

Simple Insole for Dynamic Foot Plantar Measurement in Walking Gait Analysis Using Force Sensitive Resistor

¹Muhammad Abdul Wahid, ²Scharta Saragih, ³Dwi Basuki Wibowo, ⁴Ismoyo Haryanto

^{1,2,3,4}Mechanical Engineering Department, Diponegoro University, Jl. Prof. Sudarto No.13, Tembalang, Semarang, 50275 Indonesia

Abstract - There are 2 types of footprint scanning, namely scanning is not burdened and burdened. The pressure distribution on the soles of the feet depends on many factors such as body mass index (BMI, kg / m²), sex, foot contact area or foot type and daily activities. Measuring the pressure distribution in the soles of the feet is done to help in orthotic shoes for sufferers on the soles of the feet and certain sports shoes. For this purpose, we must know the parts of the foot that receive a large load when walking, running well. The human foot is divided into 3 parts, namely the top, middle and back. The purpose of this study is to improve and conduct testing to study the distribution of the soles of the feet both while walking and then carrying out the validation of the results of the assessment with several studies that have been done by previous researchers. In this study to study the pressure distribution on the feet, the insole has been placed 24 sensors (12 sensors on each foot). Sensor data will approve with microcontroller, and the final results are shown using special software. Tests data were obtained from 10 subjects with foot size 40 and body mass varying. Tests are performed when 1 running cycle consists of 4 phases, namely heel strike, loading response, terminal position, and preswing.

Keywords: Pressure Distribution, FSR, Gait Analysis.

I. INTRODUCTION

There are 2 types of footprint scanning, namely scanning is not burdened (unloaded) and burdened (loaded). An unloaded scan is performed using a 3D scanner that produces the contours of the sole of the foot. This type of scan is intended, among other things, to estimate the deformation of the sole of the foot when standing [1], insole design (shoe insole) with contour shape [2], and evaluating of foot type (flat foot or high arch)[3].

There are 2 types of loaded foot scans, namely scans that are intended only to determine the 2D shape of the soles of the feet and to determine the distribution of pressure on the soles of the feet when standing or walking. The first type of scan, commonly called footprint scanning, is aimed at determining shoe size [4], evaluating the type of foot, estimating the sex

and height of the perpetrator from the footprints left behind, and identifying ancient animal species [5]. Specific-load scanning of the sole of the foot in its two fields of study is called pedobarography. The measuring instrument is usually called a force plate. The results of these pedobarography measurements are very useful to determine the distribution of the load on the sole of the left/right foot in post-amputation diabetic patients, to determine the effect of standing posture on the distribution of the load on the soles of the feet, to determine the type of sole of the foot and its effect on the distribution of the load on the feet. the sole of the foot, to help design orthotic shoes for people with calcaneal spur (growth of a needle in the heel bone) [3], and to determine behavior and performance when walking and running (gait analysis).

This study aims to design simple insole for dynamic foot plantar measurement. Number of sensors, material and methods are adapted from another researcher before. For validation this tool is tested on walking activities.

II. MATERIAL AND METHODS

Device consist of 24 sensor will be place on each insole (12 on left and 12 on right side). Sensor is FSR-400 series are made by Interlink Electronics with 0,46 mm thickness and 12.7 mm diameter of measuring area. It can be sensitive from 100 gram until 10 kg or 1.5–150 psi in pressure. Before use, the sensor is calibrated with a maximum load of 6 kg (6000 grams). This selection is based on the results of previous studies using the same type of sensor. The calibration results can be shown in Table 1.

Table 1: Voltage (V) Measurement result base on load (gram)

Load (gram)	Voltage (Volt)
0	0
100	0.469
200	0.665
400	0.865
500	1.109
800	1.383
1000	1.505
1500	1.737
2000	1.843
2500	1.911
3000	1.955
3500	2.038

