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Detection of The Lower Limb Asymmetries and Discomfort Considering Foot Pressure as an Attribute

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Abstract - A greater number of diseases and chronic conditions are making their presence since more than a decade. It has really taken its toll during the COVID-19 period. Our concern is totally the lower part of our body which includes the hip portion along with upper thigh, knees, lower limbs and ankles. Some diseases which we have surveyed has been taking place as such are Achilles's tendonitis, arthritis in the ankle or ankles, bunions, hammertoes, plantar pressure diseases, et cetera. There are also a lot of conditions associated with lower limb muscles such as irregular muscle toning, muscle stressing, fatigue, et cetera which takes place in individuals of almost all kinds of ages. In order to nullify these conditions, we have decided to concentrate on various foot pressure points in our body. We will be analyzing the positions and intensity of these pressure points and conclude our experiment by chalking out a graphical representation of all the data accumulated with the help of certain equipment. We will be asking the subject by giving instructions to place his or her feet on the multiple sensors insole normally (with no extra pressure from the subject's side). Each sole sensor will send analog input data as the values of the applied foot pressure. Voltage outputs are collected from each input sensor. We will then compare the different output from different sensors with predetermined standard data (collecting from those who have normal Body Mass Index range). The comparative graph of the current subject and the standard data will then be able to help us to analyze where the disease condition is taking place.

Key Words: Foot pathology, foot pressure points, lower-limb asymmetry, sole sensor, body mass index range.

1. INTRODUCTION

The activity of running or walking by any normal human is the ability to move with the support of the two legs that is placed alternatingly to provide both support and propulsion.

We can also say that the ultimate segment of the body that provides support to the human during the gravitational and inertial loads are the feet. It is obvious that our locomotion is affected by the body weight that our foot bears. How the forces move from heel to mid stance to push off regions are of great significance. Human gait is the systematic study of their locomotion where the legs swing forward. The orientation and the activity of the foot during gait analysis is mostly used for the estimation of magnitude of forces acting thereby, timing of motor unit function, any walking abnormalities for pre-surgical assessment or treatment follow ups. In order to understand an abnormal gait, it is necessary to study the norm Pressure measurement is already used in a variety of situations. It provides information about gait mechanics and has a wide range of applications, i.e., in clinical situations and in sports. [1,2]. For this work, it is important to get the understanding about weight distribution. Real time visualization of pressure mapping is also incorporated because it makes it much easier to understand your data gait and process the information. Flat feet are also a cause which needs to be looked at. Almost a very low arch or no arch is visible for the people with flat feet which implies that their feet is prone to be flat on the ground. There are 33 joints in a human foot that keeps holding 26 different bones together and also has over 100 muscles, tendons, and ligaments. The arches act as a spring to the step and help to evenly divide the body weight across the feet and legs. By the structure of the arches, one can determine how a person walk. For adaptability to stress and a variety of surfaces, the arches have to be sturdy and flexible as well.

The fundamental elements of gait cycle are stance and swing phases. Out of the total gait cycle, the stance phase accounts for 60% and the swing phase comprises of the remaining 40%. In the stance phase, the foot is mostly in contact with the

ground and bears the full weight of the body. The swing phase begins at the toe off of the foot. In swing phase, the foot is off the ground and keeps swinging forward so as to begin the next stance. In the meantime, body weight is transferred to the other foot (Figure 1) [1,2].

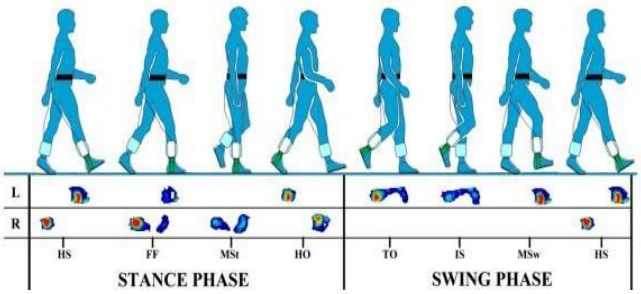


Fig -1: Gait Cycle

An example of in-shoe plantar pressure measurement during the major phases and events of a full gait cycle (right heel strike to right heel strike). HS = heel strike, FF = foot flat, MSt= midstance, HO = heel off, TO = toe off, IS = initial swing, MSw = midswing. [1,2].

There have been substantial advancements in foot pressure measurement over the recent decades and which are not so cost effective. Both qualitative and quantitative analysis of the pressure generated by the feet during the span of locomotion influence the development of the measurement technology for the same. [4,5]. Information from these measurements acquired after interpretation of gait data analysis has provided prime support in the understanding and assessment of various foot pathologies and disease as well. [6-10].

