The DiaChip

Adaptable and Non-Invasive Technology to Better Lifestyle

Proof of Concept

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Section 1: Introduction

1.1. The concept itself

In this study, I propose the development of a smart, non-invasive chip/patch designed to monitor both blood glucose levels and caloric intake. This device will use advanced sensors and AI algorithms to provide continuous health insights, by learning individual patterns to predict and alert users to potential glucose spikes. It aims to offer a seamless, integrated experience to enhance health monitoring for diabetics and non-diabetics.

For this study:

1. I studied the current market scenario to identify existing glucose and calorie estimation technologies.
2. I identified the limitations of existing products.
3. I created a module to collect data based on parameters like calorie intake, sleep quality, physical activity, and blood sugar levels using existing technologies to identify the relation between these parameters and the overall health of an individual.
4. By establishing a sound relation between these parameters I will be able to advocate for the design of a single device/technology to monitor all these parameters and help the doctors and caregivers to provide an individual customized health plan.

1.2. What is already there in the market in terms of technology?

The current market for health monitoring technologies includes various solutions for both continuous glucose monitoring (CGM) and caloric intake tracking. CGM devices such as those from Dexcom, Abbott's FreeStyle Libre, and Medtronic have significantly advanced diabetes management by providing real-time glucose readings and trends.

In parallel, numerous wearable devices such as Fitbit, Apple Watch, and Garmin provide caloric expenditure tracking through activity monitoring and heart rate measurements. These devices often combine step counting, heart rate monitoring, and algorithms to estimate calories burned, but they typically do not integrate directly with glucose monitoring systems. Healbe Gobe (HEALBE FLOW™) Technology requires no blood testing or manual logging but only uses your body's information to tell you how many calories you're consuming. The glucose level increases during digestion and the cells uptake this glucose and simultaneously release water. GoBe uses a bioelectrical impedance sensor to measure the fluid moving in and out of our skin cells.

1.3. Why is our idea required?

The necessity for a unified, non-invasive solution arises from the limitations and gaps in the current technologies. Diabetics and health-conscious individuals often have to rely on multiple devices to manage their health, leading to fragmented data and increased costs. Additionally, the invasive nature of current CGM systems can be a barrier for many users, discouraging consistent use and adherence to diabetes management protocols.

Our idea aims to bridge these gaps by developing a) a smart, non-invasive chip/patch that b) simultaneously monitors blood glucose levels and c) caloric intake. This dual-function device would streamline health monitoring, reduce the need for multiple wearables, and offer a more comfortable and user-friendly solution.

Section 2: Methodology and Data Analysis Parameters

(Subsection 1)

1. A literature review was needed to understand the proof of concept and experimental design to validate it. I surveyed the existing devices like Fitbit, Apple Watch, etc. for their features, cost, and sensitivity. This part of the study took **approximately 10-12 hours in the span of 5 days.**
2. I created the study parameters and talked to various potential volunteers in the dedicated age group. I finally convinced 8 individuals to provide me the data from their wearables and information about their daily meals (to calculate the calorie intake) for 7 consecutive days. This part of the study took **approximately 5-6 hours** in the span of a week.

2.1. Parameters considered while selecting the volunteers

a) Age (35-45)
   i) Nearly the same age group of people
b) Weight
   i) Can vary
c) Gender
   i) All Males from the same demography. I was unable to find an equal ratio of volunteers from both genders and hence decided to include individuals from one gender only
d) Pre-existing conditions besides diabetes or not

2.2. Data collection and record (approximately 6-7 hours)

e) Time: 1 week

f) 3 times a day (screenshot of data) after a meal of both CGM and calorie counter (MyFitnessPal)
g) The number of steps all monitored by the same brand fitness band
h) Calorie counter: variable. Since the calorie counter devices were different with each individual, we decided to manually calculate the calorie intake by using the information about each meal from each of the volunteers. The volunteers sent me a picture of each of their meals every day for 6 consecutive days

(Subsection 2)

Ethics and safety:

During the entire study, the names and personal information of all individual volunteers were kept anonymous. No specific instructions were given to the volunteers to modulate their lifestyle pertaining to diet, sleep, or physical activities. The data was collected only after the informed consent of all volunteers.

Section 3: Results

- Data analysis: This section took the maximum time to analyze and infer from the provided information by the volunteers **(approximately 35 hours).**
- Compilation of the report and writing the discussion **(approximately 20 hours).**
- Editing and referencing **(4-5 hours)**

Eight volunteers enrolled in this study. Two had to be excluded due to insufficient data provided by them. Names and personal information were kept anonymous.