4000	2.157
4500	2.258
5000	2.317
5500	2.35
6000	2.39

The relationship between load and voltage measurements can be seen in Figure 1. The results of the validation were carried out using a polynomial approach so that the following results were obtained:

$$L = 927.7757 V^3 - 1643.867 V^2 + 1083.49 V - 31.02378$$

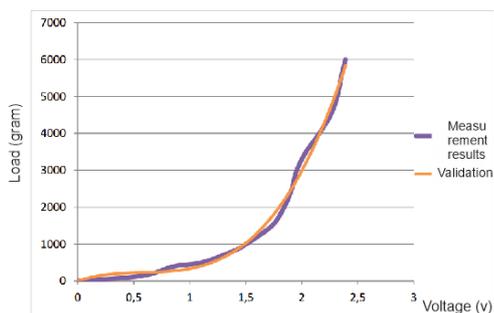
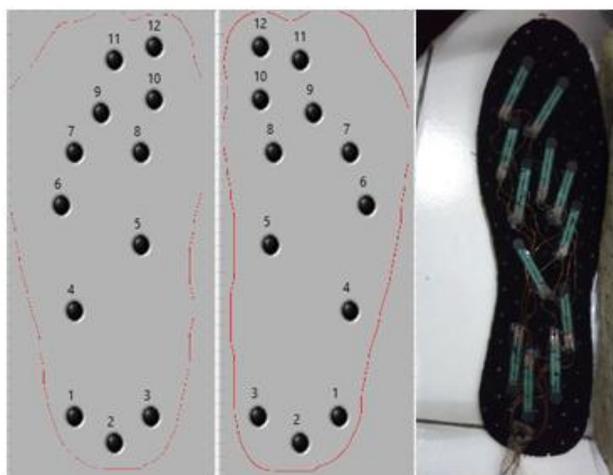


Figure 1: Relationship between Load (gram) and Voltage (V)

The insole is made of foam or silicon material with flat contours, 3 mm thick and has a foot size of 40. A total of 24 sensors are placed based on Figure 2. In more detail using the coordinate system in Table 2. Sensor placement refers to research that has been done by Albon [6].



(a) (b)

Figure 2: (a) Simple Insole for Dynamic Foot Plantar Measurement; (b) Location FSR placement

Table 2: Coordinate of FSR Placement

Sensor	Left		Right	
	x	y	x	y
1	8.6	4.1	-8.6	4.1
2	6.2	2.5	-6.2	2.5

3	3.6	4.1	-3.6	4.1
4	9.3	10.6	-9.3	10.6
5	4.4	14.6	-4.4	14.6
6	10.4	17.0	-10.4	17.0
7	9.3	20.2	-9.3	20.2
8	4.6	20.2	-4.6	20.2
9	7.1	22.6	-7.1	22.6
10	4.0	23.2	-4.0	23.2
11	6.2	25.8	-6.2	25.8
12	3.8	26.6	-3.8	26.6

The voltage on the FSR sensor is read by the Arduino Mega 2560 microcontroller. The data transmission system from each microcontroller (left and right) to the computer uses a USB serial cable through the communication port. Before being sent to the software interface, it is processed using a LabView-based DAQ. Furthermore, the data will be visualized via a computer monitor, see Figure 3.



Figure 3: Block diagram system of dynamically load gauge insole

Sensor data readings are presented and packaged with a Graphical User Interface (GUI). The sensor value is displayed with an LED display in the middle area and the real value on the left and right sides. The sensor LED will change color as the voltage reading value changes. The minimum value is shown in blue and the maximum value is shown in red, see Figure 4.

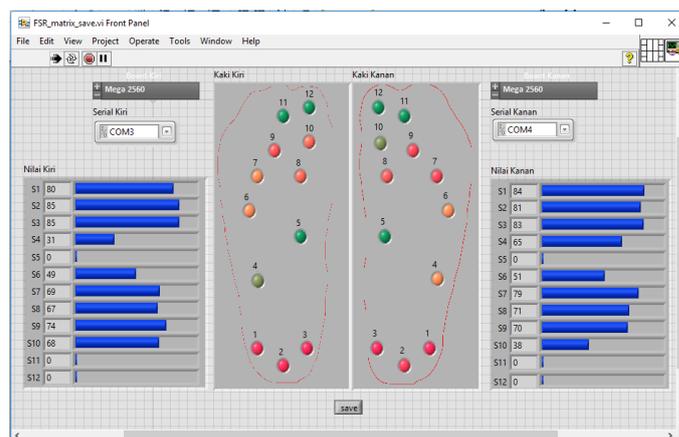


Figure 4: Graphical User Interface (GUI) of dynamically foot plantar measurement software

The next stage is the insole is inserted into a pair of shoes that are used when testing the activity of one walking cycle. The data collection stage is carried out in the heel strike, loading response, terminal stance and preswing phases (see at Figure 4). Data collection can be shown in Figure 5.