There are various diseases that are related to different chronic conditions effecting almost every individual in several ways. The way this pressure is distributed has impacted lots and this thing needs to be looked at in every possible way. (Figure 2) [11]. By pressing the various pressure points and working on them gently, reflexologists believe that it will kick start the body's natural healing powers. [12-14]

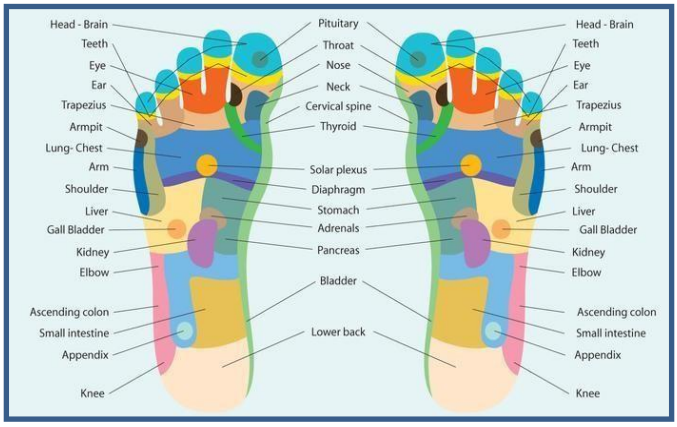


Fig -2: Foot Reflexology

Chart showing the distribution of different pressure points corresponding to different organs of the body. [11]

When the people with flat feet are standing and walking, their feet may roll to the inner side. This is commonly called as over pronation which may also cause the feet to point outward. By a person's WHR (waist-to-hip ratio), we can compare the size of their waist with that of their hips. A high WHR suggests that an individual has higher levels of visceral fat, the fat in the abdominal cavity covering major organs. [15-19]

Studies reflect that people with a high WHR are prone to CVD and diabetes. Greater Risk is for the people with higher the waist measurement in proportion as compared to the hips. Because of this, the WHR is considered as a useful tool for calculating whether a person has a moderate weight and size. Foot pressure point distribution in the whole body is governed by the person's body weight

Maintaining of the bone mass and strength is controlled by the weight-dependent loading of the skeleton. Physical attributes and physiological functions vary among each bones and also among skeletal compartments lying within a bone. Bone imparts a stiff structure essential for locomotion, behaves as a physical barrier for protection of vital organs, ensures a hospitable environment for hematopoietic cell maturation. It is also an important adipose tissue depot, considered as an endocrine organ. It also acts as a dependable and rapidly mobilizable reservoir for calcium and other essential minerals. Bone weight and mass is also responsible indirectly in contributing to body weight hence resulting in various pressure distributions throughout the foot. These were the causes responsible for foot pressure distribution. [20-24]

Surveying various chronic diseases and abnormalities, particularly affecting the lower limbs of our body in teenagers as well as adults and geriatrics, we have given our thoughts solely to the foot pressure points. We noticed while researching online that over 25-30 diseased conditions are caused due to our body weight and on how much pressure we are putting on our foot.

We will be looking into different foot pressure points as well as their positioning that are responsible for various ill-conditions today, on a visual output processing way. We will be testing our kit by taking the data from the consenting volunteers who are teenagers aging from 13-18 years as well as some adults aging from 18-27 years.

We will be using various pressure sensors for determining the intensity of the foot pressure points and then taking all the data, plotting on a graph and analyzing to get to the underlying condition. [24,25]

2. METHODOLOGY

For designing the prototype, the following block diagram is followed. Next to it, the images represents the kit developed by us.

