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Gait Analysis for Possible Ulcerations using Smartphone: A Case Study

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Abstract:- **Gait analysis is the study of body mechanics to assess individual's ability to walk. Foot ulcer may occur for various reasons, peripheral neuropathy being one of them, is a main reason for non-traumatic lower limb amputation. Main objective of our project was to study the gait pattern of individuals for differences in Ground Reaction Force value in accordance with their BMI using android mobile application to check the possibility of foot ulceration. The gait was recorded and analyzed using Diafoot, our mHealth application. To suffice the research domain of this case study, 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. Our study showed that the Ground Reaction Force values of the underweight, normal, overweight and obese individuals showed significant differences, with which we found that it is practicable to predict the possibility of foot ulceration using Ground Reaction Force value since it will eventually impact the foot plantar tissue.**

Key Words: Gait, Acceleration, Body Mass Index, Ground Reaction Force, Foot Ulceration.

I. 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 a 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].

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.

Since every advanced technology comes with the price. It is the financial barrier that holds back this analysis from turning out to be a cutting-edge technology in the field of medicine. On the other hand, 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 them are related to health tracking. Thus our main aim of this study, taking into

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account the effect of cost and this new smartphone generation we developed an application, to determine whether it is practicable to predict the possibility of developing foot ulceration, as accurately or close by, 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 separate screens for recording acceleration and Body Mass Index as shown in Figure 1 and 2.

Figure 3 represents the Ground Reaction Force screen which will compute the value based on the subject's Body Mass Index (BMI) and acceleration along y-axis.

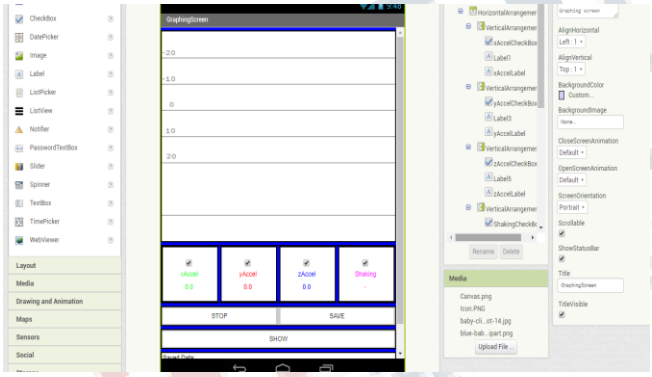

Figure 1- Graphing screen

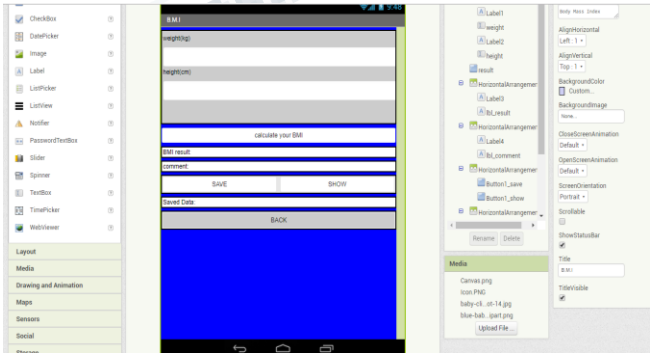

Figure 2- BMI calculator

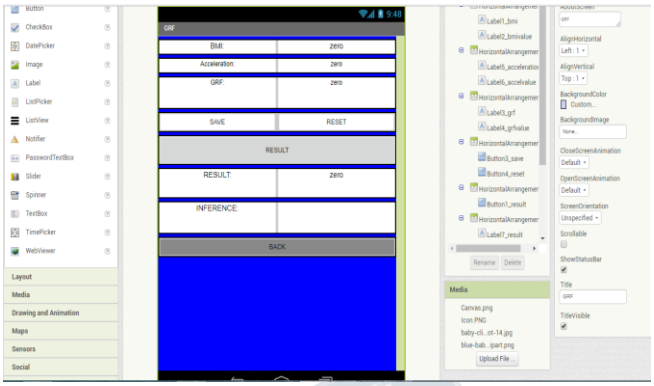

Figure 3- GRF

Subjects

As a part of our study, ten normal subjects belonging to various age groups and weight were taken for collecting acceleration and Body Mass Index. Each subject was well informed about the testing procedure and due consent was obtained prior to the testing.

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 Our developed smartphone application recorded acceleration when the subject walked a fixed distance of 8m at his/her own pace. We carried out our entire study using Samsung galaxy grand 2 and Lenovo zuk z1 smartphones. These phones are equipped with three axes accelerometer and proximity sensor. Our application is designed in such a way that it will only take the y Accel value as shown in figure 4, for computing the GRF, which will help us in predicting the practicability of implementing a smartphone for checking the possibility of developing foot ulceration.

