Low speed walking detection using wearable footstrap

Anitha Govindhan[1],Subiksha Venkat[2],Vigneshvaran B[3],Prithvi Shankar G[4]

Department of Biomedical engineering[1, 2, 3, 4]
SRM institute science and technology, Chennai, India.

Abstract-The average person's physical activity level can be accurately determined using move counting. Slow walking is often done by the elderly and others who have difficulty walking. Accelerometer-based step counters are ineffective at detecting walking steps slower than 2.2km/hr. A wearable foot-strap is built in this proposed study to accurately detect foot step counts. The configuration consists of a total of 6 FSR sensors, two of which are mounted on the shoe insole (toe and heel), and the other two are attached to a specially constructed ankle brace. The actual step count is included in the FSRs at the heel and toe since they hit their maximum capacity when a person stands on them, which decreases as the person starts to walk. As a result, the number of steps taken can be calculated using the time spent on the ground by the heel and foot, as well as the time difference between them and the power of FSRs. Since muscle potential is higher when walking than when resting, the FSR band was also included. As a result, the foot-strap values can be used as a benchmark for further research. When walking and at rest, it can also be used to cross-verify muscle ability. As a consequence, this prototype can help with accurate and precise low-speed phase count calculation.

Keywords – FSR sensor, slow walking, foot strap

I. INTRODUCTION

Walking is one of the most important activities which has been performed in day-to-day life. Walking helps to reduce fat, and also the risk of various diseases. The walking pattern is performed, which has been classified into two phases namely stance and swing phase where various muscles are involved during walking as shown in figure 1. During a stance phase, which is also called as the foot-flat stance, contractions can be felt on the muscle group in the lower extremity to sustain the stance, and to equalise the massof the body applied on the foot; whereas during a swing phase, flexors of the lower extremity are mostly involved.

In the current days, there are several gadgets and similar wearable machines such as pedometers which have been established in such a way that they monitor the walking patterns and other activities and are very easy to buy and access commercially. And as far as the slow steps are concerned, the average of the steps is only shown and not the actual number of steps walked. A lot of research demonstrates that not just the viability of the proposed approach may change but also the potential which is obtained from the muscle using FSR, for monitoring of the analysed technology to monitor better low-speed step counting [1]. Another study demonstrates the stability of FMG signals during the non-stationary tasks and which support the user interface technology by the means of machine learning by implementing proper FMG into the technology interface [2]. The compound of various techniques constitutes that the primary approach towards an ongoing gait assessment system, by the means of the restraint of non-walking influences using fuzzy based algorithm approach.[3].The chance of utilising a force sensing resistor strap for the continuous prognosis of finger actions precisely to those of the thumb, middle and index fingers [4]. A wireless wearable system that consists of four force sensorsfor the development of gait shoe [5].An economical wireless gait analysis sensor which contains a primary inertial measurement unit that was used to gather the gait data for a group of four patients detected with a balanced disorder and also, three normal subjects were considered for performing the dynamic gait index analysis tests individually while wearing a custom wireless gait analysis sensor [6]. Another study looked into the patterns of lower limb of muscular activity during very slow walking speed (< 0.28 m s−1), and to learn about the neuromuscular gain functions that reflects the phase dependent effects of walking speed on electromyography amplitude where only hale and healthy participants were considered [7]. Determination of ground reaction force using KNN algorithm [8]. Various sensors investigated which can be used in muscle activity [9]. Accuracy and precision of FSR sensor in the children with cerebral palsy [10].Detection of muscular activity with respect to speed [11]. This paper researches the gait-phase detection sensor (GPDS) integrated with well-designed electrical stimulation (FES) system for disabled people with a dropped-foot walking dysfunction [12].Speed associated alterations of muscular motion from normal to slow walking [13].This paper provides alternate measure of muscle activity via using FMG [14]. Observation of pelvic floor muscles during varying running speed [15].

