

Innovative Foot Pressure Mapping Technology On-The-Go Using Android Application

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Abstract: An average person takes thousands of steps each day, resulting in the placement extreme high pressure on one's feet. This leads to various bio-mechanical problems with grievous effects. So, there is a need for monitoring foot pressure and treating these conditions effectively. But each person's feet and walking pattern are different and unique. In this paper, we present a versatile and any-size-fit in-shoe sensor which is capable of capturing data as you walk in real-time; vivid and easy to understand graphics obtained, will let the subject and the doctor see what happens while walking. The graphics are displayed on the Smartphones using an Android application developed by us. It is wireless, portable and user friendly technology and also records the data or history for gait analysis by a podiatrician. The user friendly application will display the foot strikes dynamically as a movie, frame by frame. A podiatrician or the subject can use side by side comparisons of graphics before and after treatment to evaluate effectiveness or suggest correction.

Keywords: bio-mechanical problems, any-size-fit in-shoe sensor, Smartphones, podiatrician, wireless, portable, user friendly device, gait analysis.

I. INTRODUCTION

Podiatry or podiatric medicine is a branch of medical science devoted to the study, diagnosis, medical and surgical treatment of disorders of the foot, ankle and lower extremity. Podiatrists perform gait analysis on patients before treatment. Using gait analysis would help one determine the tools needed to control the entire environment in which the foot functions. [1] These tools may include orthotic devices, shoes, shoe modifications or even surgery. Gait analysis is also prescribed post surgery or post injury. Pressure mapping of the feet is used for:

- Measuring degree of pronation [2]
- Determining degree of ankle joint equinus [3]
- Determining patterns of weight bearing forces [4]
- Determining amount of tibial varum [5]
- Back pain can be diagnosed with pressure mapping of the foot and gait analysis [6]
- Symmetry between feet [7]
- Determining areas of highest pressure [8]
- Identifying areas of potential ulceration in diabetics. [9]
- To evaluate surgical procedures [10]
- Gait analysis of athletes for better performance [11]

The present system of gait analysis used by podiatrists is not wireless, is restricted to podiatric centres, use bulky sensors and can be monitored using software available only at labs or hospitals.

We employ a light weight, portable, wireless and user friendly system for monitoring of gait patterns. On top of that, we make use of a thin, flexible and "one-size-fits-all in-shoe" sensors. We have also made use of an android application to represent gait patterns graphically and pictorially. Gait is dynamic and everything happens quickly.

To make an assessment, we have to capture each movement every second one's heel hits the ground. Pressure mapping technology allows us to do that by capturing pressure data in each phase of foot motion, from heel contact to toe-off. The information it provides on how one's feet are functioning and how one is walking through abnormal pressure gradients, helps prescribe effective treatment.

Using this technology reveals a host of various other conditions that cannot be seen otherwise. Whether it is to assess how effective the orthotics are, to detect limb length discrepancy, assess lower back pain, identify potential areas of ulceration in diabetics and post surgery help. Athletics is a key area where assessing the athletes' foot functioning gait is critical. When a person is running, his feet are striking the ground with roughly three times of his body weight and these pressures can create significant problems for body movement and functioning. With this technology, one can enhance his or her performance, choose appropriate footwear and prevent injuries.

II. FOOT CONDITIONS AND TREATMENT

A. Arch pain

Arch pain is an indicator of inflammation with a burning sensation at the arch of the foot. Arch pain can result from a number of different causes. The most common is plantar fasciitis however other causes of arch pain include structural imbalances and foot shock/injury. Arch pain and heel pain often come together due to this shared caused. A heel spur may result if the arch pain is left untreated and allows further strain on the arch. It is treated easily with proper footwear or shock absorbing soles and if needed orthotics with a good arch support to prevent further inflammation and reoccurrence. Figure 1 shows an example of arch pain. [12]



Figure 1 Arch Pain

B. Bunions

Bunions occur on the large toe and are an enlargement of the joint at the base of the toe. It produces a painful lump of bone at the base which forms from the tissue or bone at the joint moving out of place which forces the toe to bend in a direction it normally shouldn't be facing. The bump usually occurs on the outside of the foot (at the bottom/base of the large toe). Bunions only form after years of pressure and abnormal motion on the joint from walking style, genetic foot type or bad fitting shoes.



Figure 2 Bunion

Treatment can usually be done without the need for surgery. Initially focused on relieving the pressure and pain to reduce and stop further joint deformity. Other treatments include ultrasound therapy, anti-inflammatory medications, topical lotions and icing. Figure 2 shows an example of bunions. [12]

C. Callus

Similar to corns but generally refer to the formation of dead skin on the heel (but also the large toe and ball of the foot). A callous is more an indicator of a problem (symptom) rather than a condition. Improper foot wear is the most common cause of callouses due to excessive pressure on particular areas of the foot. Correct footwear will relieve and prevent the callus from returning and inserts or orthotic devices can be used to evenly redistribute the weight along your foot correctly, preventing excessive pressure on any one spot. Figure 3 shows an example of Callus. [12]



Figure 3 Callus

D. Corns

Corns are small dense layer of dead skin cells that result from excessive pressure on the skin (and act as a 'padding' to further damage). They are a response by the body to protect the foot due to abuse and stress. The pressure that results in Corns, can be due to a number of causes including, tight and ill-fitting shoes, deformed toes, walking problems and bunions or shoes that are poorly made and rub against the toes. Corns can be easily treated by a practitioner through a number of means, one being trimming the dead skin off with a scalpel. Preventing corns in the first place is better to avoid the extra pressure that is placed on your feet.



