ROLE OF MULTIPOINT CONTACT PHOTOPLETHYSMOGRAPHY IN ASSESSING CHANGES IN BLOOD FLOW IN THE PLANTAR ASPECT OF THE CONTRALATERAL FOOT FOLLOWING AMPUTATION IN PATIENTS WITH TYPE 2 DIABETES MELLITUS- A PROSPECTIVE OBSERVATIONAL STUDY

A dissertation submitted in partial fulfilment of the requirement for the

M.S. Degree (Branch I) General Surgery examination of the

Tamil Nadu Dr. M. G. R. Medical University to be held in 2019

CERTIFICATE

This is to certify that the dissertation titled " **Role of multipoint contact photoplethysmography in assessing changes in blood flow in the plantar aspect of the contralateral foot following amputation in patients with type 2 diabetes mellitus**" is a bonafide work of **Dr. Keerthi K** in the Department of General Surgery, Christian Medical College, Vellore in partial fulfilment of requirements for the M.S. General Surgery Branch I Examination of the Tamil Nadu Dr. M.G.R University, Chennai to be held in 2019. This thesis has not been submitted, in part or full, to any other university.

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CERTIFICATE

This is to certify that the dissertation titled " **Role of multipoint contact photoplethysmography in assessing changes in blood flow in the plantar aspect of the contralateral foot following amputation in patients with type 2 diabetes mellitus**" is a bonafide work of **Dr. Keerthi K** conducted under my guidance in the Department of General Surgery, Christian Medical College, Vellore in partial fulfilment of requirements for the M.S. General Surgery Branch I Examination of the Tamil Nadu Dr. M.G.R University, Chennai to be held in 2019. This thesis has not been submitted, in part or full, to any other university.

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Principal

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DECLARATION CERTIFICATE

This is to certify that the dissertation titled "**Role of multipoint contact photoplethysmography in assessing changes in blood flow in the plantar aspect of the contralateral foot following amputation in patients with type 2 diabetes mellitus**" comprises only my original work and due acknowledgement has been made in text to all the material used. This thesis has not been submitted, in part or full, to any other university.

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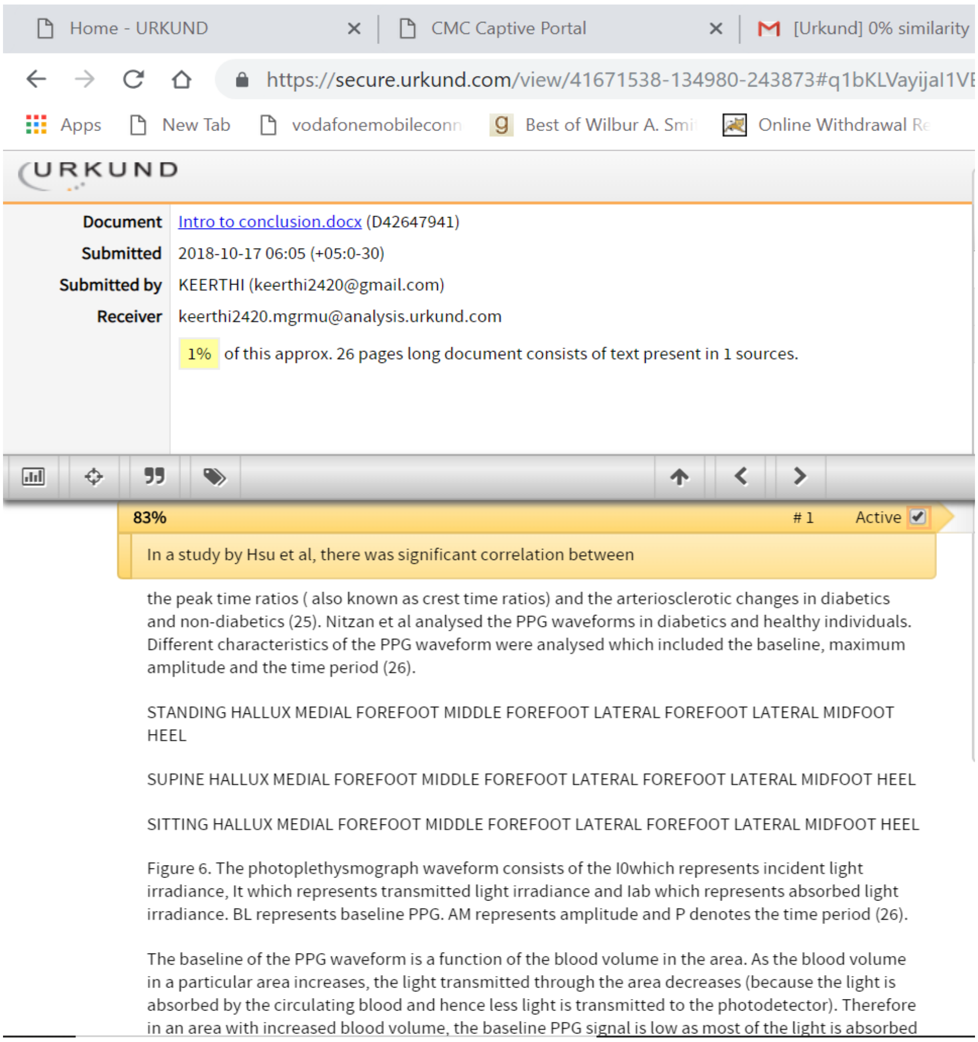
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In a study by Hsu et al, there was significant correlation between

the peak time ratios (also known as crest time ratios) and the arteriosclerotic changes in diabetics and non-diabetics (25). Nitzan et al analysed the PPG waveforms in diabetics and healthy individuals. Different characteristics of the PPG waveform were analysed which included the baseline, maximum amplitude and the time period (26).

STANDING HALLUX MEDIAL FOREFOOT MIDDLE FOREFOOT LATERAL FOREFOOT LATERAL MIDFOOT HEEL

SUPINE HALLUX MEDIAL FOREFOOT MIDDLE FOREFOOT LATERAL FOREFOOT LATERAL MIDFOOT HEEL

SITTING HALLUX MEDIAL FOREFOOT MIDDLE FOREFOOT LATERAL FOREFOOT LATERAL MIDFOOT HEEL

Figure 6. The photoplethysmograph waveform consists of the I0which represents incident light irradiance, It which represents transmitted light irradiance and Iab which represents absorbed light irradiance. BL represents baseline PPG. AM represents amplitude and P denotes the time period (26).

The baseline of the PPG waveform is a function of the blood volume in the area. As the blood volume in a particular area increases, the light transmitted through the area decreases (because the light is absorbed by the circulating blood and hence less light is transmitted to the photodetector). Therefore in an area with increased blood volume, the baseline PPG signal is low as most of the light is absorbed

ACKNOWLEDGEMENTS

Firstly, I am thankful to the Almighty for His grace and mercy through the entire course.

I would like to thank my guide Dr Pranay Gaikwad who has been an inspiration and a source of constant support to me. He was instrumental in helping me define my thesis topic and objectives. I would also like to thank him for all the times he has selflessly taken the extra effort to personally encourage me during the initial period of setbacks. I would also like to thank Dr John C Muthusami, former Head of Department of General Surgery for his timely suggestion regarding formulation of my thesis topic.

I would like to thank Dr Suresh Devasahayam who has been my co-guide. True to his nature, he had envisioned the prospects associated with the thesis topic and motivated me to pursue the same. It was only an attempt to emulate his zeal for science and research which helped me finish my thesis. I would like to thank Dr Cecil T Thomas who has also been my co-guide. He always motivated me towards perfection and accordingly gave timely inputs.

I am extremely grateful to Ms Syrpailyne Wankhar, Department of Bioengineering. It is only due to her untiring efforts that the device used in my thesis became functional and durable. I am also indebted to Mr. Sahil Gera who has unflinchingly helped me with all the technical aspects of my thesis.

I would like to thank my dear friend Dr. Farhan Adam whose timely help was key in finishing my thesis data analysis. I would like to thank my biostatistician Ms Grace Rebekah for providing me with all the necessary help and guidance.

I would like to thank Ms Evangeline Vasugi who tirelessly helped me measure toe pressures for all patients in the vascular laboratory.

I am forever indebted to my parents Col. Kumaran and Mrs. Bhuvana for their unconditional love and guidance. I am grateful to my brother Karthik for being a source of constant support. I also owe my gratitude and love to my grandparents.

I would like to thank my friends Swarna Azaria, Saneel Charles, Susmita Dey, Naveen and Niranjan Prabhu for their continued motivation.

Most importantly I would like to thank all the patients and their relatives for being a part of my study.

TABLE OF CONTENTS

1. INTRODUCTION

Diabetes mellitus has emerged as one of the most rampant metabolic disorders in the past century owing to multiple social, genetic and lifestyle factors. The effects of diabetes mellitus on the human body are numerous and multiple hypotheses have been proposed to explain these effects at a molecular level.

India has also seen a steady rise in the number of people diagnosed with diabetes mellitus or those who present with complications secondary to diabetes. Of significant interest and research is the effect of diabetes on the blood flow, both at the macrovascular level and microvascular level. One of the most debilitating complication secondary to diabetes mellitus is the development of diabetic ulcers and subsequently the need for amputation. Amputation of any kind accounts for considerable morbidity and alteration in the quality of life. Hence, there is an imminent need to screen and identify individuals at risk for developing complications in the foot secondary to diabetes.

A gamut of options are available to indirectly assess the blood flow to different parts of the body, each with its own advantages and limitations. One such modality is the use of photoplethysmography which has until now been widely used for characterising various physiological parameters like blood pressure, heart rate and respiratory rate.

To explore the use and application of photoplethysmography in assessing the blood flow to the foot is the primary objective of this study. It would facilitate the identification of areas of the foot at risk for ulceration and other changes secondary to diabetes mellitus. This could potentially pave the path for developing appropriate footwear or other offloading devices to curtail the progression of the disease. This may hopefully decrease the need for amputations, thereby resulting in a better quality of life.

2. AIM AND OBJECTIVES

AIM

To study the role of multipoint contact photoplethysmography in assessing the changes in blood flow in the plantar aspect of the contralateral foot following amputation in diabetic patients.

OBJECTIVES

Primary: To determine the peak amplitudes and peak times using photoplethysmography (photoplethysmograph) waveforms as a measure of changes in blood flow in the plantar aspect of contralateral foot in diabetic patients following amputation.

Secondary:

1. To compare the changes in blood flow over the plantar aspect of the foot in diabetic patients with age and gender matched normal subjects.
2. To map the variations in blood flow over the plantar aspect of the foot and therefore identify areas of early microvascular changes in the foot.

Null hypothesis

There are no variations in the photoplethysmography waveforms over the plantar aspect of the contralateral foot in diabetic patients following amputation.

Alternate Hypothesis

There are early microvascular changes in the feet of diabetic patients that can be assessed with the principle of photoplethysmography.

3. REVIEW OF LITERATURE

Diabetes mellitus has found its place in the global platform as one of the most rapidly emerging diseases. According to the diabetes IDF atlas, the global burden of diabetes mellitus in 2017 was approximately 451 million (1).

There are two broadly accepted types of diabetes mellitus – type I and type II. Type II diabetes mellitus is more common in the adult population. Diabetes mellitus has a multifactorial etiology. There is an interplay between impaired insulin secretion and insulin resistance which ultimately results in skewed insulin homeostasis in the body (2).

Uncontrolled type II diabetes mellitus is associated with multiple complications which can affect different parts of the body. These can be either microvascular or macrovascular (3). Microvascular complications encompass diabetic nephropathy, neuropathy, retinopathy. Macrovascular complications include risk of cerebrovascular disease, coronary artery disease and peripheral arterial disease.

3.1 PATHOPHYSIOLOGY AND MICROENVIRONMENT IN DIABETES MELLITUS

The effect of diabetes on the foot is the result of a complex interaction between microangiopathy and neuropathy which are co-dependent factors.

The important factors affecting microcirculation include the following:

1. Local homeostasis regulated by the autonomic nervous system- This refers to the sympathetic and parasympathetic nerve fibres innervating the arterioles and capillaries which ultimately regulate the amount of blood flow in the foot.
2. Effect of gravity and posture on the sympathetic tone- In the standing position there is pooling of blood in the lower extremities. There is an increase in hydrostatic pressure which causes higher venous pressures. This triggers the venoarterial reflex causing sympathetic vasoconstriction (4). It is a local axon mediated reflex which causes precapillary vasoconstriction in response to high venous pressures in the orthostatic position.
3. Metabolic factors- Chronic hyperglycemia causes the activation of multiple intracellular signalling pathways which results in formation of glycation end products, release of harmful reactive oxygen species, polyol formation, decreased angiogenesis and recruitment of immune cells for wound healing. These ultimately damage the endoneurium of nerve fibres (5).
4. Endothelial factors- The endothelium releases several cytokines, growth factors and neurotransmitters which regulate blood flow. For example- acetylcholine, prostaglandins, endothelin, histamine and bradykinin released from the endothelium cause vasoconstriction whereas nitric oxide, prostacyclin and endothelium-derived hyperpolarizing factor result in vasodilation (6).

3.2 ANATOMY OF THE SKIN AND MICROVASCULATURE

The skin has two distinct layers:

1. The epidermis
2. The dermis which is further broadly divided into
    - Papillary dermis which is superficial
    - Reticular dermis which is deep

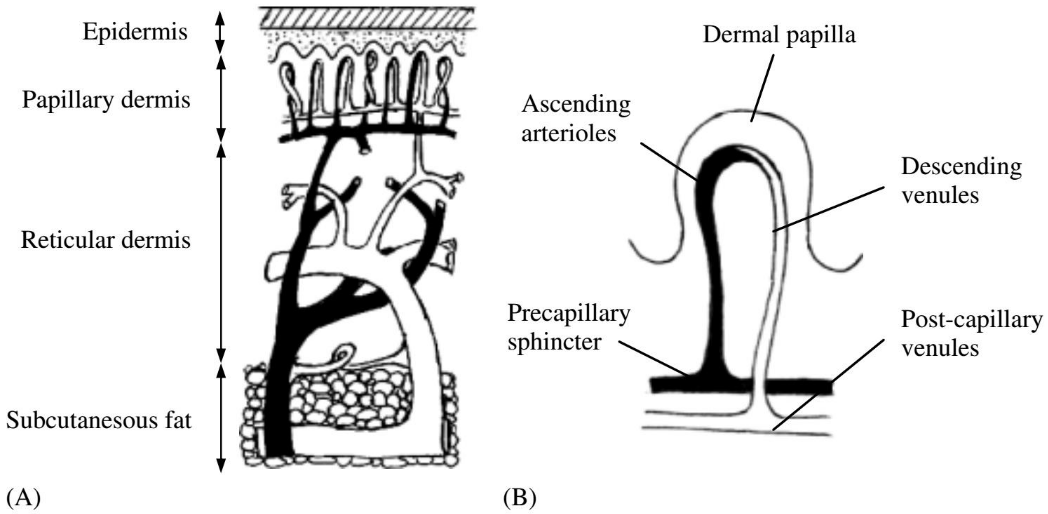


Figure 1. Anatomy of the microvasculature of the skin. (A) shows the dermal layer of the skin where the upper capillary loops are nutritive and the lower capillary loops form arteriovenous shunts which are involved in thermoregulation. (B) shows a dermal papilla with a single capillary loop (6)

It is shown that 80-90 percent of the blood flow in the skin is through the deeper arteriovenous shunts and only 10-20 percent is through the superficial nutritive capillary layer (7).

Arteriovenous shunts are low resistance systems which allow flow of blood freely between arterioles and venules. These shunts are innervated by the adrenergic(sympathetic) and cholinergic(parasympathetic) nerve fibres. These arteriovenous shunts are numerous in the glabrous (non hairy) skin and sparse in the non glabrous (hairy) areas (8). In a neutral environment, the sympathetic tone predominates and keeps the microvasculature in a vasoconstrictive state.

In patients with diabetes mellitus, neuropathic changes occur in the foot. These neuropathic changes cause a disruption of the normal sympathetic tone of the vasculature in the foot. This corroborates the finding that in diabetics there is an apparent increase in the local blood flow of the foot. The arteriovenous shunts are opened up due to the loss of normal sympathetic vasoconstrictive effect (9). This has also been termed as ‘capillary steal’ because the blood is shunted from the nutritive capillaries of the skin to the underlying arteriovenous shunts thereby depriving the skin of its nutrition. This predisposes the skin to ulceration and delayed wound healing.

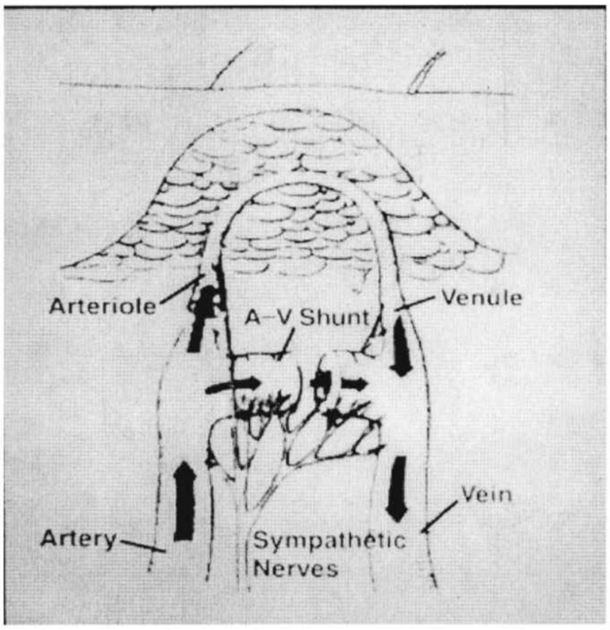


Figure 2. Normal vasculature of the foot (8)

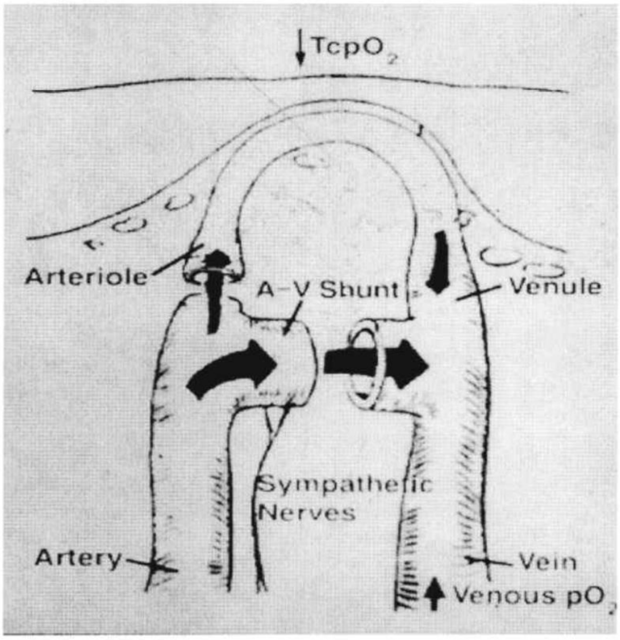


Figure 3. Loss of sympathetic tone and opening up of arteriovenous shunts in patients with diabetes mellitus (8)

Parving et al elucidated the **hemodynamic hypothesis** of diabetic microangiopathy which stated that in early diabetes there is an increase in the microvascular blood flow in the capillaries and arterioles (10). It occurs due to direct damage caused by polyols and advanced glycation end (AGE) products in hyperglycaemic states. There is a decrease in peripheral arterial resistance which causes increased blood flow through the arterioles and capillaries. This apparent increase in the blood flow has a detrimental effect on the vascular endothelial basement membrane. In response to the raised local blood flow there are shearing forces acting on the endothelial surfaces which results in an inflammatory response. This results in enhanced permeability of the basement membrane causing aggregation of various extracellular matrix proteins and over a period of time contributing to arteriosclerosis. There is also a decrease in the size of the capillary with pericyte degeneration (11). These arteriolar basement membrane changes prevent the microvasculature from appropriately dilating in response to increased demands, i.e., loss of normal reactive hyperemia.

This increase in the blood flow through the arteriovenous shunts can also lead to subclinical edema of the foot.

3.3 CONVENTIONAL METHODS OF ASSESSING MICROVASCULAR CHANGES IN DIABETICS

Early microvascular changes are present in the feet of diabetic patients which contributes to the aetiology of diabetic ulcers, vascular compromise and need for amputations. Many investigatory modalities have been proposed to assess these microvascular changes which include ankle brachial index (ABI), toe-brachial index (TBI), toe pressures, transcutaneous oxygen pressure (TcPO2) and laser doppler flowmetry.

3.3.1 ANKLE BRACHIAL INDEX

The ankle brachial index is widely used as a tool to assess the blood supply to the lower limb. It has been used in the diagnosis of peripheral vascular disease. Calculation of ankle brachial pressure index involves the following steps(12)

- Measuring systolic pressure across the brachial artery of both upper limbs
- Measuring systolic pressure across dorsalis pedis artery of each lower limb
- Measuring systolic pressure across posterior tibial artery of each lower limb
- Ratio of highest ankle pressure(across dorsalis pedis or posterior tibial) to the highest brachial pressure gives the Ankle Brachial pressure index

An ankle brachial index of ≤ 0.90 mmHg is generally indicative of peripheral arterial disease (13). ABPI of <0.4 is associated with severe peripheral arterial disease and increased incidence of gangrene, need for amputations and delayed wound healing.

An ABPI of >1.3 is seen when the vessels become hardened or incompressible. This is seen especially in patients with diabetes mellitus where there is calcification of the tunica media layer of the arteries. This can also be present in the elderly and those with chronic renal disease. Hence in diabetics, ABPI becomes unreliable as a diagnostic tool (14). ABPI is a poor indicator of the microvascular changes occurring in the foot because the measurements in ABPI are taken proximal to the ankle (15).

In such patients where the ankle brachial index is unreliable, toe brachial index or toe pressures have been used. The toe brachial index is the ratio between the systolic pressure measured at the hallux and the brachial systolic pressure. The toe brachial index can be considered a better indicator of distal perfusion but there is a concomitant broad range of error when utilizing a manual sphygmomanometer and handheld Doppler to measure toe systolic pressure (15).

3.3.2 TOE PRESSURE

Toe pressures have also been used as an indirect means to measure blood flow across the foot. They are considered more representative of the microcirculation of the foot when compared to ankle brachial pressure index. Toe pressures less than 30mm of mercury are an indicator of poor wound healing in patients with diabetic foot. Toe pressures can be measured using various methods. The commonly used method involves placing a cuff around the first toe (16). A photoplethysmograph probe is then placed over the pulp of the first toe which identifies the blood flow in the particular area and represents them as waveforms. The cuff is inflated until there is disappearance of the waveform. The cuff is further inflated to about 20mm above this pressure. Then the cuff is slowly deflated until there is return of the waveform. The cuff pressure at which the first systolic peak reappears is taken as the toe pressure(17).

3.3.3 TRANSCUTANEOUS OXYGEN TENSION

Transcutaneous oxygen tension is another noninvasive method to assess tissue perfusion. The TcPO2 is an indirect measurement of the partial pressure of arterial oxygen (PaO2) and does not reflect oxygen delivery or oxygen content(18). The basic principle involved is the placement of sensors over an area of skin which causes a local rise in temperature (37 degree Celsius to 45 degree Celsius). This rise in temperature causes enhanced flow of oxygen in the nutritive capillaries which can then be assessed by the TcPo2 sensors. In comparison to other microvascular assessments, TcPO2 is relatively time consuming and cumbersome. It takes about 30 minutes or longer as the electrode requires at least 15 minutes to warm up and the sensors require calibration(19). It is also argued that the measurements of TcPO2 are not accurate and reliability of results is equivocal. Callosities or thickening of the skin, edema of the limbs can result in falsely decreased TcPO2 values. There can also be falsely increased values due to patient movement and increased capillary flow.

3.3.4 LASER DOPPLER FLOWMETRY

This is another method of assessing the perfusion of the skin. Laser doppler flowmetry (LDF) uses monochromatic wavelength of light which is scattered by the moving red blood cells and detected by a photodetector. The laser doppler flowmetry is determined by the concentration of the red blood cells and the velocity of red blood cells in a given area. This ultimately represents the blood volume in the given area. The output from LDF is expressed in terms of 'perfusion flux' instead of simple flow. This is because the LDF detects changes in the light that is scattered only by the moving red blood cells and not the static cells (20). There are different bands that are generated in the laser doppler signal corresponding to the cardiac, respiratory, myogenic, neurogenic and endothelial physiological processes. These components can be segregated and each of them can be studied individually thereby providing a means to assess microvascular changes(20). The disadvantage of LDF is its restriction in assessing only one region area of interest.

All the above conventional methods of assessing blood flow in the lower limbs predominantly represent the macrovascular status of the limb with no direct measurement of the microvascular blood flow. Therefore, a need arose to explore methods which assess the changes in microvascular blood flow of the foot. This led to interest in alternate modalities like photoplethysmography. There was also a foreseeable need to find methods to assess distal blood flow over the foot accurately. Since photoplethysmography is a more direct indicator of the local blood flow in a particular area, it can arguably be considered a better representative of the distal blood flow in the foot.

3.4 PHOTOPLETHYSMOGRAPHY

Photoplethysmography (PPG) is an optical non-invasive mode of detecting changes in the pulsatile arterial blood flow. It is an indicator of volume changes in the peripheral arteriovenous channels.

The word ‘plethysmos’ is derived from Greek and means ‘increase’.

The photoplethysmograph waveform consists of a pulsatile AC (Alternating current) component and a relatively stable DC (Direct current) component. The pulsatile AC component corresponds to the cardiac cycle and has a frequency of usually 1 Hertz. This AC component is superimposed on the DC component. The DC component is determined by physiological changes in the autonomic nervous system, respiratory system and the thermoregulatory system (21). The DC component is also affected by the native tissue characteristics and the average circulating blood volume in the area of interest.

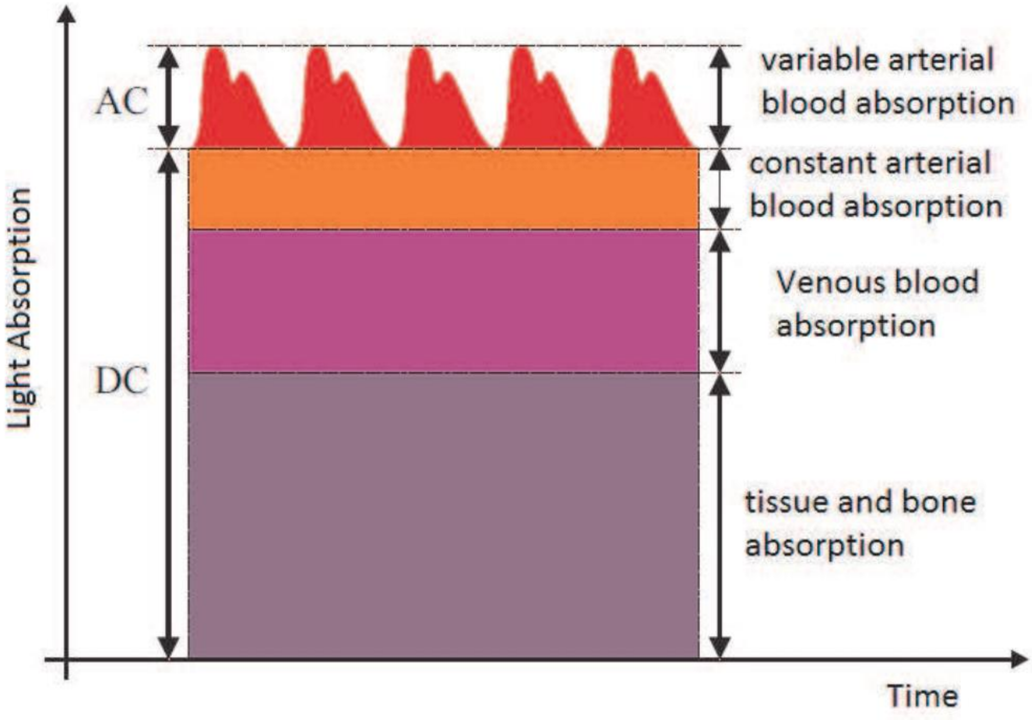


Figure 4. Illustration of the AC component and the DC component. The AC component is dynamic whereas the DC component is more dependent on the variable native tissue characteristics. The waveform captured by the PPG is predominantly the pulsatile AC component. (22)

3.4.1 PPG WAVEFORM

A typical PPG waveform has an anacrotic phase followed by a dicrotic phase (includes the dicrotic notch). Figure 5 demonstrates an ideal PPG waveform which includes a systolic peak and diastolic peak corresponding to the respective phases in a normal cardiac cycle (23). In the figure P1 denotes the peak systolic amplitude, P2 denotes the peak diastolic amplitude and t1 denotes the time period between two peaks. The systolic peak is directly influenced by the blood volume ejected during systole of the cardiac cycle. The diastolic peak on the other hand is influenced by the systemic vascular resistance.

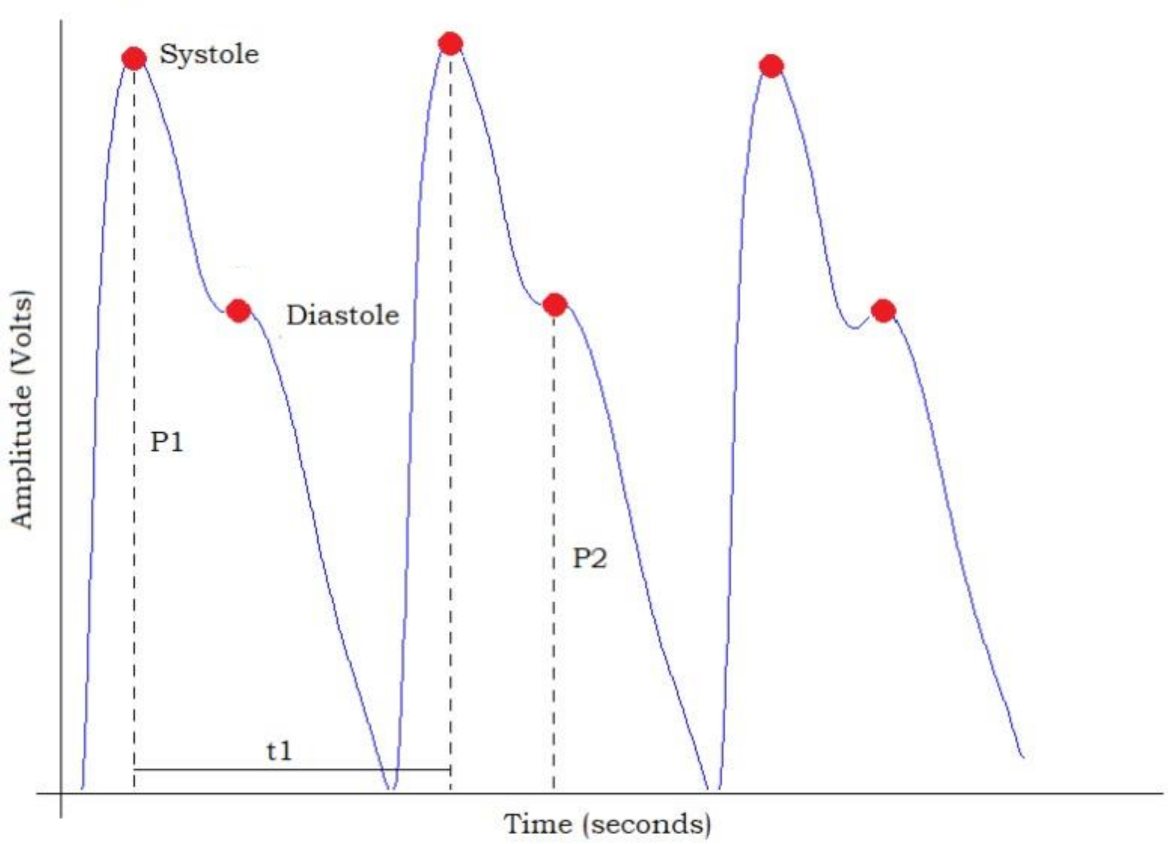


Figure 5. Ideal PPG waveform with systolic and diastolic peaks

PPG is being studied as a good indicator of heart rate variability (HRV) and changes in blood volume. Heart rate variability is assessed by studying the systolic peaks in a typical PPG waveform.