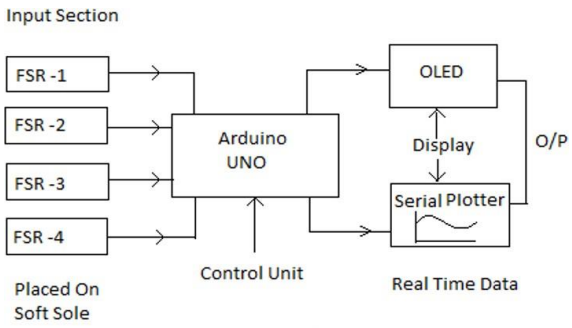


Fig -3: Block Diagram for the unit to be developed

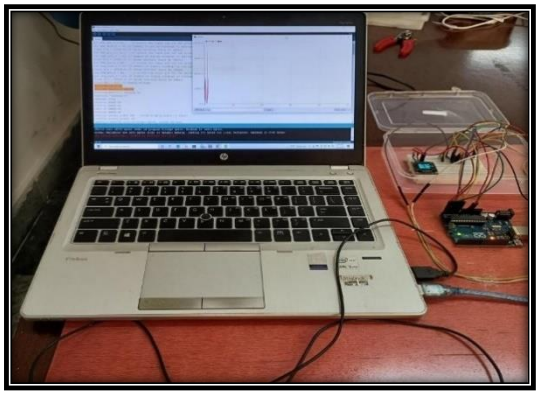


Fig -4a: Partial Set Up

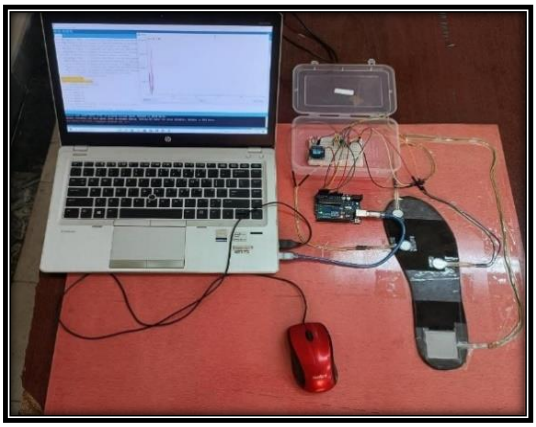


Fig -4b: Complete Unit

A subject is given instruction to put his/her feet on the sole consisting of multiple sensors, no need to apply extra pressure from his/her side. Data Capturing from different subjects is shown in Figure 5. Sensor location allocation is done as per the chart given in table 1.

Each sensor (FSR/ photo resistor) of the sole sends analog input data as the values of applied force (from subject). Then the resistance outputs are collected from each input of the sensors processed by the microcontroller (Arduino Uno / Nano) wrt to 5Volt. The block diagram is depicted in Figure 3. Figure 4a and Figure 4b represents our actual set up during the work. Very small deformation of inductance in each sensor will provide different outputs resistance, and it is reflected from the procedures. Different outputs from different sensors are compared with the predetermined standard data (collected from those who have normal Body Mass index- mainly we are focusing on the age group of 20-30 years). The outputs from the standard data and the outputs of recent subject's data will differ at some points, it will show the huge pressure differences for those who aren't in the normal BMI range. The comparative graph of current subject and the standard data helps us to analysis actually where the deviance will occur.

Fig -5: Data Capturing

The protocol for sensor placement while capturing the data from the subjects

FSR Sensors no.	Different portion of foot (insole attachment)
FSR1	Toe, Hallux
FSR2	Metatarsal
FSR3	Metatarsal
FSR4	Lateral and Medial Calcaneus

Table 1): Sensor location identification

Associated disabilities with those points

Feet points	Related Disabilities (pre-diagnosis)
FSR-1	Morton's Neuroma, Sesamoiditis, Gout, Big Toe, Bunions etc.
FSR-2&3	Metatarsalgia (major inflammatory condition in the ball of foot),flat feet.
FSR-4	Heel pad Syndrome, Plantar Fasciitis(Athletes, teachers & waitresses),calcaneal spur (bony outgrowth forms on the heel bone) etc.

Table 2): Disabilities related to feet points

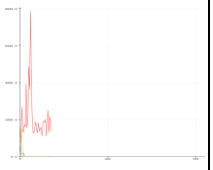
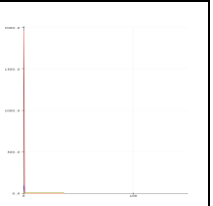
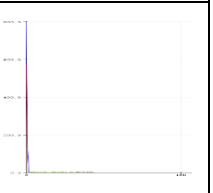
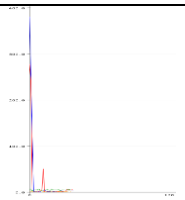
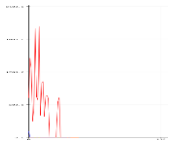
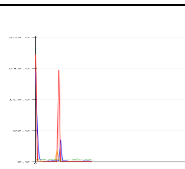
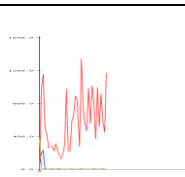
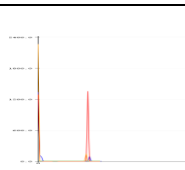
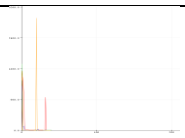
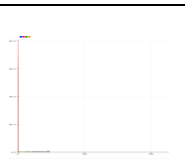
Different pressure point related diseases that are shown in table 2 are described below:

- Morton's neuroma is a painful condition affecting the ball of foot. Area between the third and fourth toes is the most common place. Person suffering from Morton's neuroma may feel as they are standing on a pebble in shoe or on a fold in socks.
- Sesamoiditis is another disease where there is inflammation of the sesamoid bones in the ball of the foot and the tendons they are embedded in.
- Gout is another common and complex form of arthritis that can disturb any person.
- Metatarsalgia is that specific clinical condition in which the ball of foot has pain and are inflamed. People deeply and actively involved in running, jumping might develop this.
- Plantar fasciitis is a typical condition causing pain in the bottom of the heel. Damage or Tear in the ligaments are majorly due to the too much pressure on feet. The plantar fascia gets inflamed, and the inflammation leads heel pain and stiffness.