Figure 4 Corn

Wearing correctly fitting shoes, thick socks when participating in sports can help reduce the possibility of corns forming. Figure 4 shows an example of corn. [12]

E. Flat feet

Flat feet are defined as the inner arch of the foot being more flat than normal. This condition appears most commonly in children, although can appear in people of any age. The range of causes for flat feet can be from genetic (bone and tendon positioning) to acquired and related to other conditions like trauma or cerebral palsy. In adults it is usually the result of soft tissue injuries where they tendons and ligaments have been torn. The earlier the treatment for flat feet the better as if left untreated over time it can develop into a number of painful conditions. For children each case is different and needs to be determined by a podiatrist to assess whether it is within normal change, or potentially needs some preventative measure. General treatment involves better quality footwear, or specially made orthotics. Figure 5 shows an example of flat foot. [12]



Figure 5 Flat foot

F. Fore-foot pain

Forefoot pain is pain normally arising in the sole of the feet that can also be accompanied by swelling, burning and numbness, however often there is none. The pain is often present when the foot is under load (weight) for only a short duration. The exact causes can be quite varied but include bad fitting footwear, trauma (sports related), problems with the actual mechanics of the foot and inflammation in the joints.

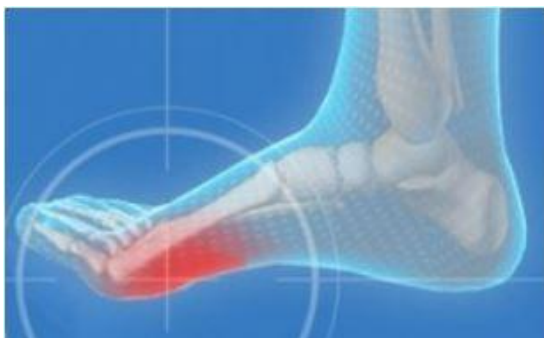


Figure 6 Fore-foot pain

It is mostly treated with orthotics and corticosteroid injections and if the condition is severe a surgical procedure may be needed. Figure 6 shows example of fore-foot pain. [12]

G. Heel pain

Heel Pain is a condition that is extremely common in adults and one of the most treated conditions in Podiatry. It's usually caused due to simple day to day tasks and exercise. The most common cause of heel pain is inflammation in the plantar fascia (the connective tissue of the foot). The pain most frequently persists in the side or bottom rear of the heel. Different treatments are available depending on the exact cause of heel pain, but orthotics are one of the most commonly used options. Figure 7 shows an example of heel pain. [12]



Figure 7 Heel pain

H. Back/Hip/Knee pain

Foot health is not only about the feet, but many painful symptoms in the knees, hips and back can be a result of bad foot posture. There are potentially a number of different abnormalities of the foot that can lead to pain in these areas. For instance, over pronation (where the foot rolls in too much) causes the leg to rotate inwards towards the other leg, and stresses the knee joint, resulting in pain.



Figure 8 Back pain, hip pain and knee pain

Another common problem is the leg length discrepancy, which can result in back and hip pain. Among other treatments, many of these can be treated with orthotics, correcting the positioning of the foot and alleviating the stress of the upper part of the body, removing the pain. Figure 8 shows an example for Back pain, hip pain and knee pain. [12]

I. Diabetic foot care

Diabetic foot care is an extremely important preventative measure that all Diabetics need to be aware of. Diabetes can cause foot problems due to nerve damage which affects how the senses in the foot can detect sensation, trauma and pressure. It can also affect circulation in the lower body which leads to reduced ability to repair wounds and fight infections. All diabetics should routinely have a consultation and foot examination to keep on top of any potential issues. It is critical for diabetics to prevent foot problems with simple precautions that can be done every day. Figure 8 shows effect of diabetes on foot. [12]



Figure 9 shows effect of diabetes on the foot

III. CUSTOM MADE ORTHOTICS AND FOOT CARE

A. Orthotics

Most people don't give their feet a second thought, not until they hurt. Most foot pain is the result of a faulty relationship between the bones and muscles of the foot. Even the slightest misalignment of the bones and muscles can cause a lot of discomfort. Misalignment can result in a number of problems, such as pronation, flat feet, persistent ankle sprains, bunions, corns, calluses, even back and neck pain. Podiatrists specialise in ensuring that your feet are properly aligned, by custom making orthotics to fit your particular needs. They are made of high impact materials, such as plastic and super-strength woven fibres, and they're designed to be inserted right into all types of shoes. Depending on your day to day activities we can customise the thickness, and types of padding to cater to your shoes or sports activities. Once orthotics is slipped inside your shoes, they fit comfortably to your foot. So comfortably, in fact, that once you start wearing them you won't want to walk without them again. As your foot rests on the orthotic it is gently and consistently directed into the

correct position for walking, running, and standing. With a pair of custom orthotics, pressure points, improper rotation of the foot, and painful muscle strain are all reduced because your foot is functioning properly. The podiatrist gives a complete examination and determines your particular foot problem. A plaster impression will then be made of your feet held in the correct position. When the casts are finished, they are sent to the orthotic laboratory where they are then used to manufacture your orthotics. Here technicians, following the podiatrist's specifications, add special heel lifts, or built-ups to customise an orthotic to correct your specific problem. [13] Figure 10 shows custom made orthotics.

