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NonInvasive Wearable Sensors to detect onset of hypoglycemia: A Literature Review

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Introduction: Hypoglycemia is a prevalent condition where diabetic patients experience low blood glucose. There are approximately 300 million diabetic patients in the world; at least 30 million of those are in the United States. Diabetic patients facing hypoglycemia continue to grow but the condition worsens as patients lose awareness the more episodes that occur. Mild hypoglycemia is characterized as blood glucose below 70mg/dl and severe as blood glucose below 40mg/dl (Kalra et al., 2013). Severe hypoglycemia may cause loss of patient's awareness and in some cases fatality. Loss of awareness leads to a 6-fold increase in the risk of death. While in most cases hypoglycemia is treated through medication and diet (e.g. fast-acting carbohydrates), a popular technology among diabetic patients; especially those with hypoglycemia unawareness; is continuous glucose monitors (CGM). While CGMs have shown promise, these devices are expensive, invasive, and not always accurate throughout the day (Bay et al., 2013). Hypoglycemic events are associated with several signs and symptoms such as fatigue, sweating, and pale skin, but tremors seem to be a prevalent symptom as well. One study has reported that around 20% of hypoglycemic patients stated that trembling is the first symptom they notice indicating low blood sugar (Muhlhauser, 1991), and another showed that 77.5% of diabetic patients who are aware of their symptoms experience tremors (Berlin, 2005). Our research aims at investigating the efficacy of using hand (or leg) tremor to predict the early onset of hypoglycemic events. Work is in progress to design and develop a non-invasive sensor-based wearable system that detects hypoglycemic tremor with high sensitivity and specificity.

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Method: A systematic review of literature is in progress to search variety of medical and engineering databases to identify research related to hypoglycemia detection, wearable sensors, and tremor. The studies considered are those pertaining to diabetic patients who have been assessed for the symptoms of hypoglycemia and the sensors used in order to predict a hypoglycemic episode. One of the main objectives of the study is to understand hypoglycemia and its symptoms, and to document technological interventions, related detection methods and sensors, as well as their shortcomings and opportunities. We hypothesize that tremor has not been used for hypoglycemia detection. The research is motivated by the preliminary review evidence that suggests current sensor-based technologies to address diabetes and hypoglycemia suffer from low patient engagement and satisfaction due to intrusiveness, low accuracy, and price. Results: While the review is in progress, we expect to have completed the search by January and plan to present the comprehensive findings at the conference. Our preliminary findings suggest a large research gap in non-intrusive technologies and methods to detect hypoglycemic events. While a frequency band of 10-14 Hz in the wrist for hypoglycemic tremors has been suggested in the literature (Rana & Chou, 2015), there is very little research done on utilizing this phenomenon to predict hypoglycemia. Most research relies on other symptoms such as skin conductance and body temperature which have been shown to cause inaccurate predictions (Howsmon & Bequette, 2015). In understanding the tremors, it is important to consider at the time the tremors start to occur in relation with particular activities, food consumption, and blood sugar; as well as the location of these tremors and their prevalence. The current review found studies that assess and promote user-centered design, and the usability of wearable sensors. This includes usability studies, human factors and FDA requirements, and other recommendations to be incorporated into developing a wearable sensor. Wide range of factors related to patient comfort and usability were identified, they include optimizing between battery life and data processing, size, location on the body. These findings are in line with other studies such as those done on wearable sensors for detection of Parkinson's disease (Rigas et al., 2012). Despite these preliminary findings, comprehensive guidelines to design for wearability had not been offered. Based on these and upcoming findings a taxonomy for design criteria for wearability will be presented. Conclusion: Diabetes is a growing epidemic and the occurrence of hypoglycemia for diabetic patients is prevalent and potentially fatal. Detecting the onset of hypoglycemia is vital and tremors seem to be a viable symptom. Our preliminary findings from a systematic literature review suggest a general gap in technological interventions for early detection and recognition of hypoglycemic events. In particular, our current findings show that tremor detection technologies have not been utilized in this domain. Sensors assessing tremor frequency could be an alternative approach to current sensors in the market and may contribute to non-intrusive, high accuracy and low cost solutions. This review will inform a taxonomy of design considerations for non-intrusive wearable technologies. Our future work aims at addressing this gap by utilizing a user-centered design of a wearable device to detect the early onsets of hypoglycemic events by measuring tremor.