Gait Analysis for Possible Ulcerations using Smartphone

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Abstract- **Diabetes Mellitus prevalence is much higher than estimated. It is estimated that approximately around 8% of diabetic people develop foot ulcer and around 1.8% lose their lower limb, by amputation. Main objective of our project was to develop an android mobile application to check the possibility of foot ulceration in individuals such that the percentile of lower limb amputation due to foot ulcer can be reduced as well as prevented. For this purpose, gait of individuals was analyzed with respect to their Body Mass Index. The gait was recorded and analyzed using Diafoot, our mHealth application. To suffice the research domain of this project, smartphone with the application was attached to the lower thigh of the subject. The subject was asked to walk a fixed distance of 8m and the developed application recorded acceleration, speed, step count, Body Mass Index and Ground Reaction Force. Kinetic parameters were defined based on the subject's Body Mass Index. and acceleration. The Ground Reaction Force values of the underweight, normal, overweight and obese showed significant differences as compared to the standard Ground Reaction Force value. Based on this difference, the possibility of developing foot ulceration is computed. However, this novel technique has few drawbacks which can be overcome in future research.**

Index Terms— Gait, Acceleration, Body Mass Index, Ground Reaction Force, Foot Ulceration.

1. INTRODUCTION

Diabetic foot, one of the most common and debilitating manifestations of type 2 diabetes mellitus (T2MD), is the leading cause of worldwide non-traumatic lower extremity amputations ensuing major medical, social and economic costs [1]. While diabetic neuropathy is believed to be major cause of foot ulcerations, biomechanical alterations associated with the person's gait also plays an integral role in the development of foot ulcer which leads to non-traumatic lower extremity amputations. In recent years number of researches has been carried out to assess the interconnection between biomechanical parameters and development of foot ulcer. Many factors lead to the alteration of biomechanical parameters associated with gait. Most notable factors are body mass index (B.M.I.) and age.

Gait is a cyclic activity associated with human locomotion. One gait cycle is defined as the sequence of events that take place between one heel strike to the consecutive heel strike of the same foot. Gait analysis is simply the study of human locomotion. Nowadays, various disciplines get benefited through this analysis. In medical field, number of pathological abnormalities has been diagnosed through gait patterns. Recent studies show how body mass index affects human gait. Most of the studies related to locomotion tasks have been carried out on different B.M.I groups, and their main focus was on spatiotemporal characteristics of gait, foot plantar pressure and the possible relationships between posture and B.M.I. [2]. These studies revealed strong link between a person's body mass and orthopedic problems due to overloading on the musculoskeletal structures as, in obese condition [3][4][5][6]. Collectively they stated that higher the B.M.I., more the alterations in human gait. When compared with normal weight individuals other B.M.I categories showed significant differences in plantar pressure and foot mechanics [7].

$$BMI = \frac{Weight(kg)}{height * height\ (m^2)}$$

Walking speed is a result of a complex coordination of multiple body structures and functions. They are reliable measure for assessing as well as monitoring functional and overall health of the individual. Studies have shown that age plays an important role in influencing walking speed. The study revealed that age and walking speed are proportional to each other, higher the age, lower the walking speeds [8]. Ground reaction force (GRF) is a force exerted by the ground on a body in contact. Generally, it is used to evaluate the ability of individual to produce force and power. The GRF characteristic is taken as important descriptor of pathological gait. It can be easily obtained during routine clinical gait analysis for complementary measure for standard data reporting. GRF measurement was used earlier in various studies i.e. identification of muscle forces in human lower limb during sagittal plane movements, in the monitoring of the physiotherapy process after complex surgery or in hemiplegic, cerebral palsy and stroke patients. Normal human walking is characterized by the vertical displacement of the body center of gravity (COG) that moves through a complete cycle of vertical motion with each step or 2 cycles during each stride. Depending on the gait speed, the COG rises twice during gait cycle. The center of gravity is affected by the position of the lower and upper extremities which moving independently with the trunk. With the increased use of force platforms, COG displacement based on ground reaction forces during motions with continuous ground contact have been calculated through a simple dynamic equilibrium based on Newton's Second Law [9]. In case of acceleration, the y component of GRF normalized to body weight is represented as the sum of acceleration along y component and force of gravity whose result is divided again by force of gravity.

$$GRF_y[BW] = \frac{a_y + g}{g}$$

Where, ay = y acceleration of the accelerometer
g = Force of gravity
[BW] = Body weight

The latest generation of smartphone is increasingly viewed as handheld computers rather than as phones, due to their powerful computing capabilities and open operating systems that encourage new application development. We found a higher percentage of mobile apps in which the majority of health tracking. There was only management application while there was not any self-assessment of foot ulcer app. Thus, the main aim of our project was to use all these parameters to determine the possibility of foot ulceration using our developed mobile health application, as accurately as it is obtained through conventional gait analysis.