B. Diabetic foot care

Foot wounds or foot ulcers are one of the most common complications associated with chronic diabetes. [14] It has been estimated that 5% of those with diabetes will experience foot ulcers. Such wounds can be classified as neuropathic, vascular-neuropathic or vascular in origin. A key factor in diabetic foot is that dynamic pressures are higher than in those without diabetes. The causes for increase in dynamic pressure are thought to include bony deformity, retraction of toes, pes cavus, a lack of soft tissue cushioning, callus formation and limited joint mobility.



Figure 10 Custom made orthotics



Figure 11 Foot ulcers



Figure 12 Foot amputated due to gangrene

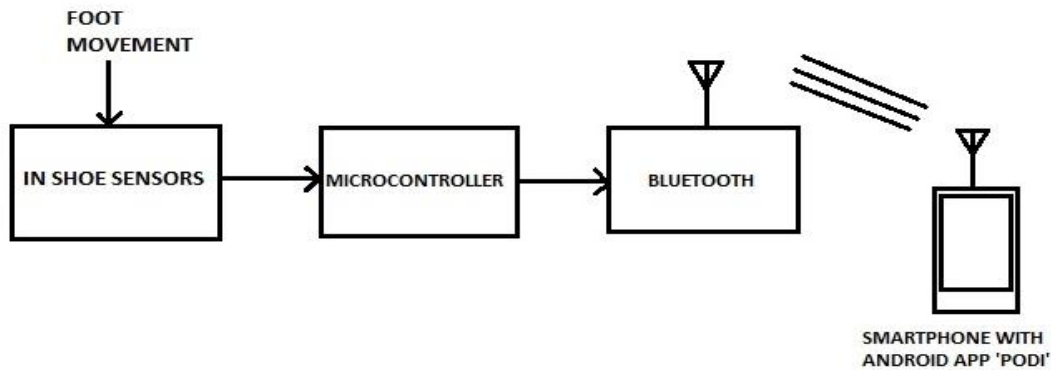


Figure 13 Block diagram of the foot pressure mapping technology

The loss of protective sensation (LOPS) from peripheral neuropathy leads to silent injury from biomechanical stresses when higher pressures are present. Effective pressure reduction strategies are effective in healing and preventing foot wounds. If this condition worsens, it will lead to a condition called gangrene in diabetics and the infected area must be amputated. [15] Figure 11 shows foot ulcers. Figure 12 shows part of a foot amputated due to gangrene.

the same application because of the varying foot sizes of people. The subject, by wearing the shoe with sensor can continue the daily routine activities.

IV. METHODOLOGY

A. Block diagram

Figure 13 shows the block diagram of the foot pressure mapping technology. We make use of a sensor that is thin, flexible and which can be cut into any shape depending on the size of the foot and can be placed in shoes. Figure 14 shows the in-foot sensor. Figure 15 shows how the sensor can be cut to fit inside the shoe of a specific person thereby eliminating the use of different sized sensors for

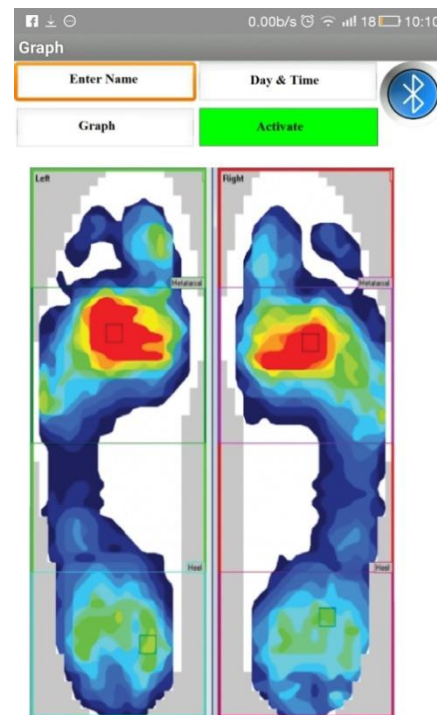


Figure 16 Screen shot of the Android application 'Podi'

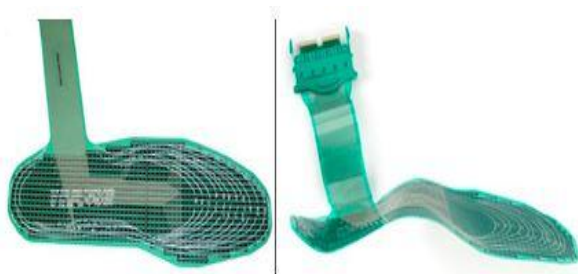


Figure 14 In-shoe sensor



Figure 15 Sensor being cut according to requirement

The input to the pressure sensor is the pressure applied on it by the foot of the subject which is continuously processed by the microcontroller and sent to the Smartphone via a Bluetooth device for the monitoring of gait. Wireless data transmission eliminates the hindrance caused due to long wires and Smartphone interface helps the subject for user friendly, self analysis and anytime-anywhere analysis of foot movement. In fact these gait patterns can be monitored in real time and can also be stored in the SD card for comparing results before and after treatment. We have developed an android application which displays graphical and pictorial data of the feet in real time. Also points of highest pressure are indicated in a square box. The regions are color coded. Red indicates highest pressure; blue indicates lower pressure and white

indicates no pressure. Figure 16 shows the screen shot of the android application ‘Podi’ developed by us. Figure 17 shows color coding pattern of foot pressure.