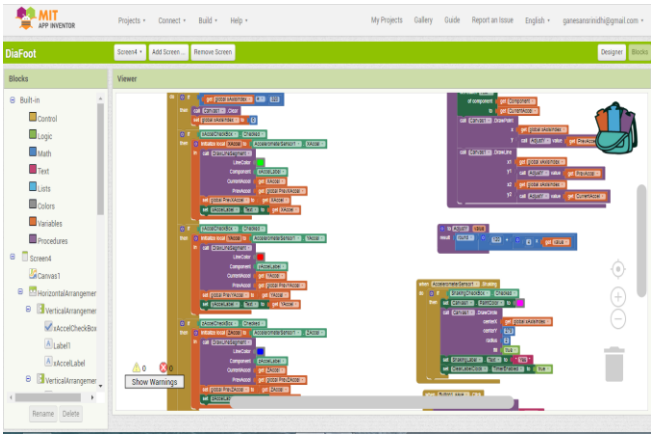

Figure 4- Graphing screen block editor

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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 5. The user has to manually feed the height and weight value to obtain BMI result. The application developed will also display comments based on the standardized Body Mass Index range.

Figure 5- BMI block editor

Both these values of acceleration and BMI are stored in tinydB format in our smartphone application.

Our application was designed in such a way that it calculates ground reaction force as shown in figure 6, by taking the recently computed BMI value and y Accel value as inputs.

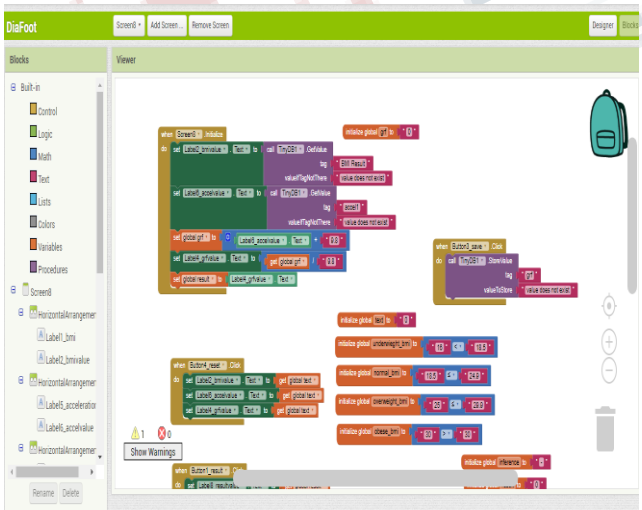

Figure 6- GRF block editor

III. RESULT

Data

Table 1 represents the data collected from ten subjects belonging to different age groups and Body Mass Index.

NAME	AGE	GENDER	WEIGHT in kg	HEIGHT in cm	BMI	X Accel	Y Accel	Z Accel	GRF
GANESAN	50	Male	79	172	26.70362	0.15323	9.87369	-1.00556	2.00752
KALAISELVI	50	Female	45	154	18.90453	-0.25857	10.01734	-0.85234	2.0222
SRINIDHI	21	Female	56.5	166	20.5017	-0.38307	9.56723	2.8922	1.9762
MOHANA	21	Female	90	167	31.88776	-1.89621	9.70131	1.35991	1.9899
KATHIRVELU	36	Male	75	174	24.7721	-0.26815	9.63427	0.63207	1.9831
MUTHU	36	Male	82	170	28.3737	0.42138	9.63427	-1.20668	1.9831
MADHAN	32	Male	71	167	25.45807	0.32716	6.83784	0.73405	1.6977
BILAL	35	Male	64.2	169	22.4782	-0.06704	9.68215	-1.36948	1.988
JP	28	Male	68	177	21.70513	0.72784	9.90242	-0.91937	2.0104
RAMRAJ	24	Male	72	168	25.5102	-0.68953	9.55765	-1.88663	1.9753

Table 1- Data Obtained

From the collected data we found that the Ground Reaction Force for each varied with his/her acceleration and Body Mass Index (BMI). It can also be seen that this distribution is not uniform. We found that despite higher BMI if the subject's pace is normal, then his/her GRF value was less, i.e., the possibility of developing foot ulceration is low since the force impact on the foot plantar tissue is low. On the other hand, if the subject's BMI is normal but his/her pace is high, the GRF value computed showed a higher risk of developing a foot ulcer.

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. Only two parameters can be obtained using this application. Clinical trials need to be performed before incorporating into everyday use. 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. Though we conducted our study only on ten normal subjects, after interpreting the data obtained we conclude that it is practicable to predict the possibility of developing foot ulceration using a hand held device by every individual in his/her home without the need of conventional gait lab.

The analysis, if, obtained from the traditional methodology can give us a very 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. Many other sensors like gyroscope for angle measurement, external force sensor and pedometer etc. can be incorporated to measure wide gait parameters. The app can also be updated as a full time gait monitoring app by making it fully automated and adding features that are available on the conventional gait analysis setup.

DISCUSSION

D. 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.

E. Acknowledgement

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