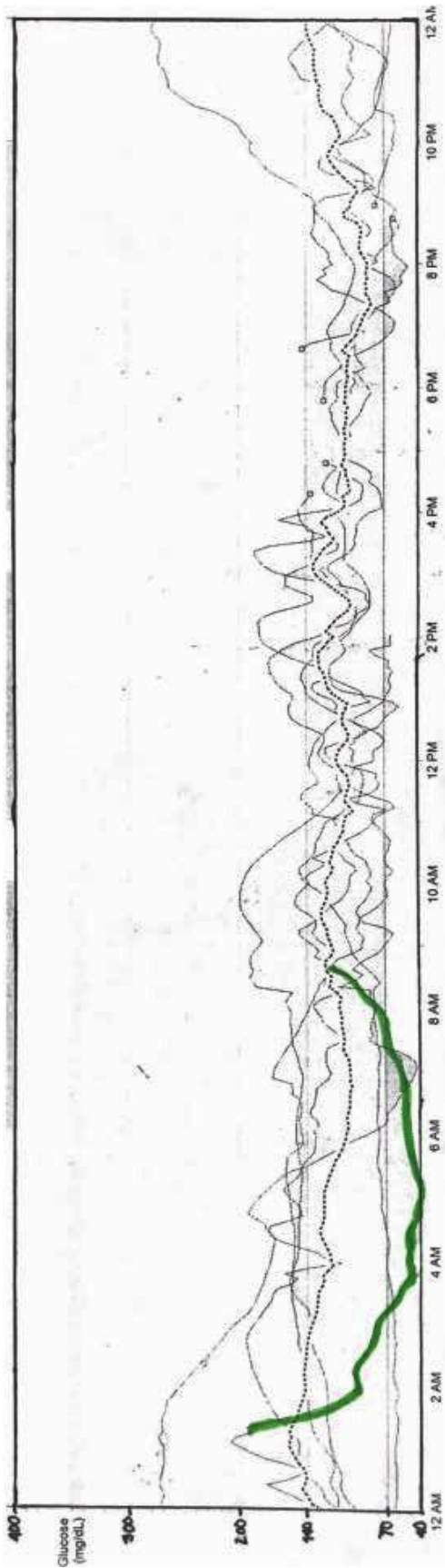


Figure 4: Off Season Continuous Glucose Monitor Low. This graph is from the subject's CGM again, however the point where the subject had a significant hypoglycemic episode is highlighted.