3.RESULTS AND DISCULLSION

Observation Made on Nature of Deformation

After developing the kit, data was taken from various male subjects in the age group of 20-30years and the corresponding graphs were studied

Sub-ject	AGE (Yr)	WT (kg)	FSR1 (ohm)	FSR2 (ohm)	FSR3 (ohm)	FSR4 (ohm)	Graphical view
S1	23	79	20.33	0.85	4.63	1.05	
S2	24	55	1.18	0.27	4.64	0.57	
S3	29	55	1.63	0.33	4.73	0.90	
S4	21	65	2.72	0.78	3.61	1.09	
S5	32	97	17.85	2.56	5.36	0.85	
S6	21	74	2.32	0.36	6.24	1.75	
S7	23	85	3.42	217.05	4.70	2.36	
S8	21	67	2.62	0.26	4.68	1.02	
S9	21	66	1.87	0.88	4.54	0.53	
S10	22	78	1.64	0.38	4.62	0.58	

Our research focuses on detecting of the lower limb asymmetries of the human body with the help of foot pressure points as the main parameter. The feet are flexible structures of bones, muscles, and soft tissues that let us stand upright and perform activities like walking, running, and jumping.

The forefoot contains the five toes (phalanges) and the five longer bones (metatarsals). The mid foot is a pyramid-like collection of bones that form the arches of the feet. These include the three cuneiform bones, the cuboid bone, and the navicular bone. The hind foot forms the heel and ankle. The talus bone supports the leg bones (tibia and fibula), forming the ankle. The calcaneus (heel bone) is the largest bone in the foot. Muscles, tendons, and ligaments run along the surfaces of the feet, allowing the complex movements needed for motion and balance. Almost all the organs in our body are connected to our foot via numerous pressure points. These pressure points under certain parameters could cause several kinds of diseases and chronic conditions in human body. We experimented with people of 20-25 years of age and different weight and got their individual graphical representation of foot pressure points. Here, what we noticed is that the structure of their feet and their weight is playing the key roles. Differently structured feet when placed on the soft insole with force sensitive resistors, we are getting a graph of voltage against resistance.

In the first case, fifth case and seventh case (from the table showed above), the value of the voltage is much higher due to their body weight and their force distribution accordingly. But in all the other cases, we get an almost linear representation of the force distribution.
The seventh case (from the table above) graph is exceptional as we get an overly high FSR2 value. His plantar pressure distribution indicates some problem in his ligament (as we got to know from the subject). Here FSR2 is a small round sensing resistor which provides greater accuracy to the sensing subject. So we could say that due to the subject's body weight and shape of the foot, their pressure is concentrated more on the FSR2 part than the other sensors.
The rest subject's cases show almost linear graphs which indicate that almost equal pressures are sensed by the sensors on the insole.

4. CONCLUSIONS

Our work focuses on detecting of the lower limb asymmetries of the human body with the help of foot pressure points as the main parameter. Flexible structures of bones, muscles, and soft tissues comprise the feet and these feet let us stand upright and carry out activities like walking, running, climbing and jumping. In the forefoot, there are five toes (phalanges) and the five longer bones (metatarsals). The mid foot comprises of a pyramid-like collection of bones forming the arches of the feet. It has the three cuneiform bones, the cuboid bone, and the navicular bone. The hind foot is the area forming the heel and ankle. The talus bone forming the ankle provides the support to the leg bones (tibia and fibula). The largest bone in the foot is the calcaneus (heel bone). The complex movements needed for motion and balance is allowed by the muscles, tendons, and ligaments running along the surfaces of the feet.

Almost all the organs in our body are connected to our foot via numerous pressure points. These pressure points under certain parameters could cause several kinds of diseases and chronic conditions in human body. We experimented with people of 20-25 years of age and different weight and got their individual graphical representation of foot pressure points. Here, what we noticed is that the structure of their feet and their weight is playing the key roles. Differently structured feet when placed on the soft insole with force sensitive resistors, we are getting a graph of voltage against resistance.

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LIST OF ABBREVIATIONS:

FSR: Force Sensing Resistor
WHR: Waist to Hip Ratio
CVD: Cardio Vascular Disease
HS = heel strike,
FF = foot flat,
MSt = midstance,
HO = heel off,
TO = toe off,
IS = initial swing,
MSw = midswing.

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