Another parameter that can be measured is the ***pulse transit time(PTT)*** i.e., the time taken for the pulse wave to travel from the aorta to the peripheral region of interest. The pulse transit time has an inverse relationship with the blood pressure (24). This PTT has been used for non-invasive continuous measurement of blood pressure.

Another variable that has been studied using PPG is the ***pulse wave velocity (PWV***). PWV refers to the velocity of the arterial pulse from one arterial segment to another. The pulse wave velocity is a determinant of the arterial compliance. When there is arterial rigidity or stiffness secondary to multiple factors including diabetes mellitus, it is reflected as a change in pulse wave velocity.

There are studies which have proposed the concept of ***pulse rate variability*** (***PRV)*** as a surrogate for heart rate variability(HRV). The difference between PRV and HRV is the transit time taken for the blood column to travel from the heart to the periphery. Hence PRV is dependent on the pulse transit time (PTT).

In a study by Hsu et al, there was significant correlation between the peak time ratios (also known as crest time ratios) and the arteriosclerotic changes in diabetics and non-diabetics (25).

Nitzan et al analysed the PPG waveforms in diabetics and healthy individuals. Different characteristics of the PPG waveform were analysed which included the baseline, maximum amplitude and the time period (26).

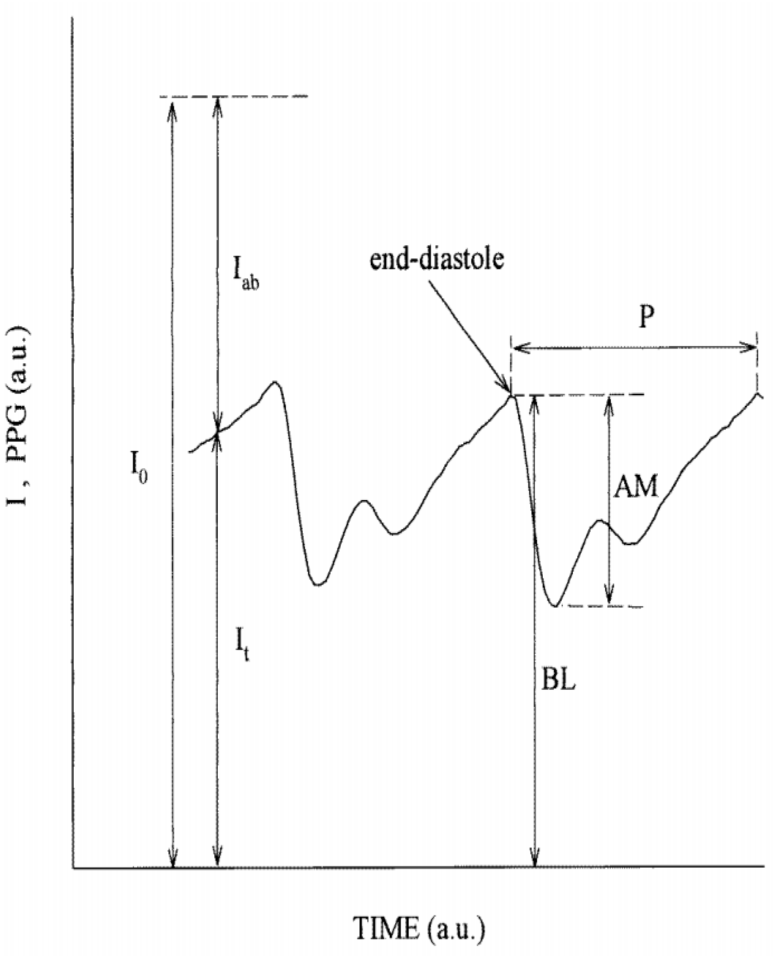


Figure 6. The photoplethysmograph waveform consists of the I_0which represents incident light irradiance, I_t which represents transmitted light irradiance and I_{ab} which represents absorbed light irradiance. BL represents baseline PPG. AM represents amplitude and P denotes the time period (26).

The baseline of the PPG waveform is a function of the blood volume in the area. As the blood volume in a particular area increases, the light transmitted through the area decreases (because the light is absorbed by the circulating blood and hence less light is transmitted to the photodetector). Therefore, in an area with increased blood volume, the baseline PPG signal is low as most of the light is absorbed by the blood and there is attenuation of the light. This explained why females had a larger baseline PPG as compared to males(the blood volume in females is lower than in males over a given surface area).

One of the most commonly studied aspects of the PPG waveform is the amplitude which is directly proportional to the increase in systolic blood volume with each cardiac cycle. The amplitude changes in response to the local blood flow. The local blood flow in the area is affected by both adrenergic and cholinergic nervous systems. However, there is an adrenergic predominance in the hands and feet, thereby displaying a marked response to vasoconstriction (27).

3.4.2 <u>PRINCIPLES OF PPG</u>

The PPG sensor consists of

- A light source which is usually a red or infrared light emitting diode (LED)
- A photodetector.

There are two types of propagation of the infrared light

1. Transmittance
2. Reflectance

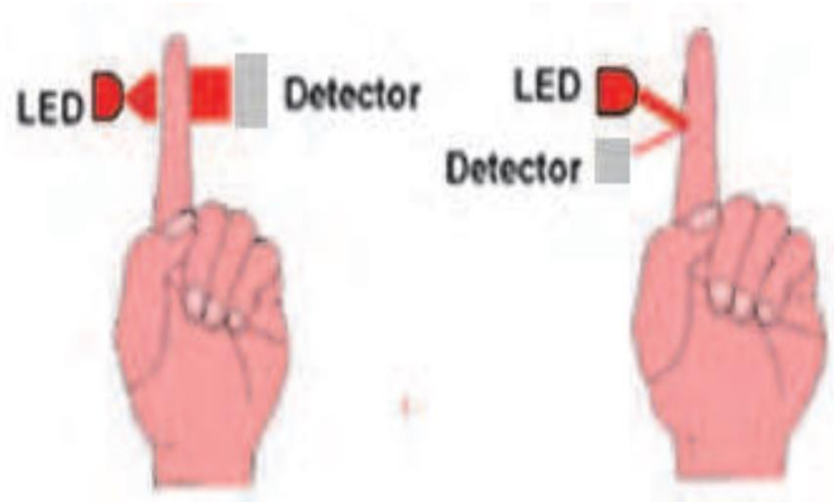


Figure 7. The first illustration shows transmittance type photoplethysmography and the second shows reflectance type photoplethysmography (22)

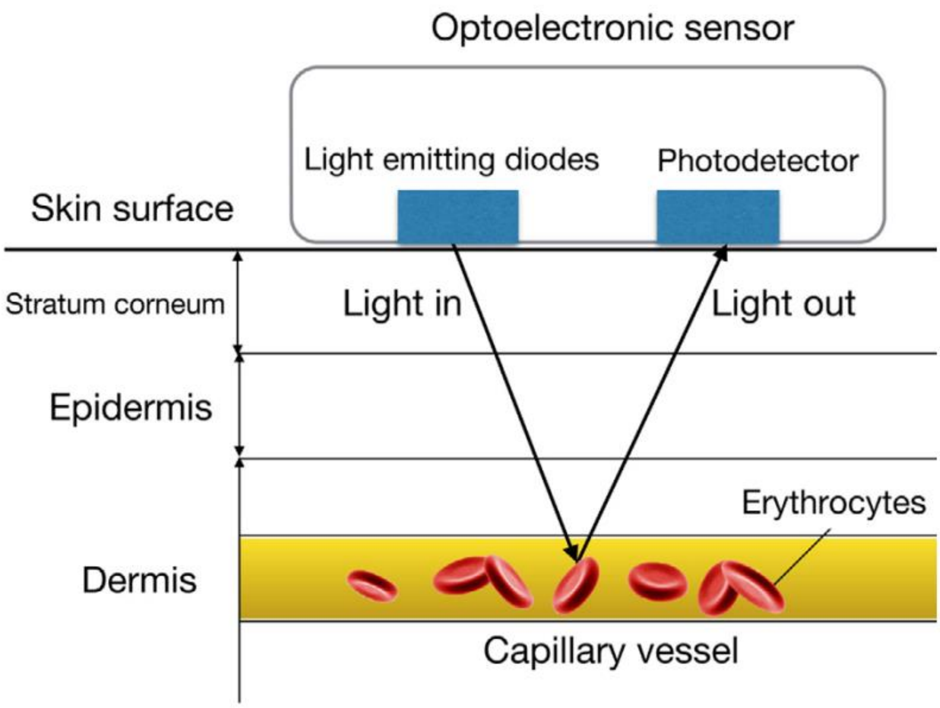


Figure 8. Light traverses the layers of the skin and is reflected by the red blood cells in the cutaneous circulation (28)

In the **transmittance** type the light emitting diode and the photodetector are on diametrically opposite sides. Hence the light traverses through the intervening skin, bone, vessels and other tissues to fall on the photodetector on the opposite side.

In the **reflectance** type the light emitting diode and the photodetector are on the same side. Hence the light penetrates the skin and reaches the underlying blood vessels where it is reflected back proportional to the blood volume and oxygenation in the particular area.

The different sites where PPG can be measured are the fingers, toes, forehead, wrist and ear since these areas have abundant capillary networks.

3.4.3 OPTICS OF PPG

The interaction of light with biological tissue can be of varying types- absorption, reflection, transmission, scattering, refraction and fluorescence.

- **Concept of optical water window**

  Almost 70 percent of the human body is made of water. Water absorbs the longer ultraviolet and infrared wavelengths in the range 250- 1000nm. The shorter wavelengths are absorbed by the melanin chromophores present on the epidermal layer. However, there is a narrow range of wavelength (650nm - 1350nm) corresponding to the red and near infra-red spectra that allows them to pass through water. This is sometimes referred to as the near infrared (NIR) window or optic window. In this window, there is maximum scattering of light which can be received by the PPG photodetector. This is the rationale for using red and near infrared wavelength as the light source in PPG.

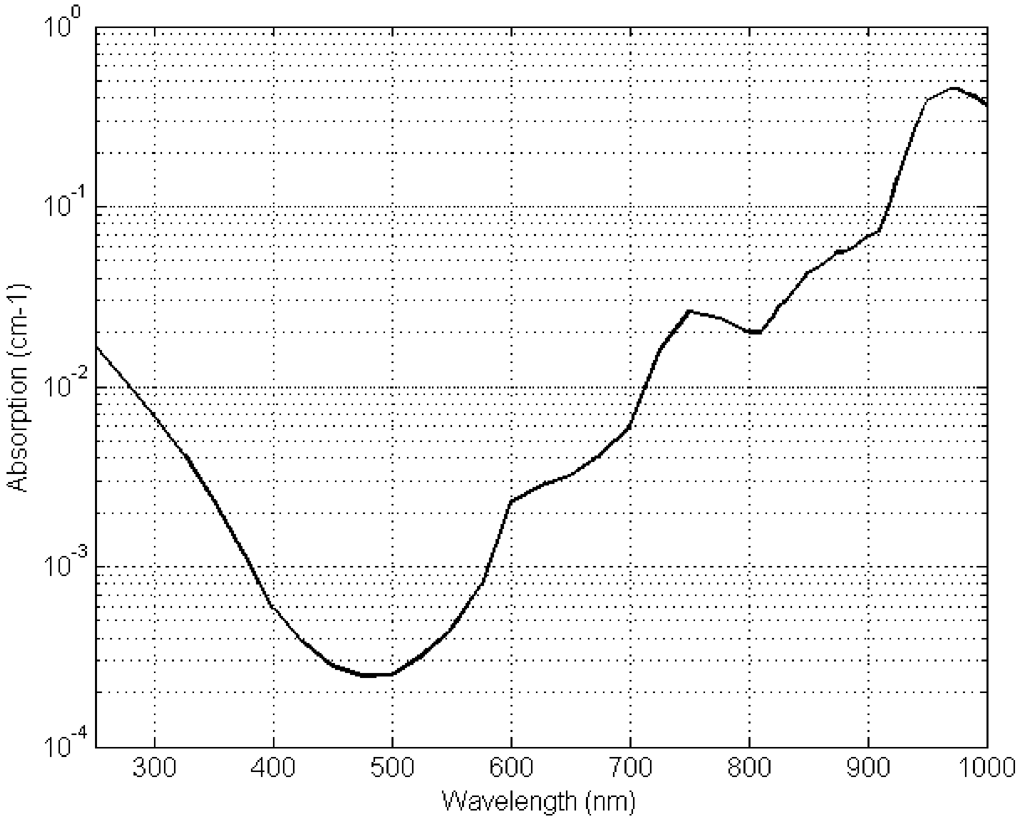


Figure 9. Absorption spectrum of water (29)

- **Isobestic wavelength**

Blood consists of haemoglobin and deoxyhemoglobin which have varied absorption spectra. These are represented as molar extinction coefficient.

Figure 10 shows that oxyhemoglobin has absorption peaks at 420nm and 580nm

Deoxyhemoglobin has absorption peaks at 410nm and two secondary peaks at 550nm and 600nm respectively.

The points at which both the curves intersect are termed isobestic points and the corresponding wavelengths are referred to isobestic wavelengths. This corresponds to about 805nm- near infrared range. At these wavelengths the absorption of light is largely independent of blood oxygen saturation.

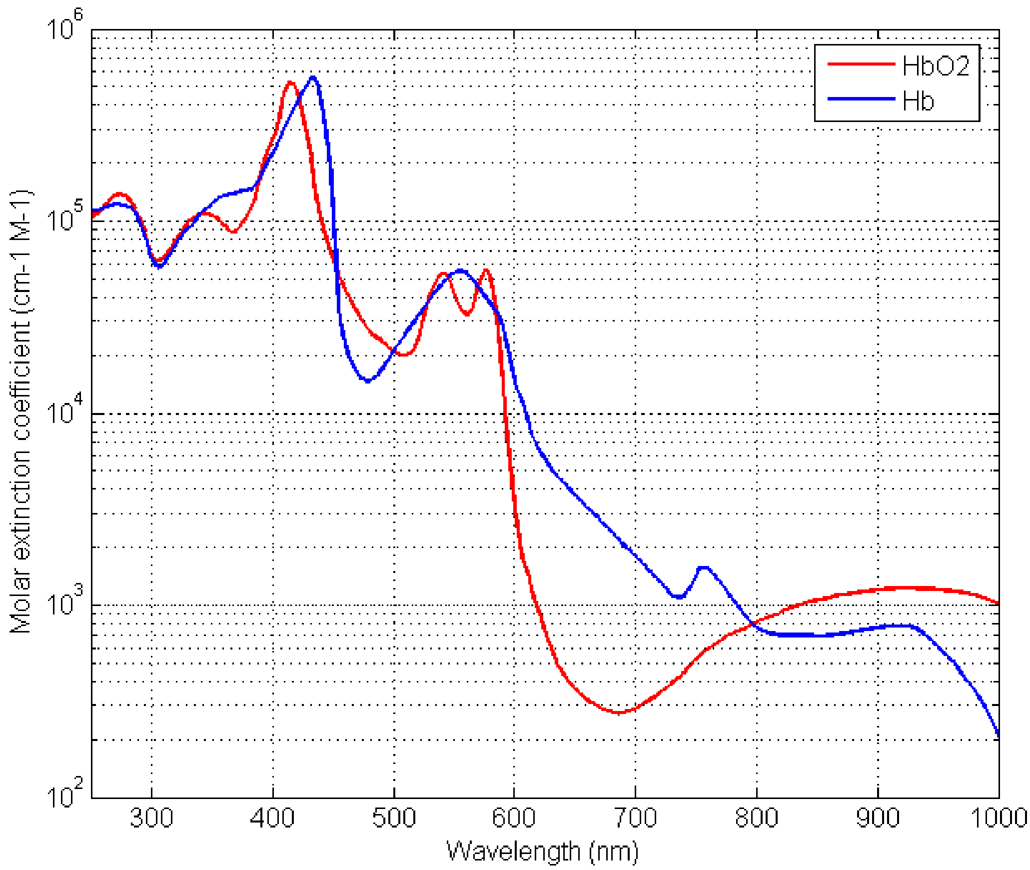


Figure 10. Absorption peaks of oxyhemoglobin and deoxyhemoglobin (30)

In summation the optics of PPG is based largely on **the Lambert- Beer law**(31) which states that the light transmittance **(A)** i.e., the ratio of transmitted light I_o to incident light I through a particular medium is expressed in terms of its wavelength dependent molar coefficient of absorption **(ε)**, concentration of the transmitted media **(c)** and the length **(l)** of the optical path.

$$A = \log_{10} \frac{I_o}{I} = \varepsilon l c$$

Therefore, when light passes through an absorbing medium (example – blood), its intensity decreases exponentially as the concentration of the medium and the length of the optical path increase.

3.4.4 APPLICATIONS OF PPG

Photoplethysmography has found a place in the commercial market for its use in the following fields

1. Measurement of oxygen saturation
2. Measurement of heart rate and study the variability in PPG with each cardiac cycle
3. To study the physiological effects of respiration
4. Non-invasive indirect measurement of haemoglobin (32)
5. Measurement of blood pressure

Some of the novel applications under research are the use of PPG for measurement of venous saturation and its use in measurement of different rheological characteristics (eg- clot formations, platelet aggregation, fibrin cross-linking and shearing forces on the red blood cells) (33,34) .

3.4.5 FACTORS AFFECTING PPG

The PPG signal can be affected by various external factors which include

- Contact between the skin and the PPG sensor

- Motion artefacts and movements of the blood vessel wall (32)
- Ambient light
- Ambient temperature which affects the local vasomotor autonomic system and thereby indirectly affecting the regional blood flow
- Local tissue and anatomical factors like thickness of tissue, presence of callosities
- Skin pigmentation
- Baseline blood flow in the area of interest (25)
- Orientation of the red blood cells in the blood column

The light emitting diodes use either the red (600-750nm) or the infra red (850-1000nm) wavelength bandwidth. However there has been a growing interest in exploring other wavelengths of the spectrum in the PPG light emitting diodes. In a study by Jiyoung Lee et al it was propounded that the green wavelength PPG has less motion artifacts compared to the red or the infrared wavelength PPG (35). This can be explained by the observation that longer wavelengths (red and infrared) have lesser absorption and hence greater penetration whereas the shorter green wavelength has higher absorption and lesser penetration. Therefore as the depth of penetration decreased the motion artifacts also reduced.

Hertzman in 1938 elucidated in great detail the application of PPG in measuring the blood flow of the skin in different areas of the body. He also studied the factors affecting PPG measurement which included local temperature, underlying surface area of contact, depth of the vascular bed from the skin and intensity of illumination (36).

In a study by Chang et al, the different characteristics of the photoplethysmograph waveforms were studied and it was concluded that there was significant difference in the PPG characteristics in patients with metabolic syndrome and normal subjects(37). Hence, it was proposed that the changes in the arterial wall secondary to the biochemical and physiological changes can be detected by PPG. PPG can detect changes in the arterial system caused by microvascular insult secondary to varied causes.

In a study by Kim et al, the blood volume ratios between the toe and the finger were measured using PPG and doppler (9). A significant difference was established in the blood volume ratios in diabetics and non-diabetics. There was a higher blood volume change in diabetics. This study also elucidated the possible correlation between skin temperature and blood volume changes. Diabetics were found to have increased local rise in temperature over the skin of the foot. This could be due to dilation of the arteriovenous shunts and poor local vasoconstrictive thermoregulatory mechanism. This reiterated the understanding that early changes in the foot secondary to diabetic neuropathy and microangiopathy can be detected using non-invasive, easy and reproducible alternatives like PPG.

3.5 NON-CONTACT PHOTOPLETHYSMOGRAPHY

Apart from the conventional contact photoplethysmography using infrared or near infrared sensors, there has been a recent surge of interest in exploring the option of non-contact photoplethysmography. In a pilot study by Nundy et al, a smartphone was used to capture videos of the face of subjects. These videos were then analysed and the colour of the reflected light was used to assess the heart rate and respiratory rate of the subject (38),. The hue (colour) generated from different regions of the face was plotted as a function of time and then further processed to calculate the required heart rate.

3.6 PURPOSE OF THIS STUDY

Photoplethysmography has shown promising results in various biological applications and has also been studied as a reliable indicator of the local blood flow in a given area. Hence, we have attempted to expand its application in studying the changes in the blood flow over the plantar aspect of the foot in diabetics who had undergone amputation. As these individuals had already lost a part or whole of one lower limb, the other limb was indeed precious. This reiterated the imminent need to effectively detect changes in the foot of the precious limb as early as possible. We hoped to use photoplethysmography as an effective, reliable screening tool in diabetics to detect early microvascular changes in the foot. This would further pave the way for decreasing the incidence of amputations and promote limb preservation. It would enhance the quality of life of the patients affected with diabetes and help in timely intervention to preserve the precious limb.

4. METHODOLOGY

4.1 FUNDING AND APPROVAL

This study was approved by IRB Min No. 10364 dated 03.11.2016 (Annexure 1).

Funding for the study was given by the Fluid Research Grant (Annexure 2).

4.2 STUDY DESIGN

It was designed as a prospective case control study.

4.3 SETTING

The study was conducted in the inpatient wards under the Department of General Surgery Units I to IV, Christian Medical College, Vellore.

The measurement of toe pressures both for cases and controls was done in the Vascular Laboratory in the Surgery Outpatient department.

The development, calibration and technical modifications of the photoplethysmograph device was done in the Department of Bioengineering, Christian Medical College, Vellore.

The period of recruitment was from January 2017 to June 2018.

4.4 PATIENT POPULATION

The patients recruited for the study were from the inpatient wards. The predominant patient population was from Tamil Nadu, West Bengal, Andhra Pradesh and Bangladesh.

4.5 INCLUSION CRITERIA

Cases

All patients (age > 18 years) who were known to have type II diabetes mellitus and had undergone any form of amputation in one lower limb (includes both major and minor amputations i.e., ray amputations, transmetatarsal amputations, below knee amputations, above knee amputations) were included. Their diabetic control status was assessed by measuring HbA1c levels.

Controls

Age- and gender- matched individuals without diabetes mellitus who had not undergone any form of amputation were recruited as controls. The age matching allowed an interval of two standard deviations i.e., +/- two years of age.

4.6 EXCLUSION CRITERIA

- Patients with traumatic amputation.
- Patients with known vascular disease requiring surgical intervention
- Patients with ulcers over the precious foot

4.7 INFORMED CONSENT

Both cases and controls were explained about the proposed study. They were given the information sheet elucidating the details of the study after which they were given adequate time to ask questions. The information sheet and consent form were available in English, Hindi, Tamil, Telugu and Bengali. The informed consent was then obtained from the subject in the presence of a witness.

4.8 DATA COLLECTION

The data collection was done solely by the principal investigator. All the cases and controls were recruited according to the inclusion criteria. Demographic details of the subjects were collected which included name, age, gender and address. The diabetic status was assessed and the subjects were interviewed regarding the duration of diabetes mellitus, treatment details if any and whether they were currently experiencing symptoms of diabetes mellitus. Presence of other concomitant illnesses including systemic hypertension, chronic kidney disease, peripheral vascular disease, ischemic heart disease and cerebrovascular disease were documented.

A detailed history of amputation was then elicited with respect to the side of amputation, level of amputation and number of amputations.

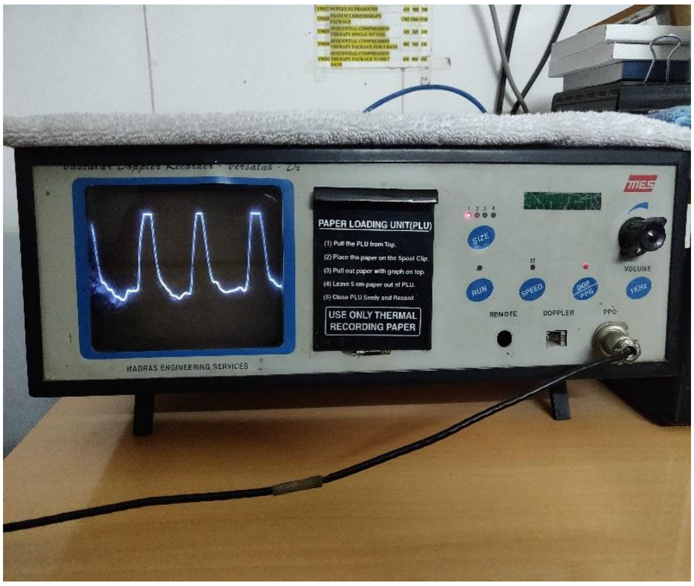
Baseline parameters of height, weight, body mass index and blood pressure were measured.

4.8.1 MEASUREMENT OF TOE PRESSURES

Both cases and controls then underwent measurement of toe pressures in the Vascular laboratory in the General Surgery outpatient department. Toe pressures were measured as a baseline assessment of the blood flow in both diabetics and non-diabetics. This is because in current practice toe pressures are considered a reasonably fair tool in detecting distal blood flow of the foot.

The skin surface over the pulp of the hallux was first cleaned with alcohol or an alternative antiseptic. A sensor was then placed over the pulp of the toe and secured with a Velcro or adhesive tape. A digital pressure cuff measuring 2cm in width was then securely positioned around the base of the hallux. This cuff was connected to a monitor which displayed the normal waveforms corresponding to the cardiac cycle. The cuff was then inflated until disappearance of the waveform was noted. The cuff was further inflated to about 20mm above this pressure. The cuff was then gradually deflated until return of waveform. The cuff pressure at which the first systolic peak reappeared was taken as the toe pressure.

(A)



(B)

Figure 11. Measurement of toe pressures. (A) The sensor around the hallux with the cuff surrounding it. (B) Systolic waveform on the screen

4.8.2 LABORATORY INVESTIGATIONS

According to the inclusion criteria, all the cases had type II diabetes mellitus. Their diabetic status was assessed by measuring the HbA1c levels.

All the controls were non diabetic and this was confirmed by assessing for symptoms of hyperglycemia and measuring random blood glucose values (according to the American Diabetes Association 2018 for diagnosis of type II diabetes mellitus, the presence of classic symptoms of hyperglycemia or hyperglycemic crisis with random blood glucose levels of $\geq$ 200mg/dl is one of the criterion for diagnosis of type II diabetes mellitus) (39)

4.8.3 USE OF PHOTOPLETHYSMOGRAPHY TO ASSESS BLOOD FLOW

The photoplethysmograph sensors consisted of an infrared light emitting diode. This light emitting diode used the principle of reflectance photoplethysmography where the emitter and the receiver were at the same end. The wavelength was 520 nanometres.

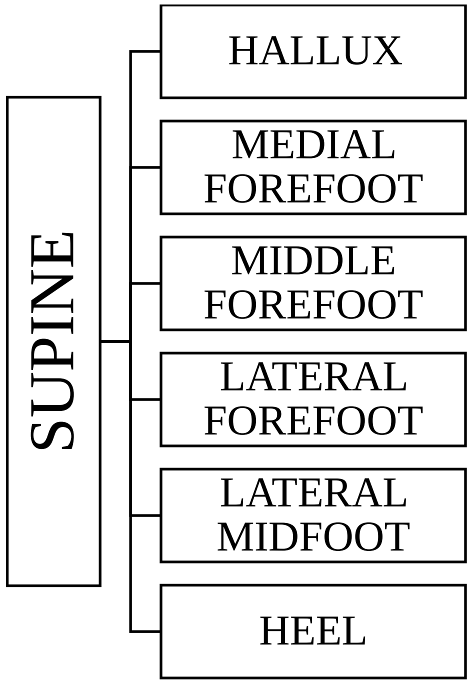
The photoplethysmograph measurements were done under standard conditions. The subjects were placed in the supine position, relaxed and acclimatized for approximately 5 minutes before the examination. The subjects were not allowed to smoke, drink beverages containing caffeine or use medications with vasoactive effects atleast two hours before examination. The foot was thoroughly examined for the presence of scars, deformities, ulcers, callosities, pigmentation and any other visible or palpable abnormality.

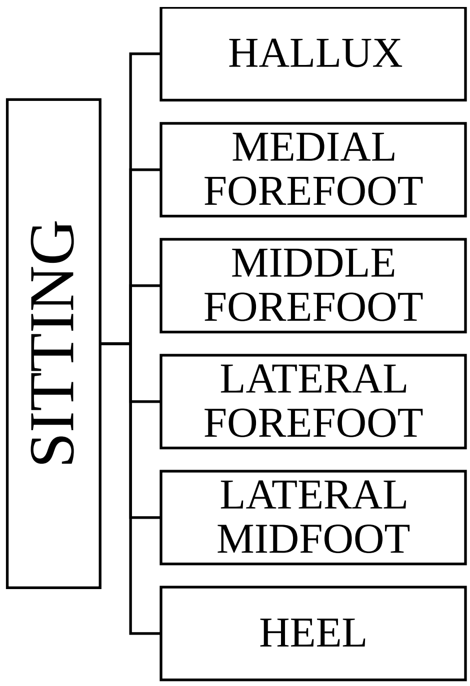
The plantar aspect of the foot was cleaned with an alcohol based antiseptic solution. The Photoplethysmograph sensors were placed on the sole of the foot and each sensor covered an area of $3cm^2$ over the following points

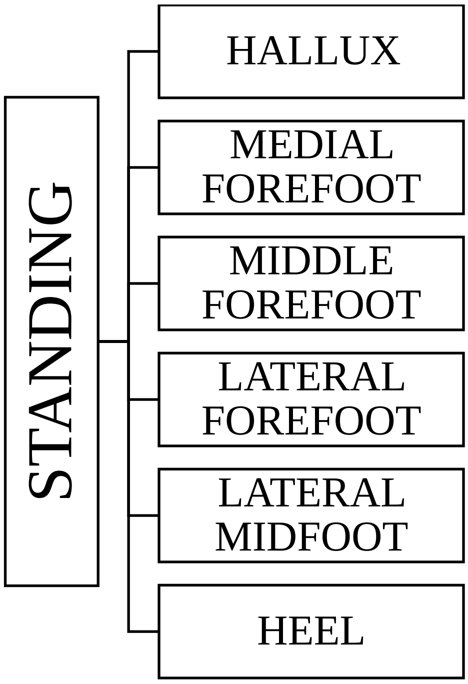
- hallux
- medial forefoot
- middle forefoot
- lateral forefoot
- lateral midfoot
- heel

The study was done in three different positions of the patient-

- supine
- sitting with the feet on the ground
- standing


SUPINE
HALLUX
MEDIAL FOREFOOT
MIDDLE FOREFOOT
LATERAL FOREFOOT
LATERAL MIDFOOT
HEEL


SITTING
HALLUX
MEDIAL FOREFOOT
MIDDLE FOREFOOT
LATERAL FOREFOOT
LATERAL MIDFOOT
HEEL



In each of the above positions, the sensors were placed in the same six anatomical positions over the plantar aspect of the foot. The sensors were securely positioned using adhesive tape. A contact pressure was ensured in all the stages either using a black muslin cloth in the supine position and a sponge as a force cushion under the foot to maintain pressure in the sitting and standing positions. The vertically applied pressure was precalibrated in the Department of Bioengineering using a healthy subject with the help of a weighing machine as a tool to assess force under recording foot and monitored by a force guage. This helped in validating the use of these sensors for patients of any stature, build, weight and height.

The sensors were directly connected to an indigenously designed data acquisition system called CMCdaq (Christian Medical College data acquisition system). This device was designed by the Bioengineering Department of Christian Medical

College, Vellore. It consisted of a preamplifier and set of low pass filters. It also had an inbuilt current-to-voltage converter circuit and an analog-to-digital converter card operating at a sampling rate of 1000 Hz.

The data generated from the CMCdaq was routed to a laptop which had the user interface software for CMCdaq.