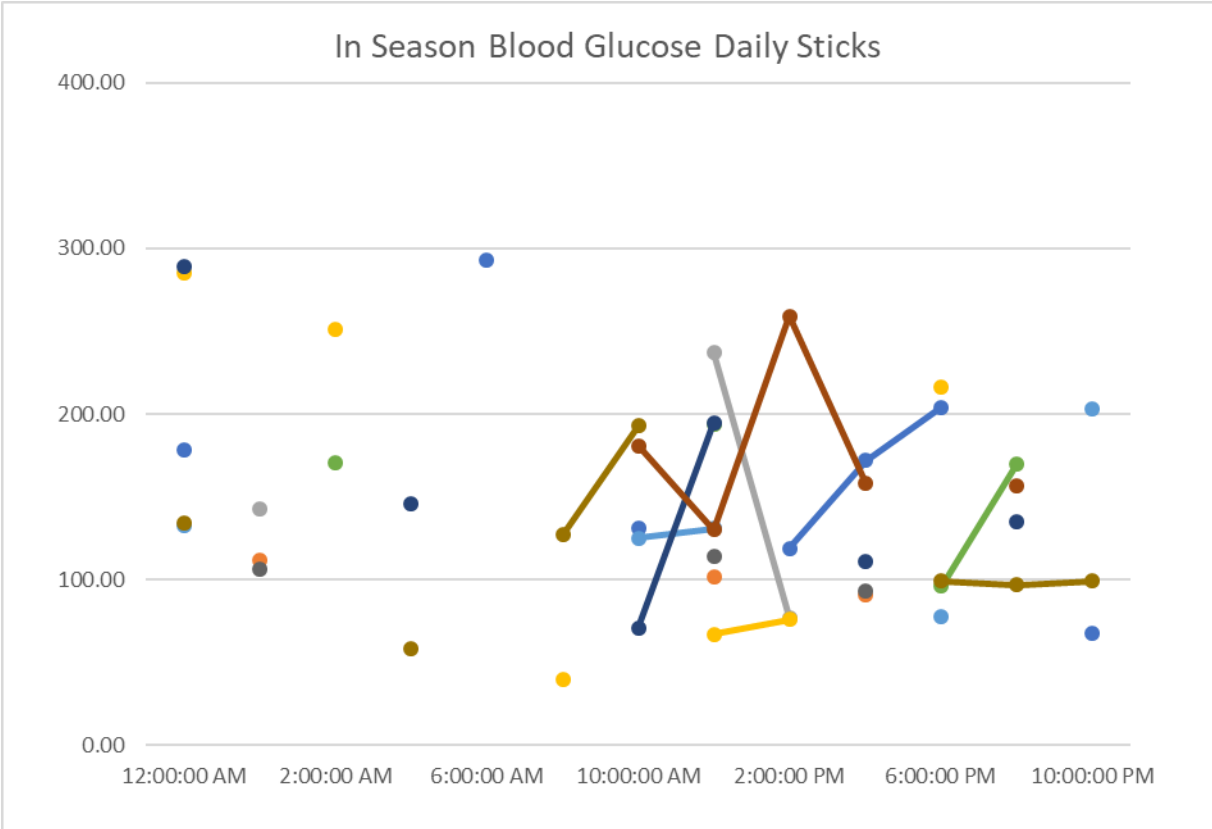


Figure 5: In-Season Blood Glucose Daily Sticks. This is the graph of all the manual finger sticks the subject performed over 24 hours during a 10-day period while in-season. Each day is represented by a different color, and the horizontal axis represents time, and the vertical axis represents mg/dL of blood glucose.

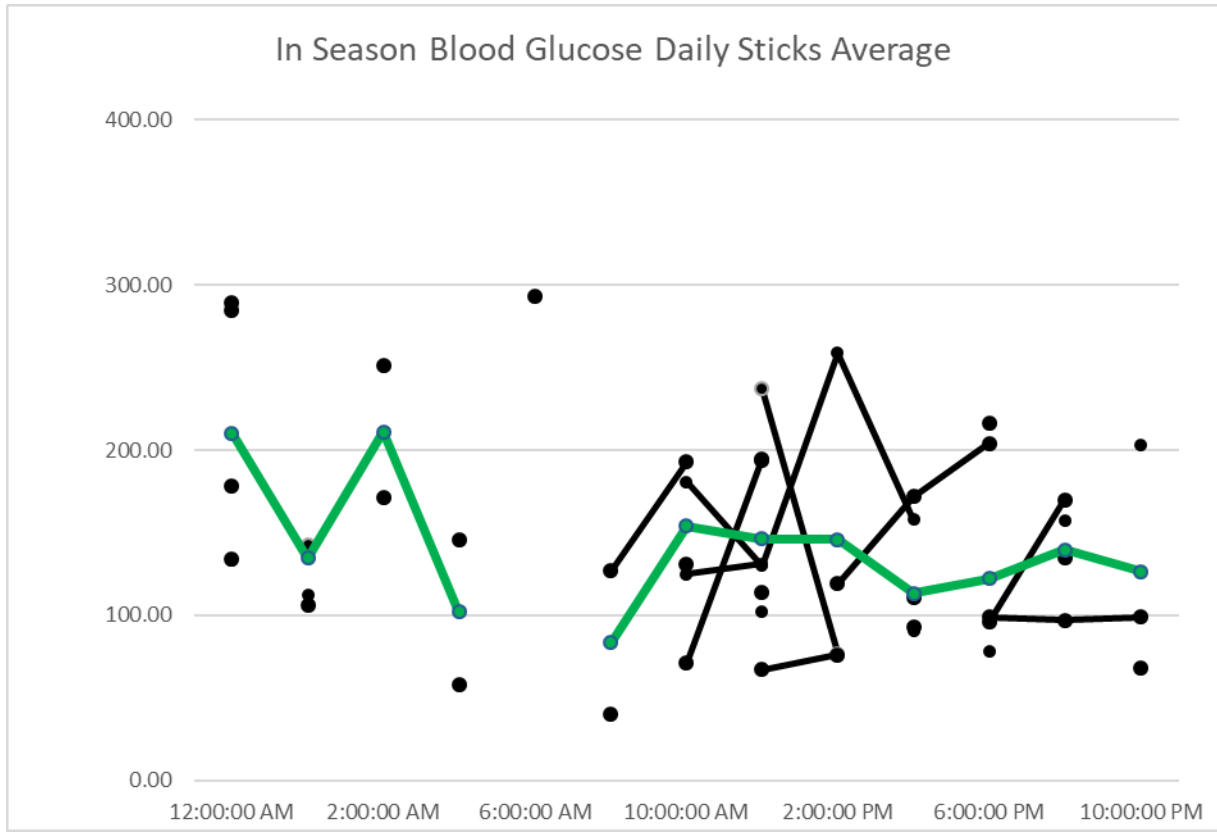


Figure 6: In-Season Blood Glucose Daily Sticks Average. This is the graph of the daily finger sticks in-season again, however the green line showcases the average blood glucose levels over the 10-day period.