Table 1:

Case	**Gender**	**Age**	**Weight**	**Conditions**	**Diet**
I	Male	44	120 Kg	Diabetic	Calorie control diet
II	Male	36	104 Kg	Borderline diabetic + Hypothyroidism	Unbalanced
III	Male	43	85 Kg	Non-diabetic	Balanced

IV	Male	35	75 Kg	Borderline diabetic	Balanced
V	Male	40	90 Kg	Non-diabetic	Balanced
VI	Male	43	102 Kg	Diabetic	Balanced

Table 2: Data analysis with the complete record
(https://docs.google.com/spreadsheets/d/1WlICvfLeOo8LKD2lCMtrOCd6qeZOgTED4LdN7ekAo4k/edit?usp=sharing)

Case 1: Male, 44 years of age, overweight, Diabetic, and on calorie control diet. The data was taken for 6 consecutive days. The volunteer was taking on an average of 1000 calories a day with a protein-rich diet and walking an average of 11966 steps daily. Interestingly, the data showed blood sugar level fluctuations on the days with the least physical activity and less than 6 hours of sleep. This data indicates that besides calorie intake and type of diet, sleep cycle and physical activity also influence blood sugar levels. Therefore it is imperative to suggest a technology that incorporates all factors to improve the lifestyles of diabetic people.

Case 2: Male, 36 years of age, overweight, Borderline diabetic with hypothyroidism. The data was taken for 6 consecutive days. The volunteer took an average of only 614 calories daily with an unbalanced diet and walked an average of 3215 steps daily, implying a sedentary lifestyle. The data suggested that this volunteer was on a very low-calorie diet which in turn aggravated the blood glucose condition. Very low-calorie diets (often below 1500 calories) can be counterproductive for people with hypothyroidism and might worsen blood sugar control.

Case 3: Male, 43 years of age, slightly overweight, Non-Diabetic. With physical activity. The data was taken for 6 consecutive days. The volunteer took an average of only 1008 calories daily with a balanced diet and walked an average of 5900 steps daily along with 4 days of workout. The data showed a direct relation between blood sugar balance and physical activities ie. The fluctuation in blood sugar was minimal on days with proper physical activities.

Case 4: Male, 35 years of age, slightly overweight, Borderline-Diabetic., sedentary lifestyle The data was taken for 6 consecutive days. The volunteer took an average of 1728 calories daily with a balanced diet and walked an average of 2075 steps daily. This data suggested that besides diet and physical activity, poor quality of sleep also affects blood sugar levels adversely.

Case 5: Male, 40 years of age, muscular weight, Non-Diabetic. Active lifestyle. The data was taken for 6 consecutive days. The volunteer took an average of only 2169 calories daily with a balanced diet and walked an average of 11776 steps daily. This data depicts a nearly ideal situation where the key parameters like diet, physical activity, and sleep cycle are well balanced and thus show no steep fluctuations in blood sugar levels.

Case 6: Male, 43 years of age, overweight, and diabetic. The data was taken for 6 consecutive days. The volunteer took an average of only 2480 calories daily with a balanced diet and walked an average of 6677 steps daily. The data describes that an abrupt change (increase or decrease) in the calorie intake throughout the day might also spike the blood sugar levels and a continuous unmonitored diet might lead to diabetes.

Section 4: Discussion

The present study included 6 individuals with different lifestyles and eating habits. The concept behind this study was to establish a relationship between calorie intake, sleep quality, physical activity, and blood sugar levels. The cases studied here are diabetic, borderline diabetic, and nondiabetic individuals either on specific diet plans or following traditional normal Indian diet. Parameters like sleep hours and quality of sleep were also considered while analyzing the data. This approach not only establishes interrelation between all these parameters but also highlights the importance of developing a single technique that includes all these parameters to help individuals especially diabetic patients to monitor and control their lifestyles holistically. Also, the doctors and caregivers can monitor to create customized diabetes management plans for such individuals.

Case 1 highlights the significant impact of physical activity and sleep on blood sugar control in a diabetic individual. Despite calorie control and a protein-rich diet, fluctuations in blood sugar levels were directly correlated with reduced physical activity and insufficient sleep. This finding confirms the importance of addressing these lifestyle factors along with modifications in diet for effective diabetes management (Thirunavukkarasu et al. 2024).