II. MATERIALS AND METHODS

A. Mobile Health Application Development

Mobile application development is a general term used to denote the entire process of developing application software through hand held devices like smartphones which can be preinstalled on devices to provide a web browser experience. Our mobile application was developed using a tool called MIT App Inventor. This inventor tool is equipped with all the required user interfaces which can be made functional through the block editor logic. Our smartphone health application consists of 8 screens.

Screen 1- It is the main app outline which consists of all the functional buttons of other screens, as shown in figure 1.

Screen 2 & 3- It provides the necessary information about foot ulceration to the user and enables the inbuilt accelerometer sensor to record the acceleration values along three axes.

Screen 4- It provides both the pictorial and numerical representation of the acceleration as shown in figure 2.

Screen 5- It displays the BMI of the user based on the user defined height and weight values as shown in figure 3.

Screen 6 & 7- It displays the number of steps taken by the user to cover a prefixed distance and speed of the user based on the time taken to cover that fixed distance as shown in figure 4.

Screen 8- It displays the final result, possibility of developing foot ulceration, based on the GRF value as shown in figure 5.

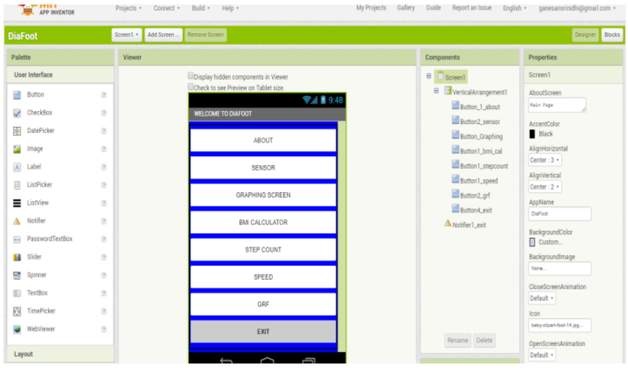

Figure 1- App main screen

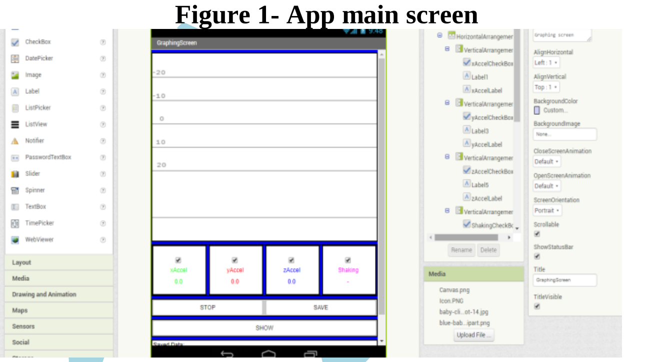

Figure 2- Graphing screen

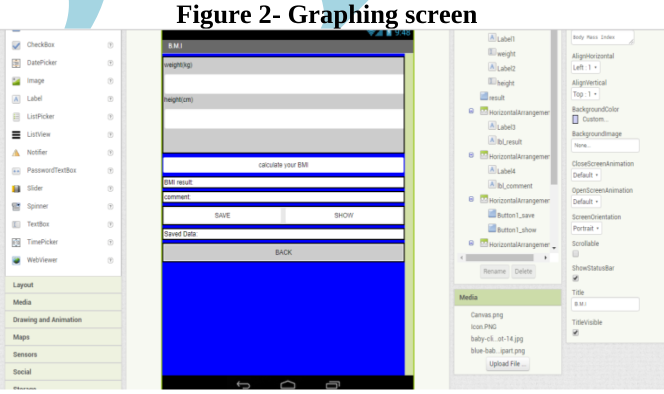

Figure 3- BMI calculator

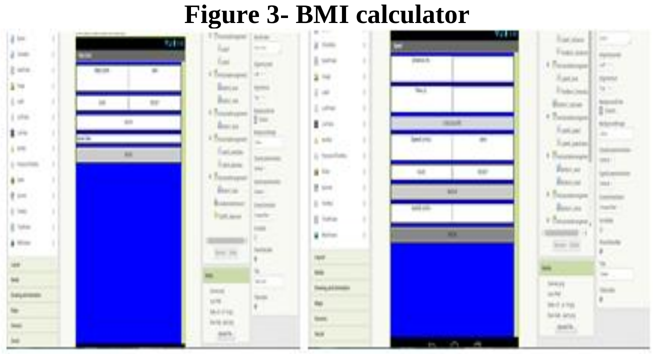

Figure 4- Step count and Speed calculator

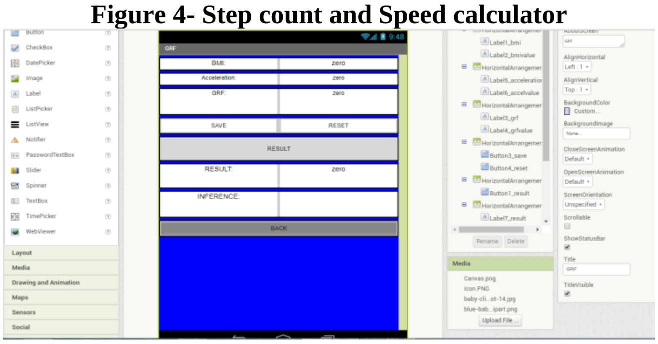

Figure 5- GRF and Final result

B. Subjects

