SAS® GLOBAL FORUM 2017

April 2 – 5 | Orlando, FL

Know Thyself

Diabetes Trend Analysis

USERS PROGRAM

Know Thyself: Diabetes Trend Analysis

Caroline Bell, Taylor Larkin, and Dr. Denise McManus

The University of Alabama

ABSTRACT

Throughout history, the phrase "know thyself" has been the aspiration of many. The trend of wearable technologies has certainly provided the opportunity to collect personal data. These technologies enable individuals to know thyself on a more sophisticated level. Specifically, wearable technologies that can track a patient's medical profile in a web-based environment, such as continuous blood glucose monitors, are saving lives. The main goal for diabetics is to replicate the functions of the pancreas in a manner that allows them to live a normal, functioning lifestyle. Many diabetics have access to a visual analytics website to track their blood glucose readings. However, they often are unreadable and overloaded with information. Analyzing these readings from the glucose monitor and insulin pump with SAS®, diabetics can parse their own information into more simplified and readable graphs. This presentation demonstrates the ease in creating these visualizations. Not only is this beneficial for diabetics, but also for the doctors that prescribe the necessary basal and bolus levels of insulin for a patient's insulin pump.

INTRODUCTION

Diabetes can be categorized into two major groups: Type 1 and Type 2. This study focuses on the effect of basal and bolus rates on the blood sugar readings of Type 1 Diabetics. A diabetic can use three major pieces of technology in the treatment and regulation of their ailment. This includes an insulin pump, continuous glucose monitor, and blood glucose meter. The readings from these devices are recorded to a medical software that can be accessed by medical professionals and the patient for a greater understanding of the patient's daily blood sugar levels.

The insulin pump controls bolus and basal insulin rates. Bolus insulin is given generally after meals to compensate for sugars ingested, whereas Basal insulin is small increments of insulin given at the top of the hour for long acting results. Combined, basal and bolus rates generally emulate the normal rise and fall of blood sugar levels of a healthy human. The results of this study will be able to determine when these rates are too high and low for the personal diabetic. The diabetic, once speaking to a medical professional, will be able to make decisions that are more informed on their personal health based on these recommendations.

Currently, the graphs used by medical professionals are cumbersome and hard to understand. However, with the help of Base SAS®, clearer visualizations can be created for greater patient understanding. Through the creation of multiple datasets and execution of SAS® graphing procedures, the present study uses a month's worth of diabetes data to develop easier-to-use visualizations to better understand the 24-hour trends seen in daily life.

METHODS

The data for this study comes from Medtronic CareLink®, a personal therapy management software for diabetes. It takes information from a diabetic's insulin pump, continuous glucose monitor, and blood glucose meter and condenses it into several reports. It is organized in a time series beginning on August 8, 2016 at 12:00:00 until September 8, 2016 at 23:56:00.

When downloading the data from CareLink®, the dataset included 40 variables and 10,896 observations. The Continuous Glucose Monitor takes blood glucose readings every five minutes and requires a calibration based off the blood glucose meter every 12-hours. The blood glucose monitor takes readings four to six times a day, generally before meals and bedtime. Several observations are duplicates or provide no useful information for the purpose of new graphical representation. For this analysis, only the variables Date, Time, Hour, Sensor Reading, and Blood Glucose Reading are used. Additionally, any observations that do not contain any Blood Glucose Reading or Sensor Reading are deleted, as seen in Figure 1.

```
data work.cgm;
 set cgm.carelink_upload_data;
 Hour = hour(Time);
 BG_Reading=input(BG_Reading__mg_dL_,best.);
 Sensor_Reading=Sensor_Glucose__mg_dL_;
 keep Date Time Hour Sensor_Reading BG_Reading;
 if BG_Reading = . and Sensor_Reading = . then delete;
 run;
```

Figure 1: Base SAS® code for dataset creation

Know Thyself: Diabetes Trend Analysis

Caroline Bell, Taylor Larkin, and Dr. Denise McManus

The University of Alabama

METHODS (CONTINUED)

Figure 2 represents CareLink's® visualization of the continuous glucose monitor during the previously stated dates. This visualization's color scheme is misleading and average blood glucose, as noted as the dotted line, is unreadable to the average person.