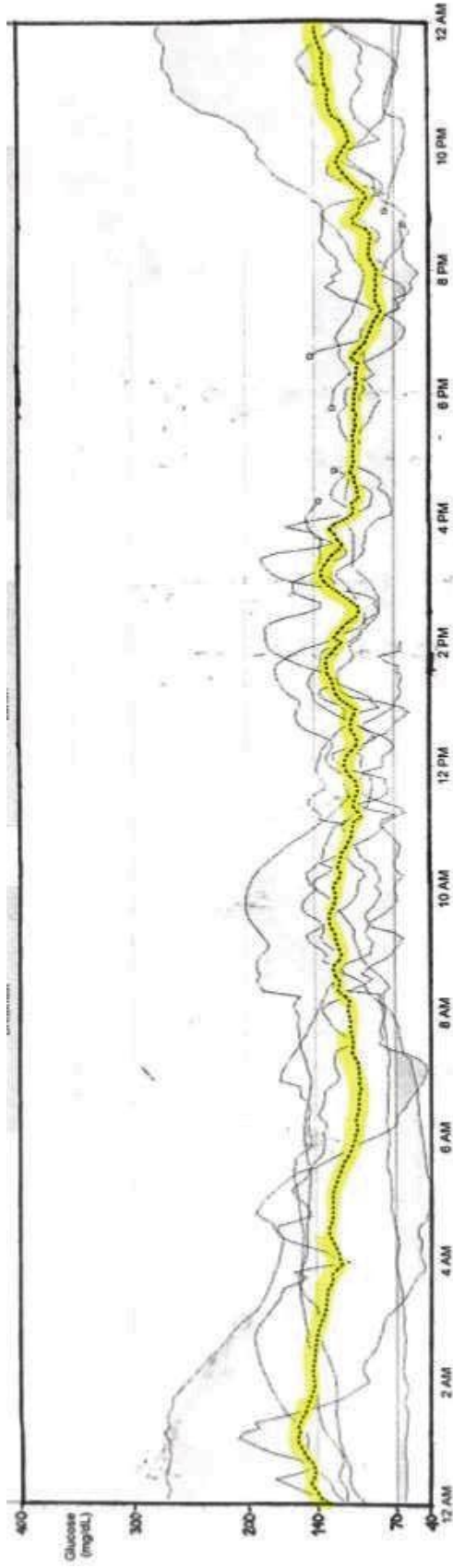


Figure 7: In-Season Continuous Glucose Monitor Output. This graph was collected from the subject's CGM. It shows blood glucose readings every five minutes for 24 hours over a 10-day period. The yellow line is the average over the 10-day period.

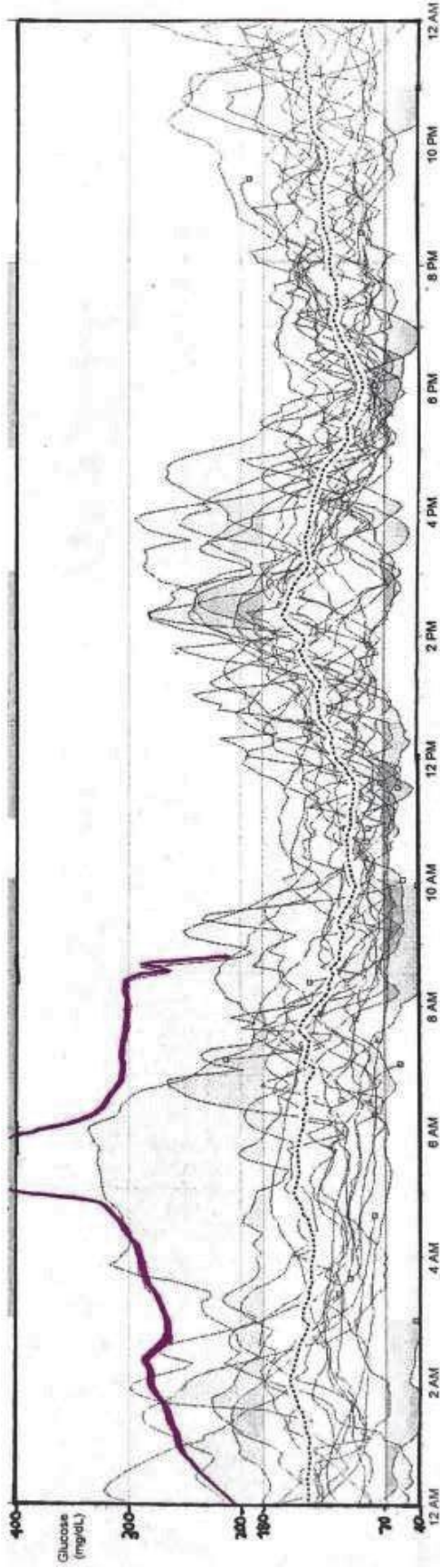


Figure 8: In-Season Continuous Glucose Monitor High. This graph is from the subject's CGM again, however the point where the subject had a significant hyperglycemic episode is highlighted.