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# Prediction of nocturnal hypoglycemia on type 1 Diabetics by measuring the HRV through a Pulse Sensor

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**Background, Motivation and Objective.** The exponential increase of the number of people with Diabetes around the world has led to the development of devices that can measure biological signs and, according to results, adopt procedures to improve the life quality of those afflicted by the disease. For example, some are made specifically for glucose level control, especially in the case of predicting hypoglycemia (low blood sugar) during the night. Among the technologies used for having a better glucose control, the CGM (Continuous Glucose Monitoring) system is one of the most used by patients with Type 1 Diabetes, but it has proven to be unaffordable and non-ergonomic for many. The development of an affordable device that can predict nocturnal hypoglycemia in a more comfortable way and with great accuracy is, therefore, the goal of this project.

**Methods.** The prediction of hypoglycemia was performed using the HRV (Heart Rate Variability) method by Simon Cichosz et al. (2014) in their study on the use of the HRV together with CGMs to obtain better results on the prediction of hypoglycemia. Their work proved that right before and during hypoglycemia, the HRV tends to reduce with the rise of the person's heart beat caused by the release of some hormones. Focusing on this relation, we propose to use a simple pulse sensor together with an Arduino microcontroller to measure the Inter Beat Interval (IBI) during normal and low glucose levels, which will allow us to set a standard value of IBI that will indicate the hypoglycemia. Further analysis will be possible by comparing the results in Poincaré Plots, which relates previous data with actual data, obtained with the software Processing and the Excel tool PLX-DAQ.

**Results.** The first assays made with the proposed device permitted the verification of the relation expected between the IBI and the Hypoglycemia episode, with a visible decrease in the IBI (from 800 ms ± 200ms to 500 ms ± 100 ms) right before the glucose levels went under the 70mg/dL value. The tests with the Pulse Sensor attached to the ear were unvalidated due to extreme variance and dispersion of measured IBI points. When attached to the finger, the Pulse Sensor turned in better results. Using the official Pulse Sensor from World Famous Electronics llc. resulted in good data with low noisy signals for the heart rate variability. The standard behaviour of the IBI during a period of euglycemia (normal glucose levels) can be seen on Figure 1, ranging from 700 ms to 1000 ms. Figure 2 shows the variation noticed on the behaviour during a hypoglycemia. Both analyses were performed on the author of this project, a 23 years old female diabetic with no history of heart diseases, during the night. The prototype was put inside a wooden box, being composed of a buzzer (with its volume controlled by a potentiometer through a PWM Arduino port) and a red LED, for the alert system. It can be plugged to a computer capable of plotting graphs on Processing or Excel, or plugged directly to a 5 V energy source, for using the alert system only. Table 1 shows the monthly expenditures comparation between a Medtronic Enlite Sensor (CGM) and the prototype proposed in this project, in brazilian reais, during 12 months. Even in the

worst case of needing to change the whole hardware every month, it still equals only about 10% of the CGM price (a final expenditure of R$ 32,707.56 for the CGM versus R$3,569.04 for the prototype at the end of the year).

**Discussion and Conclusions.** The results obtained with the Pulse Sensor attached to the finger were more accurate than those obtained attaching it to the ear. There is a remarkable difference on the data acquired by using the professional Pulse Sensor and a pulse sensor based only on the light reflection. The results obtained proved the expected relation and indicate the possibility of predicting nocturnal hypoglycemia using only the HRV, as can be seen by the different aggrupation areas of the measured IBIs on Figures 1 and 2. The device used has shown to be less expensive and more comfortable to the user than the CGMs available on the market, as can be seen on the comparation presented at Table 1. More tests will be executed on a broader range of patients and a more compact prototype (possibly wireless and using a wearable technology) will be made on future iterations. The tests have indicated that the device should be used during periods of stability, such as during the sleep, since the HRV is easily affected by daily activities.

**Figure** 1: Poincaré Plot during nocturnal euglycemia period

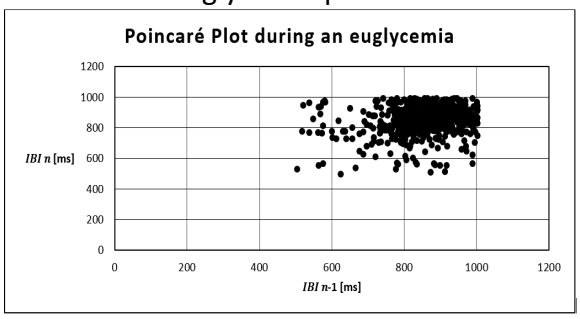



**Figure** 2: Poincaré Plot during nocturnal hypoglycemia period

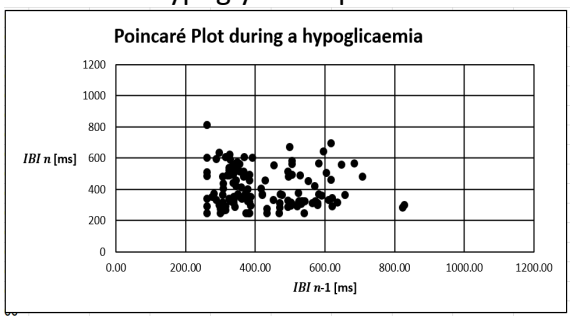
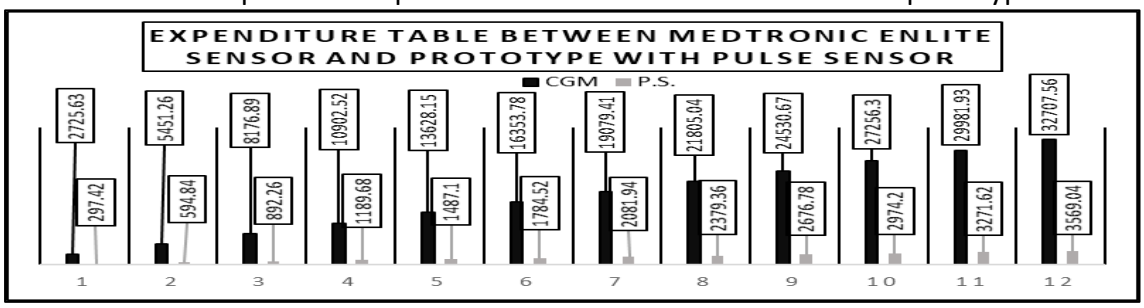



**Table** 1: Expenses comparation between Medtronic CGM and prototype.




**Keywords: Diabetes; HRV; IBI; Hypoglycemia; Pulse Sensor; Arduino.**