In this proposed design, the use of force myography (FMG) is explored as an alternate solution to accelerometer for counting steps. FMG consists of FSRs which record the movements of the limbs while undergoing various muscle activities. These FSRs are used by placing them in the insoles of the shoes so that the gait activities can be monitored by the assessment of foot pressure distribution on the ground even while walking slowly. The contraction and relaxation of the extensors during the flat-foot stance and also the flexors during swing phases would exert various force distributions on the FSR band due to the pressure applied while walking, giving rise to a distinctive FMG pattern. All these approaches differ from each other and none of the approaches were used to record the walking speed (<2.2 km/hr). in this paper we designed the prototype which is used the low walking speed which is below 2.2 km/hr. It can be concluded that the FSRs on the insole of the shoe and the band tied on the ankle along with the EMG senor will help to detect slow walking steps more accurately and precisely.

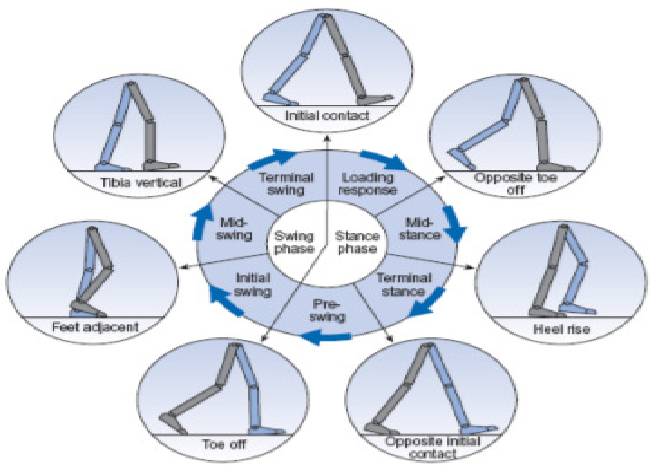

Figure 1. The image depicts the normal walking pattern of a human being

Source: IJCAM MATERIAL (A REVIEW OF GAIT CYCLE AND ITS PARAMETERS)

II. MATERIALS AND METHODS

2.1 Block diagram of proposed study -

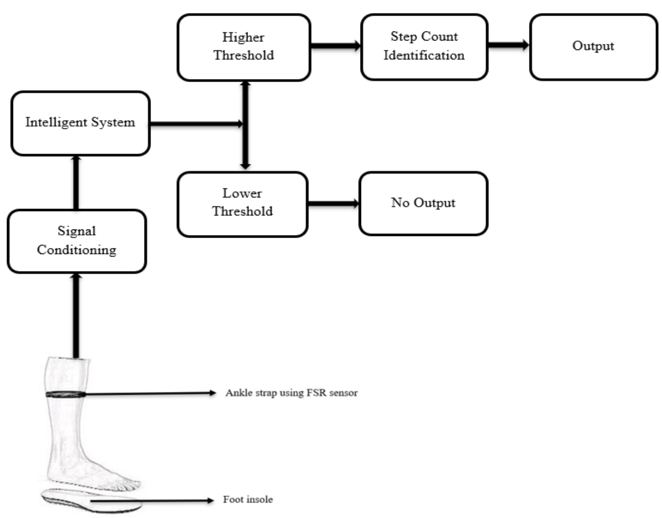

Figure2. Arrangement of components and sequential block diagram

The muscle potential obtained from the calf muscle using ankle strap and from the foot insole causes the change in resistance on the FSR. The change in resistance obtained from each FSR is being transmitted to the intelligent system. The intelligent system in our project is Arduino pro mini which measures the pressure with high threshold value and forwards the unprocessed data to the computer via Bluetooth and it is driven by four 1.5volt battery. The raw data obtained from Bluetooth has been converted to digital signal by programming to obtain the result is displayed on the computer screen in excel format.

III. MATERIALS USED IN PROPOSED STUDY

The FSR sensor allows us to detect physical pressure and squeezing undergoes change in resistance when force is applied. The force sensitivity ranges from less than hundred grams to ten kilograms. The FSR is made up of 2 layers which are separated by a spacer. The FSR used is Inter LINK 402 FSR shown in figure 3. Its diameter is about 18.3 mm. The microcontroller that is used is Arduino pro mini shown in figure 4. It is based on ATmega328.It has 14 digital input/output pins alongwith 6 analog inputs. Each pin can deliver or accept a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 kilo Ohms. The AT mega328 is provided with 32 kB of flash memory for storing code.