Case 2 highlights the dangers of extremely low-calorie diets, particularly in individuals with hypothyroidism. The data demonstrates how such restrictive diets can worsen blood glucose imbalances. This case points towards the necessity for personalized diets based on individual metabolic needs and health conditions (Hage et al. 2011).

Case 3 describes the positive correlation between physical activity and blood sugar regulation. The non-diabetic participant with a balanced diet and regular exercise exhibited minimal blood sugar fluctuations, emphasizing the role of physical activity in maintaining glucose homeostasis.

Case 4 further supports the findings of Case 1, indicating that poor sleep quality can negatively impact blood sugar control even in individuals with borderline diabetes. This case highlights the importance of considering sleep as a critical factor in diabetes management (Tsereteli et al. 2021; Knutson 2007).

Case 5 serves as a reference point for a nearly ideal health profile. The non-diabetic participant with a balanced diet, high physical activity levels, and likely adequate sleep exhibited stable blood sugar levels. This case emphasizes the potential for optimal health when lifestyle factors are well-balanced.

Case 6 demonstrated the impact of calorie fluctuations on blood sugar levels. The diabetic participant's blood sugar spikes correlated with abrupt changes in calorie intake. This finding emphasizes the need for consistent dietary patterns to maintain blood glucose control.

4.1. Limitations of this study & Future research:

The present study however has a few limitations. Sample size, accuracy of the wearable sensor used to collect the data, and possible errors by the volunteers in recording daily meal data could have affected the results. Initially, I considered 8 volunteers for the study, but 2 had to be omitted because insufficient data was provided by them. For Case Study 6th, the alcohol consumption data was not considered as it was not clear if the subject had low or moderate levels of consumption. The interrelation between calorie and glucose monitoring with alcohol consumption needs to be studied in the future.

Further research is required to explore the long-term effects of these lifestyle factors on blood sugar control, as well as to investigate the optimal combinations of diet, exercise, and sleep for different populations as well as different individuals. Additionally, studies examining the impact of this proposed device on diabetes management outcomes would be very valuable.

4.2 Feasibility of the proposed technology:

The feasibility of our concept is supported by ongoing research and technological advancements. The integration of multi-sensor systems for non-invasive glucose monitoring has shown promise in recent studies (Fuller et al. 2020). Similarly, the reliability of caloric tracking via wearables has been well-documented by Dimitratos et al. 2020, Hussain et al. 2022, Ghazvini F, and Abbaspour 2020. AI plays a crucial role in synthesizing data from these sensors, creating a robust system capable of providing accurate and predictive health insights.

By leveraging AI, our device can learn individual dietary habits and predict glucose fluctuations based on deviations from these patterns. This predictive capability enhances the device's utility for diabetics and non-diabetics, providing personalized insights and proactive health management.

4.3. Merging Two Technologies for Cost-Effectiveness:

Combining non-invasive glucose monitoring with caloric intake tracking into a single device simplifies the user experience and proves more cost-effective. Users no longer need to invest in separate devices for glucose and activity monitoring (Fuller et al. 2020), and the integration of these functions into one wearable can lower production and maintenance costs. This holistic approach also ensures more cohesive data analysis, leading to better health outcomes.

4.4. How is it going to make life better than existing tech?

Our device will simplify health management by consolidating two critical functions into one wearable, reducing the burden of using multiple devices. Its non-invasive nature will likely improve user adherence and comfort. Additionally, the predictive capabilities enabled by AI will empower users with proactive health management tools, potentially leading to better glucose control and overall well-being.

4.5. Some limitations of the proposed technology:

Despite its potential, there are challenges and limitations to consider. Achieving high accuracy in non-invasive glucose monitoring remains a significant hurdle. Sensor placement and individual variations in skin and tissue characteristics can affect readings. Moreover, integrating caloric intake monitoring with glucose data requires sophisticated algorithms and extensive user data to train the AI effectively.

In conclusion, I have tried to establish the importance and need for an AI-enabled technology that combines the characteristics of different wearables present in the current market to monitor glucose levels in the blood and caloric intake along with other information like sleep, stress levels, physical activity, etc. The case studies done in this report are unique and have incorporated data from two individuals with diabetes where one is on calorie controlled diet while the other is not, an individual with diabetes and thyroid issues, two volunteers with borderline diabetic condition, but one with an active lifestyle while the other with a sedentary lifestyle. The study also included a healthy non-diabetic individual with an active lifestyle to include this information as control data. The data presented in these 6 cases strongly supports the development of a non-invasive device that can provide real-time data and personalized recommendations, and could revolutionize diabetes management and promote overall well-being.

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