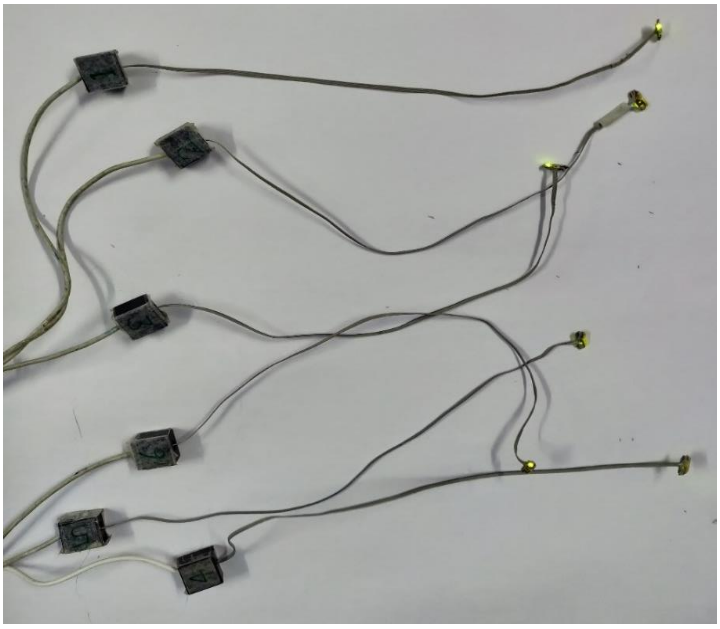


Figure 12. The six photoplethysmography sensors with the preamplifier

Figure 13. The indigenous CMC data acquisition system with input from all six channels and output routed to a laptop

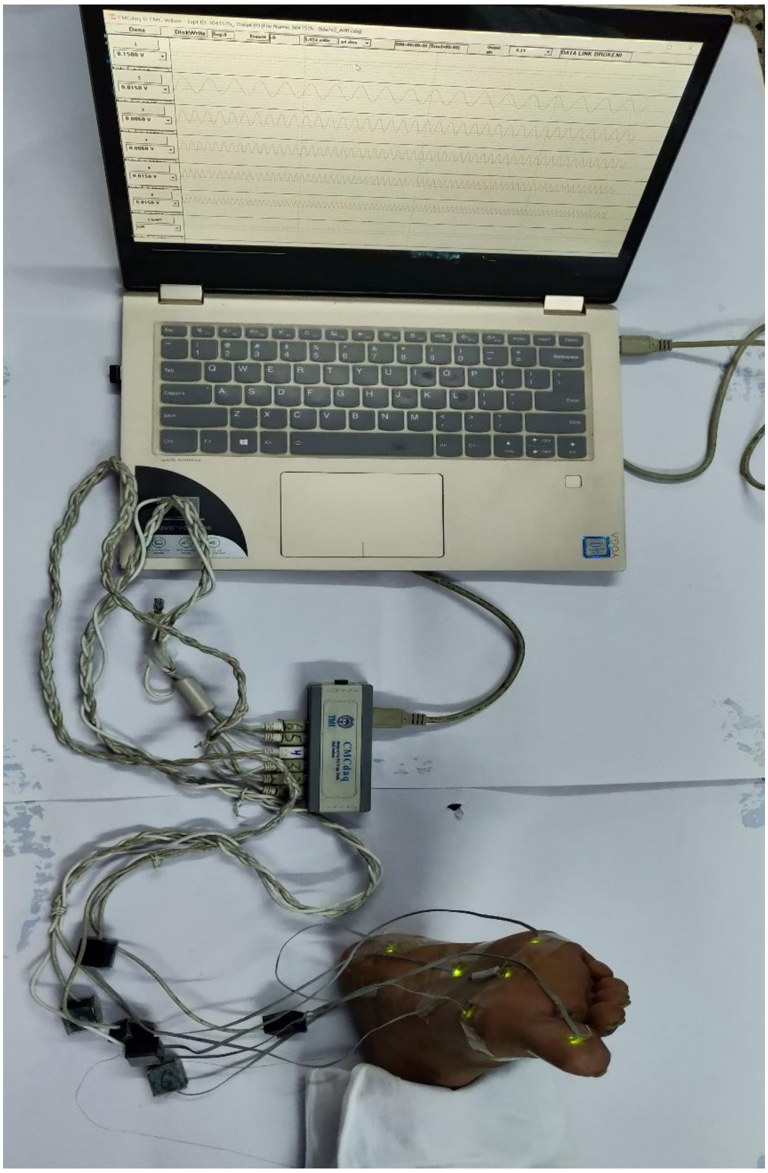


Figure 14. Integrated setup showing the sensors from the foot with preamplifiers connected to the CMCdaq and further routed to the laptop

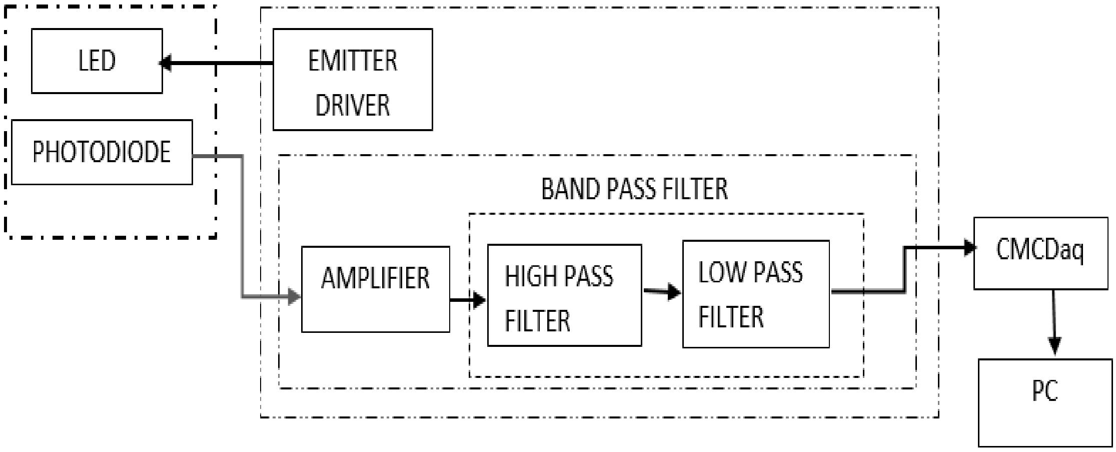


Figure 15. Schematic representation of the entire setup showing receiver, input, processing and output.

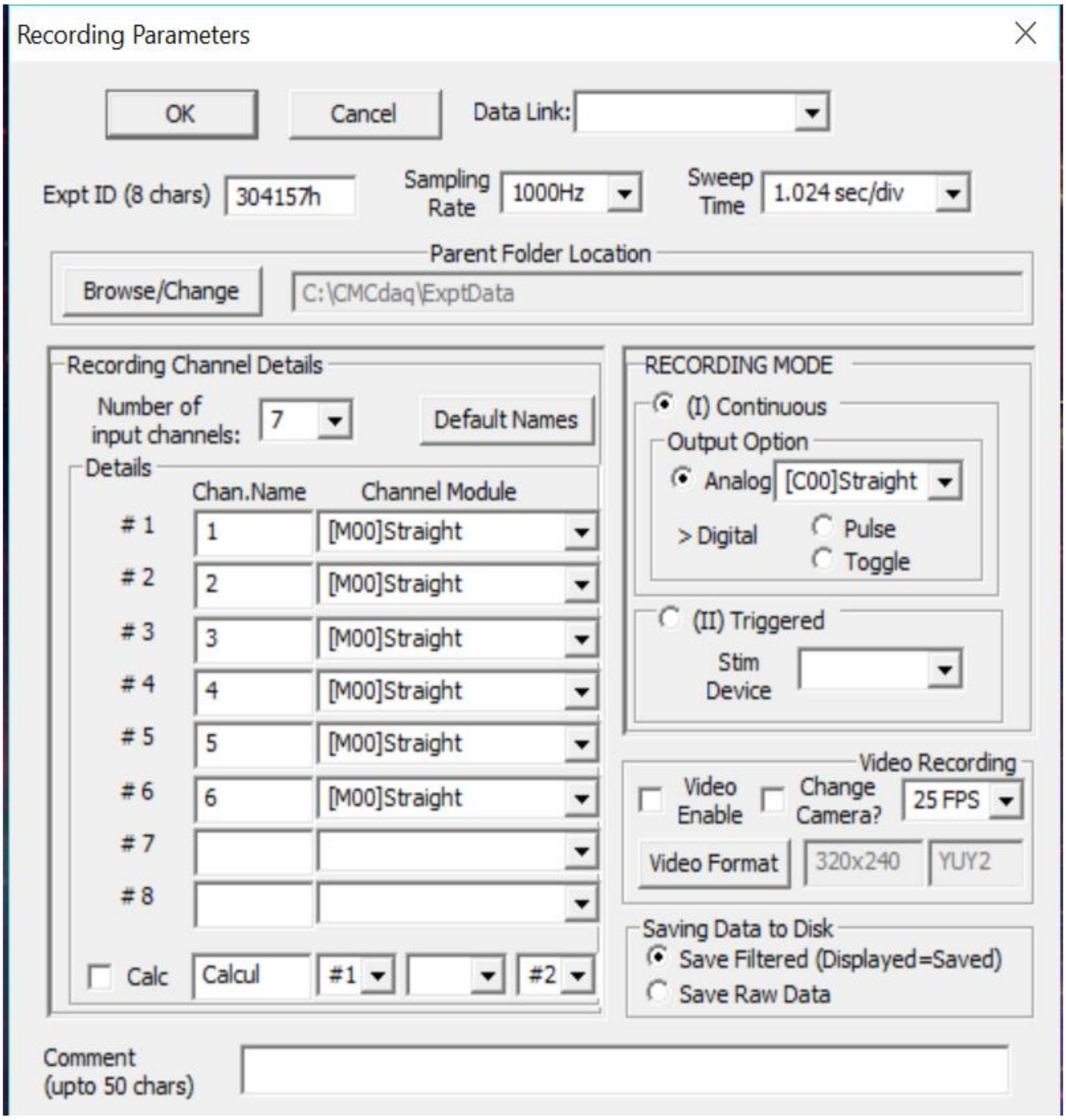


Figure 16. CMCdaq user interface showing the pre-recording settings for the six channels required for recording the waveform

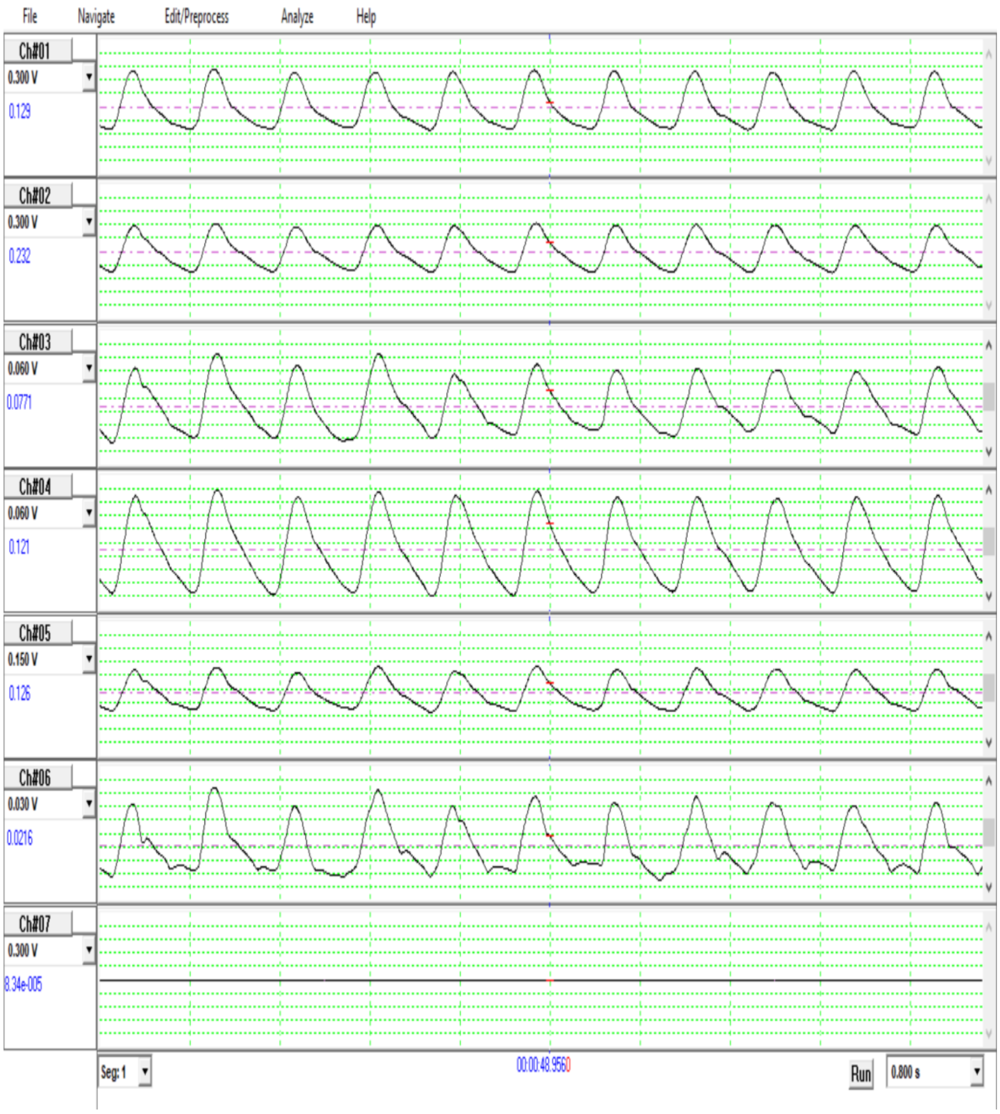


Figure 17. Six channels showing the PPG waveform in the respective six regions of the foot.

The waveforms were represented as time- domain waveforms in arbitrary units. The raw data of waveforms was passed through a low-pass filter of 5Hz and the baseline drift was also eliminated using a baseline filter. This enabled the data to have minimal noise.

The waveform consisted of an upstroke culminating in the peak amplitude. This corresponded to the systolic phase of the cardiac cycle. It was followed by a downstroke corresponding to the diastolic phase of the cardiac cycle. The X- axis represented the time domain.

At the end of data collection there were three segments of waveforms generated – one for each of the positions assumed by the patient as mentioned above and each recording segment was of a duration of one minute.

Each segment further consisted of six waveform PPG recordings from each of the six anatomical landmarks over the foot. Thus, at the end of the recording there were eighteen sets of waveforms generated for analysis.

Each segment that was recorded was processed further by using baseline correction and low pass digital filtering to smoothen the data and limit data noise to a minimum. This processed data was then exported as a text format as shown in Figure 18.

Format View Help

-0.064009	0.00402723	-0.00175735	0.000328762	-0.0570988	-0.0152777	-0.00367854
-0.0520707	0.00834403	0.000688967	0.00152748	-0.0533693	-0.0107645	-0.00542571
-0.0408489	0.0130636	0.00333037	0.00295456	-0.0501347	-0.010455	-0.00706538
-0.0301567	0.0178878	0.00574106	0.00408661	-0.0471552	-0.0120021	-0.00843298
-0.0187719	0.0231046	0.00785572	0.00522461	-0.0437294	-0.0120521	-0.00934642
-0.00642252	0.0281026	0.00960244	0.0059965	-0.042249	-0.0142139	-0.00971485
0.00673002	0.032871	0.0115438	0.00667876	-0.0413951	-0.013163	-0.00979646
0.0205748	0.0376763	0.0135114	0.00730086	-0.0400609	-0.0099481	-0.0100101
0.0345154	0.0420943	0.0153337	0.00762267	-0.038706	-0.00725521	-0.0103703
0.0478004	0.0467126	0.0179529	0.00845512	-0.0358443	-0.00229978	-0.0107253
0.0598158	0.0512405	0.0216078	0.00941071	-0.0331488	-0.000504479	-0.0110144
0.0711652	0.054952	0.0255191	0.0100147	-0.0308072	-0.000311166	-0.0110935
0.0826069	0.0586527	0.0286352	0.010565	-0.0275505	0.000907259	-0.0109748
0.0941355	0.0623419	0.0307386	0.0108634	-0.0257563	-0.000733548	-0.0108959
0.106161	0.065956	0.032843	0.0114992	-0.0242519	-0.000280697	-0.0107158
0.118003	0.0694825	0.0352602	0.0126831	-0.0218864	0.00169452	-0.0101985
0.128994	0.0722092	0.0373703	0.0139095	-0.0196952	0.0031761	-0.00980175
0.139901	0.0749114	0.0395031	0.0154587	-0.0164563	0.00787193	-0.00978786
0.150264	0.0780387	0.0416566	0.0168278	-0.0135058	0.0101354	-0.00999724
0.159663	0.0806126	0.0434321	0.0179111	-0.0107744	0.0108761	-0.0103252
0.168562	0.0827635	0.045163	0.0193743	-0.00684756	0.0130358	-0.0104123
0.176944	0.084817	0.0468281	0.020663	-0.00432416	0.0113083	-0.0101891
0.251957	0.0978406	0.0619024	0.0243714	0.00480187	0.0133239	-0.00880412
0.254643	0.0966253	0.0625888	0.0237081	0.00626295	0.0162653	-0.00880562
0.256561	0.0954852	0.062741	0.0233579	0.00740651	0.0180206	-0.00909892
0.258153	0.0951387	0.0625838	0.0236246	0.00890627	0.0206563	-0.00945777
0.259786	0.0950773	0.0621324	0.023666	0.00853971	0.0186084	-0.00948305
0.261604	0.0952408	0.0619057	0.0236088	0.0075488	0.0164769	-0.00933585
0.263399	0.0960247	0.0622706	0.0237847	0.00802716	0.0166654	-0.00921092
0.252784	0.0882302	0.060086	0.0235852	0.00475208	0.018441	-0.00680349
0.249802	0.0869684	0.0594289	0.0222897	0.00413135	0.0160098	-0.00675871
0.246745	0.0854395	0.058224	0.0211166	0.00399288	0.0160294	-0.00651344
0.243713	0.0840768	0.0568163	0.0203022	0.00348314	0.0164795	-0.00639528
0.239822	0.0820074	0.0552834	0.0194177	0.00189592	0.0163002	-0.00648122
0.235231	0.0793331	0.0543692	0.019255	0.0018329	0.0186583	-0.00676584
0.215686	0.0680086	0.0512459	0.0195491	-0.00289974	0.0138421	-0.00694415
0.211475	0.0652026	0.0500851	0.0194847	-0.00520991	0.0145235	-0.00746641
0.206715	0.0626171	0.0488743	0.0192807	-0.00672202	0.0162018	-0.00781666

Figure 18. PPG Waveforms exported as text file for further analysis

These values corresponded to the respective points on the waveform. This data was then analysed using a self written program on the MATLAB R2018a (9.4.0.813654) version.

The different characteristics of the waveform that were analysed were

1. Peak amplitude – First the peaks and troughs were identified as shown in Figure 19. The peak amplitude was then calculated as the difference between the peak and the trough. Further the mean peak amplitude for a given segment of waveform was calculated.
2. Peak time – this was calculated as the time taken to attain the peak amplitude. This was also referred to as the rise time.

A graphical superimposed waveform for all the six regions was also generated as depicted in figure 20. This allowed visual appreciation of the difference in the amplitude in the six regions of the foot.

This exercise was repeated for all the three segments with six waveforms each.

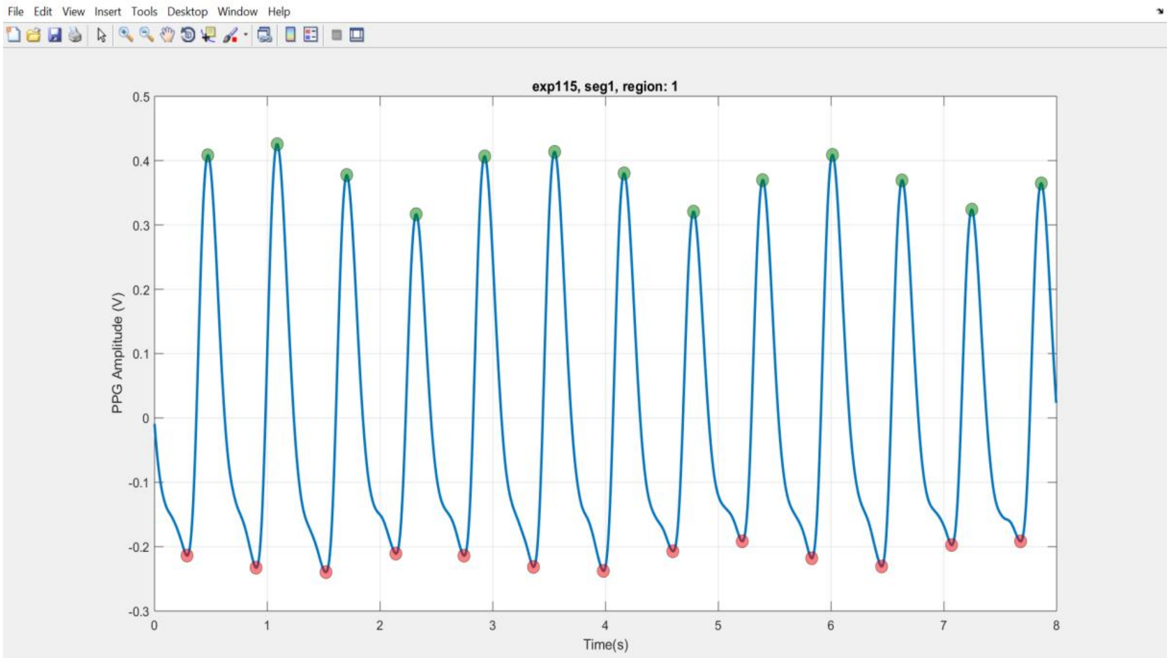


Figure 19. The peaks denoted in green and the troughs in red. Peak amplitude calculated as the difference between the peak and trough.

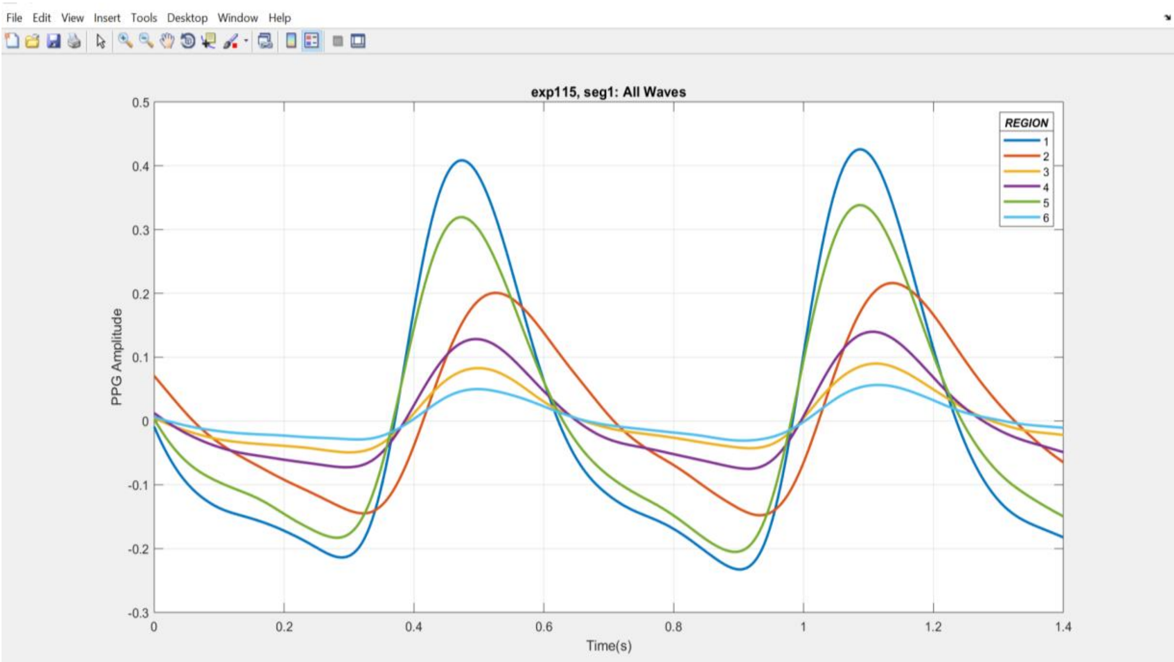


Figure 20. Superimposed waveforms from all six regions of the foot

4.8.4 CHALLENGES ENCOUNTERED AND MITIGATION MEASURES TAKEN

- One of the earliest difficulties faced involved calibration of the device. As this was an indigenously developed design it required intensive modelling and re-modelling of circuits which was generously done by the Department of Bioengineering on multiple occasions. Each of the photoplethysmograph sensors were soldered to the underlying circuit and subsequently wired to the CMCdaq.
- Once the recruitment and recording commenced, there were numerous occasions when the sensors malfunctioned. One of the probable reasons was the undue pressure on the sensors when the study was in the sitting or standing

positions. This issue was resolved by securing the sensors onto a firmer and sturdier base. There were also instances when new sensors had to be procured to replace the defunct ones.

- The CMCdaq, the in-house data acquisition system was one of the most efficient and compact data acquisition systems. However, once the recording of data began, it was noticed that in order to process large volumes of data being received through six sensors over the foot, a few technical aspects of the circuitry and the mother board involving the CMCdaq had to be readjusted to meet the demands. This was also resolved promptly by our Department of Bioengineering.
- On placing the sensors over different regions of the foot, there was an initial incongruity in the waveforms generated. There was immense noise affecting the data output. Also, it required that each sensor be placed and adjusted on the foot in an attempt to visualise the best waveform. This was done on a trial and error basis where the sensors were placed on a particular region of the foot and then had to re-sited around the region of interest until the desired waveform appeared. This cumbersome task was overcome by introducing low pass filters into the system which helped in eliminating majority of the noise generated and also ensured greater sensitivity of the sensors.

4.8.5 DIAGRAMMATIC ALGORITHM OF THE STUDY

All patients with type 2 diabetes mellitus who had undergone any form of lower limb amputation were recruited as cases.

Patients with no diabetes and no history of amputation were recruited as controls.

Patients with traumatic amputations, known vascular disease requiring surgical intervention and patients with ulcer over the precious foot were excluded

- Informed consent obtained
- Collection of demographic details
- Laboratory biochemical investigations- HbA1c levels measured for diabetics recruited as cases and random blood glucose levels measured for controls to rule out diabetes mellitus

Toe pressures were measured in vascular laboratory for both cases and controls

↓

Multipoint contact photoplethysmograph sensors were placed on the sole of the precious foot in six regions namely the hallux, heel, medial forefoot, middle forefoot, lateral forefoot and lateral midfoot.

↓

The photoplethysmograph waveforms generated were routed through the CMC data acquisition system to a laptop

↓

Processing and filtering of data was done using the CMCdaq user interface

↓

Data was exported for further analysis and interpretation

4.9 STATISTICAL METHODS

CALCULATION OF SAMPLE SIZE

With reference to Hubena G et al, the range of peak time from the photoplethysmography waveform was found to be 140-154 ms among the diabetic group and 120-133 ms among the non-diabetic group (40). Assuming 150 ms for diabetic group and 130 ms for the non-diabetic group with an expected difference between the groups to be 20 ms, with alpha error at 5% and with a maximum power of 80% for a two-sided test, we needed to study at least 42 cases and 42 controls.

Two Means - Hypothesis testing for two means

Pulse Peak time

Table 1

Standard deviation in group I (Pulse peak time in milliseconds	35 ms
Standard deviation in group II (Pulse peak time in milliseconds	30 ms
Mean difference (Expected difference)	20 ms
Effect size	0.615385
Alpha error (%)	5
Power (1- beta)(%)	80
1 or 2 sided	2
Required sample size per group	**42**

Based on mean pulse amplitude with proportion of 69%to 86% among the diabetic and 37% to 54% among the non-diabetic and assuming the proportion to be 75% and 50% respectively with the power at 80% and alpha error at 5% for a two-sided test we needed to study 58 diabetic amputees and 58 normal subjects.

Two Proportion - Hypothesis Testing - Large Proportion - Equal Allocation

Mean Pulse amplitude

<u>Table 2</u>

Proportion in group I (Mean amplitude among Diabetic group)	0.75
Proportion in group II (Mean amplitude among Non Diabetic group)	0.5
Estimated risk difference	0.25
Power (1- beta) %	80
Alpha error (%)	5
1 or 2 sided	2
Required sample size for each arm	**58**

$$n = \frac{2S_p\,2\left[Z_{1-\alpha/2}+Z_{1-\beta}\right]2}{\mu^2}$$

$$S_p^2 = \frac{S_1^2+S_2^2}{2}$$

Where S_1^2 =Standard deviation in the first group

S_2^2 = Standard deviation in the second group

μ^2 = Mean difference between the samples

α = Significance level

1- β = Power

$$N=\frac{\left\{Z_{1-\alpha/2}\sqrt{2\,P\,(1-P)}+Z_{1-\beta}\,\sqrt{P_1\,(1-P_1)+P_2(1-P_2}\right\}2}{(P_1-P_2)2}$$

$$P=\frac{P_1+P_2}{2}$$

α = Significance level

1 – β = Power

P_1 = Proportion in the first group

P_2 = Proportion in the second group

Therefore, considering both parameters namely peak amplitude and peak times the sample size was calculated as 58 in each arm.

During the period of recruitment, 58 cases and 58 controls were recruited. However for eight out of the 58 cases, the photoplethysmograph waveforms were significantly erratic and with inherent data noise. The data generated from these eight cases was not feasible for analysis of the peak amplitudes and peak times due to poor quality of the waveforms generated.

Following attempts were made to address the problem-

- Adjustment of the photoplethysmograph sensors over the foot
- Ensuring proper connections between the sensors and the data acquisition system

- Re-soldering and repair of two of the sensors that had abruptly stopped recognising signals
- Repair of two ports in the CMC data acquisition system which were producing poor waveform output
- Attempt to reduce noise and filter data using the CMC data acquisition software

Despite the above rectifications, the waveform output generated was not suitable for analysis. Therefore, out of the 58 cases recruited findings from eight cases had to be excluded from the final analysis.

Thus, there were 50 cases and the corresponding matched 50 controls that were finally analysed. The power of the study was re-calculated with 50 cases and 50 and found to be between 74% to 86% which was within acceptable limits.

Data entry was done using EpiData 3.1 and the analysis was done using Statistical Package for Social Sciences (SPSS) version 21.

5. RESULTS

A total of 50 cases and corresponding age and gender matched 50 controls were analysed.

GENDER

Males constituted 72 percent of the cases and controls whereas females constituted the remaining 28 percent.

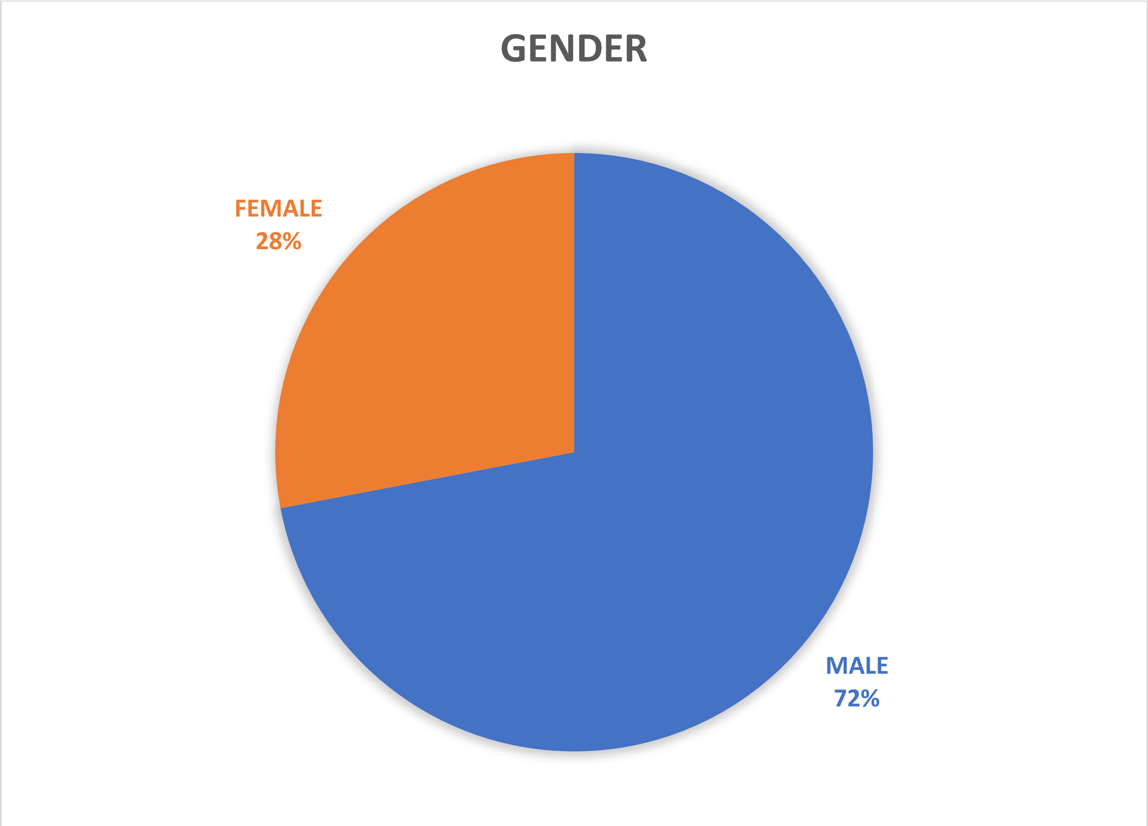


Figure 21. Distribution of males and females in the study (n =100)

AGE DISTRIBUTION

The average age in cases was 54.84 years with a standard deviation of 8.36. Since the controls were age and gender matched, the average age in controls was 54.66 with standard deviation of 8.90.