Figure3. FSR sensor

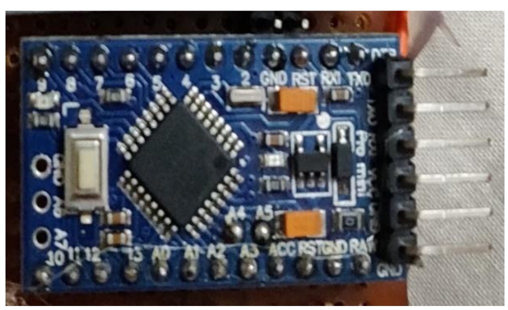

Figure 4.Arduino pro mini

Figure 5. Bluetooth device

HC-05 Bluetooth Module shown in figure 5 is an unchallenging bluetooth SPP module; it is outlined for transparent serial wireless connection. This HC-05 module works on dual operating modes, one is the Data mode in which it can cast and obtain data from other bluetooth devices and the next mode is the AT Command mode where the default device settings can be altered depending upon the requirement. The designed ankle strap which consists offour FSR sensors are stitched on standard Velcro with equal distance in the form a band for placing it in the calf muscles as shown in figure 6. The insole consists oftwo FSRs are stitched in the place of heel and toe of a shoe sole shown in figure 7 for measuring stance phase and swing phase. Python is an expound, and works in the concept of objects data in the form of fields and code, an upraised programming language with complicated semantics. It is convenient to learn the syntax, ithighlights readability and therefore deducts the cost of program maintenance. The latest version of Python used is Python 3.0.

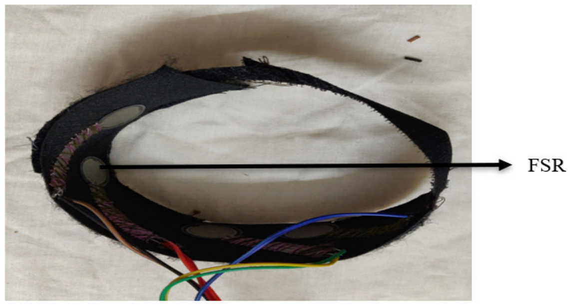

Figure 6. Designed ankle strap

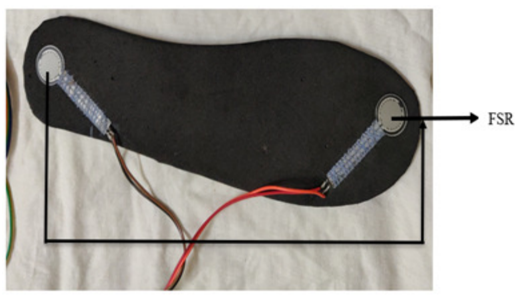

Figure 7. Foot insole

IV. EXPERIMENTAL PROCEDURE

The participant is made to walk slowly wearing the insole and foot strap. The environment is made conducive for the participant to walk properly and without any strain or discomfort. After performing the experiment by all the participants, the values were obtained with the help of Arduino pro mini and the data is transferred via Bluetooth to the system. The raw data obtained from Bluetooth has been converted to digital signal by using python software in order to obtain the results which will be displayed on the computer screen in excel format along with the recording of date and time. Python software used in our project is easy and the syntax is simple to learn and perform coding.

Table -1 Details of participants

Age (years)	Gender (Male : Female) Ratio	Weight (Kg)
55-65	3:2	70 ±3.6

20 Participants (Table 1) belonging to age categories of both the sexes were considered for this project. Participants suffering from various walking disorders were not considered and a written consent stating the same was obtained from each participant before the experiment. Each participant is allowed to walk at slow speed (<2.2Km/hr). The participant is made to walk 9 steps at a slow speed according to their convenience. Two FSR

sensors that are stitched to the insole is placed below the right foot such that the heel and toe of the foot are in contact with the FSRs. The band made out of 4 FSR sensors is tied to the right foot's ankle. The complete designed foot strap is shown in figure 8.