As a part of our project, ten normal subjects of various age groups and weight were taken for data collection. Each subject was well informed about the testing procedure and due concern was obtained prior to the testing.

C. Data Acquisition

Attention was paid particularly on the position of smartphone which has the inbuilt accelerometer sensor. The smartphone was vertically fixed at the lower thigh for recording acceleration and at the upper knee region for recording step count. Our developed smartphone application recorded both acceleration and step count when the subject walked a fixed distance of 8m at his/her own pace. We carried out our entire project using Samsung galaxy grand 2 and Lenovo zuk z1 smartphones. These phones are equipped with three axes accelerometer and proximity sensor. Depending upon the relation between force of gravity, acceleration and subject's movement the values are distributed along three separate components i.e. x Accel (horizontal movement), y Accel (forward and backward movement), z Accel (vertical movement). Our application is designed in such a way that it will only take the y Accel value for computing the GRF, which will predict the possibility of foot ulceration, as shown in figure 6.

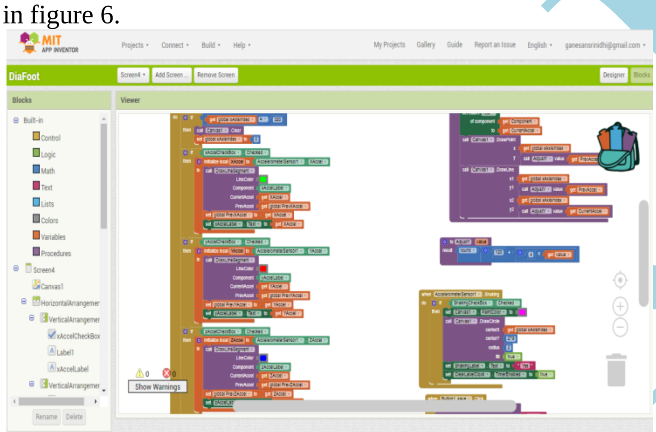

Figure 6- Graphing screen block editor

The body mass index value, which is one of the main input for GRF computation is calculated based on the standard BMI formula incorporated in our application, as shown in figure 7.

Figure 7- BMI block editor

Speed is computed using the standard formula. All these values of acceleration, BMI, step count and speed are stored in tinydB format in our smartphone application.

GRF is computed by importing the stored current BMI value and y Accel value and the result which predicts the possibility of foot ulceration is expressed in the form of percentile.