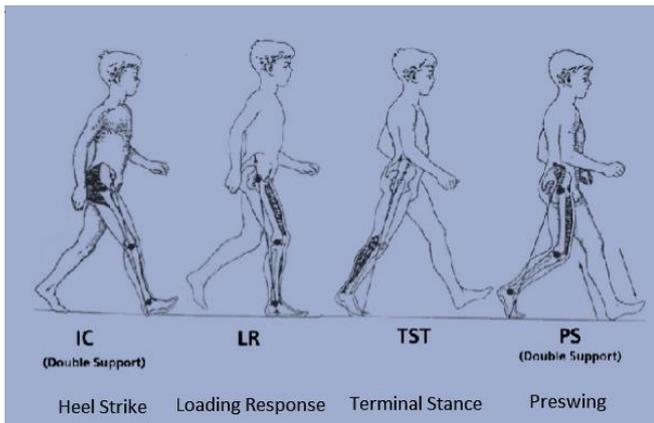


Figure 5: Walking phase: heel strike, loading response, terminal stance, preswing

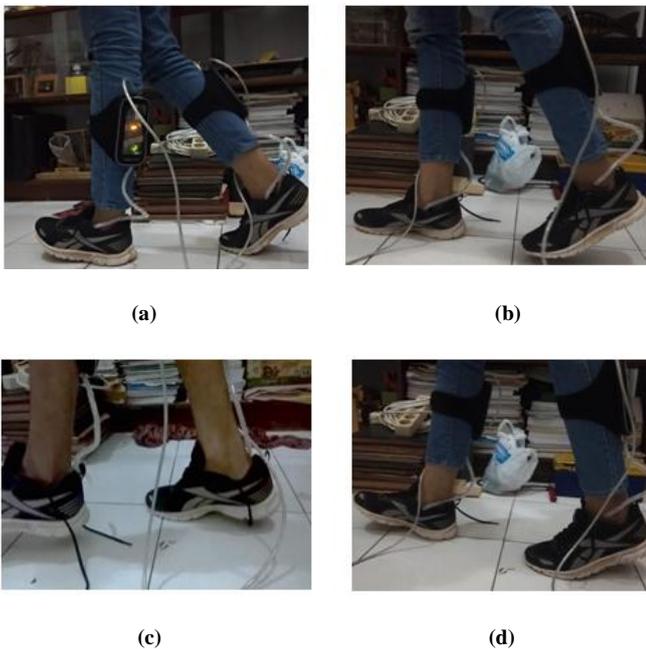


Figure 6: Example data collection process each of phase; (a) Heel strike; (b) Loading response; (c) Terminal Stance and (d) Preswing

III. RESULTS AND DISCUSSIONS

Measurements were carried out by involving 10 correspondent people with foot size 40 and varying weight. Correspondent detail data can be seen in Table 3. FL, FW and Foot Area values obtained from testing using footprint.

Table 3: Correspondence data of measurement

No	Weight (kg)	BMI	Footh Length (mm)	Footh Wide (mm)	Foot Area (mm ²)
1	47	17,70	238,44	128,05	9583,11
2	45	17,57	232,72	93,75	8961,63
3	51	18,29	235,26	92,10	8538,40
4	63	23,71	233,87	99,21	11422,41
5	75	31,22	227,51	91,08	10934,17
6	72	26,45	226,88	88,54	7789,68

7	61	22,96	265,62	136,69	13748,14
8	47	19,56	226,88	88,54	9976,04
9	64	26,30	219,19	89,13	519,19
10	56	22,43	221,92	96,80	11353,09

Data collection includes the heel strike, loading response, terminal stance and preswing phases. The results of measuring the distribution of foot load on walking activities in each phase in detail can be seen in Tables 3,4,5 and 6.