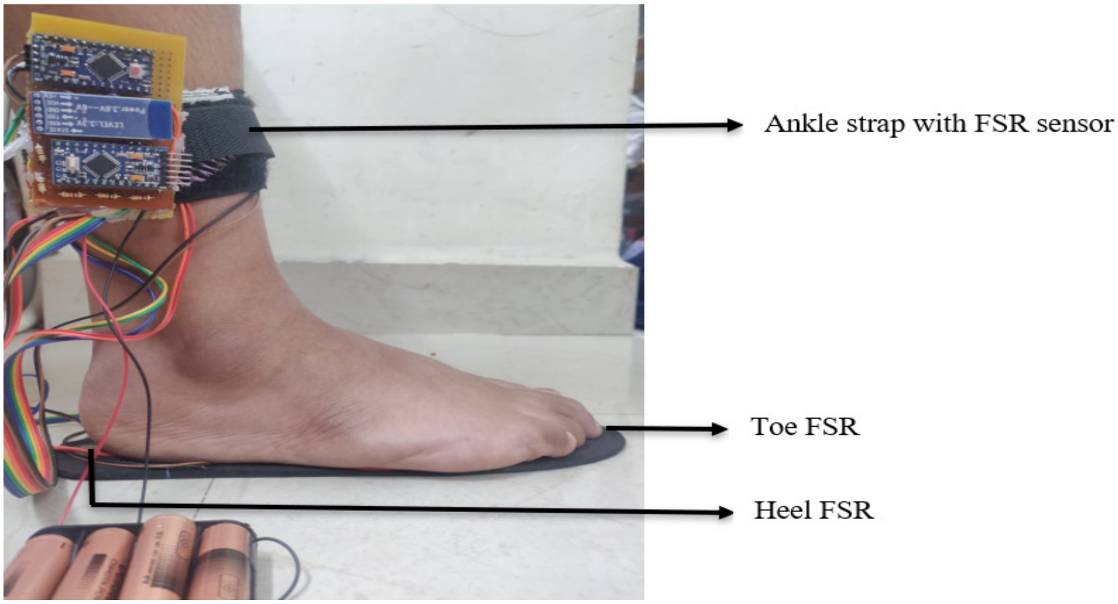

Figure 8. Designed foot strap

V.RESULT AND DISCUSSION

Table -2 Heel Vs FSR

Step count	Time (sec)	Heel (mV)	FSR (mV)
1	0	1.79	0.0875
	0.16	1.53	0.2750
	0.29	1.31	0.2825
	0.43	0.89	0.2800
	0.54	0.97	0.3050
	0.65	1.21	0.2950
	0.83	1.54	0.2100
	0.96	1.83	0.1850
2	1.04	1.85	0.1830
	1.15	1.57	0.2400
	1.27	1.36	0.2850
	1.38	1.11	0.2950
	1.5	0.92	0.3125
	1.63	1.02	0.2823
	1.76	1.28	0.2571
	1.85	1.59	0.2310
	1.98	1.8	0.1810
3	2.02	1.84	0.1860
	2.14	1.69	0.2600
	2.26	1.37	0.2900
	2.39	1	0.3025
	2.53	0.92	0.3200
	2.68	1.12	0.2925

	2.82	1.44	0.2550
	2.95	1.86	0.1825
	3.04	1.89	0.1799
	3.17	1.57	0.2600
	3.33	1.18	0.2800
4	3.42	0.96	0.2975
	3.6	1.07	0.3270
	3.73	1.28	0.2725
	3.81	1.55	0.2275
	3.93	1.83	0.1800
	4.01	1.87	0.1820
	4.13	1.62	0.2525
	4.27	1.29	0.2950
	4.41	1	0.3075
5	4.58	0.8	0.2973
	4.66	1.08	0.2876
	4.73	1.26	0.2715
	4.85	1.57	0.2275
	4.97	1.81	0.1790

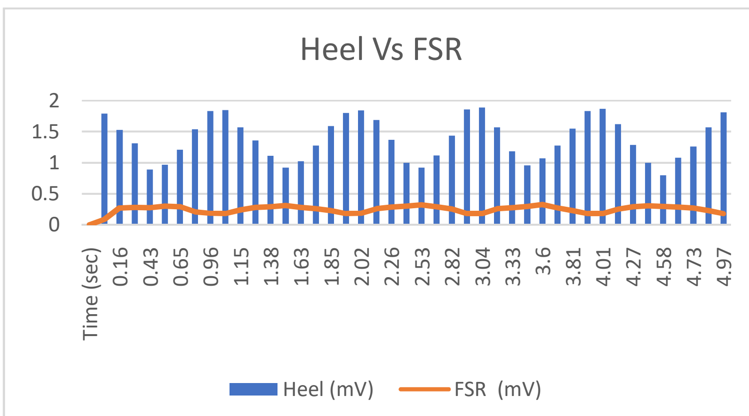

Figure 9. The above graph shows the potential of heel and FSR in millivolts (mV)

From the above tabulation table 2 and its corresponding graph figure 9, it can be understood that when the foot is at the rest position (in contact with the ground), the potential recorded from the heel FSR is maximum and the potential recorded from the FSRs on the foot strap is minimum. When the foot is in motion (during stance and swing phase), the potential recorded from the heel is minimum and the potential recorded from the FSRs is maximum.