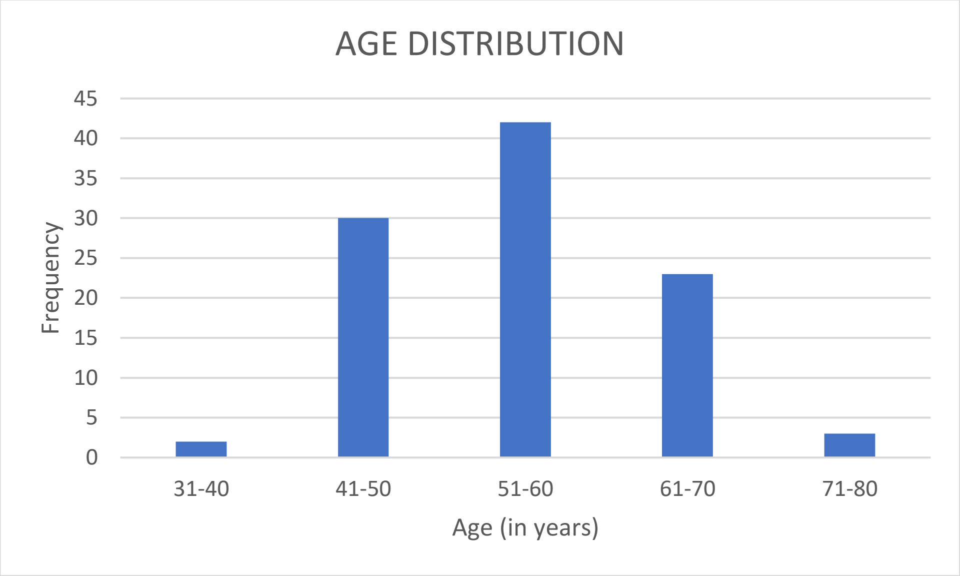


Figure 22. Age distribution (n=50)

DURATION OF DIABETES

The duration of diabetes mellitus in cases was noted. The maximum number of cases had a duration of diabetes between 61-120 months i.e., five to ten years. The mean duration was 110.96 months with a standard deviation of 76.40.

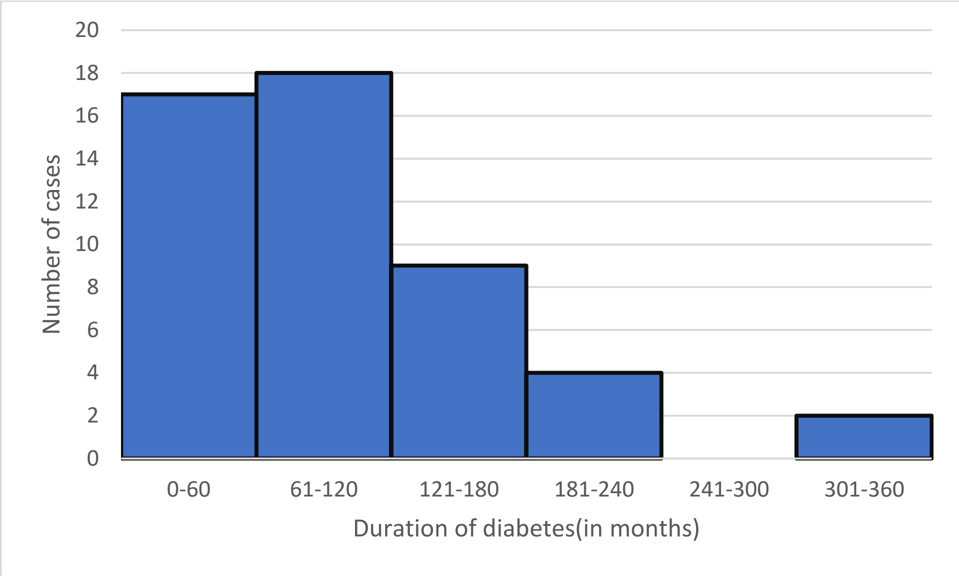


Figure 23. Duration of diabetes mellitus among cases (n=50)

TREATMENT FOR DIABETES

Of the fifty diagnosed cases of diabetes mellitus, 49 were under treatment for the same. 22 of the cases were on oral hypoglycemic agents alone, 22 were on both oral hypoglycemic agents and insulin and four patients were on only insulin. Two cases were not on any treatment as they were newly diagnosed.

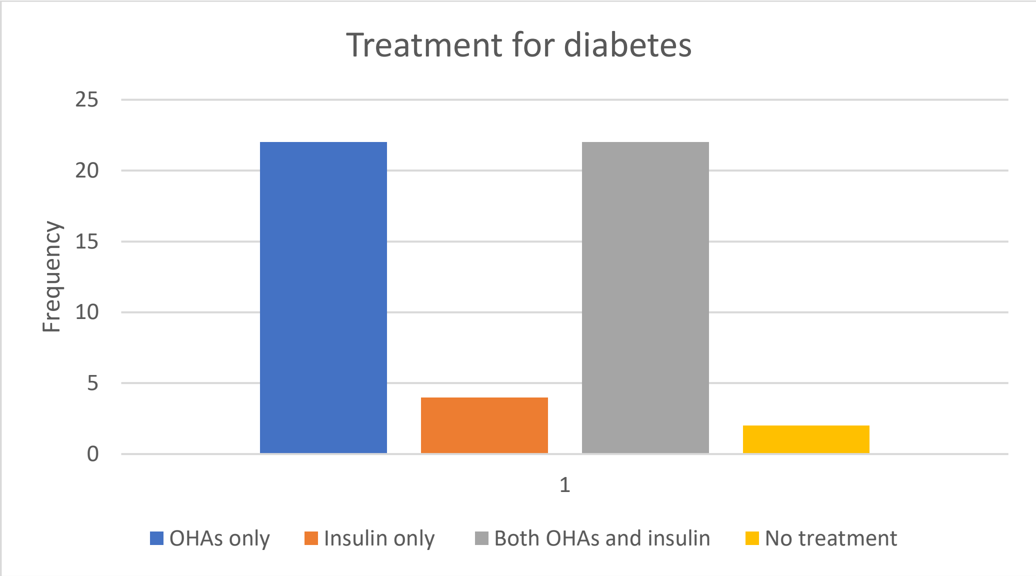


Figure 24. Treatment taken for diabetes mellitus among cases

The other data collected included height, weight, body mass index and blood pressure. As demonstrated in Table 3, there was no statistically significant difference between cases and controls except for diastolic blood pressure. It was noted that the diastolic blood pressure in controls was higher than in cases. However, in both cases and controls the diastolic blood pressure was within the normal range, hence it would be safe to assume that it had low clinical significance.

Table 3

VARIABLES	**Cases(n=50) Mean±SD**	**Controls(n=50) Mean±SD**	**p Value**
Age (in years)	54.84±8.36	54.66±8.9	0.917
Height (in cm)	166.44±6.70	163.46±10.27	0.093
Weight (in kg)	66.86±8.81	66.28±15.40	0.818
Body Mass Index	24.08±2.26	24.26±5.41	0.822
Systolic Blood pressure (mm Hg)	119.00±12.50	120.08±10.18	0.64
Diastolic Blood Pressure (mm Hg)	71.48±8.72	75.36±6.57	**0.014**
Toe Pressures (mm Hg)	100.48±44.45	96.2±44.24	0.624

The mean height among cases was 166.40cm and among controls was 163.46cm. The mean weight among cases was 66.86kg and among controls was 66.28kg. As was evident, there was no significant variation between the two groups with respect to the height and weight. The mean body mass index was 24.08 among the cases and 24.26 among the controls which again did not show statistical significance.

The mean toe pressures in the cases group (100.48 mm Hg) was higher than controls (96.2 mm Hg) but there was no statistically significant difference between the two groups.

COMORBID ILLNESSES

The associated comorbid illnesses analysed were systemic hypertension, chronic kidney disease, ischemic heart disease, peripheral vascular disease and cerebrovascular disease.

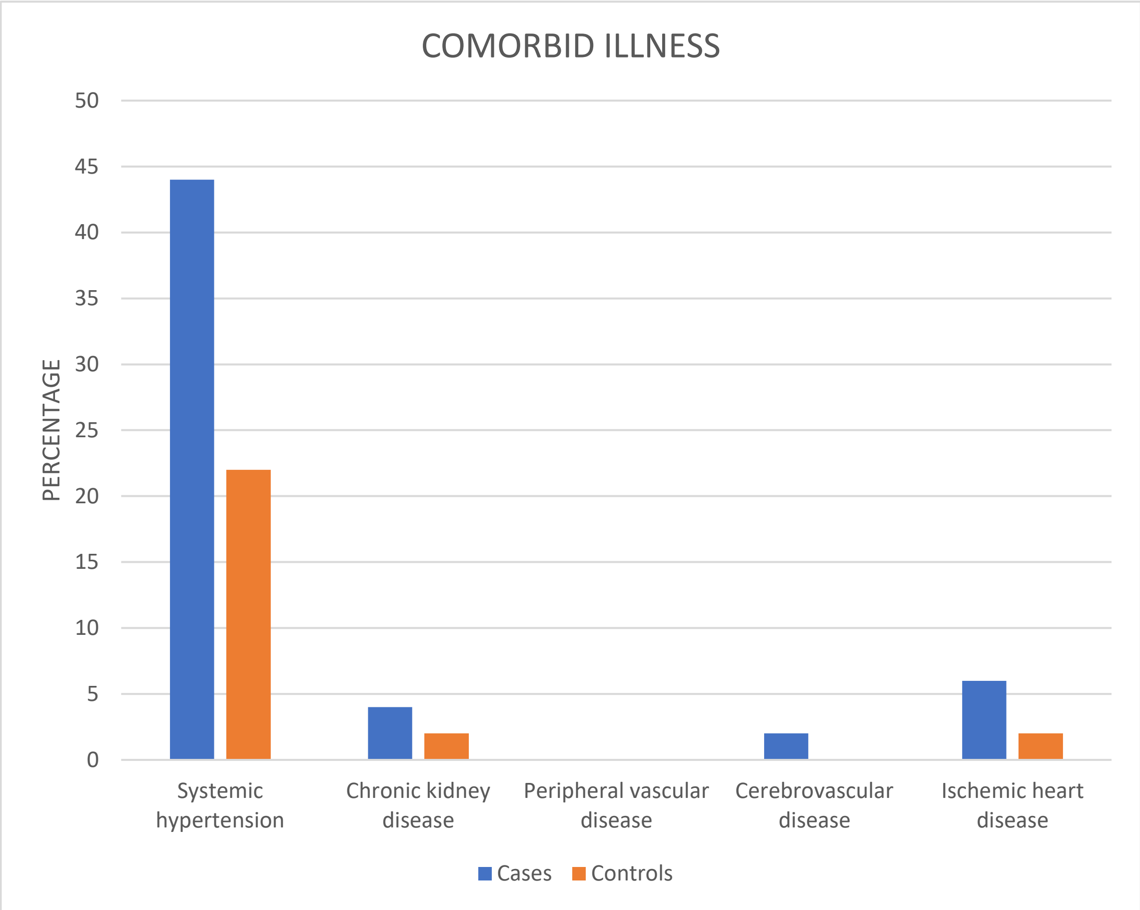


Figure 25. Comorbid illnesses among cases and controls (n=50 cases + 50 controls)

The most prevalent comorbid illness amongst both cases and controls was systemic hypertension. 44% of the cases and 22% of controls had systemic hypertension. On application of the Pearson Chi-square test, the p-value was 0.019 showing a statistically significant difference between the two groups. This reiterates the positive association of diabetes mellitus with systemic hypertension.

LEVEL OF AMPUTATION

All cases had undergone amputation at different anatomic levels. Ray amputation constituted 42% of the amputations, followed by 38% of below-knee amputations. Transmetatarsal amputation and above-knee amputation constituted 16% and 4% of the cases respectively.

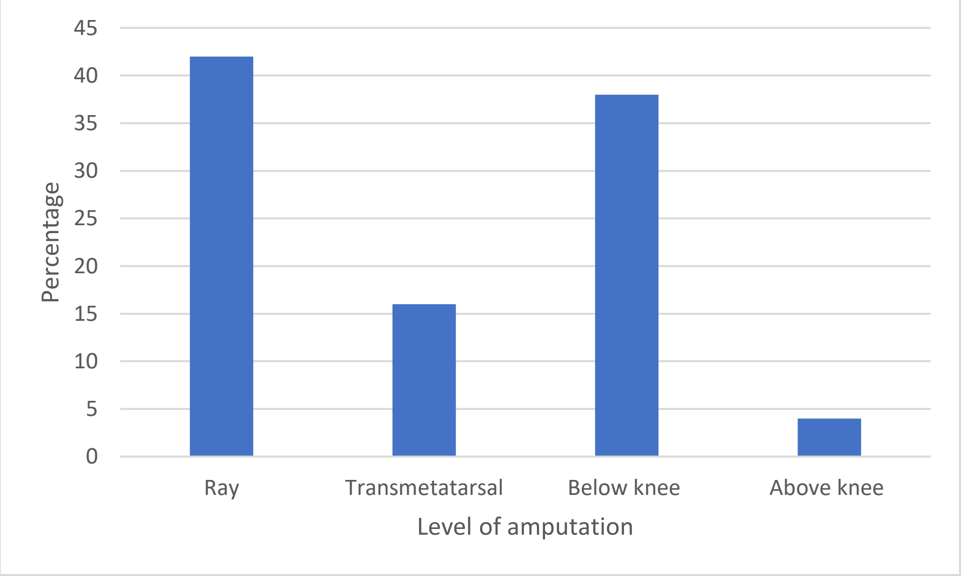


Figure 26. Level of amputation in cases (n=50)

HbA1c LEVELS

The serum HbA1c levels in cases were analysed and majority of the diabetics had HbA1c between 8.1-10%. The mean HbA1c level was 9.156 with a standard deviation of 2.22.

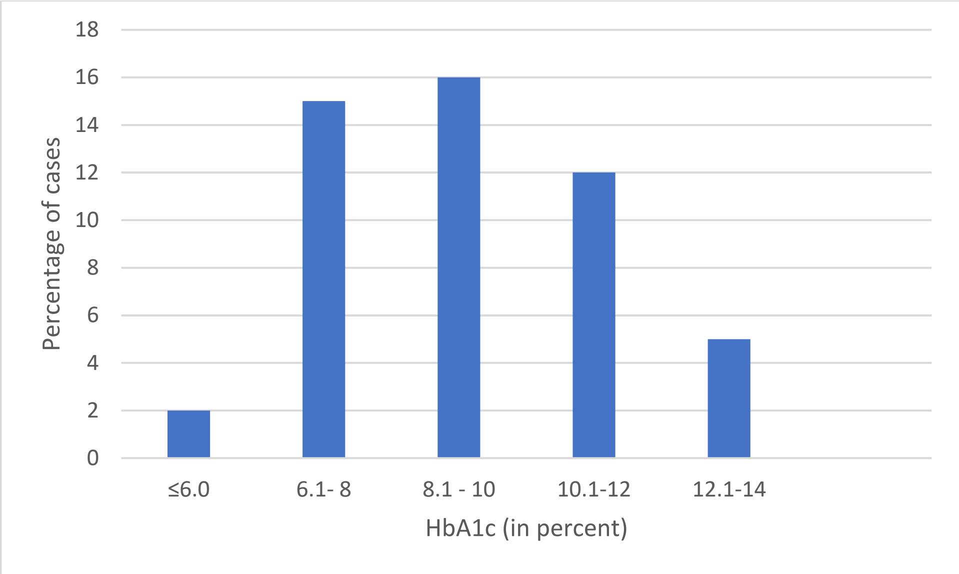


Figure 27. HbA1c levels among cases (n=50)

PHOTOPLETHYSMOGRAPH WAVEFORMS

The parameters of the photoplethysmography that were assessed were

- Peak pulse amplitude
- Time taken to attain the peak amplitude.

PEAK AMPLITUDE

The peak amplitudes were arbitrarily measured in volts. However, the data obtained for peak pulse amplitude required logarithmic transformation to normalise the data.

After normalisation of data it was subjected to analysis. The mean and standard deviation was calculated for each position. The data was then analysed using Levene's test for equality of variances and independent t-test for equality of means. The results were presented after applying antilogarithmic function.

As shown in Tables 4,5 and 6, in the supine position it was observed that in all the six regions of the foot, the peak amplitude in cases was consistently higher than the peak amplitude in controls. However, statistically significant difference was seen in three regions of the foot namely medial forefoot, middle forefoot and lateral forefoot.

The other two positions i.e., sitting and standing, did not show significant difference in the peak amplitude between the cases and controls in any of the regions of the foot.

PEAK TIMES

The peak time was measured in seconds. The mean and standard deviation was calculated using t-test. The data was then analysed using Levene's test for equality of variances and independent t -test for equality of means.

The peak times were analysed for both cases and controls for all three positions. There was statistically significant difference in the peak time in the heel of the foot in the sitting position. However, there was no other region with significant difference in the peak times between cases and controls.

SUPINE

Table 4

MEASURED PARAMETERS	CASES (n=50) MEAN ±SD	CONTROLS (n=50) MEAN ± SD	p VALUE
HALLUX			
Peak amplitude	0.37 ± 3.59	0.29 ± 4.44	0.391
Peak time	0.22 ± 0.05	0.23 ± 0.03	0.462
MEDIAL FOREFOOT			
Peak amplitude	0.11 ± 3.39	0.06 ± 3.25	**0.014**
Peak time	0.22 ± 0.05	0.23 ± 0.03	0.472
MIDDLE FOREFOOT			
Peak amplitude	0.10 ± 2.23	0.03 ± 4.30	**<0.001**
Peak time	0.23 ± 0.05	0.23 ± 0.02	0.708
LATERAL FOREFOOT			
Peak amplitude	0.10 ± 2.86	0.02 ± 3.86	**<0.001**
Peak time	0.22 ± 0.56	0.23 ± 0.03	0.133
LATERAL MIDFOOT			
Peak amplitude	0.12 ± 2.32	0.09 ± 3.82	0.372
Peak time	0.22 ± 0.05	0.27 ± 0.28	0.258
HEEL			
Peak amplitude	0.04 ± 3.46	0.03 ± 4.67	0.246
Peak time	0.42 ±1.27	0.23 ± 0.03	0.300

Cases: The mean peak amplitude in the supine position was 0.109 volts with standard deviation of 3.497 volts. The mean peak time was 0.254 seconds with standard deviation of 0.522 seconds.

Controls: The mean peak amplitude in the supine position was 0.063 volts with standard deviation of 3.975 volts. The mean peak time was 0.236 seconds with standard deviation of 0.117 seconds.

<u>SITTING</u>

<u>Table 5</u>

MEASURED PARAMETERS	**CASES (n=50)** MEAN ± SD	**CONTROLS (n=50)** MEAN ± SD	**p VALUE**
HALLUX			
Peak amplitude	0.19 ± 3.56	0.21 ± 4.35	0.706
Peak time	0.22 ± 0.06	0.22 ± 0.03	0.486
MEDIAL FOREFOOT			
Peak amplitude	0.07 ± 3.22	0.06 ± 3.63	0.617
Peak time	0.23 ± 0.05	0.22 ± 0.02	0.164
MIDDLE FOREFOOT			
Peak amplitude	0.05 ± 2.77	0.04 ± 2.97	0.700
Peak time	0.24 ± 0.06	0.23 ± 0.03	0.424
LATERAL FOREFOOT			
Peak amplitude	0.06 ± 3.78	0.05 ± 4.30	0.251
Peak time	0.24 ± 0.05	0.23 ± 0.03	0.290
LATERAL MIDFOOT			
Peak amplitude	0.08 ± 3.56	0.11 ± 4.14	0.211
Peak time	0.23 ± 0.05	0.22 ± 0.03	0.153
HEEL			
Peak amplitude	0.02 ± 3.90	0.04 ± 4.31	0.058
Peak time	0.24 ± 0.06	0.22 ± 0.02	**0.024**

<u>Cases:</u> The mean peak amplitude in the sitting position was 0.063 volts with standard deviation of 3.975 volts. The mean peak time was 0.235 seconds with standard deviation of 0.054 seconds.

<u>Controls</u>: The mean peak amplitude in the sitting position was 0.069 volts with standard deviation of 4.223 volts. The mean peak time was 0.224 seconds with standard deviation of 0.027 seconds.

STANDING

Table 6

MEASURED PARAMETERS	**CASES (n=50)**	**CONTROLS (n=50)**	**p VALUE**
	MEAN ± SD	**MEAN ± SD**	
HALLUX			
Peak amplitude	0.25 ± 4.22	0.26 ± 3.03 0.22 ±	0.883
Peak time	0.23 ± 0.05	0.04	0.339
MEDIAL FOREFOOT			
Peak amplitude	0.07 ± 4.95	0.06 ± 3.63	0.620
Peak time	0.23 ± 0.05	0.23 ± 0.04	0.835
MIDDLE FOREFOOT			
Peak amplitude	0.06 ± 4.01	0.06 ± 3.78	0.807
Peak time	0.23 ± 0.51	0.23 ± 0.04	0.656
LATERAL FOREFOOT			
Peak amplitude	0.05 ± 5.1	0.04 ± 5.05	0.538
Peak time	0.23 ± 0.05	0.23 ± 0.04	0.839
LATERAL MIDFOOT			
Peak amplitude	0.05 ± 5.31	0.09 ± 4.90	0.096
Peak time	0.22 ± 0.04	0.22 ± 0.03	0.632
HEEL			
Peak amplitude	0.01 ± 7.17	0.02 ± 7.10	0.488
Peak time	0.24 ± 0.05	0.24 ± 0.04	0.464

Cases: The mean peak amplitude in the standing position was 0.057 volts with standard deviation of 6.165 volts. The mean peak time was 0.230 seconds with standard deviation of 0.049 seconds.

Controls: The mean peak amplitude in the standing position was 0.063 volts with standard deviation of 5.395 volts. The mean peak time was 0.226 seconds with standard deviation of 0.036 seconds.

BOX PLOTS SHOWING RELATIONSHIP BETWEEN THE THREE POSITIONS AND PEAK AMPLITUDE IN CASES AND CONTROLS

1.

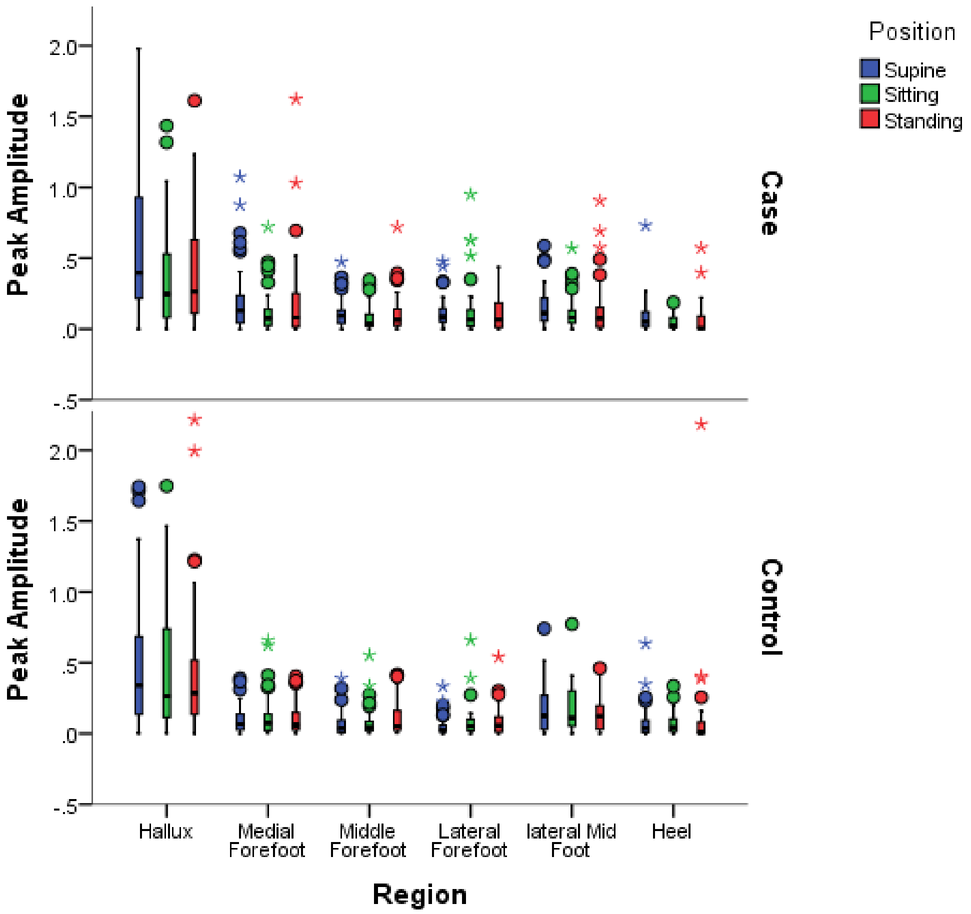


Figure 28. A box plot showing the peak amplitude for both cases and controls in all the six regions of the foot.

It is observed that the maximum amplitude in both cases and controls is at the hallux.

2.

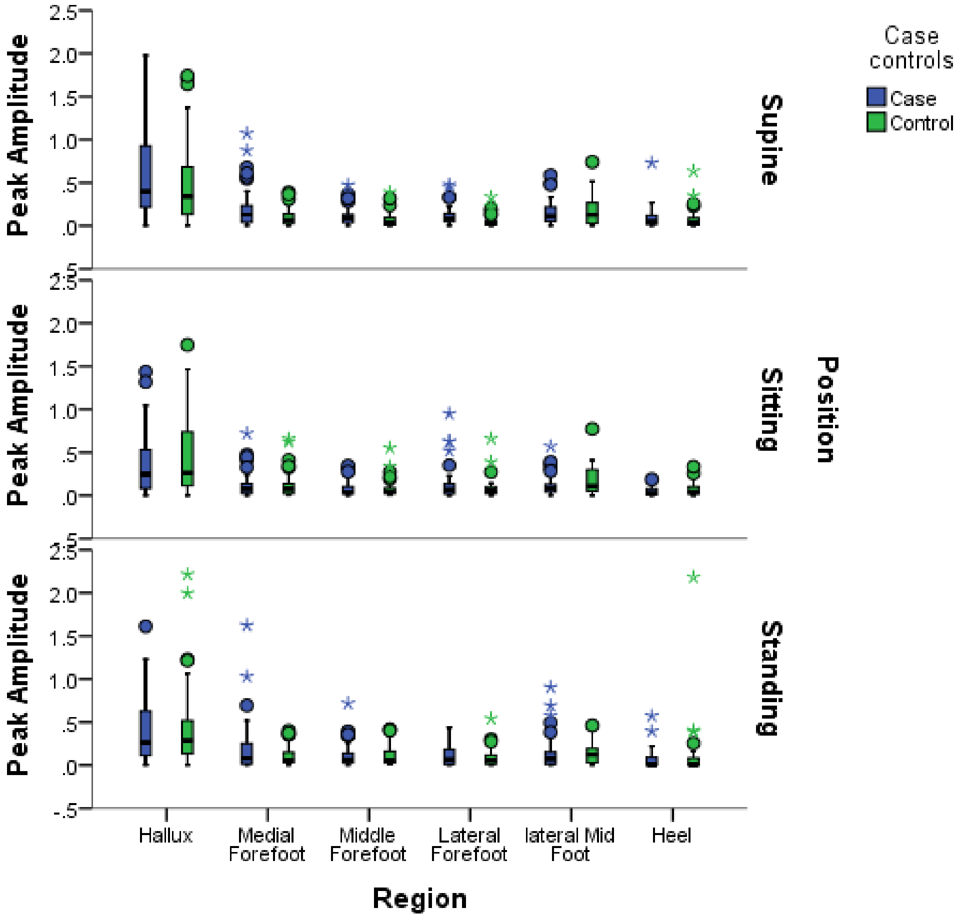


Figure 29. Box plot showing the peak amplitude in the three different positions

On further analysing each region of the foot in the three different positions, it was found that in all three positions, the maximum amplitude was consistently high at the hallux.

RECEIVER OPERATING CHARACTERISTIC CURVES

1.

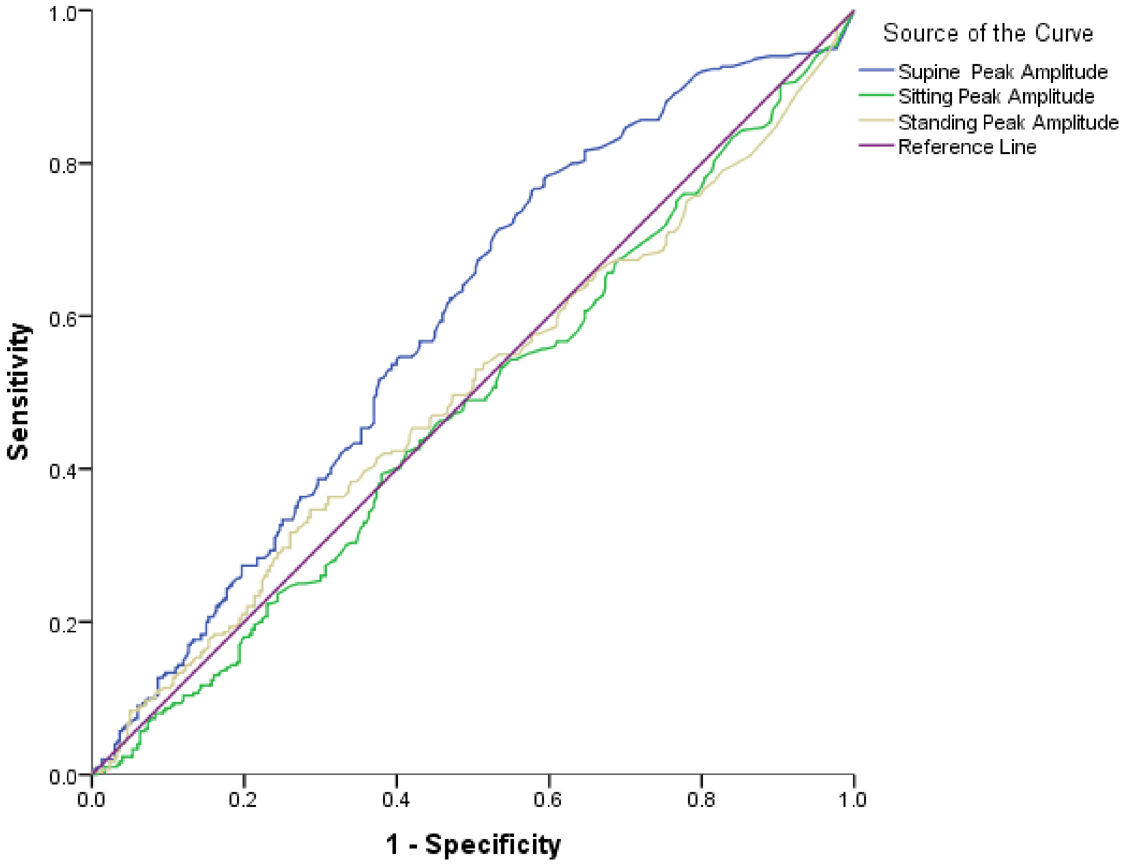


Figure 29. ROC plotted for the peak amplitudes in three different positions namely supine, sitting and standing.