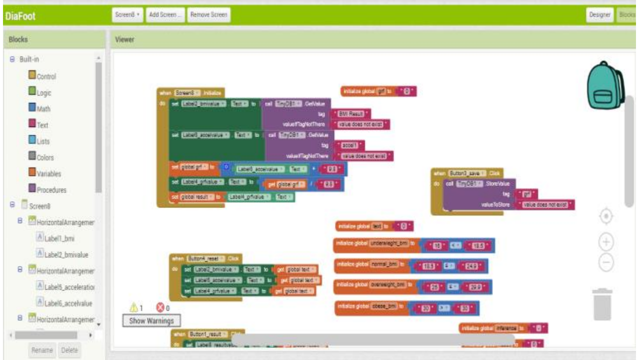

Figure 8- Final result block editor

III. RESULT

A. App Framework

Our developed mobile health platform has a user friendly fully automated interface loaded with the ability to save the recorded values such that the user can reevaluate his/her gait and compare the same with former result. Figure 9 shows the acceleration value of the user, recorded using Diafoot and the BMI value calculated based on the user defined input. Figure 10 shows the step count and speed value and Figure 11 shows GRF value based on the recorded BMI and acceleration values imported from the respective screens. Final result is displayed in the form of percentile.

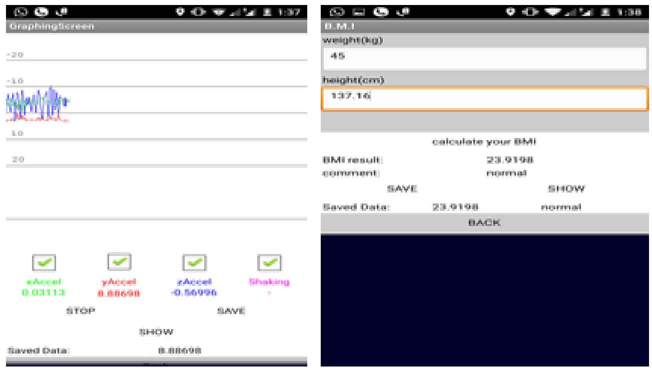

Figure 9- Graphing Screen and BMI Calculator

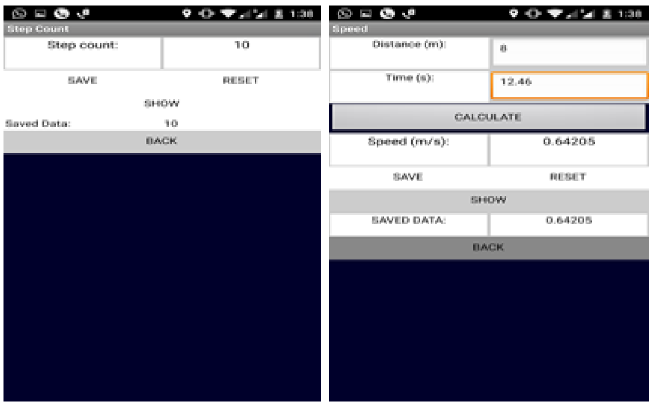

Figure 10- Step Count and Speed Value

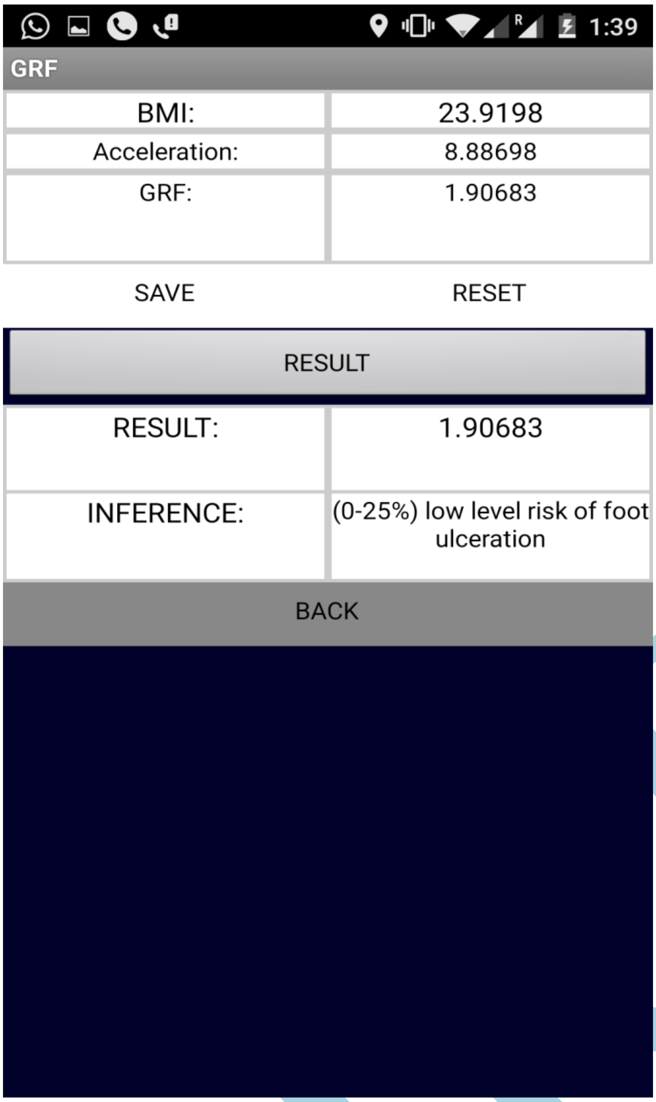

Figure 11- Final result

B. Data

Table 1 represents the data collected of subjects belonging to different age groups and BMI.

NAME	AGE	GENDER	WEIGHT in kg	HEIGHT in cm	BMI	X Accel	Y Accel	Z Accel	DISTANCE in m	TIME in s	SPEED in m/s	STEP COUNT	GRF
GANESAN	50	Male	79	172	26.70362	0.15323	9.87369	-1.00556	8	10.71	1.33875	6	2.00752
KALAISELVI	50	Female	45	154	18.90453	-0.25857	10.01734	-0.85234	8	12.46	0.642	11	2.0222
SRINIDHI	21	Female	56.5	166	20.5017	-0.38307	9.56723	2.8922	8	10.02	0.7984	7	1.9762
MOHANA	21	Female	90	167	31.88776	-1.89621	9.70131	1.35991	8	8.07	0.991	7	1.9899
KATHIRVELU	36	Male	75	174	24.7721	-0.26815	9.63427	0.63207	8	7	1.143	5	1.9831
MUTHU	36	Male	82	170	28.3737	0.42138	9.63427	-1.20668	8	12.63	0.633	7	1.9831
MADHAN	32	Male	71	167	25.45807	0.32716	6.83784	0.73405	8	7.37	1.085	7	1.6977
BILAL	35	Male	64.2	169	22.4782	-0.06704	9.68215	-1.36948	8	7.31	1.094	10	1.988
JP	28	Male	68	177	21.70513	0.72784	9.90242	-0.91937	8	7.15	1.118	5	2.0104
RAMRAJ	24	Male	72	168	25.5102	-0.68953	9.55765	-1.88663	8	8.34	0.959	6	1.9753

Table 1- Data Obtained

IV. LIMITATIONS