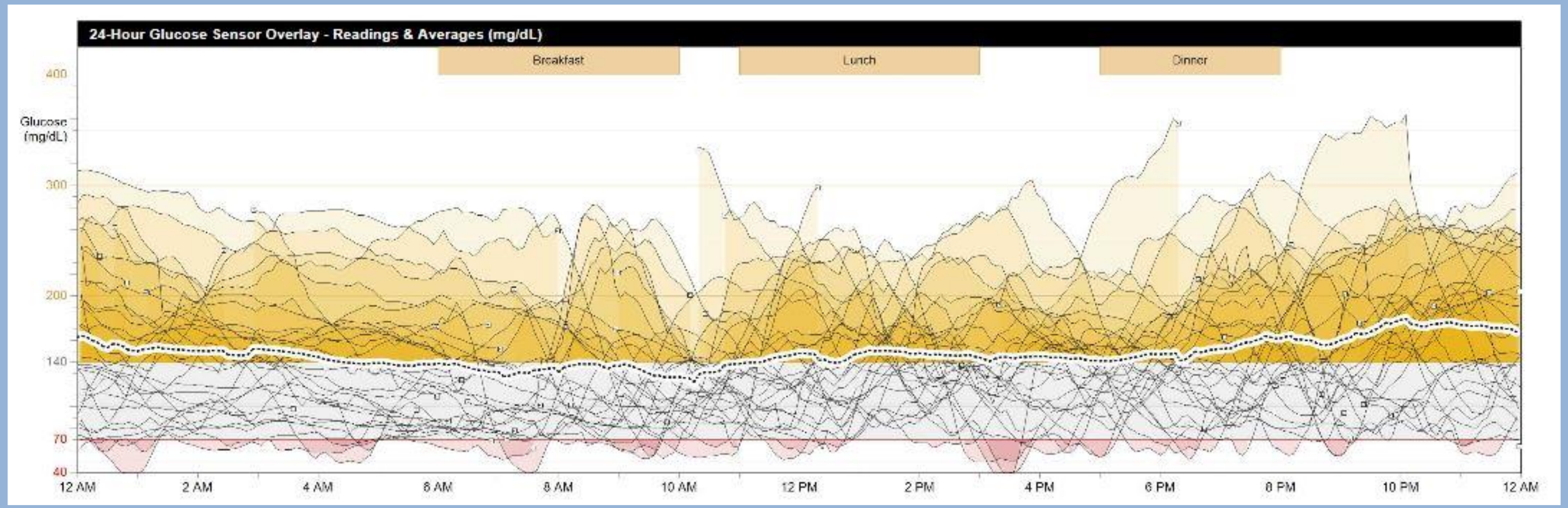

Figure 2: Medtronic CareLink® 24-Hour Glucose Sensor Overlay

Using PROC SGPLOT, a visualization replication is created that matched CareLink's® graphs for medical professionals in Base SAS®, seen in Figure 3. The data, while useful, is currently presented in a format where the average patient would be confused or overwhelmed by the information presented. In order to understand these data points, a graph of the min, mean, and max for 30 days' worth of blood sugar readings (see Figure 4), along with the mean and one standard deviation (see Figure 5), is produced to look at trends. These graphical representations are able to better indicate when too much or not enough insulin is being introduced into the body.