The ROC plotted showed significant area under the curve (AUC) and p-value only for the supine position.

Table 7

POSITION	AUC	p- VALUE
SUPINE	0.592	**<0.01**
SITTING	0.479	0.383
STANDING	0.500	0.986

2.

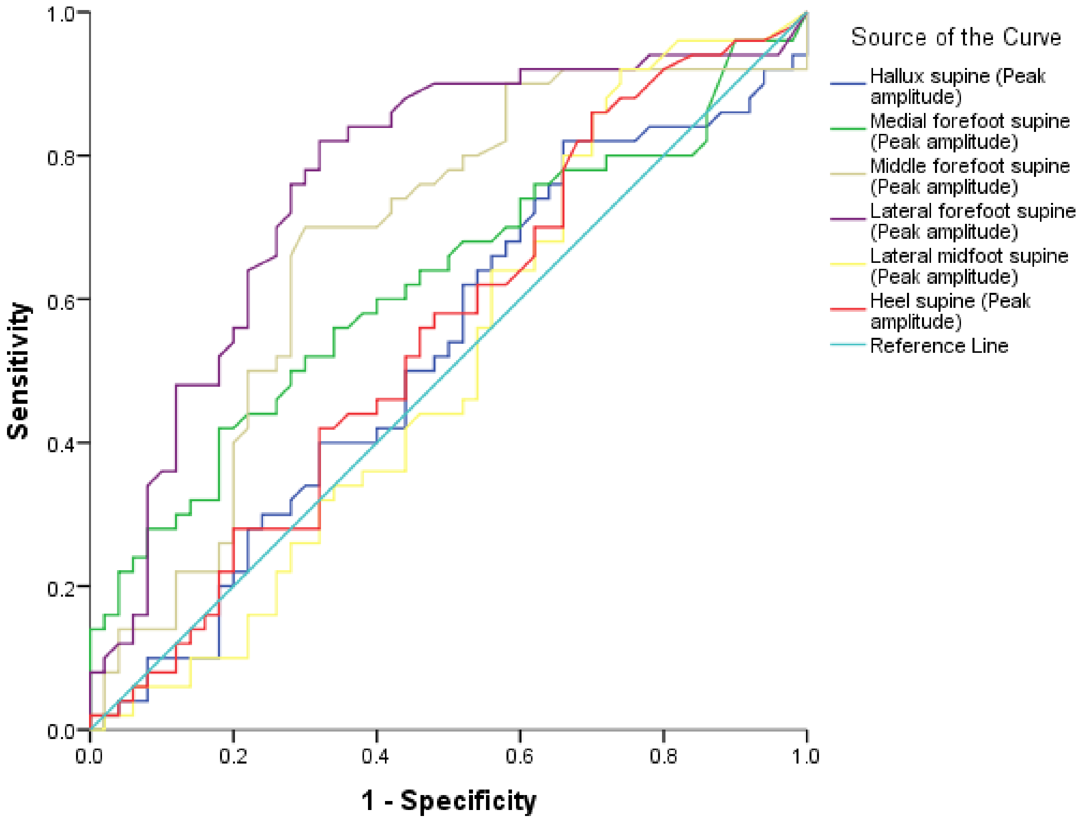


Figure 30. ROC plotted for the peak amplitudes in the supine position for all the six regions of the foot namely hallux, medial forefoot, middle forefoot, lateral forefoot, lateral midfoot and heel.

Table 8

REGION	AUC	p- VALUE
HALLUX	0.528	0.627
MEDIAL FOREFOOT	0.622	**0.036**
MIDDLE FOREFOOT	0.677	**0.002**
LATERAL FOREFOOT	0.763	**<0.001**
LATERAL MIDFOOT	0.513	0.825
HEEL	0.552	0.374

Since the peak amplitude in supine position showed statistical significance, it was further analysed by each region of the foot. Interestingly, the data revealed that all three regions of the forefoot namely medial forefoot, middle forefoot and lateral forefoot had significant area under the curve and p-value. This translates to better discriminative capacity of the PPG sensors to assess blood flow in the forefoot region than in the hallux, midfoot or heel. Hence the likelihood of PPG accurately assessing the microvascular blood flow in the region of the forefoot is significantly greater than the other regions.

Generalised linear regression models were used to compare the change or difference in peak amplitude between the six regions of the foot. As shown in Table 9, hallux was taken as the reference region and the other five regions were compared to it. It showed statistically significant decrease in the pulse peak amplitude between hallux and all the other regions of the foot

Table 9

MEASURED PARAMETERS (REGION)	**BETA VALUE**	**95% CONFIDENCE INTERVAL**	**p VALUE**
Hallux vs Medial Forefoot	-0.465	-0.621, -0.309	**<0.001**
Hallux vs Middle Forefoot	-0.521	-0.682, -0.360	**<0.001**
Hallux vs Lateral Forefoot	-0.449	-0.688, -0.210	**<0.001**
Hallux vs Lateral Midfoot	-0.453	-0.619, -0.286	**<0.001**
Hallux vs Heel	-0.532	-0.696, -0.367	**<0.001**

Similarly, the generalised linear model was also used to compare the change in peak amplitude between the three positions as shown in Table 10. The supine position was taken as the reference and was then compared to sitting and standing positions. It was observed that there was statistically significant decrease in the peak amplitude when the subject assumed a sitting position from supine position.

When the position of the subject was changed from supine to standing, there was a decrease in the peak amplitude, but it was not statistically significant.

Table 10

MEASURED PARAMETERS (POSITION)	**BETA VALUE**	**95% CONFIDENCE INTERVAL**	**p VALUE**
Supine Vs Sitting	-0.230	-0.373, -0.087	**0.002**
Supine Vs Standing	-0.107	-0.356, 0.142	0.401

TOE PRESSURES

Pearson correlation statistical analysis was done to assess the relationship between peak amplitude and toe pressures. As depicted in table 11, there was significant positive correlation between peak amplitude and toe pressures for both cases and controls. Even though this positive correlation was not consistent in all six positions across the three assumed positions, the overall positive correlation between the two different variables is definite.

Table 11

VARIABLE (Peak amplitude)	SUPINE		SITTING		STANDING	
	Pearson correlation coefficient	**p-Value**	**Pearson correlation coefficient**	**p-Value**	**Pearson correlation coefficient**	**p-Value**
HALLUX						
Cases	0.298	**0.036**	0.379	**0.007**	-0.058	0.688
Controls	0.425	**0.002**	0.225	0.117	0.118	0.415
MEDIAL FOREFOOT						
Cases	0.026	0.860	0.243	0.089	0.156	0.279
Controls	0.313	**0.027**	0.184	0.200	-0.019	0.898
MIDDLE FOREFOOT						
Cases	0.114	0.429	0.169	0.242	0.104	0.473
Controls	0.415	**0.003**	0.380	**0.006**	0.174	0.226
LATERAL FOREFOOT						
Cases	-0.001	0.992	0.120	0.405	0.163	0.258
Controls	0.145	0.314	0.266	0.062	0.410	**0.003**
LATERAL MIDFOOT						
Cases	0.079	0.585	0.044	0.761	0.054	0.711
Controls	0.145	0.317	0.415	**0.003**	0.388	**0.005**
HEEL						
Cases	0.167	0.245	-0.227	0.113	-0.068	0.640
Controls	0.460	**0.001**	-0.035	0.807	-0.052	0.721

DURATION OF DIABETES

The relation between peak amplitude and duration of diabetes mellitus was analysed as shown in Table 12. Interestingly, there was significant negative correlation between the peak amplitude in the supine position in the hallux and medial forefoot with duration of diabetes.

However, in the sitting position there was significant positive correlation between the peak amplitude in middle forefoot and lateral midfoot with duration of diabetes. There was also positive correlation between peak amplitude in lateral midfoot in supine position and duration of diabetes.

In the standing position there was no correlation between the peak amplitude and duration of diabetes in any of the regions of the foot.

Table 12

VARIABLE	SUPINE		SITTING		STANDING	
	Pearson correlation coefficient	**p-Value**	**Pearson correlation coefficient**	**p-Value**	**Pearson correlation coefficient**	**p-Value**
HALLUX Peak amplitude	-0.351	**0.012**	-0.123	0.393	-0.243	0.089
MEDIAL FOREFOOT Peak amplitude	-0.298	**0.035**	-0.004	0.980	0.021	0.884
MIDDLE FOREFOOT Peak amplitude	-0.125	0.386	0.307	**0.030**	0.100	0.491
LATERAL FOREFOOT Peak amplitude	0.307	**0.03**	0.041	0.776	0.044	0.764
LATERAL MIDFOOT Peak amplitude	-0.132	0.360	0.330	**0.019**	0.119	0.411
HEEL Peak amplitude	-0.231	0.107	0.008	0.954	0.117	0.417

6. DISCUSSION

A total of 50 cases and appropriately age and gender matched 50 controls were analysed. In addition to demographic details, various physiological parameters including height, weight, body mass index and blood pressure were analysed.

There was no significant variation between the two groups with respect to the height, weight and the body mass index. The mean systolic blood pressure was almost comparable between cases and controls. However, interestingly the mean diastolic blood pressure among controls was significantly higher than in cases but the values were within normal limits.

The aforementioned physiological parameters which included height, weight, body mass index and blood pressure could be regarded as potential confounding factors in the assessment of peripheral blood flow over the foot. As there was no statistical significance amongst cases and controls, it translated to good matching and a decreased likelihood of these being confounding variables in the study. Therefore, the changes in blood flow as assessed by PPG was more likely only due to the variables of interest namely, diabetic status and the presence of amputation of the contralateral limb in cases.

Toe pressures which are widely used as an indirect measure of the peripheral blood flow over the foot were measured for both cases and controls and analysed. The mean toe pressures measured for the cases were higher than in the control group. This corroborates with our understanding that in diabetics, there is an increased stiffness of the arteries and arterioles due to extracellular matrix deposition and sclerosis in the tunica media which could explain the higher toe pressures among the cases(40). However, there was no statistically significant difference between the cases and controls. Therefore, it can be suggested that probably toe pressures alone are not sensitive enough to detect early microvascular changes in the contralateral foot in patients who had undergone amputation. Even if the precious contralateral foot in our cases had early microvascular changes, it was not detected by the conventional toe pressures. This further strengthens our purpose of the study to find an alternative method to detect early changes.

A study by Sonter et al comparing the intra-rater and inter-rater reliability of toe pressures in diabetics and non-diabetics also showed no statistically significant difference in the toe pressures between cases and controls even though toe pressures had better reliability when compared to toe brachial index and ankle brachial index(41). In a meta-analysis by Sonter Ja it was concluded that low toe pressures (less than 30mm Hg) were associated with poor wound healing and higher risk of amputation, however there was a significant heterogeneity in the toe pressures measured(42). Therefore, it may be argued that even though absolute values of toe pressures are indirect indicators of blood flow of the foot, they may not be the best tool to differentiate between the microvascular blood flow in diabetics and non-diabetics.

Among the co-existent illnesses analysed it was found that systemic hypertension had a higher prevalence among cases which corroborates with the consensus that patients with diabetes mellitus have a higher risk of concomitant systemic hypertension. This has been attributed to probably similar mechanism of microvascular injury at the molecular level in both diabetes and hypertension (43).

On analysis of the photoplethysmograph data, the peak amplitude was maximum at the hallux for both cases and controls in all three positions consistently. Therefore, this indicates that the blood flow in the superficial plantar surface of the hallux is more compared to the other pressure points. This confirms the conjecture that in diabetics when there is loss of sympathetic tone, opening up of arteriovenous channels occur and cause an apparent increase in the blood flow (9). According to the results of this study hallux can be considered an important region of the foot for assessing microvascular changes that can be easily identified using PPG. Therefore, assessment of distal microcirculation is a better indicator of the overall status of the foot.

It was also observed that there was significant difference in the peak amplitude in the forefoot region in the supine position between the study and control groups. There was an increase in the peak amplitude among cases in all three regions of the forefoot namely medial forefoot, middle forefoot and lateral forefoot. This is an important result of the study because it has shed light on our understanding of pressure points of the foot and the resultant effect of early microvascular changes. Based on the study it can be suggested that the forefoot is probably more sensitive and reliable in manifesting early microvascular changes. Moreover, there are no previous studies or literature which have measured peak amplitudes of PPG in these regions in diabetics versus normal subjects.

This was further supported by statistical analysis which showed that compared to the hallux, the other regions showed a significant decrease in amplitude. Therefore, even though hallux is the region of maximum blood flow, the forefoot would be a better region to detect change in blood flow in diabetics and non-diabetics.

This difference was not observed in the other positions namely sitting and standing. The common underlying variable is the force exerted in assuming these two positions. It can thus be concluded that in the resting supine position with the foot being unloaded**,** the PPG has maximum sensitivity in detecting changes in blood flow between diabetics and non-diabetics in the forefoot compared to other regions of the foot.

Another important result of the study was the significant change noticed in the peak amplitude when subject assumed a sitting position from supine position. In the sitting position, the foot is on the ground with due pressure. Hence, in amputees whose precious limb bears a significant load, it has been demonstrated that there is significant reduction in the peak amplitude on assuming a sitting position. This can be attributed to the cumulative result of direct pressure causing dampening of waveforms and early microvascular changes in the foot causing an apparent decrease in the amplitude.

Important practical implications of the study

The study has proved with reasonable confidence that photoplethysmography is a safe, reliable, non-invasive and sensitive indicator of microvascular changes in the foot in diabetics. It has detected changes in the blood flow of the foot even in the absence of any external manifestations in the foot.

In our study PPG has detected changes in blood flow in the two groups which the conventional toe pressures failed to detect. This is of considerable significance and has far reaching implications in detecting and diagnosing early subclinical changes in persons with diabetes even in the absence of ulceration or other gross changes in the foot. Hence it may find an important place as a predictor tool for screening patients with diabetes. It would serve as an adjunct to the already existing diabetic foot clinics in detecting early changes.

In view of the results of the study we can suggest footwear that would effectively address the pressure points in the foot. This would greatly reduce the incidence of diabetic foot and subsequent need for amputations.

In an era where the rates of amputations secondary to diabetes mellitus are increasing exponentially, any attempt at limb salvage is a welcome relief.

Our study has shown promising results towards this objective.

7. LIMITATIONS

At the outset this study was a novel attempt to explore the application of PPG in assessing blood flow in the foot. There is very limited literature and background knowledge on the use of PPG for this purpose. Therefore, there was lack of adequate standardisation and validation of the device used. It required modifications and alterations at every step in tandem with new challenges faced during the study. However, towards the end of the study it was a robust, indigenous model which required further application and use in the future for studying a larger population.

The PPG waveform is impregnated with countless parameters and variables which we are yet to explore. For example, there are various aspects of the waveform including area under the curve, pulse width, peak to peak interval, first order derivatives, second order derivatives, Fourier transformation and augmentation index, all of which have not been studied. This study has generated data that needs further intense analysis, comprehension and interpretation.

According to the results of the study, the effect of pressure over the PPG sensors in the sitting and standing positions was quite significant thereby causing occasional dampening of the waveforms. Design modifications maybe needed in future to address this issue.

8. CONCLUSION

In congruence with our primary objective the peak amplitude and peak times were established in the contralateral limb in diabetic patients who had undergone amputation. There was significant increase in the peak amplitude among the amputees with diabetes as compared to non - diabetics. The mean peak amplitudes for cases in the supine, sitting and standing positions were 0.109, 0.063 and 0.057 (in arbitrary units of volts) respectively. The corresponding mean peak amplitudes in controls in supine, sitting and standing positions were 0.057, 0.069 and 0.063 (in arbitrary units of volts) respectively.

The mean peak time for cases in the supine, sitting and standing positions were 0.254 seconds, 0.235 seconds and 0.230 seconds respectively. The corresponding mean peak time for controls in the supine, sitting and standing positions were 0.236 seconds, 0.224 seconds and 0.226 seconds respectively. However, there was no statistically significant difference.

Hence peak amplitude was a better indicator of the changes in blood flow than peak times.

In fulfilment of secondary objectives, the different regions of the foot were mapped according to their blood flow and it was established that the hallux had maximum blood flow but the forefoot was a better representative of the change in blood flow.

This study can therefore be considered a basis for adopting the use of PPG to assess distal microvascular blood flow as it is more representative of the local blood flow when compared to other conventional modalities.

We can also recommend the use of appropriate footwear for the precious limb in diabetic amputees with due consideration to the forefoot region.

9. REFERENCES

1. Cho NH, Shaw JE, Karuranga S, Huang Y, da Rocha Fernandes JD, Ohlrogge AW, et al. IDF Diabetes Atlas: Global estimates of diabetes prevalence for 2017 and projections for 2045. Diabetes Res Clin Pract [Internet]. [cited 2018 Mar 5]; Available from: https://www.sciencedirect.com/science/article/pii/S0168822718302031

2. Scheen AJ, Lefèbvre PJ. Pathophysiology of Type 2 Diabetes Mellitus. In: Oral Antidiabetics [Internet]. Springer, Berlin, Heidelberg; 1996 [cited 2018 Mar 5]. p. 7–42. (Handbook of Experimental Pharmacology). Available from: https://link.springer.com/chapter/10.1007/978-3-662-09127-2_2

3. Fowler MJ. Microvascular and Macrovascular Complications of Diabetes. Clin Diabetes. 2011 Jul 1;29(3):116–22.

4. Iwase M, Imoto H, Murata A, Nakamura U, Nohara S, Uchizono Y, et al. Altered Postural Regulation of Foot Skin Oxygenation and Blood Flow in Patients with Type 2 Diabetes Mellitus. Exp Clin Endocrinol Diabetes. 2007 Jul 23;115(07):444–7.

5. Kolluru GK, Bir SC, Kevil CG. Endothelial Dysfunction and Diabetes: Effects on Angiogenesis, Vascular Remodeling, and Wound Healing. Int J Vasc Med [Internet]. 2012 [cited 2018 Aug 22];2012. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3348526/

6. Chao CYL, Cheing GLY. Microvascular dysfunction in diabetic foot disease and ulceration. Diabetes Metab Res Rev. 2009 Oct;25(7):604–14.

7. Flynn MD, Edmonds ME, Tooke JE, Watkins PJ. Direct measurement of capillary blood flow in the diabetic neuropathic foot. Diabetologia. 1988 Sep;31(9):652–6.

8. Vinik AI, Erbas T, Park TS, Pierce KK, Stansberry KB. Methods for Evaluation of Peripheral Neurovascular Dysfunction. Diabetes Technol Ther. 2001 Mar;3(1):29–50.

9. Kim DW, Kim SW, Kim SC, Nam KC, Kang ES, Im JJ. Detection of Diabetic Neuropathy Using Blood Volume Ratio of Finger and Toe by PPG. In IEEE; 2007 [cited 2018 Aug 12]. p. 2211–4. Available from: http://ieeexplore.ieee.org/document/4352763/

10. __H.-H. Parving, G. C. Viberti, H. Keen, J. S. Christiansen, and N. A. Lassen. Hemodynamic Factors in the Genesis of Diabetic Microangiopathy. Metabolism. 1983 Sep: 32(9):943-9

11. Cameron NE, Eaton SEM, Cotter MA, Tesfaye S. Vascular factors and metabolic interactions in the pathogenesis of diabetic neuropathy. Diabetologia. 2001 Nov 1;44(11):1973–88.

12. Doppler assessment and ABPI: Interpretation in the management of leg ulceration [Internet]. [cited 2018 Mar 17]. Available from: http://www.worldwidewounds.com/2001/march/Vowden/Doppler-assessment-and-ABPI.html

13. Khan TH, Farooqui FA, Niazi K. Critical Review of the Ankle Brachial Index. Curr Cardiol Rev. 2008 May;4(2):101–6.

14. Al-Qaisi M, Nott DM, King DH, Kaddoura S. Ankle Brachial Pressure Index (ABPI): An update for practitioners. Vasc Health Risk Manag. 2009;5:833–41.

15. Scanlon C, Park K, Mapletoft D, Begg L, Burns J. Interrater and intrarater reliability of photoplethysmography for measuring toe blood pressure and toe-brachial index in people with diabetes mellitus. J Foot Ankle Res. 2012 Jun 7;5:13.

16. Hinchliffe RJ, Brownrigg JRW, Apelqvist J, Boyko EJ, Fitridge R, Mills JL, et al. IWGDF guidance on the diagnosis, prognosis and management of peripheral artery disease in patients with foot ulcers in diabetes: IWGDF Guidance on Peripheral Artery Disease. Diabetes Metab Res Rev. 2016 Jan;32:37–44.

17. Tehan PE, Barwick AL, Sebastian M, Chuter VH. Diagnostic accuracy of resting systolic toe pressure for diagnosis of peripheral arterial disease in people with and without diabetes: a cross-sectional retrospective case-control study. J Foot Ankle Res [Internet]. 2017 Dec 19 [cited 2018 Aug 26];10. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5735897/

18. Restrepo RD, Hirst KR, Wittnebel L, Wettstein R. AARC Clinical Practice Guideline: Transcutaneous Monitoring of Carbon Dioxide and Oxygen: 2012. Respir Care. 2012 Nov 1;57(11):1955–62.

19. Yamada T, Ohta T, Ishibashi H, Sugimoto I, Iwata H, Takahashi M, et al. Clinical reliability and utility of skin perfusion pressure measurement in ischemic limbs—Comparison with other noninvasive diagnostic methods. J Vasc Surg. 2008 Feb;47(2):318–23.

20. Lal C, Unni SN. Correlation analysis of laser Doppler flowmetry signals: a potential non-invasive tool to assess microcirculatory changes in diabetes mellitus. Med Biol Eng Comput. 2015 Jun;53(6):557–66.

21. Allen J. Photoplethysmography and its application in clinical physiological measurement. Physiol Meas. 2007;28(3):R1.

22. Abdallah O, Bolz A. Adaptive Filtering by Non-Invasive Vital Signals Monitoring and Diseases Diagnosis. In: Garcia Morales L, editor. Adaptive Filtering Applications [Internet]. InTech; 2011 [cited 2018 Aug 19]. Available from: http://www.intechopen.com/books/adaptive-filtering-applications/adaptive-filtering-by-non-invasive-vital-signals-monitoring-and-diseases-diagnosis

23. Moraes JL, Rocha MX, Vasconcelos GG, Vasconcelos Filho JE, de Albuquerque VHC, Alexandria AR. Advances in Photopletysmography Signal Analysis for Biomedical Applications. Sensors [Internet]. 2018 Jun 9 [cited 2018 Aug 14];18(6). Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6022166/

24. Yang C, Tavassolian N. Pulse Transit Time Measurement Using Seismocardiogram, Photoplethysmogram, and Acoustic Recordings: Evaluation and Comparison. IEEE J Biomed Health Inform. 2018 May;22(3):733–40.

25. Hsu P-C, Wu H-T, Sun C-K. Assessment of Subtle Changes in Diabetes-Associated Arteriosclerosis using Photoplethysmographic Pulse Wave from Index Finger. J Med Syst [Internet]. 2018 Mar [cited 2018 Mar 9];42(3). Available from: http://link.springer.com/10.1007/s10916-018-0901-1

26. Nitzan M, Babchenko A, Khanokh B, Landau D. The variability of the photoplethysmographic signal - a potential method for the evaluation of the autonomic nervous system. Physiol Meas. 1998;19(1):93.

27. Awad AA, Haddadin AS, Tantawy H, Badr TM, Stout RG, Silverman DG, et al. The relationship between the photoplethysmographic waveform and systemic vascular resistance. J Clin Monit Comput. 2007 Nov 8;21(6):365–72.

28. Zhao D, Sun Y, Wan S, Wang F. SFST: A robust framework for heart rate monitoring from photoplethysmography signals during physical activities. Biomed Signal Process Control. 2017 Mar;33:316–24.

29. Hale GM, Querry MR. Optical Constants of Water in the 200-nm to 200-Mm Wavelength Region. :9.

30. Optical Absorption of Hemoglobin [Internet]. [cited 2018 Mar 18]. Available from: https://omlc.org/spectra/hemoglobin/

31. Cejnar M, Kobler H, Hunyor SN. Quantitative photoplethysmography: Lambert-Beer law or inverse function incorporating light scatter. J Biomed Eng. 1993 Mar;15(2):151–4.

32. Yuan H, Memon S, Newe T, Lewis E, Leen G. Motion artefact minimization from photoplethysmography based non-invasive hemoglobin sensor based on an envelope filtering algorithm. Measurement. 2018 Feb 1;115:288–98.

33. Estimation of instantaneous venous blood saturation using the photoplethysmograph waveform - IOPscience [Internet]. [cited 2018 Aug 8]. Available from: http://iopscience.iop.org/article/10.1088/0967-3334/36/10/2203/meta

34. Njoum H, Kyriacou PA. Photoplethysmography for the Assessment of Haemorheology. Sci Rep [Internet]. 2017 May 3 [cited 2018 Aug 8];7. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5431178/

35. Jihyoung Lee, Matsumura K, Yamakoshi K, Rolfe P, Tanaka S, Yamakoshi T. Comparison between red, green and blue light reflection photoplethysmography for heart rate monitoring during motion. In: 2013 35th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC) [Internet]. Osaka: IEEE; 2013 [cited 2018 Aug 19]. p. 1724–7. Available from: http://ieeexplore.ieee.org/document/6609852/

36. Hertzman AB. THE BLOOD SUPPLY OF VARIOUS SKIN AREAS AS ESTIMATED BY THE PHOTOELECTRIC PLETHYSMOGRAPH. Am J Physiol-Leg Content. 1938 Oct 31;124(2):328–40.

37. Chang Y-W, Hsiu H, Yang S-H, Fang W-H, Tsai H-C. Characteristics of beat-to-beat photoplethysmography waveform indexes in subjects with metabolic syndrome. Microvasc Res. 2016 Jul;106:80–7.

38. Algorithms for Monitoring Heart Rate and Respiratory Rate From the Video of a User's Face. IEEE J Transl Eng Health Med [Internet]. 2018 Apr 12 [cited 2018 Aug 15];6. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5957265/

39. Drive ADA 2451 C, Arlington S 900, Va 22202 1-800-Diabetes. American Diabetes Association Releases 2018 Standards of Medical Care in Diabetes, with Notable New Recommendations for People with Cardiovascular Disease and Diabetes [Internet]. American Diabetes Association. [cited 2018 Sep 29]. Available from: http://www.diabetes.org/newsroom/press-releases/2017/american-diabetes-association-2018-release-standards-of-medical-care-in-diabetes.html

40. Romanos MT, Raspovic A, Perrin BM. The reliability of toe systolic pressure and the toe brachial index in patients with diabetes. J Foot Ankle Res. 2010 Dec 22;3:31.

41. Sonter JA, Chuter V, Casey S. Intratester and Intertester Reliability of Toe Pressure Measurements in People with and Without Diabetes Performed by Podiatric Physicians. J Am Podiatr Med Assoc. 2015 May;105(3):201–8.

42. Ja S. The predictive capacity of toe blood pressure and the toe brachial index for foot wound healing and amputation: A systematic review and meta-analysis. 2014;22(4):13.

43. Mancia G. The association of hypertension and diabetes: prevalence, cardiovascular risk and protection by blood pressure reduction. Acta Diabetol. 2005 Apr;42(S1):s17–25.

ANNEXURE 1

OFFICE OF RESEARCH
INSTITUTIONAL REVIEW BOARD
CHRISTIANMEDICALCOLLEGE,
BAGAYAM, VELLORE 632002, TAMIL NADU, INDIA

Ref: FG/10364/11/2016

March 23, 2017

To,

The Treasurer
Christian Medical College,
Vellore.

Dear Mr. Robby Pria Sundersingh,

Sub: **Fluid Research Grant NEW PROPOSAL:**
Role of multipoint contact photoplethysmography in assessing changes in blood flow in the plantar aspect of the contra lateral foot following amputation in patients with type 2 diabetes mellitus.
Keerthi.K, PG Registrar, General surgery, Dr Pranay Gaikwad, Employment Number: 31224, General Surgery, Unit I, Dr Cecil Thankachan Thomas, Employment number-32376, General Surgery, Unit I, Dr Suresh Devasahayam, Employment number-15028Bioengineering, Ms. Susmita Dey, Employment number –21267, Bioengineering, Ms Grace Rebekah J, Employment number- 32070, biostatistics.

Ref: IRB Min No: 10364 [OBSERVE] dated 03.11.2016

The Institutional Review Board at its meeting held on November 03rd 2016 vide IRB Min. No.**10364** accepted the project for *A sum of 87,000/- INR (Rupees Eighty Seven thousand only Only) will be granted for 20 Months.*

Kindly arrange to transfer the sanctioned amount to a separate account to be operated by Dr. Keerthi.K (keerthi2420@gmail.com) and Dr. Pranay Gaikwad (pranay@cmcvellore.ac.in)

Yours sincerely,

Dr. Biju George.
Secretary (Ethics Committee)
Institutional Review Board, CMC, Vellore.

CC: Dr. Keerthi.K, Department of General Surgery, CMC, Vellore.
Dr. Pranay Gaikwad Department of General Surgery, CMC, Vellore
File.

OFFICE OF RESEARCH
INSTITUTIONAL REVIEW BOARD (IRB)
CHRISTIAN MEDICAL COLLEGE, VELLORE, INDIA

Dr. B.J. Prashantham, M.A., M.A., Dr. Min (Clinical)
Director, Christian Counseling Center,
Chairperson, Ethics Committee.

Dr. Anna Benjamin Pulimood, M.B.B.S., MD., Ph.D.,
Chairperson, Research Committee & Principal

Dr. Biju George, M.B.B.S., MD., DM.,
Deputy Chairperson,
Secretary, Ethics Committee, IRB
Additional Vice-Principal (Research)

November 10, 2016.

Dr. Keerthi.K,
PG Registrar,
Department of General Surgery,
Christian Medical College,
Vellore – 632 002.

Sub: **Fluid Research Grant NEW PROPOSAL:**
Role of multipoint contact photoplethysmography in assessing changes in blood flow in the plantar aspect of the contra lateral foot following amputation in patients with type 2 diabetes mellitus.
Keerthi.K, PG Registrar, General surgery, Dr Pranay Gaikwad, Employment Number: 31224, General Surgery, Unit I, Dr Cecil Thankachan Thomas, Employment number-32376, General Surgery, Unit I, Dr Suresh Devasahayam, Employment number-15028Bioengineering, Ms. Susmita Dey, Employment number –21267, Bioengineering, Ms Grace Rebekah J, Employment number- 32070, biostatistics.

Ref: IRB Min. No. 10364 dated 03.11.2016

Dear Dr. Keerthi.K,

The Institutional Review Board (**Blue**, Research and Ethics Committee) of the Christian Medical College, Vellore, reviewed and discussed your project titled "Role of multipoint contact photoplethysmography in assessing changes in blood flow in the plantar aspect of the contra lateral foot following amputation in patients with type 2 diabetes mellitus." on November 03rd 2016. I am quoting below the minutes of the meeting.

The Committee raises the following queries:

1. More details of wave form, amplitude peak in write up
2. Methodology – What standardization procedures are needed – please put in details
3. There is no data sheet available
4. Why have you selected contralateral limb of the amputated limb to be studied – is it useful to study it when the machine is not standardized
5. What happens normally to the blood flow in the normal limb after an amputation – will it be abnormally raised.
6. If the machine is not standardized –what is the gold standard at present
7. Information sheet in English and Tamil not available.

Ethics Committee Blue, Office of Research, 1st Floor, Carman Block, Christian Medical College, Vellore, Tamil Nadu 632 002
Tel: 0416 – 2284294, 2284202 Fax: 0416 – 2262788, 2284481 E-mail: research@cmcvellore.ac.in

OFFICE OF RESEARCH
INSTITUTIONAL REVIEW BOARD (IRB)
CHRISTIAN MEDICAL COLLEGE, VELLORE, INDIA

Dr. B.J. Prashantham, M.A., M.A., Dr. Min (Clinical)
Director, Christian Counseling Center,
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Dr. Anna Benjamin Pulimood, M.B.B.S., MD., Ph.D.,
Chairperson, Research Committee & Principal

Dr. Biju George, M.B.B.S., MD., DM.,
Deputy Chairperson,
Secretary, Ethics Committee, IRB
Additional Vice-Principal (Research)

8. Tamil version needs to be modified

Drs. Keerthi.K and Pranay Gaikwad were present during the presentation of the proposal and satisfactorily responded to the queries raised by the Members. After discussion, it was resolved to **ACCEPT the proposal after receiving the suggested modifications and answers to the queries.**

Note:
1. Kindly HIGHLIGHT the modifications in the revised proposal.
2. Keep a covering letter and point out the answer to the queries.
3. Reply to the queries should be submitted within 3 months duration from the time of the thesis/ protocol presentation, if not the thesis/protocol have to be resubmitted to the IRB.
4. The checklist has to be sent along with the answers to queries.