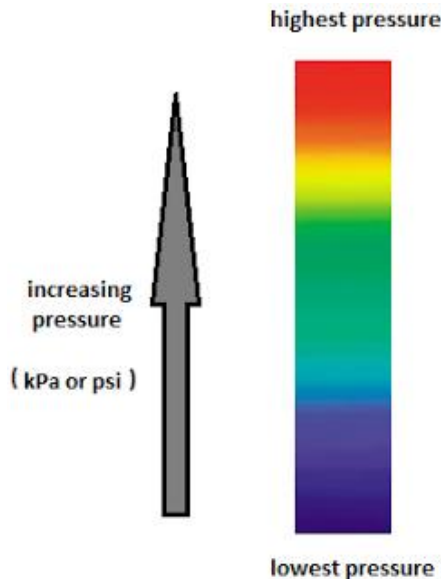


Figure 17 Color coding pattern of foot pressure

B. Design and Working

The pressure applied by the foot on the in-shoe sensors is the input parameter in our system. We use in-shoe sensors which are thin, flexible, light weight and fit-all size. The in-shoe sensor which is as shown in the figure 14 and figure 15 shows how it can be cut to fit all shoe size. The input pressure is fed to the microcontroller for processing. The processor output is sent to the Smartphone wirelessly through Bluetooth. Here, we have used HC-05 Bluetooth module which has a decent transmission range of 30 feet. [16] An android application named ‘podi’ is installed in the Smartphone which is responsible for displaying pressures of the foot in the form of graphics. The pressure on each point of the foot is measured in kPa or N/m² or Psi according to convenience. The color coding of pressure on the foot is as shown in figure 16 and figure 17 respectively. The sensors used are capable of sensing real time gait and foot pressures and our application installed in the Smartphone can be modified to suit any unit of measurement. Also a graph of force/kilogram vs. time is plotted and peak values of the pressure of both feet can be measured and recorded simultaneously. A provision is made to enter the patient’s name, weight, date and time. There is a stop and activate button to start displaying or recording the same. This application is developed in such a way that the recording can be done in real-time even when the application is running in the background and regular alerts are obtained. By this a person need not keep the Smartphone in unlocked state always, and can record the values when the mobile screen is locked. The frame-by-frame monitoring of both the feet is as shown in figure 18, figure 20, figure 22, figure 24 and figure 26. Figure 19, figure 21, figure 23, figure 25 and figure 27 show their corresponding Force vs. Time graphs.

V. RESULTS

Table 1 shows the comparison between our system and the present foot pressure monitoring system used by pediatricians at hospitals. Figure 28 shows the parts of the foot bottom and Figure 29 shows the most common cause of pain on the bottom of the foot. Locate the number close to where the pain is occurring to know the following conditions.

- Bursitis- A sac filled with fluid that initially acts to protect an area but becomes inflamed.
- Capsulitis- Inflammation of a ligament attaching two bones together.
- Metatarsalgia- Pain directly under the ball of the foot due to irritation of the bone.
- Morton’s Neuroma- Irritation of a nerve passing between metatarsal bones.
- Plantar Fasciitis- Inflammation of the long ligament on the bottom of the foot.
- Turf Toe- Usually an athletic injury similar to Capsulitis occurring on the big toe.
- Sesamoiditis- Inflammation of one of two small bones just behind the big toe.

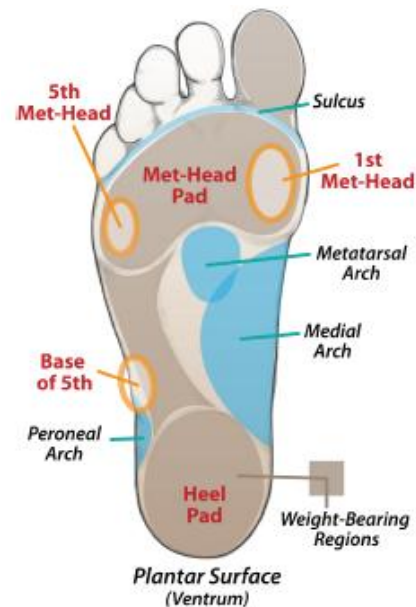


Figure 28 Parts of the foot bottom



Figure 29 most common cause of pain on the bottom of the foot

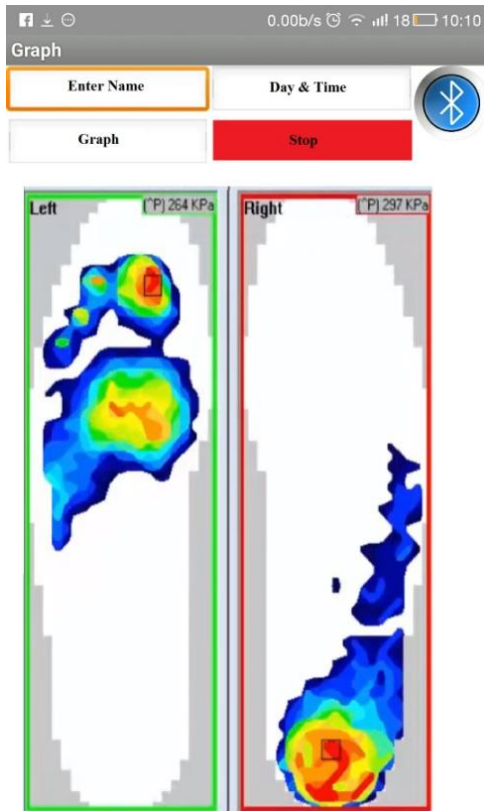


Figure 18 Pictorial representations (frame 1)