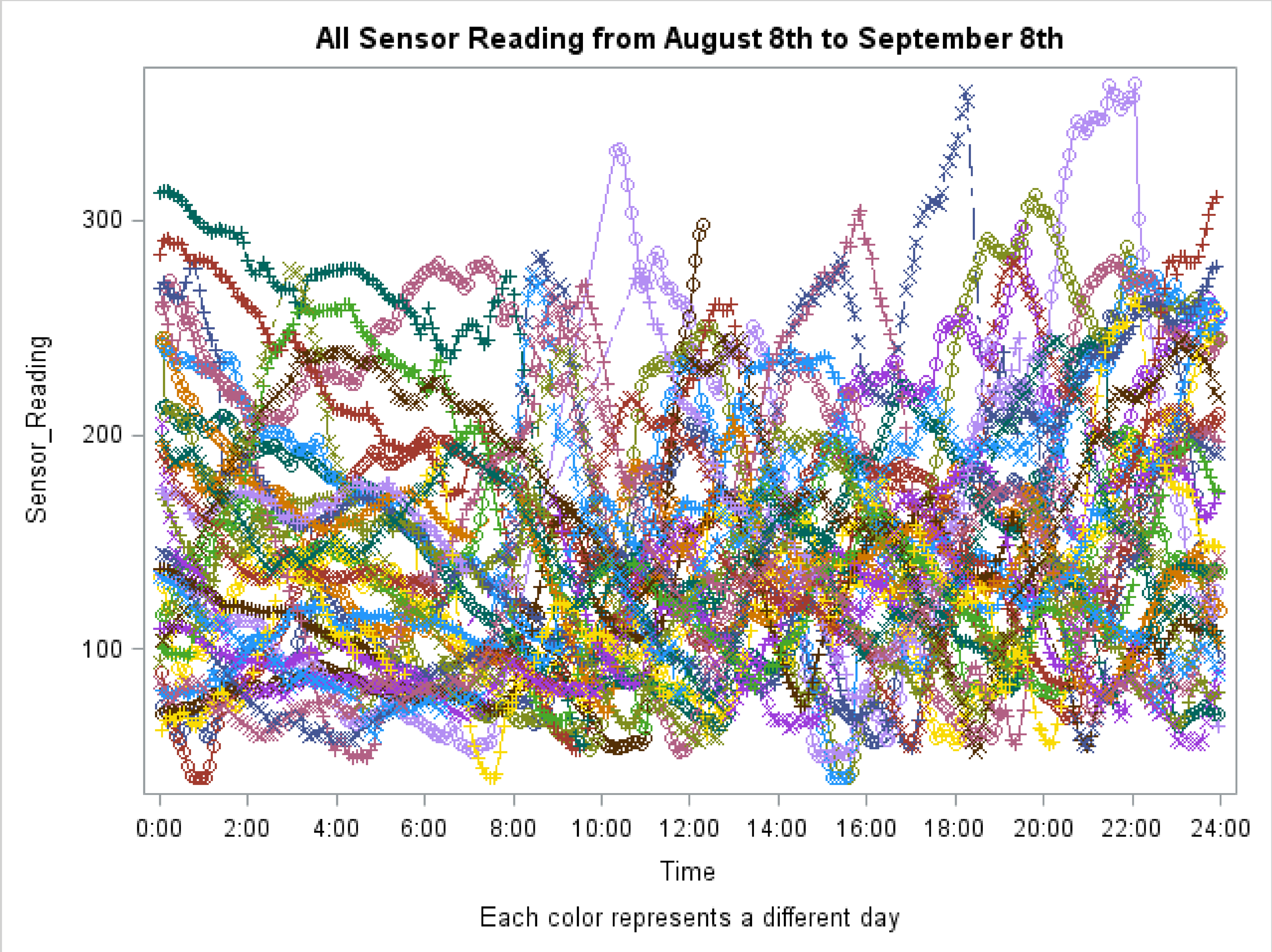

Figure 3: SAS® Graph of CGM Readings

Know Thyself: Diabetes Trend Analysis

Caroline Bell, Taylor Larkin, and Dr. Denise McManus

The University of Alabama

RESULTS

In order to create easier to read visualizations, the first graph displays the min, mean, and max of every 5 minutes in a 24-hour period, seen in Figure 4. Averaging a month's worth of data can show trends of too much or too little insulin in the body. Figure 4 indicates that too much insulin is in the system or low blood sugar occurs during 7AM to 9AM and again at 2PM to 4PM. This could indicate that too much insulin is being given for meals. Another observation to mention is the high blood sugars towards the end of the day and the low blood sugar at the beginning. Since this is personal data, it should be noted that this anomaly is due to evening exercises. This evening exercise results in higher blood sugar at night, due to the reduction on basal insulin to account for burning sugar during the exercise. The lower blood sugar in the morning is a combination of insulin and exercise reducing the blood sugar to a low point.