Email the details to research@cmcvellore.ac.in and send a hard copy through internal dispatch to Dr. Biju George, Addl. Vice-Principal (Research), Principal's Office, CMC.

Yours sincerely,

Dr. Biju George
Secretary (Ethics Committee)
Institutional Review Board.

Dr. BIJU GEORGE
MBBS., MD., DM.
SECRETARY - (ETHICS COMMITTEE)
Institutional Review Board,
Christian Medical College, Vellore - 632 002.

Cc: Dr Pranay Gaikwad, Department of General Surgery - 1, CMC Vellore.

IRB Min. No. 10364 dated 03.11.2016

Ethics Committee Blue, Office of Research, 1st Floor, Carman Block, Christian Medical College, Vellore, Tamil Nadu 632 002
Tel: 0416 – 2284294. 2284202 Fax: 0416 – 2262788, 2284481 E-mail: research@cmcvellore.ac.in

ANNEXURE 2

“ Role of multipoint contact photoplethysmography in assessing changes in blood flow in the plantar aspect of the contralateral foot following amputation in patients with type 2 diabetes mellitus”

DATA EXTRACTION/CLINICAL RESEARCH FORM

DATA EXTRACTION SHEET

IRB Protocol ID:

Hospital ID ☐☐☐☐☐☐☐

Unique ID number

Demographic details

Name:

☐☐ Age:

Gender: Male ☐ Female☐

Address:

Phone number:

History

1)Known patient of diabetes mellitus Yes☐ No☐

- If yes, duration of diabetes ☐☐ ☐☐

YY MM

2)Whether on medical treatment for diabetes Yes☐ No☐

- If yes, what is the treatment? ☐Oral hypoglycemic agents only
  ☐Insulin only
  ☐Both oral hypoglycemic agents and insulin
  ☐Irregular treatment

3) Whether currently experiencing any of the following symptoms

☐Increased thirst

☐Increased hunger

☐Increased urination

4)Comorbid illnesses

- Systemic hypertension Yes ☐ No ☐
- Chronic kidney disease Yes ☐ No☐
- Peripheral vascular disease Yes☐ No ☐
- Ischemic heart disease Yes ☐ No ☐
- Cerebrovascular disease Yes☐ No☐

5)Medication history – Name and dose of drugs being taken ______________ ______________

6)History of amputation of the lower limb Yes ☐ No☐

(includes toe amputation, foot amputation, below

knee amputation and above knee amputation)

- If yes, what was the level of amputation (check all the boxes that apply and provide the date of surgery)

Tick the boxes	Side	Anatomical site	Date of surgery
☐	Right	First toe	
☐	Right	Second toe	
☐	Right	Third toe	
☐	Right	Fourth toe	
☐	Right	Fifth toe	
☐	Right	Transmetatarsal (amputation at the level of midfoot)	
☐	Right	Below knee	
☐	Right	Above knee	
☐	Left	First toe	
☐	Left	Second toe	
☐	Left	Third toe	
☐	Left	Fourth toe	
☐	Left	Fifth toe	
☐	Left	Transmetatarsal (amputation at the level of midfoot)	
☐	Left	Below knee	
☐	Left	Above knee	

Clinical parameters

1) Height (in cm) ☐☐☐

2) Weight (in kg) ☐☐☐

3) Body mass index ☐☐

4) Blood pressure (mm ☐☐☐ / ☐☐☐ Hg)

5) Toe pressures measurement over the big toe of the precious foot (mm Hg)

Side	Toe pressures (mm Hg)

Laboratory investigations

1) HbA1c (in percent) – To be done for all patients with diabetes who have undergone amputation ☐☐

2) Random blood glucose levels(mg/dl) – To be done for all individuals planned to be taken in the comparison group, in order to rule out diabetes ☐☐☐

3) **Photoplethysmography data**

Which foot is being studied? Right ☐ Left ☐

Supine

Anatomical region	Peak amplitude(millivolts)	Peak times(milliseconds)
Hallux		
Heel		
Medial forefoot		
Middle forefoot		
Lateral forefoot		
Lateral midfoot		

Sitting

Anatomical region	Peak amplitude(millivolts)	Peak times(milliseconds)
Hallux		
Heel		
Medial forefoot		
Middle forefoot		
Lateral forefoot		
Lateral midfoot		

Standing

Anatomical region	Peak amplitude(millivolts)	Peak times(milliseconds)
Hallux		
Heel		
Medial forefoot		

Middle forefoot		
Lateral forefoot		
Lateral midfoot		

ANNEXURE 3 – CONSENT FORM

Format for Informed Consent Form for Subjects

Informed Consent form to participate in a research study

Study Title: Role of multipoint contact photoplethysmography in assessing changes in blood flow in the plantar aspect of the contralateral foot following amputation in patients with type 2 diabetes mellitus.

Study Number: ____________

Subject's Initials: ________________ **Subject's Name:** ____

Date of Birth / Age: __________________________

(Subject)

(i) I confirm that I have read and understood the information sheet dated ___________ for the above study and have had the opportunity to ask questions. [ ]

(ii) I understand that my participation in the study is voluntary and that I am free to withdraw at any time, without giving any reason, without my medical care or legal rights being affected. [ ]

(iii) I understand that ***the Sponsor of the clinical trial***, the Ethics Committee and the regulatory authorities will not need my permission to look at my health records both in respect of the current study and any further research that may be conducted in relation to it, even if I withdraw from the trial. I agree to this access. However, I understand that my identity will not be revealed in any information released to third parties or published. [ ]

(iv) I agree not to restrict the use of any data or results that arise from this study provided such a use is only for scientific purpose(s). [ ]

(v) I agree to take part in the above study. [ ]

Signature (or Thumb impression) of the Subject/Legally Acceptable

Date: _____/_____/______

Signatory's Name: ________________________________ Signature:

Or

Representative: ________________

Date: _____/_____/______

Signatory's Name: ________________________________

Signature of the Investigator: ______________________

Date: _____/_____/______

Study Investigator's Name: ________________________

Signature or thumb impression of the Witness: __________________________

Date: _____/_____/______

Name & Address of the Witness: ____________________________

____

ANNEXURE 4 – INFORMATION SHEET

TITLE OF STUDY

Role of multipoint contact photoplethysmography in assessing changes in blood flow in the plantar aspect of the contralateral foot following amputation in patients with type 2 diabetes mellitus.

PATIENT INFORMATION SHEET

You are being asked to enroll in a study that aims to measure changes in blood flow over the foot using the technology of "photoplethysmography". Please take time to read/listen to the following information. The study personnel will be available to answer any questions/clarifications that you may have in this regard.

Description of the study

The study aims to use the technology of "photoplethysmography" which is a simple, non-invasive device that uses light waves to measure changes in blood flow over a particular area of the body. This will be used in the form of small sensors placed over the sole of the foot which will measure the blood flow and display the information on a computer. The sensors will be placed in the following locations- the big toe, heel and four other points over the sole of the foot. The entire process will take only about ten minutes. You will also undergo measurement of your toe pressures. Measurement of toe pressures is a painless, non-invasive investigation which involves placement of a sensor and a small blood pressure cuff on the big toe for about two minutes. A photograph of the foot will also be taken using a smart phone.

For diabetics who have undergone amputation and are to be enrolled in the study, a blood test called HbA1c will be done which indicates the blood sugar control over the past three months.

For normal individuals who will form part of the control group, a random blood sugar level will be checked and if found to be less than 200mg/dl in the absence of symptoms of increased thirst, increased appetite and increased urination, then they will be included in the study as the control population.

Advantages or expected benefits of being enrolled in the study

There are no immediate benefits to being a part of this study. There will be no change in the treatment provided. There are no monetary benefits provided. The results of this study will be useful for future patients in identifying areas of the foot that show early harmful changes due to diabetes.

Foreseeable risks or inconveniences

You might experience some discomfort or pain while blood is withdrawn for checking blood glucose levels and HbA1c levels. You will not be asked to pay for any of the tests or procedures during the course of the study.

Study participation and withdrawal

Refusal to participate in the study or withdrawal from the study will not lead to any penalty, compromise of your medical care or loss of benefits.

Confidentiality of the data collected

The data collected shall remain strictly confidential. Only the study personnel will be able to match your identity to the collected data. If the results of the study are published, you will not be named in any of the publication or presentation of results.

In addition to the information provided above, if you have any further questions or clarifications, kindly contact principal investigator.

ANNEXURE 5- DATA SET

slno	cc	idno	hospno	name	age	gender	address	phno
1	1	2	567039G	V.SUDHAKAR	42	1	EGUVACHENTHAPALLI,TIRUPATHI,517561	9652709440
2	2	1	830337G	DR.G.P.REDDY	41	1	3/547,ARAVINDA NAGAR,KADAPPA,AP.	9703413302
3	1	4	726364	PAUL PADMANABHAN	45	1	NAINIAPPAN STREET,KAGITHAPATTARAI,VELLORE.	9566541304
4	2	3	594669G	ARUMUGAM S	43	1	21/15,METTU ST,SORAKALPET,KATPADI VELLORE	9585450928
5	1	6	589153G	ASOKAN	46	1	462,KOIL ST,CHINNA KOMESWARAM,AMBUR,VELLORE.	9843590841
6	2	5	168549H	VIJAYARANGAN	46	1	3,MUNISAMY ST,TOWN ARCOT VELLORE.	8524860501
7	1	8	936314G	BALAJI	50	1	4/3,ARUNDATHI MEL ST,SAMARIKSHI KUPPAM,GUDIYATTAM,	9629747924
8	2	7	450545B	RAMU	48	1	5,5TH CROSS ST,BHARATHI NAGAR EXTN.THARAPADAVEDU.	9952388602
9	1	10	359510B	ANANDARAJ	50	1	100,SRINIVASA NAGAR BYPASS ROAD,VELLORE.	9952126099
10	2	9	236154H	M.S VISVANATHAN	48	1	SEELANAIKENPATTI,5/258 ALAGUNAGAR,SALEM,TN,636201.	9003762629
11	1	12	935194G	ELUMALAI	58	1	SAIDAPET,VELLORE	8675672678
12	2	11	388789D	SWAPAN DAS	58	1	TUFANGANJ,LANGALGRAM,COOCH BEHA,WB.	9474431380
13	1	14	990277G	DILIPKUMAR GHOSH	52	1	POOGABAGAN,BHAGABANDH,BANKURA,WB,722146	9593817199
14	2	13	221369H	JEBASELVAN	54	1	4/20,5TH CROSS ST. SAMAYAPURAM,PORUR,CHENNAI.	9841795512
15	1	16	815356F	MD.PHIROJKHAN	46	1	102,RAJABAN,P.O.P.S,RANIGANJ,BARDHWAN,WB.	7319392964
16	2	15	915760B	RAJA	46	1	1/4,EB NAGAR,PHASE 3,SATHUVACHARI,VELLORE	
17	1	18	046215H	GAUTAM NAG	53	1	KATIGORAH,LACHAR,ASSAM	9954159630
18	2	17	306321F	SHAHNUR	52	1	9,SOUTH CENTRAL RD,KHULNA,BANGLADESH	9748409045
19	1	20	482692G	SRINIVASAN	55	1	144,PILLAIYAR KOIL ST.PONAMPET,WALLAJAH.	9843245461
20	2	19	307640H	SUDHARSHAN	57	1	413/A GANDHI MAIN ROAD,SADUPERI,VELLORE	9786939408
21	1	22	975732G	CHANDAN MAITI	63	1	20/32,BAGMUNDI,PURULIA,WB.	9332179255
22	2	21	546949F	SESHAGIRI RAO B.	64	1	12-21-24/3,ST.ANNS HOSTEL GATE,NARASARAO PETGUNTUR	8333947371
23	1	24	938501G	ARUMUGAM	56	1	155/A VANNIYAR ST,RAGHUNADHAPURAM,VIL,T.V.MALAI	9865599849
24	2	23	365898G	SOLAPURI	58	1	214,MURUGAR KOIL ST,FILTER BED MEDU ,OT,VELLORE	8190864559
25	1	26	829623D	SEKAR G	56	1	44/23,NATTARAMPALLI,TIRUPATTUR.	9944020697
26	2	25	197627H	PRABIR KUMAR	58	1	SAYAM APT,FLAT F-2 36,BIDHAN PARK BARGANAS WB.	8335080346
27	1	28	304157h	sagadevan k.	55	1	43,MALAPPA MANDIR ST,THUTHIPET,ADUKAMPARAI,VELLORE	8870360474
28	2	27	108346H	REGI	57	1	KERETH GARDEN,KUMULI,IDUKKI,KERALA.	9447065719
29	1	30	576632A	NIRANJAN DAS	57	1	HARAKUMAR,KANTAL BERIA WB,741126	8348648849
30	2	29	579925G	MANI	58	1	GOVINDASAMY,KONNERIKUPPAM ST,KONNERI,VELLORE	9597445726
31	1	32	144799H	MD.TAHIR MIRZA	57	1	11,HARUN BARI 1ST LANE,CHITTARANJAN AVENUE KOLKATT	8420957389
32	2	31	363154F	SEKAR P.	58	1	60,KALIKAPURAM,EDAYANSANTHU,VELLORE	9952390433
33	1	34	685656C	MAHESHWARAN	55	1	4/115,PILLAIYAR KOIL ST,VANDRANTHANGAL,VELLORE.	9843348488
34	2	33	241751H	MD.SHAMSUL HAQ FAKIR	57	1	WEST MOHD BAGH-962,MERAJ NAGAR,BANGLADESH	9007060219
35	1	36	383613D	THAMBIDURAI	58	1	31,ANNA ST,KALINJUR,KATPADI,VELLORE.	9894940542
36	2	35	664666G	ABDUL RAHMAN	60	1	CHARAK PATHAR,KALYANPUR,DHANBAD,JHARKAND.826004	7654676005
37	1	38	406713D	PARIMAL SARKAR	59	1	LANKAMURA POST OFFICE,TRIPURA AGARTALA	8794057407
38	2	37	235802H	FEKADU	61	1	ADDIS ABABA,HOUSE-148,ETHIOPIA	6385583185
39	1	40	585387G	VEERAMANI	61	1	162,DR.AMBEDKAR NAGAR,BANGALORE ROAD,VELLORE FORT.	9994516055
40	2	39	305449H	MANIKAM	60	1	1/120 mallgunda,vaniyambadi,vellore.	9688142738
41	1	42	149525H	CHITTARANJAN	63	1	PO,BANKADAHA,BANKURA,WB.	7908696484
42	2	41	163889H	NARASIMHA	62	1	H.NO.15-56,SREERAMULU ST,MADANAPALLI,CHITOOR,AP.	9177117354

43	1	44	996296G	DEVDASS C	65	1	VENKATASAMUDRAM,VELLORE	9597618644
44	2	43	195137H	SADASIVAM	63	1	PARIYA KOLAPADI,CHENGAM,TIRUVANNAMALAI.600704	9943368567
45	1	46	589577G	VIJAYAKUMAR	65	1	53,DHANALAXMI NAGAR,PUDHUR PUDUMANAI,GUDIYATTAM,	9080593120
46	2	45	228889H	BIRENDRA	63	1	MAUJA FATEHPUR,J.L.NO.131,MURSHIDABAD,WB,742132	9264591587
47	1	48	939454G	VELLIYAN	65	1	KOVAMPATTU VILLAGE,13/NA,T.V.MALAI,632102	9159482368
48	2	47	161147H	M.P.VERMA	63	1	SOUTH BANKATI,336 B,GOPALGANJ,BIHAR,841409	8235048835
49	1	50	948878F	P.VIJAYAKUMAR	52	1	ALAMARAM ST,SEDUVALAI,VIRINCHIPUKAM,VELLORE.	9500219703
50	2	49	934275G	THANGAVEL	50	1	PAZHAIYURMARVADI,DHARMAPURI	9942079925
51	1	52	591321G	MAHADEVAN	67	1	1/34,THERKU ST, PULIYANTCON,WALAJAPET.	9487333329
52	2	51	597472G	SUBASH CHANDRAN	66	1	SEETHARAMAN ST,THIPPASAMUDRAM,ANAICUT VELLORE.	782596688
53	1	54	583380G	NATARAJAN	70	1	307/A MANTHOPPU,2ND ST,KAMALAKSHIPURAM,OTTERI,VELL	9629540520
54	2	53	828438F	SYED GOLAM	72	1	SYED MANSION,SOUTH BHATIARY,BANGLADESH	7397604639
55	1	2	835184G	BHAGYALAKSHMI	34	2	2-41,MR PALKI VILLAGE.	9989093455
56	2	55	385635G	SANGEETHA	32	2	32/A,RAMCHETTY ST,VENGALAPURAM,TIRUPATTUR,VELLORE.	992538534
57	1	58	008453H	ROPASHY	42	2	CHOTTAGRAM,NAG COLONY,CHITTAGONG,BANDAR.	9378196119
58	2	57	995368G	BHARTI BISWAS	41	2	HANSKHALI ROAD,BETALA PARA,NADIA,WB,74121.	8158800578
59	1	60	937257G	SARASWATHI R.	45	2	A3/14,NORTH POLICE QUARTERS,BANGALORE ROAD,VELLORE	8015638954
60	2	59	096389G	RINKU SAHA	45	2	DUM DUM,GHUGU DANGA,24,PARGANAS,KOLKATA	9836477714
61	1	62	937771G	RANI	45	2	1ST STREET,VASANTHA NAGAR,KONAVATTAM.	9360215795
62	2	61	091453H	PUSHPA PRADHAN	44	2	ECHEY BUSTY,KALIMPONG,DARJEELING	9933025518
63	1	64	591883G	SANTANAHORE	48	2	ASHOKNAGAR NORTH,24,PARGANAS,WB.	9232575618
64	2	63	388780D	ANIMA DAS	46	2	TUFFANGAN,LANGALRAM,COOCH BEHAR WB.	9474431380
65	1	66	183025H	POONGOTHU	53	2	161,VELAPADI ST,KARUNKALIKUPPAM,PUTHUR POST.	7094182494
66	2	65	112255H	REENA BORAH	54	2	KALIMPONG,10,MICE TUNY BOTAY,DARJEELING.	9732774085
67	1	68	926686G	MST LAILY BEGUM	49	2	110,CHOTOBONGRAM,POLLOBI ABASIK SOPURA,RAJASTHAN	
68	2	67	041928F	SAROJ	50	2	8,KEDAR DUTTA LANE BANKURA KOLKATTA	8489037909
69	1	70	594697G	YASHODAMA	60	2	18-1-519,BAVANI NAGAR,TIRUPATI.	9493430197
70	2	69	351186H	CHANDRABAI R.	60	2	KARLAMPAKKAM VILLAGE,THIRUVALLUR	6380533095
71	1	72	936455G	MUTHULAKSHMI	60	2	14/12,GANDHIJI ST.THORAPADI,VELLORE.	9566708751
72	2	71	351266H	RUKAMMAL	62	2	230,MADHAVELI,WALAJAH,TN.	9566347272
73	1	74	596819G	BHAGBATI	69	2	MAMUDPUR,TEGHORI JOTEVIRAM PURBA ,MEDIPUR,WB.	6281921548
74	2	73	802802B	MENAKA	67	2	41,PHASE1,TNHB,SATHUVACHARI,VELLORE.	7708078560
75	1	76	350862H	LILA GORE	53	2	BENAGARIA,BANKURA,WB.	6296939941
76	2	75	051049H	PRATIMA MAITRA	53	2	IOC ROAD,WARD 35,SAHID COLONY,BAKTHI NAGAR,WB.	9564955695
77	1	78	591541G	NAWAB T A	66	1	DALAL GARDEN,REDITHOPE,AMBUR.	8248778704
78	2	77	930614G	SATHYAM CHETTY	64	1	QR.NO.LIG 37Q,BAKUI ROAD,JAMSHEDPUR.	8092148123
79	1	80	826790G	SUCHANDRA GUHA	44	2	MAHAJATI NAGAR,AGARPARA NORTH24,PARGANAS,WB.	8981586387
80	2	79	212787H	AMENA KHATUN	42	2	HOUSE3 MOULOVIPARA,1ST LANE KHULNA,BANGLADESH	
81	1	82	669299C	PREMA	58	2	36,SANJEEVIPURAM,BAGAYAM,VELLORE.	9092495006
82	2	81	874186C	RAMIZA BEE	60	2	46,3RD STREET,KUMARAPPA NAGAR,KATPADI.	9080978098
83	1	84	327109J	VENKATESAN	53	1	PILLAIAR KOIL ST,YADAMARI VILLAGE CHITOOR.	9025548481
84	2	83	303980H	YOGENDRA SINGH	52	1	SONAS VILLAGE,KHIZERSARAI,GAYA NADARA,GAYA,BIHAR/	9939716513
85	1	86	784063D	VENKATESAN K P	64	1	34,NEW STREET,VELLORE.	999426784311
86	2	85	596240G	SUBRAMANI	63	1	261,NAVITHAR STREET,VELIAGRAM,PALLIPATU,THIRUVALLU	9751335869
87	1	88	934108G	VILVANATHAN	73	1	SANDIMATU ST,MALPATI,VELLORE.	9047497771

88	2	87	306242H	SASADHAR	75	1	SIJUMAKHANA VILLAGE,DAPAH PO PURULIA,WB.	9382068305
89	1	90	961657G	MAMUD MULLA	51	1	MAHESDARI SOUTH 24 PARGANAS WB.	8420890267
90	2	89	180313H	POULRAJ	49	1	25-559-73,OLD PRASANTH NAGAR,CHITOOR,AP.	9701720711
91	1	92	932817F	CICILIN	55	2	4/128,WIKRAMASI MEDU,VADUGANTHANGAL,VELLORE.	9055740428
92	2	91	145041G	SUSAMA CHAUDARI	54	2	BANKURA PRATAP BAGAN,BANKURA,WB.	9474019331
93	1	94	475493F	CHINNA PANCHULIYA	57	1	2-1975/4,CHENNA REDDY ST,PILER,CHITOOR.	9959388429
94	2	93	594229G	MUNIYAPPAN	60	1	22,KURINJI NAGAR,SATHUVACHARI	9843690585
95	1	96	187188H	KUPPURAJ G	43	1	215,JJ NAGAR,KUPPAMPATTI ROAD,JALAGANDAPURAM.	9750602908
96	2	95	938865G	MANIKANDAN	42	1	37,RAMAR KUDUYIRUPPU,KALAMBUR THIRUVANNAMALAI.	9677571910
97	1	98	271287H	HRIDYANAND	47	1	GHWATI,KAMRUP,ASSAM	9952288062
98	2	97	377360F	VIJAYAKUMAR	45	1	LADAMA SIDHAPA,MADHUBANI,BIHAR	9674162116
99	1	100	591851G	RAHMAN S	52	1	20-166,RANGA REDDY STREET,CHITOOR.	9133356665
100	2	99	661046D	SARAVANAN	50	1	1A,3RD WEST CROSS ROAD,GANDHINAGAR,VELLORE.	9994086366

slno

1	dm	dmyes	dmtreat	dmtreatyes	symptom	htn	ckd	pvd	ihd	cvd
2	1	3	1	3	4	0	0	0	0	0
3	0		0		4	0	0	0	0	0
4	1	120	1	1	4	1	0	0	1	0
5	0		0		4	0	0	0	0	0
6	1	12	1	1	4	0	0	0	0	0
7	0		0		4	0	0	0	0	0
8	1	1	1	1	4	0	0	0	0	0
9	0		0		4	0	0	0	0	0
10	1	180	1	1	4	0	0	0	0	0
11	0		0		4	0	0	0	0	0
12	1	120	1	1	4	1	0	0	1	0
13	0		0		4	0	0	0	0	0
14	1	84	1	3	4	1	0	0	0	0
15	0		0		4	0	0	0	0	0
16	1	48	1	1	4	0	0	0	0	0
17	0		0		4	0	0	0	0	0
18	1	184	1	3	4	1	0	0	0	0
19	0		0		4	0	0	0	0	0
20	1	156	1	3	4	1	0	0	0	0
21	0		0		4	0	0	0	0	0
22	1	96	1	3	4	1	0	0	0	0
23	0		0		4	0	0	0	0	0
24	1	120	1	3	4	1	0	0	0	0
25	0		0		4	0	0	0	0	0
26	1	36	1	3	4	0	0	0	0	0
27	0		0		4	0	0	0	0	0
28	1	60	1	1	4	0	0	0	0	0
29	0		0		4	1	0	0	0	0

30	1	60	1	1	4	0	0	0	0	0
31	0		0		4	0	0	0	0	0
32	1	180	1	2	4	0	0	0	0	0
33	0		0		4	1	0	0	0	0
34	1	120	1	3	4	1	0	0	0	0
35	0		0		4	1	0	0	0	0
36	1	72	1	3	4	1	0	0	0	0
37	0		0		4	0	0	0	0	0
38	1	360	1	3	4	1	0	0	0	0
39	0		0		4	0	0	0	0	0
40	1	108	1	3	4	0	0	0	0	0
41	0		0		4	0	0	0	0	0
42	1	72	1	1	4	0	1	0	0	0
43	0		0		4	1	0	0	0	0
44	1	84	1	1	4	1	0	0	0	0
45	0		0		4	0	0	0	0	0
46	1	60	1	3	4	0	0	0	0	0
47	0		0		4	0	0	0	0	0
48	1	36	1	1	4	0	0	0	0	0
49	0		0		4	1	0	0	0	0
50	1	120	1	1	4	1	0	0	0	0
51	0		0		4	0	0	0	0	0
52	1	144	1	1	4	0	0	0	0	0
53	0		0		4	0	0	0	0	0
54	1	180	1	1	4	0	0	0	0	0
55	0		0		4	0	0	0	0	0
56	1	6	1	3	4	0	0	0	0	0
57	0		0		4	0	0	0	0	0
58	1	12	1	3	4	1	0	0	0	0
59	0		0		4	0	0	0	0	0
60	1	60	1	2	4	0	0	0	0	0
61	0		0		4	0	0	0	0	0
62	1	2	0		4	0	0	0	0	0
63	0		0		4	0	0	0	0	0
64	1	240	1	1	4	0	0	0	0	0
65	0		0		4	0	0	0	0	0
66	1	84	1	1	4	0	0	0	0	0
67	0		0		4	1	0	0	0	0
68	1	276	1	3	4	1	0	0	0	1
69	0		0		4	1	0	0	0	0
70	1	96	1	3	4	1	0	0	0	0
71	0		0		4	0	0	0	0	0
72	1	180	1	3	4	1	0	0	0	0
73	0		0		4	0	0	0	0	0
74	1	48	1	4	4	0	0	0	0	0

75	0		0		4	0	1	0	0	0
76	1	60	1	2	4	0	0	0	0	0
77	0		0		4	1	0	0	0	0
78	1	180	1	1	4	0	0	0	0	0
79	0		0		4	1	0	0	0	0
80	1	60	1	2	4	1	0	0	0	0
81	0		0		4	0	0	0	0	0
82	1	240	1	3	4	1	0	0	0	0
83	0		0		4	1	0	0	0	0
84	1	84	1	1	4	1	0	0	0	0
85	0		0		4	1	0	0	0	0
86	1	180	1	3	4	1	0	0	0	0
87	0		0		4	0	0	0	0	0
88	1	108	1	1	4	0	0	0	0	0
89	0		0		4	0	0	0	0	0
90	1	60	1	1	4	0	0	0	0	0
91	0		0		4	0	0	0	0	0
92	1	120	1	1	4	0	1	0	0	0
93	0		0		4	0	0	0	1	0
94	1	180	1	1	4	0	0	0	1	0
95	0		0		4	0	0	0	0	0
96	1	120	1	3	4	1	0	0	0	0
97	0		0		4	0	0	0	0	0
98	1	216	1	3	4	1	0	0	0	0
99	0		0		4	0	0	0	0	0
100	1	120	1	3	4	0	0	0	0	0
	0		0		4	0	0	0	0	0

slno	height	weight	bmi	sysbp	diasbp	side	toepress	hbalc	Rbgl
1	170	62	21.45	110	70	2	60	6.4	
2	189	100	27.99	120	80	2	176		120
3	165	70	25.71	130	50	2	80	11.6	
4	168	55	19.49	130	70	2	0		111
5	167	72	25.82	110	70	2	50	7.1	
6	154	75	31.62	130	70	2	110		124
7	166	68	24.68	130	60	2	154	6.6	
8	158	74	14.1	120	80	2	50		90
9	178	70	22.09	140	80	2	60	12.9	
10	168	70	24.8	140	80	2	166		109
11	172	69	23.32	110	70	2	80	11.6	
12	171	70	23.94	110	80	2	80		114
13	169	60	21.01	130	80	2	140	11.1	

14	166	70	25.4	110	70	2	110		181
15	172	74	25.01	140	80	1	160	11.7	
16	169	65	22.76	120	80	1	120		87
17	164	62	23.05	120	70	1	140	7	
18	170	76	26.3	130	90	1	180		122
19	171	85	29.07	110	70	1	70	8	
20	163	53	19.95	138	82	1	120		128
21	169	70	24.51	110	70	2	160	10.7	
22	164	82	30.49	120	80	2	90		119
23	169	70	24.51	110	70	2	80	9.9	
24	166	68	24.68	110	80	2	20		129
25	169	72	25.21	110	70	2	60	7	
26	171	69	23.6	110	80	2	150		122
27	170	71	24.57	120	70	2	60	6.5	
28	174	96	31.71	140	85	2	170		82
29	171	72	24.62	110	70	2	20	9.2	
30	155	56	23.31	120	70	2	30		105
31	172	86	29.07	110	70	1	70	8.3	
32	170	85	29.41	136	86	1	130		98
33	173	90	30.07	120	70	1	90	8.1	
34	167	68	24.38	120	70	1	90		113
35	171	70	23.94	110	70	2	140	8.7	
36	165	60	22.04	130	80	2	150		111
37	172	64	21.63	120	64	2	80	10.7	
38	170	68	23.53	110	70	2	50		116
39	172	69	23.32	110	70	1	110	8.5	
40	152	43	18.61	110	60	1	90		114
41	172	69	23.32	110	70	1	40	8.1	
42	185	90	26.3	120	85	1	120		92
43	172	69	23.32	110	60	2	70	7.4	
44	169	70	24.51	120	70	2	100		112
45	171	70	23.94	110	80	1	50	10.5	
46	168	69	24.45	120	70	1	70		115
47	170	71	24.57	110	70	1	120	4	
48	165	68	24.98	140	80	1	80		173
49	171	70	23.94	130	80	2	70	11.1	
50	165	68	24.98	110	80	2	80		121
51	163	76	28.6	120	70	2	60	8.9	
52	162	60	22.86	120	70	2	70		142
53	163	60	22.58	110	70	2	130	13	
54	160	69	26.95	130	70	2	40		112
55	159	61	24.13	110	70	2	150	11.6	
56	170	76	26.3	110	60	2	80		85
57	161	62	23.92	110	70	1	200	7.4	
58	169	69	24.16	110	80	1	120		100