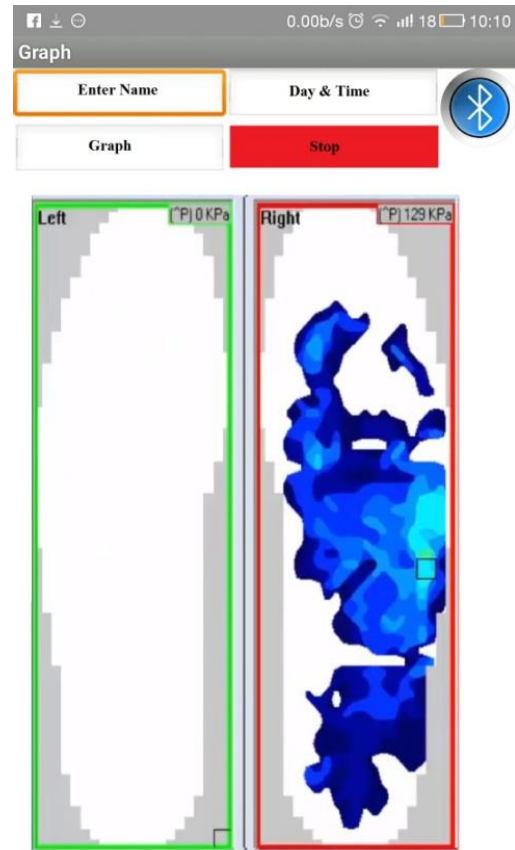


Figure 20 Pictorial representations (frame 2)

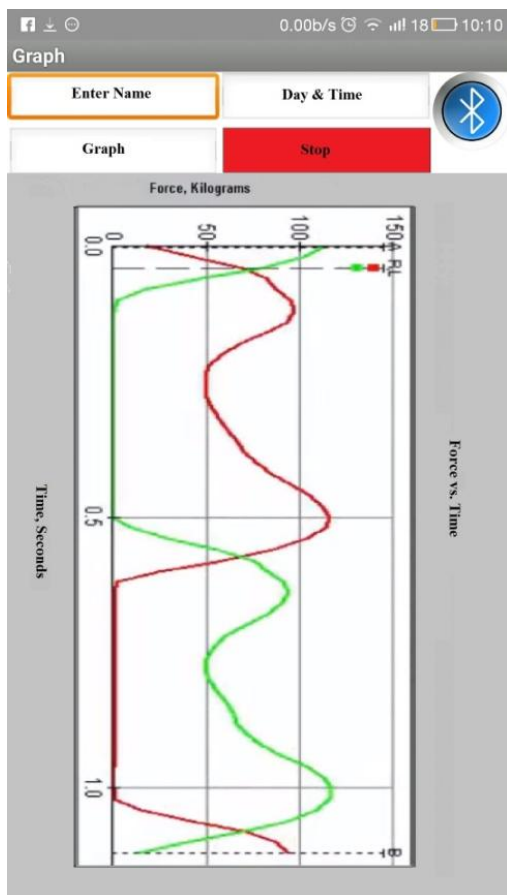


Figure 19 Force vs. Time graph (frame 1)

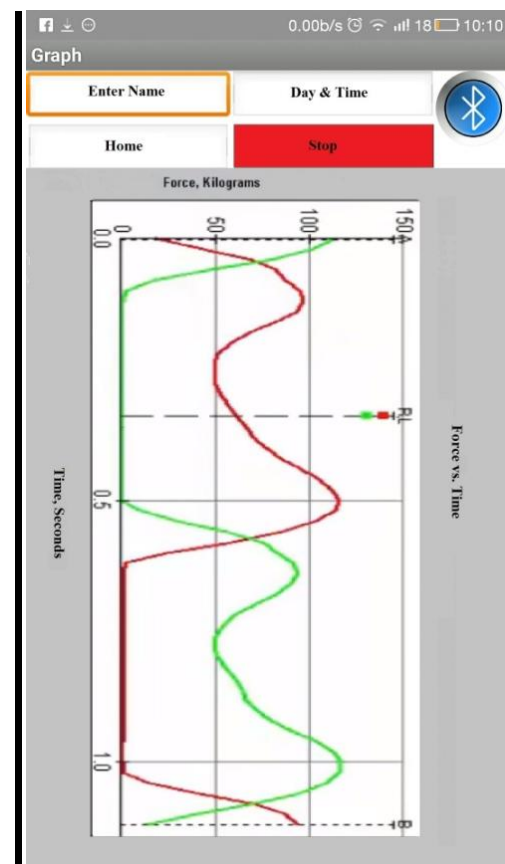


Figure 21 Force vs. Time graph (frame 2)