Table -3 Toe Vs FSR

Step count	Time (sec)	Toe (mV)	FSR (mV)
	0	1.1	0.0875
	0.16	0.92	0.275
	0.29	0.74	0.2825
1	0.43	0.3	0.28
	0.54	0.44	0.305
	0.65	0.85	0.295
	0.83	0.94	0.21
	0.96	1.15	0.185
	1.04	1.18	0.183

2	1.15	0.98	0.24
	1.27	0.77	0.285
	1.38	0.52	0.295
	1.5	0.33	0.3125
	1.63	0.48	0.2823
	1.76	0.71	0.2571
	1.85	0.96	0.231
	1.98	1.2	0.181
3	2.02	1.19	0.186
	2.14	1.09	0.26
	2.26	0.77	0.29
	2.39	0.46	0.3025
	2.53	0.36	0.32
	2.68	0.53	0.2925
	2.82	0.84	0.255
	2.95	1.16	0.1825
4	3.04	1.21	0.1799
	3.17	0.94	0.26
	3.33	0.61	0.28
	3.42	0.38	0.2975
	3.6	0.46	0.327
	3.73	0.63	0.2725
	3.81	0.93	0.2275
	3.93	1.11	0.18
5	4.01	1.14	0.182
	4.13	1.01	0.2525
	4.27	0.65	0.295
	4.41	0.42	0.3075
	4.58	0.35	0.2973
	4.66	0.47	0.2876
	4.73	0.62	0.2715
	4.85	0.93	0.2275
	4.97	1.13	0.179

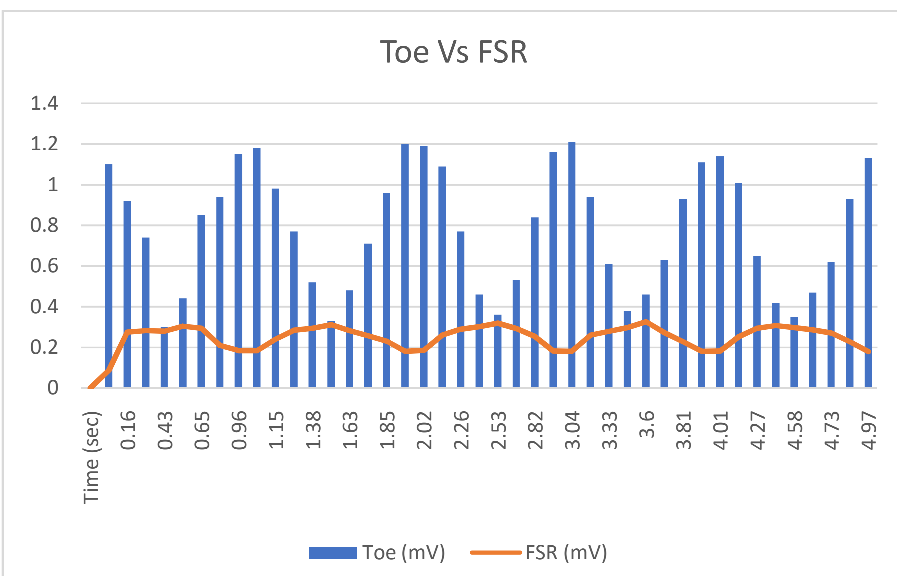

Figure 10. The above graph shows the potential of Toe and FSR in millivolts (mV)

From the above tabulation table3 and its corresponding graph figure 10, it is understood that when the foot is at the rest position, the potential recorded from the toe FSR is maximum and the potential recorded from the FSRs on the footstrap is minimum. When the foot is in motion, the potential recorded from the toe is minimum and the potential recorded from the FSRs is maximum.