Table 4: Load Distribution at heel strike phase

No Subject	Foot (R/L)	Results of Sensors Data Test (gram)											
		1	2	3	4	5	6	7	8	9	10	11	12
1	Left	850	860	850	0	0	0	0	0	0	0	0	0
	Right	0	0	0	0	0	380	790	800	790	710	820	570
2	Left	860	860	780	0	0	0	0	0	0	0	0	0
	Right	0	0	0	0	0	230	710	750	720	720	600	600
3	Left	850	870	860	0	0	0	0	0	0	0	0	0
	Right	0	0	0	0	0	400	720	750	780	830	790	450
4	Left	890	880	890	0	0	0	0	0	0	0	0	0
	Right	0	0	0	0	0	450	760	790	830	820	820	750
5	Left	910	890	880	0	0	0	0	0	0	0	0	0
	Right	0	0	0	0	0	490	840	790	850	820	800	790
6	Left	890	850	880	0	0	0	0	0	0	0	0	0
	Right	0	0	0	0	0	560	800	840	810	770	780	800
7	Left	900	870	890	0	0	0	0	0	0	0	0	0
	Right	0	0	0	0	0	310	660	710	770	760	800	770
8	Left	850	820	880	0	0	0	0	0	0	0	0	0
	Right	0	0	0	0	0	380	730	630	790	790	710	650
9	Left	910	880	890	0	0	0	0	0	0	0	0	0
	Right	0	0	0	0	0	460	720	810	750	380	800	740
10	Left	900	880	720	1	0	0	0	0	0	0	0	0
	Right	0	0	0	0	0	510	650	790	780	810	790	770

Table 4 shows that the load that occurs is on the front of the right leg (sensors 6-12) and the back of the left leg (sensors 1-3). The maximum load in this phase is 900 grams.

Table 5: Load Distribution at loading response phase

No Subject	Foot (R/L)	Results of Sensors Data Test (gram)											
		1	2	3	4	5	6	7	8	9	10	11	12
1	Left	790	750	850	840	0	760	790	560	630	670	500	500
	Right	0	0	0	0	0	0	0	0	0	0	0	0
2	Left	860	840	840	780	10	760	770	690	540	650	450	490
	Right	0	0	0	0	0	0	0	0	0	0	0	0
3	Left	830	840	850	700	0	780	810	740	690	630	480	510
	Right	0	0	0	0	0	0	0	0	0	0	0	0
4	Left	890	880	900	660	10	740	800	650	580	770	610	720
	Right	0	0	0	0	0	0	0	0	0	0	0	0
5	Left	900	860	890	840	0	790	830	740	620	820	590	640
	Right	0	0	0	0	0	0	0	0	0	0	0	0
6	Left	880	690	860	790	10	720	820	760	700	830	640	780
	Right	0	0	0	0	0	0	0	0	0	0	0	0
7	Left	900	830	880	830	0	780	790	640	560	780	600	710
	Right	0	0	0	0	0	0	0	0	0	0	0	0
8	Left	760	650	880	840	0	750	820	790	770	770	21	380
	Right	0	0	0	0	0	0	0	0	0	0	0	0
9	Left	850	750	870	850	0	800	860	800	730	720	590	520
	Right	0	0	0	0	0	0	0	0	0	0	0	0
10	Left	890	840	710	710	10	700	790	790	720	690	530	500
	Right	0	0	0	0	0	0	0	0	0	0	0	0

Table 5 shows that the load that occurs in this phase is evenly distributed over the entire area of the left foot. On the

right foot there is no load because the foot does not touch the floor. The maximum load on the back area of the left foot is 900 grams.