59	160	62	24.22	80	40	1	90	8	
60	149	101	45.49	110	70	1	90		134
61	159	61	24.13	120	70	2	160	7.6	
62	148	68	31.04	110	70	2	100		87
63	163	69	25.97	110	60	2	60	12.1	
64	161	66	25.46	110	70	2	60		110
65	161	45	17.36	110	70	1	140	9.3	
66	142	48	23.8	120	80	1	110		96
67	162	63	24.01	150	80	1	100	7.3	
68	148	50	22.83	120	80	1	130		116
69	159	61	24.13	130	80	2	90	11.9	
70	152	54	23.37	110	70	2	40		121
71	150	50	22.22	140	90	1	80	8.1	
72	151	45	19.74	110	70	1	80		132
73	150	48	21.33	110	60	1	120	6.5	
74	150	44	19.56	130	80	1	120		92
75	151	52	22.81	120	60	1	200	9.2	
76	135	37	14.07	140	70	1	90		98
77	170	72	24.91	130	80	1	70	10.9	
78	170	64	22.15	130	70	1	130		116
79	171	73	24.96	130	80	1	210	6.7	
80	172	71	24	110	70	1	100		129
81	159	58	22.94	130	80	1	110	9.3	
82	157	80	32.46	130	70	1	90		126
83	176	68	21.95	120	80	1	100	9.2	
84	173	61	20.38	120	80	1	80		110
85	164	75	27.89	130	80	2	70	13.5	
86	163	49	18.44	110	70	2	60		102
87	169	68	23.81	110	70	2	40	6	
88	168	50	17.72	110	80	2	90		121
89	171	68	23.26	110	70	1	120	6.6	
90	172	69	23.32	120	80	1	60		121
91	153	52	22.21	130	80	2	130	8.9	
92	148	47	21.46	130	80	2	44		129
93	169	60	21.01	130	80	1	90	10.2	
94	168	61	21.61	110	70	1	140		122
95	172	68	22.99	140	80	1	140	14	
96	162	37	14.1	110	70	1	50		102
97	157	61	24.75	130	80	1	80	9	
98	170	100	34.6	110	80	1	80		160
99	170	75	25.95	110	70	2	70	9.9	
100	171	70	23.94	120	80	2	220		123

slno									
1	whichfoot	halluxpa	halluxsda	halluxpt	halluxsdt	medialpa	medialsda	medialpt	medialsdt

2	2	1.43	0.092	0.234	0.01	0.546	0.075	0.246	0.027
3	2	0.684	0.042	0.206	0.002	0.13	0.007	0.209	0.033
4	2	0.981	0.071	0.205	0.003	0.373	0.055	0.205	0.007
5	2	0.209	0.014	0.237	0.016	0.034	0.003	0.253	0.44
6	2	0.002	3.643	0.226	0.079	0.091	0.003	0.216	0.006
7	2	1.338	0.044	0.233	0.017	0.122	0.013	0.225	0.057
8	2	0.929	0.025	0.211	0.003	0.344	0.008	0.199	0.003
9	2	0.657	0.036	0.192	0.008	0.067	0.003	0.187	0.021
10	2	0.282	0.003	0.222	0.005	0.014	0	0.253	0.072
11	2	0.073	0.044	0.217	0.003	0.065	0.009	0.22	0.032
12	2	1.722	0.049	0.225	0.002	0.677	0.033	0.234	0.002
13	2	1.713	0.124	0.226	0.008	0.198	0.028	0.205	0.024
14	2	0.517	0.016	0.241	0.003	0.568	0.017	0.241	0.003
15	2	0.012	0.001	0.236	0.047	0.014	0.002	0.227	0.042
16	1	0.902	0.024	0.195	0.001	0.081	0.005	0.199	0.008
17	1	0.121	0.026	0.234	0.033	0.059	0.004	0.225	0.005
18	1	1.078	0.025	0.18	0.003	0.107	0.007	0.196	0.02
19	1	1.355	0.051	0.2	0.005	0.035	0.004	0.196	0.075
20	1	0.593	0.047	0.183	0.003	0.317	0.03	0.204	0.004
21	1	0.406	0.017	0.216	0.004	0.163	0.017	0.218	0.005
22	2	0.633	0.097	0.286	0.02	0.195	0.039	0.303	0.02
23	2	0.707	0.203	0.21	0.001	0.075	0.003	0.221	0.004
24	2	0.044	0.011	0.172	0.033	0.049	0.007	0.164	0.01
25	2	0.326	0.011	0.198	0.003	0.041	0.002	0.194	0.011
26	2	0.23	0.012	0.208	0.011	0.267	0.015	0.209	0.006
27	2	0.074	0.021	0.216	0.016	0.023	0.007	0.236	0.018
28	2	1.212	0.031	0.212	0.002	0.15	0.003	0.22	0.005
29	2	0.139	0.003	0.264	0.093	0.138	0.003	0.181	0.039
30	2	0.34	0.017	0.246	0.005	0.129	0.014	0.249	0.009
31	2	0.404	0.045	0.257	0.008	0.097	0.007	0.241	0.011
32	1	0.296	0.015	0.243	0.01	0.014	0	0.192	0.073
33	1	0.502	0.025	0.186	0.005	0.213	0.009	0.186	0.006
34	1	0	0	0.257	0.077	0.334	0.016	0.265	0.006
35	1	0.48	0.043	0.258	0.006	0.093	0.012	0.268	0.014
36	2	0.217	0.013	0.191	0.012	0.131	0.01	0.192	0.014
37	2	0.58	0.01	0.242	0.039	0.058	0.003	0.249	0.046
38	2	0.058	0.011	0.28	0.058	0.136	0.017	0.3	0.008
39	2	0.094	0.014	0.243	0.01	0.027	0.008	0.264	0.038
40	1	0.65	0.036	0.195	0.003	0.179	0.013	0.189	0.004
41	1	0.044	0.005	0.266	0.023	0.008	0.001	0.272	0.025
42	1	0.606	0.021	0.211	0.004	0.015	0	0.248	0.098
43	1	0.145	0.002	0.206	0.027	0.086	0.006	0.209	0.004
44	2	0.408	0.009	0.248	0.004	0.035	0.006	0.234	0.004
45	2	1.644	0.222	0.255	0.032	0.162	0.037	0.273	0.04
46	1	0.231	0.012	0.198	0.008	0.043	0.004	0.211	0.007

47	1	0.012	0.007	0.181	0.077	0.001	0.001	0.173	0.069
48	1	0.233	0.02	0.237	0.005	0.119	0.013	0.25	0.007
49	1	0.132	0.015	0.251	0.062	0.048	0.017	0.214	0.022
50	2	1.515	0.049	0.221	0.004	0.405	0.024	0.216	0.006
51	2	0.001	0	0.18	0.115	0.025	0.009	0.198	0.091
52	2	0.581	0.01	0.21	0.005	0.121	0.006	0.202	0.005
53	2	0.281	0.008	0.276	0.038	0.014	0	0.264	0.064
54	2	0.456	0.018	0.217	0.003	0.145	0.006	0.217	0.004
55	2	0.234	0.025	0.219	0.005	0.026	0.003	0.209	0.013
56	2	1.979	0.112	0.208	0.006	0.611	0.227	0.26	0.08
57	2	0.103	0.018	0.221	0.009	0.017	0.005	0.242	0.043
58	1	0.7	0.028	0.391	0.004	0.159	0.034	0.383	0.006
59	1	0.543	0.007	0.174	0.006	0.191	0.005	0.207	0.003
60	1	0.172	0.006	0.275	0.014	0.096	0.003	0.287	0.05
61	1	0.276	0.009	0.217	0.015	0	0	0.278	0.079
62	2	0.968	0.021	0.203	0.002	0.218	0.004	0.206	0.002
63	2	0.131	0.02	0.207	0.049	0.107	0.008	0.187	0.009
64	2	0.239	0.019	0.209	0.004	0.066	0.007	0.198	0.012
65	2	0.571	0.101	0.212	0.004	0.062	0.016	0.23	0.056
66	1	0.014	0.001	0.23	0.018	0.059	0.002	0.247	0.011
67	1	1.366	0.033	0.214	0.017	0.141	0.005	0.242	0.088
68	1	0	0	0.3	0.069	0	3.035	0.143	0.073
69	1	1.742	0.059	0.232	0.005	0.122	0.001	0.251	0.028
70	2	0.197	0.004	0.195	0.003	0.135	0.002	0.203	0.003
71	2	0.997	0.047	0.225	0.003	0.145	0.002	0.225	0.006
72	1	1.221	0.012	0.192	0.002	0.161	0.003	0.196	0.003
73	1	0.262	0.013	0.197	0.003	0.022	0.002	0.202	0.019
74	1	0.287	0.011	0.233	0.034	0.014	0.001	0.231	0.026
75	1	0.143	0.004	0.265	0.047	0.094	0.011	0.254	0.014
76	1	1.181	0.033	0.207	0.001	0.148	0.001	0.222	0.004
77	1	0.231	0.063	0.214	0.011	0.146	0.002	0.254	0.094
78	1	0.074	0.008	0.235	0.131	0.017	0.002	0.237	0.035
79	1	0.135	0.006	0.2	0.01	0.009	0.001	0.206	0.006
80	1	1.536	0.056	0.215	0.003	0.161	0.013	0.212	0.014
81	1	0.633	0.043	0.227	0.01	0.006	0.001	0.222	0.017
82	1	0.298	0.002	0.262	0.025	0.015	0.002	0.254	0.027
83	1	1.339	0.037	0.232	0.008	0.247	0.024	0.231	0.006
84	1	0.178	0.068	0.223	0.007	0.236	0.402	0.223	0.01
85	1	0.973	0.048	0.335	0.106	0.064	0.011	0.237	0.077
86	2	0.28	0.005	0.248	0.004	0.014	0	0.268	0.057
87	2	0.357	0.037	0.25	0.006	0.024	0.003	0.262	0.038
88	2	0.448	0.194	0.22	0.06	0.876	0.408	0.191	0.018
89	2	0.07	0.022	0.25	0.062	0.034	0.003	0.338	0.01
90	1	1.315	0.03	0.212	0.008	1.074	0.028	0.214	0.007
91	1	0.621	0.019	0.198	0.007	0.116	0.024	0.208	0.025

92	2	0.272	0.003	0.22	0.003	0.014	0	0.222	0.006
93	2	0.553	0.039	0.189	0.076	0.311	0.03	0.195	0.009
94	1	0.386	0.118	0.204	0.018	0.031	0.012	0.206	0.024
95	1	1.373	0.083	0.223	0.004	0.389	0.017	0.224	0.005
96	1	0.132	0.002	0.241	0.004	0.049	0.003	0.243	0.012
97	1	0.227	0.047	0.253	0.052	0.034	0.003	0.255	0.045
98	1	0	0.137	0.011	0.228	0	0.065	0.007	0.224
99	1	0.137	0.001	0.261	0.017	0.135	0.004	0.259	0.012
100	2	0.461	0.017	0.226	0.003	0.065	0.004	0.229	0.009
	2	7.458	2.192	0.311	0.093	0.367	0.007	0.209	0.027

slno

1	middlept	middlesdt	laterffpa	laterffsda	laterffpt	laterffsdt	latermfpa	latermfsda	latermfpt		heelpa
2	0.257	0.067	0.144	0.027	0.217	0.024	0.258	0.066	0.256		0.123
3	0.206	0.047	0.011	0.002	0.258	0.066	0.434	0.03	0.227		0.063
4	0.208	0.032	0.138	0.012	0.208	0.006	0.242	0.076	0.21		0.121
5	0.253	0.076	0.023	0.001	0.19	0.075	0.008	0.002	0.271		0.002
6	0.213	0.016	0.055	0.001	0.216	0.009	0.039	0.002	0.216		0.053
7	0.198	0.051	0	7.237	0.21	0.089	0	4.929	0.222		0.033
8	0.203	0.007	0.06	0.002	0.202	0.009	0.208	0.006	0.198		0.732
9	0.239	0.085	0.036	0.003	0.209	0.519	0.3	0.042	0.195		0.04
10	0.217	0.062	0.088	0.006	0.21	0.01	0.059	0.003	0.221		0.127
11	0.264	0.074	0.027	0.013	0.236	0.035	0.305	0.061	0.237		0.636
12	0.232	0.005	0.335	0.012	0.23	0.003	0.208	0.031	0.236		0.218
13	0.203	0.055	0.012	0.002	0.213	0.06	0.741	0.052	0.212		0.009
14	0.242	0.004	0.109	0.004	0.245	0.006	0.165	0.003	0.231		0.042
15	0.238	0.055	0.003	0.001	0.244	0.059	0.037	0.006	0.23		0.054
16	0.193	0.014	0.101	0.005	0.197	0.006	0.048	0.004	0.191		0.07
17	0.229	0.01	0.037	0.003	0.235	0.007	0.145	0.031	0.234		0.067
18	0.195	0.015	0.046	0.005	0.195	0.023	0.208	0.011	0.179		0.001
19	0.2	0.021	0.008	0.001	0.203	0.02	0.068	0.015	0.196		0.349
20	0.196	0.009	0.192	0.016	0.191	0.01	0.493	0.038	0.187		0.073
21	0.228	0.086	0.028	0	0.197	0.027	0.171	0.011	0.222		0.006
22	0.297	0.036	0.079	0.012	0.3	0.025	0.102	0.02	0.3		0.242
23	0.205	0.13	0.005	0.001	0.232	0.03	0.133	0.009	0.215		0.084
24	0.214	0.047	0.082	0.004	0.163	0.007	0.018	0.008	0.217		0.008
25	0.228	0.066	0.005	0.001	0.198	0.014	0.016	0.003	0.193		0.016
26	0.219	0.006	0.224	0.015	0.209	0.007	0.116	0.016	0.212		0.019
27	0.243	0.054	0.08	0.019	0.238	0.048	0.079	0.038	0.248		0
28	0.224	0.048	0.058	0.001	0.239	0.067	0.066	0.003	0.232		0.08
29	0.226	0.008	0.091	0.005	0.233	0.006	0.394	0.013	0.229		0.23
30	0.244	0.017	0.03	0.003	0.261	0.049	0.055	0.007	0.253		0.05
31	0.227	0.007	0.078	0.003	0.227	0.007	0.084	0.006	0.227		0.027
32	0.276	0.049	0.038	0.01	0.257	0.056	0.037	0.012	0.261		0.004
33	0.227	0.051	0.178	0.013	0.227	0.056	0.209	0.024	0.191		0.102

34	0.173	0.091	0	4.834	0.207	0.096	0.185	0.018	0.27		0.269
35	0.259	0.052	0.041	0.004	0.269	0.037	0.101	0.011	0.268		0.056
36	0.231	0.069	0.039	0.004	0.187	0.026	0.076	0.056	0.188		0.024
37	0.226	0.018	0.129	0.01	0.234	0.024	0.5	0.029	0.217		0.027
38	0.292	0.01	0.131	0.004	0.258	0.014	0.089	0.015	0.295		0.12
39	0.247	0.068	0.014	0.034	0.283	0.064	0.121	0.034	0.257		0.029
40	0.192	0.004	0.107	0.006	0.192	0.004	0.218	0.008	0.191		0.074
41	0.226	0.1	0.001	0	0.302	0.075	0.005	0.001	0.28		0.002
42	0.202	0.009	0.135	0.011	0.221	0.018	0.253	0.017	0.213		0.013
43	0.224	0.03	0.028	0.004	0.199	0.018	0.275	0.024	0.211		0.216
44	0.215	0.007	0.08	0.002	0.223	0.023	0.106	0.007	0.237		0.074
45	0.281	0.073	0.021	0.004	0.278	0.067	0.029	0.006	0.309		0.031
46	0.205	0.008	0.161	0.01	0.197	0.003	0.135	0.012	0.201		0.017
47	0.216	0.038	0.029	0.001	0.153	0.064	0.018	0.005	0.214		0.001
48	0.237	0.019	0.051	0.004	0.228	0.021	0.091	0.009	0.239		0.064
49	0.236	0.043	0.024	0.006	0.245	0.048	0.071	0.014	0.239		0.001
50	0.23	0.072	0	0	0	0	0.133	0.039	0.269		0.125
51	0.214	0.088	0.007	0.002	0.279	0.129	0.006	0.002	0.167		0.005
52	0.197	0.01	0.063	0.006	0.2	0.008	0.047	0.007	0.192		0.152
53	0.238	0.005	0.1	0.003	0.241	0.009	0.269	0.02	0.266		0.007
54	0.224	0.006	0.155	0.011	0.223	0.005	0.142	0.01	0.228		0.027
55	0.254	0.077	0.002	0.001	0.211	0.039	0.214	0.021	0.209		0.097
56	0.315	0.08	0.328	0.051	0.218	0.035	0.588	0.138	0.244		0.177
57	0.228	0.019	0.026	0.005	0.221	0.014	0.161	0.018	0.225		0.025
58	0.39	0.004	0.029	0.003	0.394	0.006	0.334	0.037	0.383		0.052
59	0.202	0.011	0.224	0.005	0.197	0.004	0.244	0.006	0.217		0.038
60	0.287	0.026	0.057	0.003	0.278	0.019	0.047	0.004	0.272		0.044
61	0.226	0.03	0.013	0.002	0.218	0.028	0.052	0.007	0.23		0.004
62	0.21	0.004	0.183	0.004	0.212	0.004	0.056	0.005	0.204		0.026
63	0.188	0.024	0.031	0.008	0.205	0.044	0.126	0.037	0.194		0.058
64	0.198	0.023	0.077	0.009	0.196	0.013	0.332	0.015	0.201		0.039
65	0.221	0.06	0.025	0.006	0.226	0.058	0.053	0.02	0.211		
66	0.252	0.023	0.059	0.004	0.245	0.01	0.057	0.008	0.262		
67	0.163	0.012	0.055	0.003	0.234	0.063	0.127	0.01	0.241		
68	0.26	0.081	8.299	3.27	0.229	0.105	0	1.669	0.136		
69	0.239	0.026	0.005	0	0.256	0.035	0.293	0.049	0.241		
70	0.225	0.009	0.124	0.002	0.199	0.003	0.118	0.004	0.199		
71	0.224	0.041	0.058	0	0.208	0.026	0.291	0.011	2.201		
72	0.197	0.005	0.138	0.002	0.202	0.002	0.289	0.002	0.215		
73	0.219	0.069	0.003	0.001	0.245	0.084	0.015	0.003	0.219		
74	0.211	0.007	0.144	0.008	0.266	0.081	0.28	0.008	0.222		
75	0.238	0.016	0.091	0.009	0.255	0.01	0.335	0.044	0.246		
76	0.216	0.007	0.054	0.002	0.218	0.004	0.061	0.003	0.216		
77	0.225	0.005	0.058	0	0.233	0.107	0.146	0.003	0.214		
78	0.234	0.044	0.008	0.001	0.233	0.087	0.034	0.005	0.233		

79	0.196	0.016	0.049	0.005	0.202	0.016	0.126	0.005	0.2		
80	0.21	0.024	0.117	0.011	0.206	0.014	0.124	0.019	0.21		
81	0.215	0.03	0.014	0.001	0.223	0.016	0.174	0.023	0.225		
82	0.202	0.004	0.149	0.001	0.257	0.021	0.285	0.011	0.229		
83	0.23	0.041	0.016	0.002	0.23	0.012	0.205	0.03	0.243		
84	0.214	0.329	0.056	0.012	0.205	0.006	0.088	0.011	0.232		
85	0.225	0.06	0.031	0.008	0.222	0.05	0.046	0.012	0.235		
86	0.276	0.009	0.143	0.003	0.254	0.014	0.136	0.007	0.245		
87	0.243	0.047	0.013	0.003	0.241	0.057	0.008	0.003	0.263		
88	0.221	0.057	0.117	0.045	0.216	0.041	0.245	0.103	0.22		
89	0.284	0.067	0.033	0	0.368	0	0.029	0.015	0.331		
90	0.221	0.037	0.443	0.017	0.219	0.01	0.478	0.019	0.217		
91	0.22	0.071	0.001	0	0.178	0.094	0.004	0.001	0.226		
92	0.224	0.007	0.028	0.003	0.21	0.012	0.095	0.015	0.22		
93	0.197	0.007	0.197	0.032	0.2	0.011	0.515	0.054	0.205		
94	0.202	0.012	0.477	0.144	0.207	0.021	0.109	0.045	0.196		
95	0.225	0.009	0.334	0.013	0.219	0.004	0	4.006	0.198		
96	0.239	0.03	0.034	0.002	0.237	0.021	0.016	0.002	0.238		
97	0.296	0.08	0.015	0.007	0.254	0.086	0.087	0.014	0.218	0.021	0.015
98	0.006	0.211	0	0.118	0.011	0.215	0	0.085	0.01	0.207	0
99	0.23	0.007	0.131	0.005	0.255	0.012	0.417	0.031	0.254	0.008	0.254
100	0.214	0.021	0.018	0.003	0.228	0.028	0.075	0.006	0.227	0.01	0.01
	0.229	0.062	0	5.68	0.189	0.083	0	0	0.222	0.127	0.153

slno

1	heelsda	heelpt	heelsdt	halluxpa1	halluxsda1	halluxpt1	halluxsdt1	medialpa1	medialsda1
2	0.448	0.273	0.062	0.016	0.006	0.271	0.072	0.179	0.079
3	0.004	0.226	0.04	0.467	0.034	0.194	0.009	0.129	0.01
4	0.013	0.216	0.014	0.264	0.044	0.31	0.078	0.069	0.014
5	0.001	0.282	0.098	0.099	0.015	0.251	0.05	0.009	0.003
6	0.004	0.228	0.018	0.006	5.23	0.024	0.105	0.077	0.004
7	0.006	0.263	0.055	0.958	0.041	0.218	0.005	0.095	0.008
8	0.027	0.21	0.027	0.11	0.011	0.274	0.06	0.048	0.006
9	0.008	0.198	0.04	0.031	0.021	0.169	0.006	0.017	0.006
10	0.001	0.232	0.05	0.284	0.023	0.241	0.058	0.144	0.001
11	0.241	0.292	0.07	0.027	0.007	0.212	0.017	0.099	0.013
12	0.012	9.233	0.003	0.594	0.049	0.208	0.002	0.014	0.003
13	0.002	0.209	0.519	1.103	0.105	0.211	0.003	0.3	0.018
14	0.002	0.239	0.025	0.081	0.013	0.237	0.029	0.223	0.004
15	0.009	0.227	0.045	0.069	0.004	0.18	0.004	0.08	0.006
16	0.004	0.199	0.006	0.029	0.012	0.228	0.05	0.062	0.015
17	0.003	0.234	0.013	0.089	0.004	0.208	0.006	0.083	0.006
18	0	0.254	0.067	1.044	0.299	0.171	0.017	0.474	0.032
19	0.048	0.199	0.011	1.157	0.132	0.171	0.003	0.059	0.001
20	0.009	0.206	0.049	0.67	0.225	0.22	0.055	0.722	0.834

21	0.011	0.236	0.073	0.452	0.022	0.195	0.994	0.127	0.013
22	0.024	0.295	0.028	0.529	0.034	0.256	0.018	0.1	0.013
23	0.003	0.209	0.005	0.071	0.008	0.226	0.007	0.024	0.005
24	0.003	0.284	0.074	0.069	0.028	0.258	0.057	0.037	0.031
25	0.003	0.209	0.034	0.327	0.02	0.183	0.033	0.007	0.001
26	0.005	0.231	0.048	0.081	0.009	0.228	0.069	0.129	0.015
27	5.08	0.275	0.1	0.012	0.003	0.259	0.101	0.114	0.028
28	0.002	0.229	0.005	0.594	0.038	0.178	0.003	0.135	0.011
29	0.017	0.225	0.01	0.139	0.003	0.249	0.097	0.082	0.02
30	0.006	0.263	0.028	0.202	0.008	0.202	0.007	0.074	0.01
31	0	0.22	0.01	0.309	0.027	0.251	0.009	0.049	0.006
32	0.001	0.27	0.043	0.234	0.014	0.236	0.008	0.015	0.001
33	0.01	0.204	0.037	0.74	0.026	0.195	0.002	0.2	0.014
34	0.017	0.269	0.056	0	6.366	0.239	0.099	0.117	0.03
35	0.01	0.269	0.044	0.353	0.027	0.234	0.006	0.073	0.01
36	0.006	0.232	0.042	0.344	0.037	0.187	0.009	0.15	0.019
37	0.003	0.259	0.059	0.477	0.022	0.217	0.006	0.045	0.009
38	0.006	0.296	0.005	0.134	0.019	0.27	0.063	0.238	0.014
39	0.011	0.208	0.088	0.139	0.009	0.253	0.061	0.089	0.012
40	0.006	0.2	0.006	0.561	0.035	0.175	0.005	0.128	0.124
41	0	0.23	0.094	0.016	0.003	0.229	0.032	0.005	0.001
42	0.003	0.221	0.047	0.065	0.008	0.188	0.019	0.009	0.003
43	0.013	0.211	0.002	0.147	0.003	0.248	0.072	0.139	0.011
44	0.002	0.254	0.05	0.008	0.004	0.254	0.059	0.005	0.001
45	0.006	0.268	0.054	0.808	0.09	0.297	0.047	0.624	0.108
46	0.005	0.231	0.048	0.082	0.055	0.261	0.06	0.013	0.002
47	0	0.185	0.061	0.019	0.003	0.247	0.028	0.021	0.003
48	0.005	0.249	0.03	0.273	0.02	0.23	0.002	0.118	0.012
49	0	0.28	0.063	0.119	0.011	0.212	0.005	0.048	0.003
50	0.036	0.247	0.077	0.235	0.068	0.281	0.072	0.134	0.061
51	0.002	0.156	0.063	0.001	0	0.185	0.072	0.011	0.004
52	0.007	0.207	0.003	0.393	0.023	0.225	0.005	0.103	0.006
53	0.001	0.253	0.067	0.114	0.038	0.271	0.362	0.01	0.002
54	0.002	0.237	0.019	0.505	0.035	0.22	0.006	0.155	0.022
55	0.011	0.21	0.007	0.076	0.006	0.231	0.018	0.057	0.005
56	0.124	0.323	0.089	1.435	0.05	0.221	0.005	0.413	0.025
57	0.009	0.245	0.042	0.128	0.006	0.224	0.007	0.034	0.008
58	0.004	0.389	0.007	0.314	0.082	0.343	0.089	0.146	0.025
59	0.003	0.239	0.049	0.126	0.012	0.23	0.058	0.281	0.014
60	0.003	0.294	0.027	0.029	0.007	0.337	0.046	0.019	0.006
61	0	0.245	0.027	0.283	0.003	0.203	0.005	0.006	0.002
62	0.003	0.218	0.047	0.593	0.029	0.208	0.005	0.098	0.007
63	0.012	0.206	0.049	0.147	0.012	0.227	0.07	0.143	0.003
64	0.004	0.21	0.015	0.065	0.007	0.239	0.044	0.044	0.004
65	0.014	0.215	0.009	0.371	0.038	0.182	0.003	0.004	0.001

66	0.004	0.235	0.029	0.145	0.003	0.236	0.027	0.118	0.008
67	0.004	0.222	0.049	1.442	0.009	0.195	0.006	0.143	0.003
68	0.004	0.262	0.086	0.104	0.011	0.352	0.011	0.102	0.009
69	0.005	0.241	0.016	1.748	0.058	0.233	0.006	0.012	0.002
70	0.003	0.204	0.008	0.059	0.002	0.201	0.004	0.046	0.003
71	0.005	0.228	0.01	1.086	0.032	0.197	0.006	0.147	0.003
72	0	0.258	0.037	0.546	0.073	0.202	0.004	0.028	0.004
73	0.001	0.229	0.064	0.128	0.015	0.172	0.007	0.012	0.002
74	0.001	0.227	0.033	0.258	0.008	0.245	0.007	0.013	0
75	0.029	0.251	0.01	0.142	0.007	0.281	0.043	0.075	0.014
76	0.005	0.228	0.035	0.837	0.016	0.193	0.003	0.041	0.005
77	0.002	0.217	0.004	0.262	0.026	0.205	0.003	0.075	0.01
78	0.002	0.247	0.052	0.036	0.007	0.256	0.027	0.017	0.003
79	0	0.24	0.017	0.287	0.006	0.273	0.034	0.014	0
80	0.01	0.255	0.006	0.666	0.025	0.23	0.005	0.448	0.025
81	0.001	0.22	0.014	1.466	0.168	0.208	0.009	0.041	0.006
82	0	0.268	0.031	0.288	0.004	0.245	0.015	0.015	0
83	0.005	0.232	0.003	1.258	0.115	0.236	0.008	0.659	0.065
84	0.082	0.23	0.01	1.318	0.117	0.232	0.002	0.01	0.005
85	0.005	0.281	0.097	0.806	0.036	0.16	0.002	0.088	0.01
86	0.001	0.247	0.152	0.267	0.013	0.261	0.006	0.139	0.001
87	0.001	0.229	0.046	0.264	0.016	0.251	0.005	0.042	0.003
88	0.051	0.208	0.044	0.114	0.032	0.202	0.035	0.046	0.021
89	0.013	0.267	0.051	0.046	0.012	0.243	0.059	0.011	0.003
90	0.018	0.231	0.066	0.859	0.034	0.21	0.003	0.328	0.045
91	0.001	0.197	0.04	0.547	0.059	0.192	0.011	0.137	0.022
92	0.002	0.232	0.035	0.169	0.01	0.261	0.015	0.014	0.001
93	0.006	0.211	0.024	0.543	0.047	0.223	0.105	0.41	0.052
94	0.031	0.205	0.02	0.372	0.019	0.192	0.011	0.024	0.007
95	0.005	0.244	0.039	1.094	0.104	0.225	0.004	0.325	0.027
96	0.003	0.247	0.014	0.124	0.003	0.21	0.003	0.031	0.005
97	0.009	0.243	0.095	0.265	0.022	0.227	0.019	0.084	0.031
98	0.069	0.007	0.211	0	0.072	0.015	0.203	0	0.11
99	0.031	0.24	0.021	0.141	0.001	0.247	0.008	0.074	0.008
100	0.003	0.244	0.094	0.29	0.047	0.214	0.016	0.035	0.014
	0.005	0.21	0.005	0.872	0.021	0.219	0.004	0.341	0.007

slno

1	middlepa1	middlesda1	middlept1	middlesdt1	laterffpa1	laterffsd1	laterffpt1	laterffsd2	latermfpa1
2	0.094	0.045	0.278	0.091	0.058	0.023	0.255	0.076	0.087
3	0.126	0.011	0.228	0.055	0.013	0.001	0.21	0.041	0.377
4	0.029	0.009	0.36	0.032	0.024	0.008	0.343	0.059	0.061
5	0.015	0.001	0.255	0.074	0.007	0.002	0.264	0.074	0.004
6	0.005	0.003	0.201	0.005	0.074	0.004	0.21	0.004	0.035
7	0.079	0.005	0.259	0.058	0.391	0.017	0.213	0.006	0

8	0.016	0.004	0.314	0.065	0.016	0.009	0.295	0.071	0.023
9	0.005	0.003	0.297	0.101	0.006	0.002	0.207	0.066	0.268
10	0.065	0.017	0.231	0.032	0.125	0.015	0.231	0.049	0.047
11	0.134	0.021	0.21	0.004	0.66	0.021	0.203	0.01	0.157
12	0.008	0.002	0.261	0.088	0.008	0.002	0.239	0.082	0.011
13	0.029	0.006	0.216	0.04	0.052	0.001	0.237	0.013	0.773
14	0.017	0.005	0.242	0.052	0.01	0.005	0.22	0.046	0.012
15	0.024	0.003	0.201	0.02	0.071	0.004	0.197	0.007	0.106
16	0.114	0.017	0.206	0.007	0.01	0.006	0.264	0.075	0.044
17	0.051	0.005	0.222	0.009	0.047	0.006	0.22	0.007	0.067
18	0.312	0.043	0.19	0.028	0.153	0.002	0.288	0.102	0.199
19	0.058	0.003	0.222	0.028	0.03	0.001	0.255	0.04	0.051
20	0.346	0.302	0.198	0.039	0.627	0.407	0.291	0.063	0.37
21	0.012	0.003	0.256	0.066	0.029	0.001	0.211	0.072	0.16
22	0.045	0.019	0.285	0.096	0.052	0.015	0.275	0.071	0.068
23	0.079	0.009	0.219	0.018	0.015	0	0.223	0.084	0.071
24	0.036	0.017	0.27	0.072	0.02	0.013	0.243	0.054	0.124
25	0.039	0.003	0.195	0.01	0.015	0.001	0.229	0.074	0.028
26	0.113	0.017	0.215	0.006	0.131	0.011	0.202	0.005	0.024
27	0.094	0.028	0.225	0.023	0.1	0.03	0.208	0.024	0.109
28	0.036	0.007	0.205	0.057	0.046	0.01	0.252	0.081	0.061
29	0.053	0.009	0.295	0.064	0.137	0.006	0.223	0.089	0.314
30	0.032	0.004	0.285	0.037	0.02	0.003	0.28	0.066	0.043
31	0.035	0.005	0.257	0.035	0.061	0.007	0.247	0.047	0.033
32	0.128	0.017	0.251	0.012	0.112	0.014	0.245	0.012	0.036
33	0.029	0.001	0.263	0.04	0.029	0.001	0.271	0.041	0.409
34	0	7.25	0.209	0.071	0	7.571	0.256	0.118	0.078
35	0.029	0.003	0.268	0.037	0	5.079	0.206	0.073	0.139
36	0.039	0.009	0.219	0.053	0.087	0.011	0.19	0.01	0.085
37	0.085	0.012	0.207	0.009	0.134	0.005	0.227	0.009	0.332
38	0.277	0.006	0.258	0.025	0.107	0.004	0.253	0.008	0.174
39	0.053	0.009	0.22	0.012	0.13	0.014	0.237	0.024	0.301
40	0.057	0.006	0.181	0.013	0.128	0.01	0.179	0.004	0.138
41	0.004	0.002	0.274	0.079	0.003	0.001	0.251	0.101	0.004
42	0.015	0.003	0.237	0.067	0.143	0.007	0.207	0.013	0.13
43	0.1	0.019	0.189	0.005	0.125	0.01	0.193	0.005	0.166
44	0.007	0.003	0.236	0.044	0.005	0.002	0.235	0.063	0.006
45	0.029	0.004	0.303	0.059	0.058	0	0.222	0.004	0.058
46	0.039	0.003	0.203	0.011	0.059	0.002	0.195	0.008	0.109
47	0.081	0.011	0.223	0.011	0.065	0.006	0.234	0.006	0.177
48	0.04	0.004	0.244	0.007	0.949	0.003	0.224	0.007	0.117
49	0.013	0.003	0.217	0.059	0.06	0.005	0.216	0.009	0.102
50	0	0.601	0.226	0.098	0.16	0.075	0.234	0.071	0.123
51	0.007	0.002	0.206	0.114	0.005	0.002	0.247	0.086	0.007
52	0.147	0.009	0.221	0.004	0.23	0.011	0.226	0.005	0.074