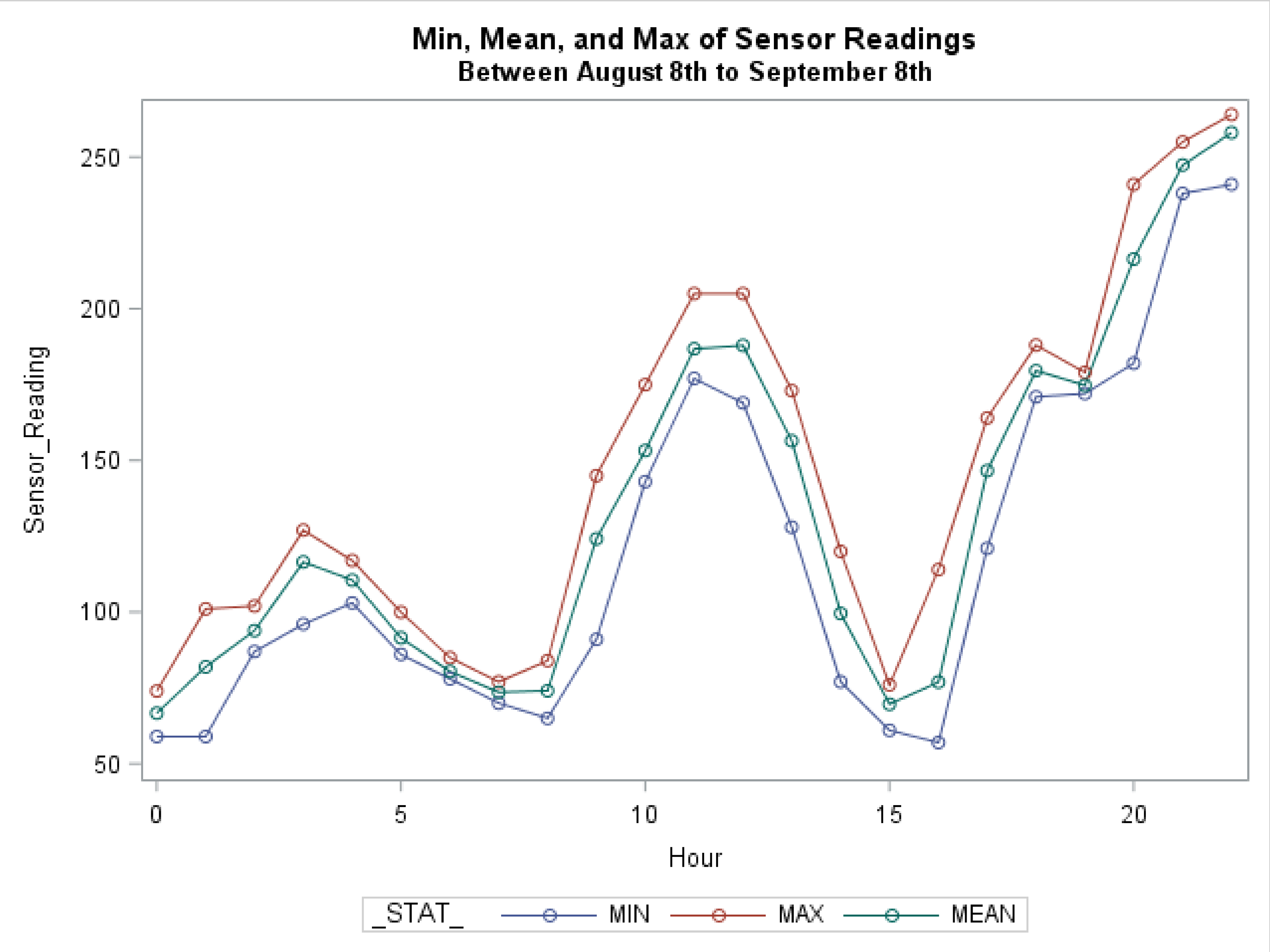

Figure 4: Min, Mean, and Max of CGM Readings

Additionally, the standard deviation is calculated from the month's worth of data, Figure 5. The goal here is to decrease the influence of outliers and see if the trends continue as previously seen in Figure 4. The upper and lower standard deviation seem to run almost parallel to the mean. This further solidifies that the downward blood sugar trends seen after breakfast, lunch, and the after dinner spike. A medical professional would be able to spot these trends and make the necessary adjustments to the diabetic's basal rate to prevent extreme blood sugar occurrences.