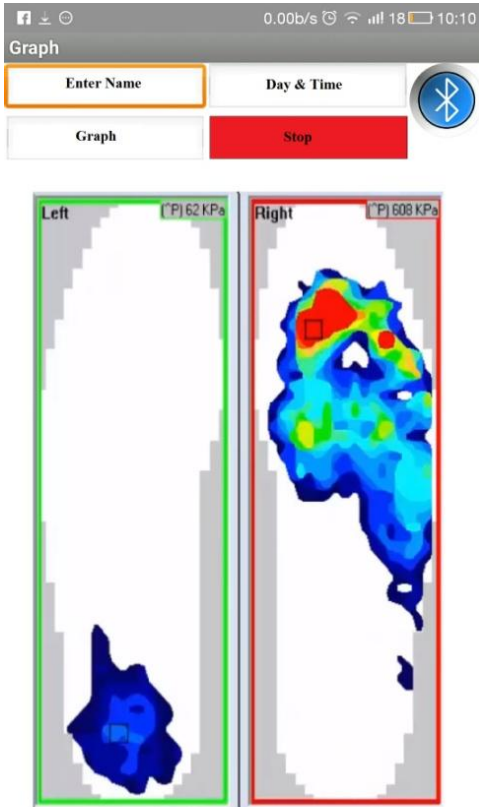


Figure 22 Pictorial representations (frame 3)

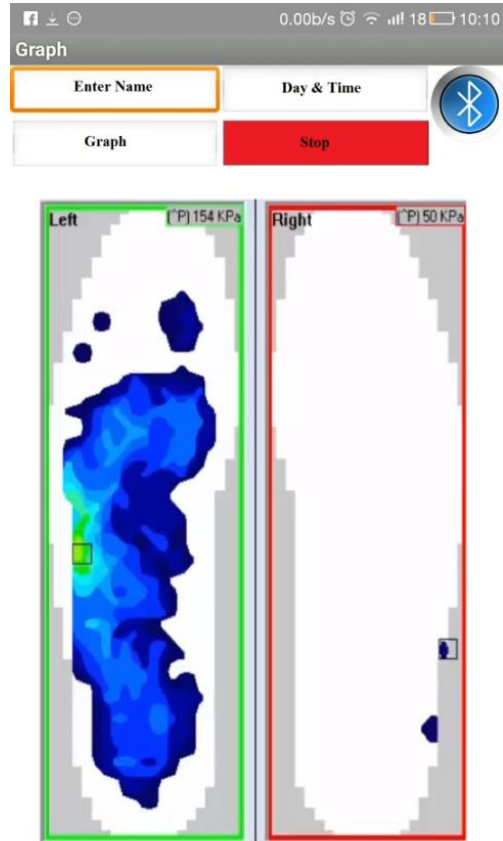


Figure 24 Pictorial representations (frame 4)

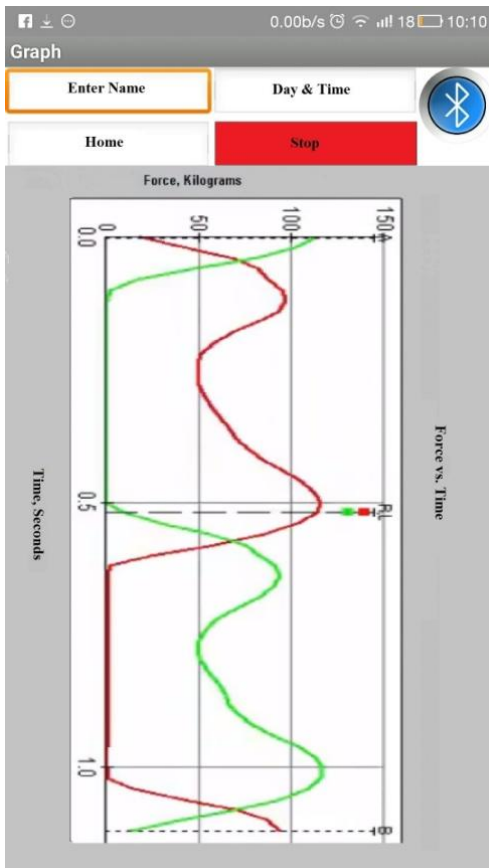


Figure 23 Force vs. Time graph (frame 3)

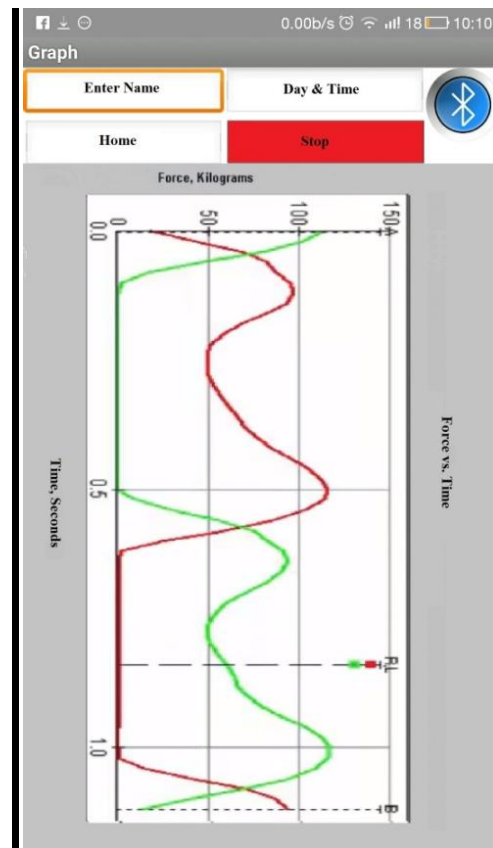


Figure 25 Force vs. Time graph (frame 4)