Table -4 Heel Vs Toe

Step count	Time (sec)	Heel (mV)	Toe (mV)
1	0	1.79	1.1
	0.16	1.53	0.92
	0.29	1.31	0.74
	0.43	0.89	0.3
	0.54	0.97	0.44
	0.65	1.21	0.85
	0.83	1.54	0.94
	0.96	1.83	1.15
2	1.04	1.85	1.18
	1.15	1.57	0.98
	1.27	1.36	0.77
	1.38	1.11	0.52
	1.5	0.92	0.33
	1.63	1.02	0.48
	1.76	1.28	0.71
	1.85	1.59	0.96
	1.98	1.8	1.2
3	2.02	1.84	1.19
	2.14	1.69	1.09
	2.26	1.37	0.77
	2.39	1	0.46
	2.53	0.92	0.36
	2.68	1.12	0.53
	2.82	1.44	0.84
	2.95	1.86	1.16
4	3.04	1.89	1.21
	3.17	1.57	0.94
	3.33	1.18	0.61
	3.42	0.96	0.38
	3.6	1.07	0.46
	3.73	1.28	0.63
	3.81	1.55	0.93
	3.93	1.83	1.11
5	4.01	1.87	1.14
	4.13	1.62	1.01
	4.27	1.29	0.65
	4.41	1	0.42
	4.58	0.8	0.35
	4.66	1.08	0.47
	4.73	1.26	0.62
	4.85	1.57	0.93
	4.97	1.81	1.13

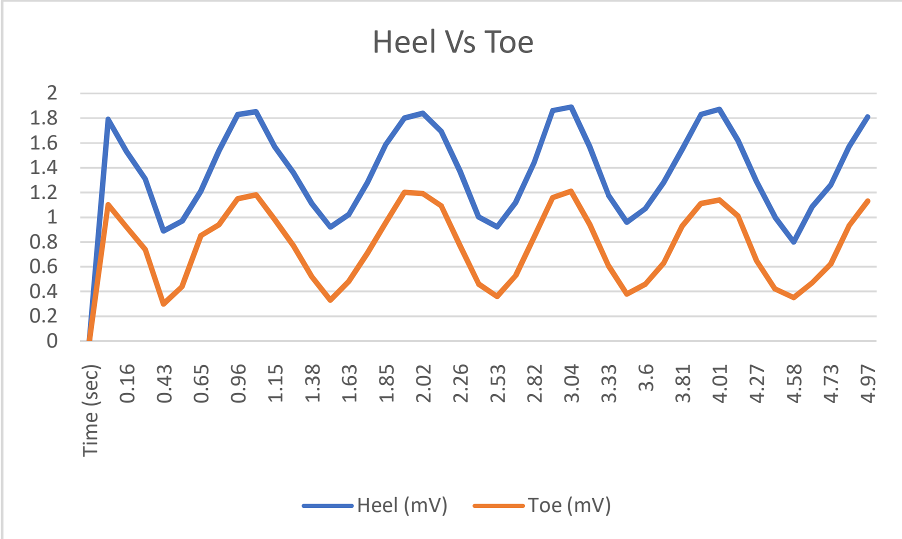

Figure 11. The above shows the potential of heel and toe are is same pattern

From the above tabulation table 4 and its corresponding graph figure 11, it is clearly seen that although the potential of both heel and toe FSRs are maximum when the foot is at rest position and the potentials of heel and toe are minimum when the FSRs are in motion, the potential recorded at the heel is much higher than that of the toe. This means that more pressure is applied to the heel than that of the toe.

Table -5 FSR comparison along with heel and toe

Step count	Time (sec)	Heel (mV)	Toe (mV)	FSR (mV)
1	0	1.79	1.1	0.0875
	0.16	1.53	0.92	0.275
	0.29	1.31	0.74	0.2825
	0.43	0.89	0.3	0.28
	0.54	0.97	0.44	0.305
	0.65	1.21	0.85	0.295
	0.83	1.54	0.94	0.21
	0.96	1.83	1.15	0.185
2	1.04	1.85	1.18	0.183
	1.15	1.57	0.98	0.24
	1.27	1.36	0.77	0.285
	1.38	1.11	0.52	0.295
	1.5	0.92	0.33	0.3125
	1.63	1.02	0.48	0.2823
	1.76	1.28	0.71	0.2571
	1.85	1.59	0.96	0.231
	1.98	1.8	1.2	0.181
3	2.02	1.84	1.19	0.186
	2.14	1.69	1.09	0.26
	2.26	1.37	0.77	0.29
	2.39	1	0.46	0.3025
	2.53	0.92	0.36	0.32
	2.68	1.12	0.53	0.2925
	2.82	1.44	0.84	0.255
	2.95	1.86	1.16	0.1825
	3.04	1.89	1.21	0.1799
	3.17	1.57	0.94	0.26