53	0.148	0.033	0.278	0.048	0.041	0.024	0.264	0.074	0.092
54	0.11	0.012	0.239	0.011	0.176	0.012	0.226	0.007	0.095
55	0.028	0.002	0.246	0.021	0.047	0.005	0.227	0.044	0.201
56	0.032	0.009	0.259	0.067	0.15	0.018	0.23	0.009	0.216
57	0.022	0.007	0.208	0.038	0.071	0.004	0.203	0.007	0.055
58	0.152	0.008	0.385	0.008	0.113	0.011	0.39	0.009	0.32
59	0.124	0.008	0.226	0.039	0.273	0.015	0.21	0.006	0.26
60	0.015	0.005	0.298	0.044	0.024	0.01	0.302	0.051	0.022
61	0.273	0.017	0.223	0.006	0.14	0.004	0.218	0.02	0.08
62	0.07	0.031	0.199	0.015	0.004	0.001	0.178	0.054	0.005
63	0.077	0.014	0.196	0.028	0.032	0.005	0.195	0.038	0.397
64	0.029	0.004	0.223	0.023	0.351	0.012	0.215	0.002	0.389
65	0.017	0.005	0.184	0.018	0.028	0.007	0.181	0.012	0.013
66	0.103	0.009	0.251	0.043	0.135	0.005	0.244	0.008	0.094
67	0.057	0.002	0.27	0.093	0.057	0.001	0.193	0.051	0.098
68	0.028	0.003	0.349	0.018	0	5.745	0.27	0.059	5.29
69	0.012	0.001	0.238	0.027	0.005	0	0.257	0.032	0.302
70	0.009	0.002	0.199	0.029	0.053	0.004	0.207	0.009	0.096
71	0.039	0.008	0.218	0.03	0.059	0.001	0.286	0.082	0.388
72	0.052	0.003	0.209	0.007	0.045	0.004	0.198	0.007	0.014
73	0.007	0.002	0.195	0.043	0.02	0.002	0.179	0.011	0.012
74	0.104	0.006	0.267	0.035	0.136	0.002	0.245	0.006	0.249
75	0.078	0.011	0.227	0.009	0.069	0.011	0.226	0.01	0.112
76	0.019	0.004	0.199	0.025	0.032	0.012	0.222	0.043	0.066
77	0.014	0.003	0.237	0.025	0.06	0.002	0.263	0.07	0.133
78	0.037	0.006	0.248	0.024	0.023	0.004	0.235	0.023	0.082
79	0.553	0.015	0.229	0.008	0.144	0.004	0.273	0.028	0.17
80	0.226	-0.025	0.235	0.02	0.626	0.025	0.222	0.003	0.571
81	0.102	0.019	0.22	0.045	0.144	0.007	0.265	0.047	0.053
82	0.125	0.006	0.198	0.004	0.146	0.002	0.242	0.003	0.285
83	0.028	0.002	0.249	0.062	0.028	0.003	0.236	0.058	0.352
84	0.02	0.009	0.272	0.072	0.008	0.003	0.237	0.083	0.065
85	0.029	0.004	0.179	0.024	0.053	0.007	0.195	0.047	0.071
86	0.203	0.01	0.265	0.004	0.125	0.006	0.246	0.007	0.11
87	0.017	0.005	0.249	0.027	0.025	0.002	0.253	0.023	0.012
88	0.025	0.009	0.261	0.089	0.014	0.005	0.246	0.078	0.047
89	0.014	0.002	0.227	0.038	0.021	0.006	0.192	0.033	0.02
90	0.022	0.003	0.298	0.122	0.028	0.002	0.249	0.05	0.065
91	0.028	0.006	0.25	0.067	0.041	0.012	0.255	0.077	0.059
92	0.083	0.007	0.282	0.026	0.112	0.012	0.267	0.028	0.125
93	0.193	0.042	0.224	0.055	0.134	0.029	0.212	0.033	0.351
94	0.048	0.01	0.203	0.036	0.518	0.016	0.186	0.005	0.163
95	0.216	0.015	0.23	0.007	0.088	0.007	0.225	0.009	0
96	0.03	0.003	0.22	0.02	0.098	0.005	0.199	0.005	0.064
97	0.086	0.029	0.214	0.037	0.011	0.003	0.227	0.078	0.142

98	0	0.024	0.005	0.201	0	0.144	0.007	0.219	0
99	0.046	0.007	0.221	0.019	0.141	0.002	0.244	0.007	0.363
100	0.032	0.031	0.203	0.043	0.006	0.003	0.232	0.064	0.004
	0.336	0.006	0.268	0.078	0	1.807	0.261	0.057	9.4

slno	latermfsd2	heelpa1	heelsda1	heelpt1	heelsdt1	halluxpa2	halluxsda2	halluxpt2	halluxsdt2
1	0.077	0.135	0.075	0.272	0.053	1.052	0.04	0.242	0.003
2	0.041	0.118	0.013	0.222	0.02	0.337	0.027	0.201	0.007
3	0.088	0.028	0.009	0.354	0.067	0.67	0.118	0.207	0.005
4	0.062	0.002	0	0.255	0.088	0.108	0.034	0.223	0.005
5	0.007	0.041	0.003	0.215	0.012	9.784	5.515	0.295	0.088
6	0.072	0.068	0.004	0.223	0.019	0.735	0.229	0.214	0.005
7	0.055	0.016	0.015	0.297	0.066	0.456	0.041	0.241	0.059
8	0.005	0.062	0.007	0.18	0.028	0.295	0.017	0.167	0.003
9	0.031	0.008	0.003	0.236	0.053	0.293	0.006	0.229	0.015
10	0.008	0.012	0.002	0.209	0.029	0.024	0.011	0.238	0.09
11	0.052	0.008	0.003	0.252	0.072	0.583	0.03	0.216	0.002
12	0.003	0.102	0.005	0.213	0.006	0.569	0.141	0.195	0.012
13	0.03	0.009	0.005	0.273	0.063	0.31	0.054	0.24	0.013
14	0.006	0	4.529	0.201	0.093	0.123	0.004	0.182	0.005
15	0.012	0.017	0.004	0.208	0.027	0.222	0.068	0.214	0.026
16	0.008	0.024	0.004	0.214	0.01	0.109	0.012	0.216	0.013
17	0.084	0.01	0.01	0.238	0.075	1.233	0.051	0.18	0.004
18	0.057	0.051	0.01	0.185	0.045	1.227	0.162	0.165	0.008
19	0.054	0.138	0.118	0.168	0.023	0.575	0.08	0.18	0.01
20	0.011	0.013	0.002	0.227	0.053	0.453	0.022	0.197	0.004
21	0.064	0.068	0.048	0.269	0.088	0.654	0.046	0.22	0.013
22	0.007	0.139	0.007	0.221	0.186	0.737	0.025	0.199	0.003
23	0.076	0.079	0.04	0.273	0.066	0.043	0.013	0.243	0.04
24	0.01	0.037	0.003	0.191	0.007	0.256	0.018	0.157	0.004
25	0.056	0.003	0.001	0.211	0.064	0.113	0.026	0.378	0.027
26	0.021	0.065	0.013	0.215	0.014	0.109	0.024	0.199	0.015
27	0.007	0.075	0.004	0.183	0.006	0.2	0.013	0.162	0.005
28	0.062	0.202	0.014	0.252	0.023	0.14	0.004	0.221	0.074
29	0.039	0.12	0.008	0.263	0.008	0.336	0.017	0.217	0.005
30	0.017	0.021	0.002	0.251	0.063	0.298	0.143	0.244	0.04
31	0.033	0.027	0.003	0.249	0.064	0.24	0.058	0.241	0.045
32	0.002	0.257	0.009	0.201	0.002	0.048	0.041	0.262	0.081
33	0.065	0.142	0.029	0.269	0.055	0.001	0	0.215	0.09
34	0.061	0.081	0.016	0.248	0.009	0.457	0.04	0.255	0.008
35	0.142	0.018	0.003	0.205	0.033	0.236	0.266	0.187	0.008
36	0.007	0.028	0.001	0.269	0.035	0.474	0.038	0.209	0.006
37	0.007	0.082	0.005	0.252	0.01	0.03	0.01	0.278	0.066
38	0.005	0	0	0.235	0.092	0.144	0.007	0.243	0.059
39	0.005	0.089	0.007	0.182	0.005	0.462	0.068	0.167	0.005

40	0.087	0.002	0.001	0.246	0.083	0.045	0.02	0.269	0.036
41	0.011	0.011	0.003	0.201	0.043	0.072	0.03	0.227	0.067
42	0.004	0.073	0.007	0.188	0.004	0.147	0.007	0.281	0.104
43	0.072	0.009	0.002	0.269	0.089	0.258	0.017	0.25	0.01
44	0.006	0.039	0.001	0.227	0.008	2.217	0.132	0.262	0.012
45	0.006	0.006	0.001	0.206	0.035	0.044	0.025	0.244	0.046
46	0.004	0.022	0.002	0.235	0.028	0.009	0.001	0.218	0.066
47	0.006	0.087	0.005	0.225	0.006	0.314	0.023	0.209	0.002
48	0.006	7.854	2.88	0.152	0.07	0.135	0.011	0.2	0.017
49	0.061	0.187	0.023	0.264	0.017	0.666	0.08	0.234	0.012
50	0.087	0.006	0.001	0.259	0.081	0	0	0.294	0.122
51	0.01	0.083	0.003	0.226	0.005	0.41	0.028	0.227	0.005
52	0.07	0.021	0.003	0.205	0.015	0.046	0.017	0.288	0.038
53	0.009	0.015	0.004	0.276	0.028	0.272	0.056	0.22	0.017
54	0.004	0.061	0.004	0.201	0.007	0.193	0.049	0.231	0.007
55	0.005	0.037	0.014	0.321	0.068	1.047	0.083	0.22	0.006
56	0.008	0.048	0.003	0.221	0.008	0.075	0.006	0.193	0.05
57	0.011	0.074	0.002	0.387	0.013	0.6	0.038	0.381	0.007
58	0.007	0.021	0.003	0.242	0.05	0.433	0.06	0.22	0.022
59	0.093	0.01	0.005	0.312	0.064	0.068	0.009	0.181	0.021
60	0.011	0.027	0.002	0.227	0.049	0.286	0.007	0.212	0.034
61	0.073	0.004	0.001	0.18	0.057	0.235	0.029	0.261	0.074
62	0.021	0.063	0.011	0.216	0.037	0.144	0.008	0.193	0.061
63	0.002	0.094	0.005	0.221	0.004	0.024	0.006	0.257	0.066
64	0.066	0.03	0.01	0.187	0.015	0.371	0.051	0.171	0.006
65	0.006	0.066	0.01	0.246	0.006	0.139	0.014	0.243	0.026
66	0.024	0.143	0.002	0.213	0.012	1.997	0.069	0.205	0.01
67	0.05	0.001	0	0.347	0.018	0.692	0.021	0.194	0.04
68	0.006	0.082	0.005	0.242	0.017	1.065	0.088	0.208	0.006
69	0.003	0.024	0.002	0.197	0.008	0.111	0.006	0.187	0.002
70	0.004	0.127	0.008	0.219	0.009	0.488	0.032	0.174	0.012
71	0.004	0.001	2.89	0.193	0.004	0.63	0.097	0.208	0.032
72	0.044	0.009	0.002	0.207	0.034	0.119	0.009	0.172	0.008
73	0.008	0.027	0.001	0.239	0.01	0.218	0.039	0.251	0.035
74	0.009	0.072	0.011	0.219	0.009	0.138	0.009	0.307	0.064
75	0.009	0.022	0.003	0.194	0.018	0.982	0.014	0.184	0.004
76	0.008	0.007	0.001	0.244	0.066	0.628	0.057	0.187	0.004
77	0.017	0.013	0.004	0.285	0.067	0.047	0.04	0.278	0.075
78	0.029	0.029	0.001	0.269	0.03	0.278	0.008	0.254	0.007
79	0.002	0.001	0	0.276	0.078	1.182	0.214	0.212	0.011
80	0.053	0.006	0.001	0.228	0.062	1.215	0.296	0.22	0.008
81	0.003	0.029	0.001	0.248	0.005	0.193	0.022	0.2	0.009
82	0.009	0.139	0.007	0.229	0.018	0.555	0.055	0.221	0.009
83	0.014	0.143	0.014	0.223	0.007	1.185	0.103	0.222	0.009
84	0.008	0.022	0.004	0.198	0.019	1.038	0.022	0.161	0.003

85	0.012	0.025	0.001	0.269	0.051	0.207	0.027	0.254	0.008
86	0.06	0.015	0.002	0.247	0.022	0.295	0.061	0.231	0.004
87	0.082	0.041	0.017	0.292	0.046	0.312	0.222	0.216	0.067
88	0.02	0.003	0.002	0.25	0.078	0.229	0.046	0.184	0.019
89	0.041	0.028	0.003	0.265	0.072	1.612	0.067	0.228	0.003
90	0.077	0.059	0.003	0.249	0.054	0.379	0.131	0.237	0.064
91	0.017	0.029	0.001	0.282	0.042	0.029	0.013	0.292	0.039
92	0.026	0.123	0.033	0.214	0.032	0.517	0.085	0.183	0.038
93	0.004	0.127	0.007	0.189	0.007	0.24	0.117	0.173	0.007
94	0.106	0.142	0.018	0.225	0.005	0.694	0.15	0.242	0.011
95	0.011	0.005	0.004	0.216	0.009	0.073	0.009	0.205	0.015
96	0.006	0.009	0.004	0.256	0.089	0.287	0.009	0.234	0.044
97	0.201	0	0.056	0.008	0.205	0	0.128	0.031	0.193
98	0.005	0.336	0.012	0.209	0.004	0.14	0.003	0.243	0.009
99	0.074	0.005	0.003	0.264	0.092	0.087	0.041	0.264	0.044
100	0.083	0.169	0.006	0.225	0.004	0.179	0.014	0.193	0.002

slno	medialpt2	medialsdt2	middlepa2	middlesda2	middlept2	middlesdt2	laterffpa2	laterffsd3	laterffpt2
1	0.243	0.003	0.133	0.006	0.25	0.005	0.066	0.004	0.237
2	0.229	0.031	0.124	0.005	0.222	0.01	0.011	0.012	0.215
3	0.21	0.004	0.067	0.026	0.24	0.06	0.212	0.046	0.21
4	0.24	0.034	0.026	0.011	0.27	0.059	0.003	0.001	0.286
5	0.199	0.007	0.048	0.005	0.193	0.009	0.047	0.004	0.196
6	0.206	0.006	0.35	0.057	0.219	0.009	0.541	0.051	0.214
7	0.199	0.005	0.131	0.011	0.27	0.068	0.125	0.009	0.189
8	0.211	0.051	0.131	0.022	0.176	0.012	0.077	0.004	0.157
9	0.236	0.03	0.124	0.008	0.202	0.029	0.146	0.004	0.228
10	0.242	0.081	0.009	0.004	0.247	0.096	0.002	0.001	0.2
11	0.248	0.063	0.01	0.006	0.249	0.043	0.008	0.002	0.253
12	0.22	0.025	0.048	0.01	0.227	0.041	0.033	0.021	0.238
13	0.239	0.025	0.087	0.035	0.261	0.051	0.049	0.023	0.242
14	0.189	0.007	0.096	0.019	0.185	0.012	0.132	0.017	0.214
15	0.27	0.05	0.099	0.013	0.213	0.011	0.038	0.014	0.222
16	0.206	0.009	0.005	0.002	0.266	0.061	0.007	0.002	0.303
17	0.186	0.007	0.158	0.017	0.185	0.011	0.435	0.02	0.18
18	0.233	0.042	0.057	0.005	0.227	0.057	0.028	0.002	0.228
19	0.197	0.026	0.181	0.07	0.192	0.039	0.245	0.029	0.175
20	0.194	0.007	0.029	0.002	0.21	0.081	0.028	0	0.171
21	0.213	0.013	0.351	0.02	0.212	0.009	0.226	0.015	0.226
22	0.208	0.008	0.149	0.004	0.232	0.045	0.15	0	0.288
23	0.234	0.023	0.029	0.009	0.248	0.04	0.062	0.012	0.229
24	0.161	0.02	0.013	0.005	0.171	0.055	0.012	0.002	0.219
25	0.274	0.043	0.099	0.038	0.314	0.048	0.148	0.052	0.241
26	0.209	0.062	0.096	0.047	0.238	0.056	0.229	0.012	0.234
27	0.194	0.077	0.013	0.003	0.301	0.085	0.005	0.001	0.221

28	0.184	0.029	0.029	0.008	0.183	0.007	0.061	0.024	0.189
29	0.238	0.065	0.056	0.016	0.215	0.031	0.158	0.044	0.221
30	0.24	0.03	0.023	0.004	0.251	0.046	0.038	0.005	0.234
31	0.135	0.004	0.177	0.075	0.288	0.076	0.067	0.014	0.211
32	0.286	0.055	0.006	0.004	0.279	0.086	0.005	0.003	0.286
33	0.256	0.003	0.344	0.012	0.261	0.003	0.001	0	0.192
34	0.29	0.069	0.179	0.005	0.269	0.061	0	4.305	0.209
35	0.188	0.027	0.062	0.01	0.176	0.012	0.021	0.009	0.204
36	0.308	0.074	0.333	0.058	0.196	0.016	0.005	0.002	0.276
37	0.267	0.061	0.126	0.492	0.276	0.067	0.138	0.008	0.227
38	0.237	0.058	0.212	0.066	0.2	0.006	0.048	0.027	0.218
39	0.169	0.014	0.175	0.085	0.17	0.033	0.401	0.073	0.16
40	0.281	0.066	0.005	0.003	0.238	0.077	0.003	0.001	0.229
41	0.199	0.112	0.14	0.085	0.199	0.076	0.019	0.004	0.244
42	0.22	0.075	0.244	0.03	0.18	0.013	0.124	0.006	0.17
43	0.248	0.003	0.259	0.006	0.245	0.003	0.195	0.006	0.235
44	0.28	0.012	0.014	0.004	0.318	0.074	0.059	0.001	0.254
45	0.231	0.045	0.024	0.002	0.212	0.01	0.046	0.003	0.205
46	0.239	0.054	0.033	0.011	0.243	0.048	0.027	0.008	0.196
47	0.215	0.003	0.117	0.007	0.219	0.004	0.116	0.022	0.212
48	0.174	0.012	0.163	0.074	0.188	0.015	0.065	0.032	0.181
49	0.246	0.034	0	5.334	0.256	0.109	0.017	0.005	0.266
50	0.253	0.12	0.005	0.001	0.232	0.126	0.003	0.001	0.248
51	0.225	0.003	0.102	0.008	0.215	0.006	0.391	0.035	0.221
52	0.281	0.068	0.161	0.068	0.261	0.061	0.008	0.005	0.304
53	0.222	0.015	0.048	0.027	0.237	0.032	0.117	0.037	0.223
54	0.235	0.047	0.01	0.004	0.309	0.053	0.04	0.01	0.223
55	0.218	0.005	0.374	0.023	0.221	0.004	0.436	0.054	0.217
56	0.209	0.061	0.024	0.017	0.283	0.073	0.083	0.017	0.205
57	0.363	0.018	0.038	0.005	0.374	0.016	0.166	0.013	0.388
58	0.245	0.064	0.323	0.121	0.238	0.078	0.302	0.099	0.231
59	0.297	0.059	0.036	0.005	0.304	0.04	0.131	0.005	0.246
60	0.324	0.067	0.057	0.018	0.255	0.023	0.064	0.042	0.247
61	0.247	0.074	0.029	0.003	0.244	0.073	0.012	0.002	0.293
62	0.193	0.042	0.418	0.065	0.189	0.007	0.13	0.012	0.212
63	0.243	0.052	0.013	0.005	0.249	0.048	0.005	0.003	0.263
64	0.195	0.353	0.05	0.099	0.199	0.035	0.002	8.789	0.201
65	0.272	0.051	0.004	0.001	0.282	0.085	0.004	0.001	0.262
66	0.204	0.096	0.049	0.007	0.197	0.104	0.057	0.001	0.181
67	0.211	0.023	0.393	0.009	0.199	0.041	0.32	0.009	0.206
68	0.214	0.02	0.005	0.004	0.285	0.064	0.003	0.002	0.248
69	0.184	0.003	0.003	0.001	0.192	0.066	0.002	0.001	0.238
70	0.209	0.026	0.05	0.006	0.184	0.021	0.06	0.002	0.229
71	0.193	0.02	0.72	0.022	0.201	0.014	0.122	0.01	0.221
72	0.168	0.025	0.029	0.005	0.177	0.016	0.025	0.002	0.162

73	0.29	0.042	0.047	0.014	0.246	0.043	0.007	0.004	0.263
74	0.249	0.037	0.41	0.031	0.227	0.006	0.126	0.012	0.241
75	0.212	0.029	0.054	0.009	0.219	0.04	0.06	0.001	0.212
76	0.265	0.072	0.06	0.003	0.247	0.073	0.06	0.001	0.242
77	0.264	0.054	0.019	0.013	0.292	0.043	0.017	0.009	0.303
78	0.257	0.006	0.353	0.048	0.209	0.006	0.136	0.006	0.247
79	0.223	0.057	0.357	0.073	0.215	0.008	0.336	0.111	0.23
80	0.3	0.069	0.402	0.086	0.233	0.045	0.093	0.031	0.227
81	0.229	0.023	0.055	0.029	0.207	0.023	0.005	0.002	0.257
82	0.227	0.005	0.016	0.005	0.214	0.034	0.027	0.003	0.27
83	0.256	0.083	0.006	0.001	0.232	0.073	0.005	0.002	0.272
84	0.17	0.02	0.017	0.003	0.232	0.076	0.055	0.004	0.199
85	0.263	0.083	0.003	0.001	0.234	0.059	0.004	0.001	0.245
86	0.229	0.006	0.035	0.007	0.231	0.012	0.023	0.003	0.233
87	0.212	0.031	0.191	0.123	0.204	0.025	0.183	0.116	0.196
88	0.178	0.02	0.069	0.012	0.185	0.034	0.076	0.013	0.177
89	0.285	0.071	0.124	0.019	0.263	0.075	0.219	0.018	0.225
90	0.192	0.03	0.037	0.013	0.234	0.078	0.056	0.01	0.269
91	0.26	0.068	0.006	0.004	0.337	0.021	0.014	0.008	0.291
92	0.248	0.079	0.311	0.113	0.25	0.07	0.275	0.077	0.217
93	0.243	0.077	0.092	0.008	0.187	0.016	0.197	0.009	0.17
94	0.248	0.022	0.162	0.063	0.237	0.011	0.121	0.042	0.252
95	0.217	0.054	0.004	0.001	0.232	0.089	0.009	0.004	0.314
96	0.219	0.007	0.076	0.016	0.242	0.045	0.045	0.004	0.215
97	0.005	0.173	0	0.11	0.025	0.18	0	0.032	0.046
98	0.287	0.096	0.028	0.004	0.298	0.048	0.117	0.012	0.27
99	0.236	0.015	0.034	0.007	0.225	0.026	0.092	0.006	0.23
100	0.211	0.049	0.119	0.006	0.2	0.003	9.718	3.472	0.213

slno	latermfsd3	latermfpt2	latermfsd4	heelpa2	heelsda2	heelpt2	heelsdt2
1	0.005	0.241	0.005	0.042	0.002	0.243	0.009
2	0.009	0.209	0.017	0.083	0.009	0.212	0.009
3	0.044	0.211	0.004	0.138	0.011	0.22	0.004
4	0.004	0.231	0.061	0.003	0.001	0.322	0.066
5	0.008	0.2	0.02	0.003	0.001	0.257	0.075
6	4.25	0.192	0.082	0	0	0.198	0.098
7	0.022	0.212	0.015	0.212	0.015	0.22	0.039
8	0.013	0.157	0.139	0.007	0.003	0.259	0.059
9	0.004	0.188	0.003	0.003	0.001	0.222	0.087
10	0.003	0.287	0.092	0	0	0.209	0.099
11	0.002	0.271	0.066	0.006	0.002	0.228	0.056
12	0.089	0.284	0.08	0.004	0.003	0.222	0.094
13	0.05	0.235	0.023	0.056	0.008	0.229	0.012
14	0.055	0.182	0.019	0	0	0.184	0.092

15	0.015	0.218	0.031	0.014	0.005	0.221	0.045
16	0.007	0.214	0.037	0.003	0.001	0.269	0.072
17	0.045	0.18	0.005	0.001	0	0.293	0.06
18	0.044	0.192	0.453	0.16	0.024	0.194	0.057
19	0.036	0.176	0.007	0.13	0.023	0.202	0.016
20	0.016	0.191	0.005	0.003	0.001	0.22	0.072
21	0.021	0.207	0.011	0.173	0.037	0.166	0.008
22	0.01	0.191	0.006	0.123	0.005	0.188	0.009
23	0.017	0.208	0.004	0.041	0.01	0.224	0.035
24	0.003	0.17	0.019	0.02	0.004	0.162	0.022
25	0.117	0.238	0.054	0.222	0.007	0.315	0.034
26	0.044	0.235	0.05	0.004	0.001	0.254	0.084
27	0.002	0.283	0.106	0.005	0.002	0.34	0.047
28	0.015	0.254	0.055	0.389	0.071	0.253	0.014
29	0.002	0.209	0.01	0.005	0.012	0.195	0.088
30	0.003	0.232	0.011	0.015	0.002	0.217	0.01
31	0.018	0.228	0.016	0.005	0.003	0.267	0.075
32	0.038	0.237	0.048	0.012	0.008	0.266	0.068
33	0.004	0.258	0.007	0.116	0.013	0.252	0.004
34	0.025	0.241	0.076	0.081	0.01	0.239	0.019
35	0.008	0.227	0.057	0.003	0.001	0.272	0.076
36	0.014	0.217	0.056	0.023	0.006	0.247	0.06
37	0.027	0.206	0.029	0.009	0.002	0.217	0.062
38	0.002	0.227	0.074	0	5.82	0.161	0.069
39	0.048	0.164	0.004	0.003	0.001	0.249	0.083
40	0.002	0.269	0.07	0.003	0.001	0.215	0.082
41	0.028	0.182	0.015	0.004	0.001	0.254	0.119
42	0.033	0.167	0.053	0.005	0.003	0.235	0.083
43	0.01	0.246	0.005	0.145	0.008	0.253	0.003
44	0.001	0.221	0.007	0.058	0.001	0.241	0.058
45	0.015	0.206	0.002	0.005	0.001	0.205	0.029
46	0.02	0.198	0.005	2.183	8.357	0.247	0.094
47	0.006	0.208	0.016	0.003	0.001	0.232	0.089
48	0.005	0.281	0.072	9.582	3.101	0.211	0.082
49	0.018	0.236	0.01	0.162	0.006	0.247	0.003
50	0.001	0.273	0.099	0.009	0.001	0.223	0.05
51	0.005	0.221	0.004	0.003	0.001	0.243	0.098
52	0.019	0.276	0.028	0.004	0.002	0.284	0.073
53	0.027	0.222	0.017	0.003	0	0.31	0.1
54	0.047	0.203	0.011	0.037	0.009	0.197	0.014
55	0.032	0.214	0.005	0.091	0.007	0.226	0.005
56	0.025	0.18	0.007	0.004	0.001	0.222	0.075
57	0.002	0.353	0.036	0.003	0.001	0.233	0.083
58	0.033	0.207	0.014	0.003	0.001	0.232	0.089
59	0.007	0.28	0.008	0.052	0.004	0.314	0.015

60	0.023	0.215	0.019	0.029	0.001	0.194	0.039
61	0.004	0.226	0.046	0.01	0.001	0.248	0.07
62	0.027	0.181	0.021	0.005	0.001	0.226	0.064
63	0.006	0.263	0.057	0.004	0.003	0.227	0.069
64	0.024	0.188	0.026	0.006	0.002	0.305	0.086
65	0.001	0.246	0.099	0.004	0.001	0.232	0.077
66	0.008	0.241	0.046	0.004	0.002	0.27	0.071
67	0.022	0.205	0.033	0.397	0.018	0.193	0.041
68	0.03	0.209	0.012	0.004	0.001	0.212	0.031
69	0.001	0.266	0.088	0.002	0.001	0.305	0.073
70	0.027	0.177	0.002	0.095	0.013	0.184	0.007
71	0	0.197	0.022	2.961	1.344	0.269	0.067
72	0.002	0.162	0.024	0.003	0.001	0.282	0.112
73	0.003	0.252	0.088	0.002	0.001	0.211	0.052
74	0.056	0.224	0.006	0.255	0.024	0.223	0.003
75	0.002	0.177	0.008	0.003	0.002	0.289	0.101
76	0.005	0.178	0.008	0.004	0.001	0.258	0.082
77	0.03	0.218	0.021	0.01	0.006	0.26	0.066
78	0.017	0.238	0.012	0.027	0.001	0.254	0.014
79	0.01	0.228	0.027	0.001	0	0.282	0.062
80	0.081	0.228	0.037	0.027	0.004	0.267	0.069
81	0.002	0.236	0.101	0.002	0.001	0.199	0.078
82	0.021	0.23	0.047	0.003	0.001	0.297	0.082
83	0	0.232	0.06	0.003	0	0.369	0
84	0.006	0.186	0.026	0.006	0.002	0.296	0.068
85	0.001	0.238	0.082	0.002	0.001	0.267	0.079
86	0.004	0.235	0.006	0.002	0.001	0.274	0.098
87	0.143	0.225	0.025	0.19	0.14	0.218	0.061
88	0.024	0.178	0.022	0.003	0.001	0.245	0.091
89	0.041	0.231	0.004	0.573	0.043	0.23	0.005
90	0.004	0.258	0.078	0.005	0.002	0.273	0.096
91	0.001	0.233	0.081	0.005	0.004	0.281	0.081
92	0.05	0.223	0.044	0.006	0.002	0.288	0.065
93	0.008	0.173	0.004	0.004	0.001	0.244	0.044
94	3.044	0.21	0.086	0.104	0.011	0.244	0.01
95	0.002	0.242	0.119	0.003	0.001	0.254	0.094
96	0.007	0.211	0.01	0.087	0.004	0.217	0.007
97	0.115	0.023	0.168	0	0.004	0.001	0.278
98	0.017	0.224	0.011	0.405	0.015	0.223	0.004
99	0.013	0.232	0.005	0.031	0.005	0.234	0.014
100	3.147	0.269	0.061	0.142	0.014	0.213	0.002