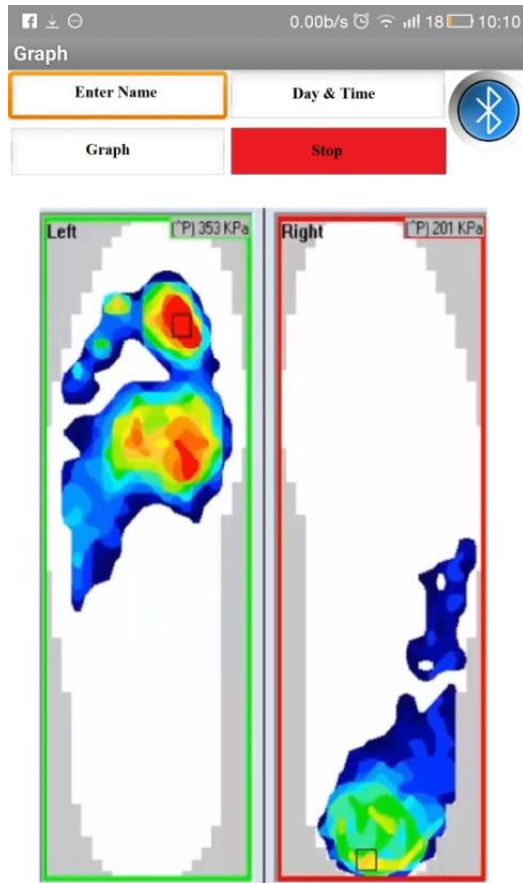


Figure 26 Pictorial representations (frame 5)

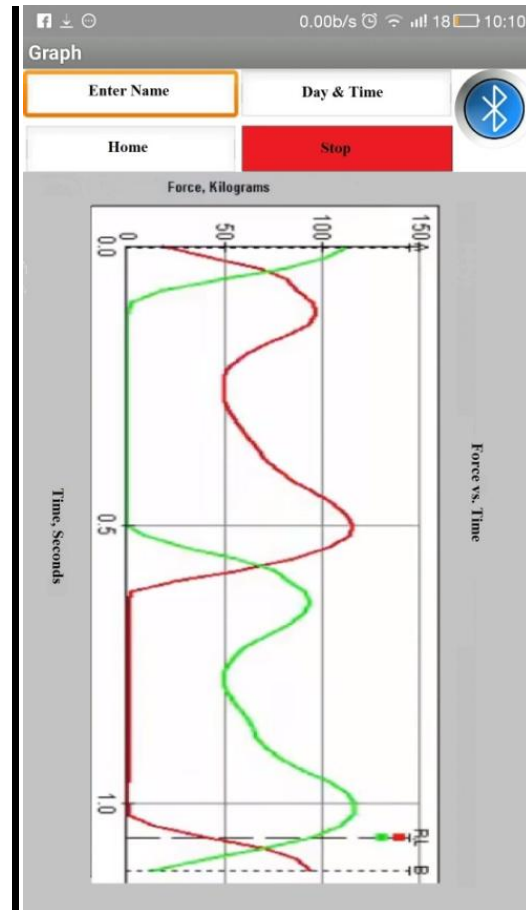


Figure 27 Force vs. Time graph (frame 5)

Publication: The Times Of India Delhi; Date: Jun 27, 2011; Section: Editorial; Page: 16;

‘In most hospitals, there’s no separate department for podiatry’

The Special Olympics currently under way in Athens might bring to the world’s attention a branch of medicine few know about: podiatry or the study of diseases of the foot and ankle. Dr Govind Singh Bisht, consultant podiatrist at Max Hospitals, is an expert and clinical director of ‘Fit Feet’ at the Special Olympics. He spoke to Shobha John:

■ Why is foot care so important for special children?

They are often neglected, not just by society, but by their families too. They have many requirements, be it the eyes, ears, feet, teeth or diet. While the Special Olympics was started in 1968, screenings for these children began in 1993. Foot screenings began only in 2003. These children have many foot-related problems – stiffness, flattening or collapse of the foot arch, fungus infection of the nails, etc.

■ Why is podiatry so important for diabetic patients?

Most diabetics have foot-related problems. In fact, it’s one of the commonest causes of hospital admission for them. India has some 50.8 million diabetics, out of which 40,000 amputations take place annually. But it needn’t be so – 50% of them can be avoided with good foot care. Diabetes affects the nerves of the foot, reducing blood supply.

Q&A This can lead to loss of sensation and greater risk of injury. Even a small injury can lead to a non-healing ulcer, gangrene and then, amputation. This can become a major financial and psychological burden. Unfortunately, there is a lot of ignorance even among medical practitioners regarding diabetic foot care. For most diabetologists, this is not their area of specialisation and



most don’t even see the foot of the patient. In a survey based on a camp conducted by the Delhi Diabetes Centre, 1,500 respondents were asked how many times their doctor had examined their feet in the last one year. Shockingly, 59% said not even once, 23% said sometimes and only 18% said during every visit. Most doctors don’t have the patience to take care of an

ulcer that takes a long time to heal and is messy.

■ What advice would you give to diabetics about foot care?

Selecting the right footwear can make all the difference to a diabetic non-healing ulcer, so make sure you are wearing the right type of shoe. Sometimes, slippers just don’t work if there’s an ulcer on the foot. Shoe bites can also cause ulcers. So buy shoes with extra width and depth, good cushioning and shock absorption. This can help in grip and balance. Also, buy footwear in the latter half of the day as that’s when swelling in the feet is more likely.