4	3.33	1.18	0.61	0.28
	3.42	0.96	0.38	0.2975
	3.6	1.07	0.46	0.327
	3.73	1.28	0.63	0.2725
	3.81	1.55	0.93	0.2275
	3.93	1.83	1.11	0.18
5	4.01	1.87	1.14	0.182
	4.13	1.62	1.01	0.2525
	4.27	1.29	0.65	0.295
	4.41	1	0.42	0.3075
	4.58	0.8	0.35	0.2973
	4.66	1.08	0.47	0.2876
	4.73	1.26	0.62	0.2715
	4.85	1.57	0.93	0.2275
	4.97	1.81	1.13	0.179

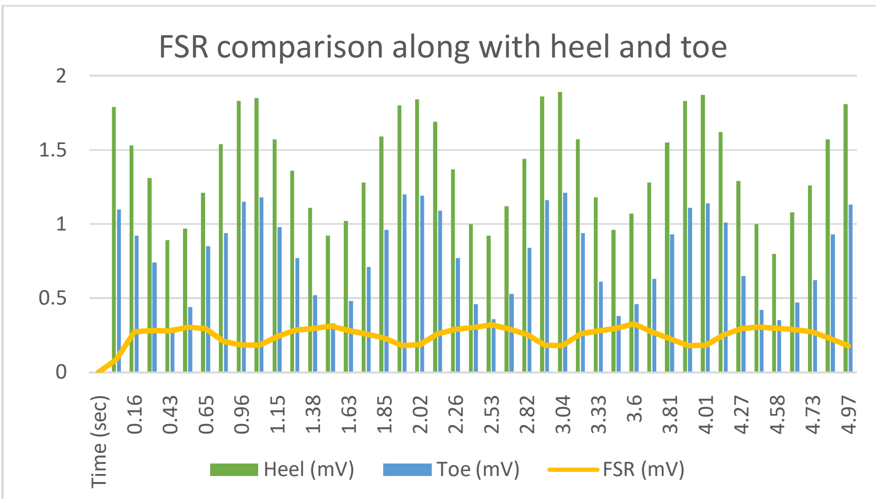

Figure 12. The above graph shows the FSR comparison along with heel and toe

From the above tabulation Table 5 and its corresponding graph figure 12, it can be concluded that maximum potentials were recorded at the heel and toe while minimum potential was recorded from the FSRs when the foot was at rest position. Minimum potentials were recorded from the heel and toe and maximum potential was recorded from the FSRs when the foot was at stance and swing phase (in motion). And also, on comparing the potentials of heel and toe, heel produced higher potential values than toe. From the above drawn conclusions, step count can be measured accurately and precisely even when walked at a very slow speed.

VI.CONCLUSION

In every step count, the maximum values obtained from the heel and toe are considered as the main input giving source. A step can be measured when the potentials of heel and toe are maximum within a stipulated time interval. If the FSR value is greater than 1.5 (average threshold value obtained from various readings), then it can be counted as a step. Also, within a particular interval of time, when the potential values obtained from the heel and toe are less, the potential values obtained from the foot strap is high. Hence, by this manner, the step count has been detected effectively.

VII.FUTURE WORK

This prototype can be used to treat people with neurological disorders. It can also be used to treat people who suffer from motor related problems after getting ethical clearance. For every step that has been detected when an elderly person or a patient walks, a voice notification mentioning each step can be designed and incorporated. The number of steps walked will be viewed on the mobile phone of the individual and a daily activity chart can be provided for the same as a motivating factor rather than incorporating this on a smartwatch since the elderly people might find it difficult to look at. This model can further be modified into a more compact and weight less device by connecting it through wi-fi instead of Bluetooth.

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