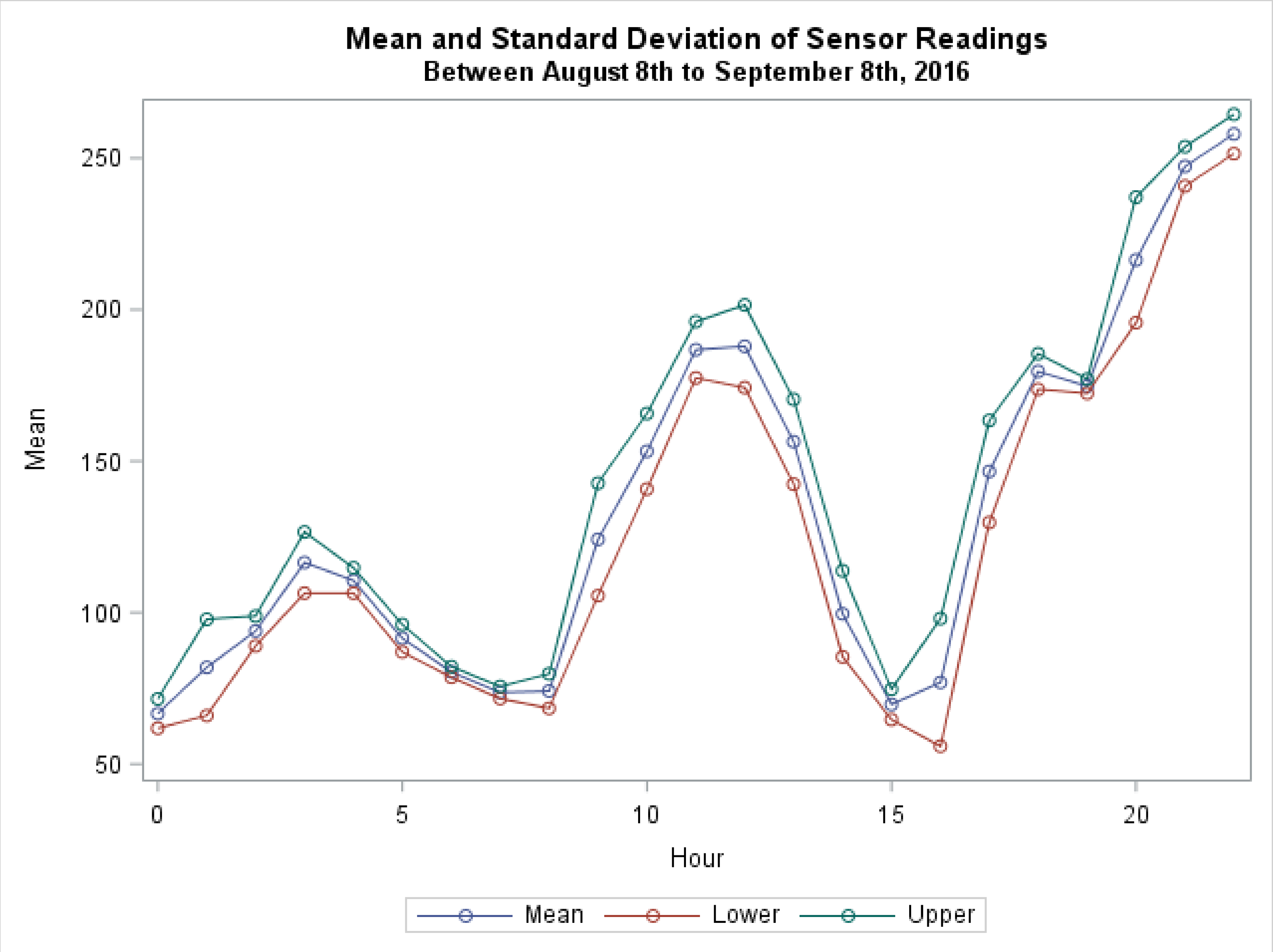

Figure 5: Mean and Standard Deviation of CGM Readings

Know Thyself: Diabetes Trend Analysis

Caroline Bell, Taylor Larkin, and Dr. Denise McManus

The University of Alabama

CONCLUSION

The techniques shown in this paper exhibit how SAS® users paired with their health data can make informed observations and start knowledgeable conversations about their health. Simplifying a month's worth of data into averages rather than daily totals can show trends that otherwise cannot be observed. Additionally, the Continuous Glucose Monitor is still considered a reliable source of blood sugar readings even though it is calibrated off the blood glucose monitor.

After concluding this analysis, the data was presented to a local endocrinologist. Certain adjustments were made to lower the basal rate for midmorning and late afternoon to counteract the downward trends. Since making these changes, the blood sugar readings have resulted in less low blood sugar instances, which helps maintain stable blood sugar readings throughout the day. The next step will be to collect a year's worth of data through the Continuous Glucose Monitor to see trends based on seasonality and the effects of stress on blood sugar readings.

Contact has been made with Medtronic regarding their graphical representation of diabetes data. The findings from this research have been submitted to Medtronic in order to enlighten them on the patient side of their software. While it is unlikely that all the findings will be implemented, certain findings such as improved coloring options and min, mean, and max of blood sugar readings can be added to their list of offered reports. This report demonstrates how using one's personal biometrics and SAS® can inform patients on their health trends.

REFERENCES

[1] Medtronic CareLink Personal. N.p., n.d. Web. 23 Feb. 2017. <https://carelink.minimed.com/patient/entry.jsp?bhcp=1>.

[2] "SAS/GRAPH(R) 9.2: Statistical Graphics Procedures Guide, Second Edition." *SAS/GRAPH(R) 9.2: Statistical Graphics Procedures Guide, Second Edition*. N.p., 20 May 2010. Web. 01 Mar. 2017.

[3] "SAS 9.4 Software." *SAS 9.4 Software | SAS*. N.p., n.d. Web. 01 Mar. 2017.

This information was presented earlier at the South Central SAS® Users Group.

SAS® GLOBAL FORUM 2017

April 2 – 5 | Orlando, FL