■ How often should a diabetic see a podiatrist?

If there are ulcers, it could be on a daily or weekly basis.

■ What are the common causes of ulcers among diabetics?

Corns, calluses, wrong footwear, injury from heating pads, skin infections, dry and cracked skin.

■ Is podiatry a branch of medicine in medical colleges?

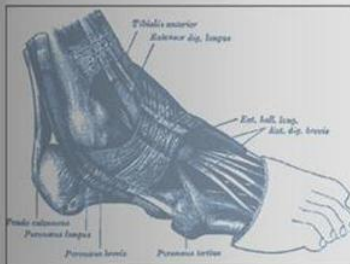
Sadly, it isn’t. Most podiatrists finish MBBS and then do a fellowship in podiatry abroad. I did it from Boston, for example. A comprehensive diabetic programme should be introduced in medical colleges. What’s worse is that in most hospitals in India, there is no separate department for podiatry. So, diabetics are often left floundering, going to orthopaedics or skin doctors in their attempt to heal their ulcers. Sometimes, it can take years for ulcers to heal. However, good skin dressings in the market help in healing them and protect the wound against bacterial and other contamination.

Figure 30 “In most hospitals, there’s no separate department for podiatry” (Publication: The Times of India Delhi; Date 27th June, 2011)



By Dr. Amandeep K. Randhawa

Your feet are complex structures responsible for



carrying your entire body weight and allowing you to move from one place to the next. Even though walking seems simple, the mechanics are very

types of foot problems. We will cover a few of them today: **PLANTAR FASCITIS:** A fancy word for heel pain,

Focus On Your Feet

complicated and it is no surprise that many of us suffer from foot pains and deformities. A root cause of many problems is something called pronation. When our foot hits the ground it should hit at a certain angle, and when that angle is increased we have a situation called "excessive pronation". With excessive pronation our weight is distributed in a less than ideal fashion over our bones and joints. This can result in many

plantar fasciitis is caused by excessive inflammation in our heel and arch. A common symptom is extreme pain with your first step in the morning, which gets better as the day goes on. **HAMMERTOES:** Muscle imbalances in the foot may tighten ligaments around the toe joints causing them to contract in a claw like position. This can lead to painful corns and calluses. **BUNIONS AND TAILORS BUNIONS:** Misaligned first and fifth toe joints that move out of place, causing a bony bump to grow on the side of your foot which can be painful and make shoes fit poorly. **NEUROMA:** Abnormal function of the foot can cause the many nerves in your feet to become irritated and enlarged leading to numbness, tingling and pain. Usually you feel this between and just below your toes. It often feels like there is a rock in your shoes! **CALLUSES:** Another word for a sort of thickening of the skin, calluses develop when the pressure we put on our feet is uneven in nature.

Podiatric physicians, the authority on diagnosing and treating issues related to the foot and ankle, often prescribe functional foot orthosis, also known as orthotics. These are a prescription in-sert for your shoes, and are designed to maintain the foot in the most effective position at all times, thus addressing alignment problems caused by excessive pronation. A prescription orthotic helps prevent the above mentioned problems from occurring, or if already

present, getting worse, by reducing the abnormal forces on the feet.

To determine if an orthotic can help, a podiatrist will evaluate the positioning and movement of your leg and foot. Once this is done a 3D model of the foot is made and the resultant model of the foot is used, along with a detailed prescription, to have an orthotic made to specifically address all areas of concern found during the exam.

The advantage of prescription orthotics is they

are custom made to fit your feet and to correct for the specific issues that you are experiencing. There are many "one size fits all" foot inserts that are seen in stores, however these devices can potentially create more problems, as they are not designed specifically for your feet.

So, if you have painful feet, call your local podiatrist today!

(For more information on this subject visit www.MetroVancouverPodiatry.com)

To make an appointment with Dr. Randhawa please call: 778-775-4566 or visit www.MetroVancouverPodiatry.com

Figure 31 "Focus on your feet" (Publication: Indo-Canadian Voice; Date: 26th January, 2013)

Table 1 Comparison between our system and the present foot pressure monitoring system used by pediatricians at hospital

Parameter being compared	Traditional Podiatry	On-the-go Pressure Mapping
Sensor used	Floor mat type sensors	In-shoe sensors
Fitting	General mat sensor with some dimensions	Sensor can be cut into any shape to fit inside any shoe size
Monitoring	1. Wired 2. PC or Laptop 3. In confined space 4. Self monitoring not possible	1. Wireless 2. Smartphones 3. Can be used on the go (Mobile) 4. Self monitoring is able
User-friendly	No	Yes
Anytime monitoring	No	Yes

VI. CONCLUSIONS

The paper and the system built would bring about a drastic change in the field of podiatry. With this any subject will be able to analyze his or her gait on-the-go: whether he or she is exerting right amount of pressure on the foot. Also, monitoring lower part of the body can be achieved post injury or post surgery. It would be a boon to diabetic patients to monitor their foot frequently.

Athletics is an area where the system would be bang-on. Figure 30 and figure 31 show two news paper articles which tell us why podiatry is important and why we have to focus on our feet. [17] We the researchers at Konigtronics have put in a lot of time and effort into this

work, which emphasizes on the importance of podiatry in day to day human activities. This is because the entire body weight is concentrated on the foot and the foot is the one which bears the maximum load and stress in the body.

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