Though this work appears easier and accurate, this has some limitations which have to be overcome before this can be applied into clinical practice. This application can be used only for the prediction of possibility of occurrence of foot ulcer in adults. Even though the user has a high risk of developing a foot ulcer based on GRF, the subject cannot just stop with the use of this app but should end up meeting with the general physician or a diabetologist to figure out the exact cause. It is an offline application which does not need internet connection but it allows only one user and reading to be taken at a time. This application is built only to support android phones and it is not supported in ios or windows phones.

V. CONCLUSION AND FUTURE ENHANCEMENT

At present, the gait assessment of computing gait parameters to identify any pathological abnormalities using a cost effective and technologically facile methodology has been progressing at a much faster rate and researchers are keen on developing mHealth application, which adds up to progress rate, to replace the conventional procedure followed in the Gait Analysis Laboratory which is time consuming and money draining. This project involves only the mobile application which includes all the required parameters needed to predict the possibility of foot ulceration. The analysis, if, obtained from the traditional methodology can give us the much detail gait values since it takes gait of the individual, as a whole, by incorporating all the sensors and taking into account all the gait parameters. This mobile application has been created as an offline application with one possible user at a time. It can be developed as an online app using the network connections which will enable multiple user facility by developing a website with wider database storage. Many other sensors like gyroscope for angle measurement, external force sensor and pedometer etc. can be incorporated to measure wide gait parameters. It can be modified to support the ios and windows phone platforms. The app can also be updated as a full time gait monitoring app by adding features that are available on the conventional gait analysis setup and also as a fall detection app to help elderly people with an alert system to notify the subject's condition to the caretaker or family members to avoid serious damage.

VI. DISCUSSION

A. Conflict of interest

The authors of this paper declare there was no conflict of interest in any form, including financial support, associated with this research.

B. Acknowledgement

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