Smartphone-based laser glucometer for non-invasive measurement of glucose level of diabetic patients

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Abstract

Self-management of blood glucose level is crucial to the health of the body. Typically, a glucose meter (or glucometer) is used to measure the approximate concentration of glucose in the blood. Initially, a blood sample is acquired by finger pricking using either a manual- or automatic- lancet. This is followed by applying the blood drop to the glucostrip which is then fed to a glucometer. However, due to slow wound healing process in diabetic patient as compared to healthy individual, this conventional sampling process would expose patients' fingers into unhealed wound and bacterial infection. More importantly, two clear limitations of invasive blood sampling are its painful process and cost of acquiring the instrument, lancet and glucostrip. It becomes even more expensive as diabetic in the state of a chronic condition, which unavoidably requires constant blood glucose monitoring. Thus, the main objective of this research is to design and develop a non-invasive optical measuring technique to automatically and painlessly measure the glucose level in the body using a custom-made device consisting of a laser pointer and a smartphone. Based on Snell's law, glucose level in the urine as a function of refractive index is correlated actual reading measured using the conventional glucometer. Images captured by the smartphone is analysed using a Matlab software to determine the refractive index of the urine sample. Calibration of the system is performed by correlating the results with that of the glucometer. Both results compare well with R-squared value of 92.9%. The system can be potentially used for remote health and patient monitoring.

Keywords: diabetes; glucose; monitoring; measurement; non-invasive

1. Introduction

Diabetes Mellitus (DM) is a chronic debilitating condition in which the body does not adequately generate or response to insulin secretion. The World Health Organization (WHO) stated that about 3.4 million people died due to high blood glucose in 2004, and 347 million people worldwide have diabetes. High glucose in blood may lead to other complications such as cardiovascular diseases, damage in nerves and veins, blindness, limb amputations and kidney damage (Kaul et al., 2013). In addition, it may also lead to complications during pregnancy, rapid aging and unhealthy weight loss (Kitzmiller et al., 2008). Amongst contributing risk factor of diabetes includes body weight, diet, gender, genetic and unhealthy lifestyle (Williamson, 2009).

There are two principal types of diabetes which are Diabetes Type 1 and Type 2. Diabetes Type 1, also known as non-insulin dependent diabetes mellitus (NIDDM), frequently happens in children and young adults. NIDDM is due to genetic inheritance. Normal individuals are protected by antibody in the immune system which seek and destroys harmful bacteria, virus, and other foreign bodies.

In the type 1 NIDDM, human leukocyte antigen (HLA) encoding genes HLA-DQA1, HLA-DQB1, and HLA-DRB1 are mutated, leading to production of autoantibody, resulting in a damaged immune system which no longer capable of discriminating between self and harmful threats. This is an autoimmune condition, whereby the body produces autoantibody that destroys insulin producing β-cells of the pancreas, affecting the normal blood glucose homeostasis (Katsarou et al., 2017). In Type 1 Diabetes, although the decay of β-cell can take several years, symptoms of this disease usually present in a much shorter period of time (Williamson, 2009).

Type 2 diabetes, also known as insulin dependent diabetes mellitus (IDDM), results from insulin resistance of the body (DeFronzo et al., 2015). Literally, people who have a healthy lifestyle such as physical activity are high, vibrant lifestyle, and do not have the habit of smoking is less prone to problems related to diabetes. Diabetes Type 2 is often faced by patients due to several factors, including insulin resistance that a state in which the body's muscles, fat, and liver cells