Table 6: Load Distribution at terminal stance phase

No Subject	Foot (R/L)	Results of Sensors Data Test (gram)											
		1	2	3	4	5	6	7	8	9	10	11	12
1	Left	0	0	0	0	10	790	840	830	840	850	660	820
	Right	0	0	0	0	0	0	0	0	0	0	0	0
2	Left	0	0	0	0	20	780	880	820	830	780	740	530
	Right	0	0	0	0	0	0	0	0	0	0	0	0
3	Left	0	0	0	0	10	800	830	830	810	860	720	830
	Right	0	0	0	0	0	0	0	0	0	0	0	0
4	Left	0	0	0	0	10	790	880	870	870	860	870	850
	Right	0	0	0	0	0	0	0	0	0	0	0	0
5	Left	0	0	0	0	10	830	890	880	870	850	840	870
	Right	0	0	0	0	0	0	0	0	0	0	0	0
6	Left	0	0	0	0	20	790	890	850	880	880	860	850
	Right	0	0	0	0	0	0	0	0	0	0	0	0
7	Left	0	0	0	0	10	800	880	850	850	870	830	780
	Right	0	0	0	0	0	0	0	0	0	0	0	0
8	Left	0	0	0	0	10	800	880	860	870	730	650	480
	Right	0	0	0	0	0	0	0	0	0	0	0	0
9	Left	0	0	0	0	10	780	900	870	880	840	820	770
	Right	0	0	0	0	0	0	0	0	0	0	0	0
10	Left	0	0	0	0	20	780	890	880	880	830	830	680
	Right	0	0	0	0	0	0	0	0	0	0	0	0

Table 6 shows that the load that occurs is in this phase on the toe of the left foot. On the right leg there is still no load because the foot does not touch the floor. The maximum load in this phase is 900 grams.

Table 7: Load Distribution at preswing phase

No Subject	Foot (R/L)	Results of Sensors Data Test (gram)											
		1	2	3	4	5	6	7	8	9	10	11	12
1	Left	0	0	0	0	0	10	750	800	810	830	710	620
	Right	820	880	830	0	0	0	0	0	0	0	0	0
2	Left	0	0	0	0	0	20	780	810	820	790	580	630
	Right	850	880	760	0	0	0	0	0	0	0	0	0
3	Left	0	0	0	0	0	10	840	780	700	780	690	800
	Right	860	870	850	0	0	0	0	0	0	0	0	0
4	Left	0	0	0	0	0	0	830	810	830	820	700	810
	Right	880	880	880	0	0	0	0	0	0	0	0	0
5	Left	0	0	0	0	0	0	870	870	860	820	720	850
	Right	870	900	890	0	0	0	0	0	0	0	0	0
6	Left	0	0	0	0	0	20	850	84	870	880	550	770
	Right	840	890	880	0	0	0	0	0	0	0	0	0
7	Left	0	0	0	0	0	20	830	800	770	850	620	790
	Right	860	890	880	0	0	0	0	0	0	0	0	0
8	Left	0	0	0	0	0	0	760	790	860	880	580	670
	Right	850	860	860	0	0	0	0	0	0	0	0	0
9	Left	0	0	0	0	0	10	860	820	870	800	680	720
	Right	870	900	880	0	0	0	0	0	0	0	0	0
10	Left	0	0	0	0	0	0	880	860	870	840	770	450
	Right	870	870	870	0	0	0	0	0	0	0	0	0

Table 7 shows that the load that occurs is in this phase on the toe of the left foot. On the right leg there is still no load because the foot does not touch the floor. The maximum load in this phase is 900 grams.

IV. CONCLUSION

This insole can be inserting at any kinds of shoes with size 40. It can be shown the load distribution with variant led color sensor and real value. There is four phase in walking activity

that collect some data, heel strike, loading response, terminal stance and preswing phase. Maximum load in this test is 900 gram. With dynamically method collected data, it can be applied at several activity, not just walking activity. This design with few number of sensor can be alternative low cost device measurement.

REFERENCES

- [1] Wibowo, D.B., Suprihanto, A., Widodo, A., dan Haryadi, G.D., Estimation of Calcaneal Deformation While Standing from the Boolean Operation Between 3D and Footprint Image and its Comparison With Lateral X-ray. MATEC Web Conferences 2014. 2018
- [2] Lee, Yu-Chi, Lin, Gloria and Wang, Mao-Jiun J. Comparing 3D foot scanning with conventional measurement methods. Journal of Foot and Ankle Research 2014, 7:44.
- [3] Wibowo, DB., Haryadi, GD., Widodo, A., Rahayu, SP. Correlation of loaded and unloaded foot area with arch index in younger flatfoot. MATEC Web of Conference 135, 00060 (2017).
- [4] Bavornrit Chuckpaiwong, James A.Nunley, et al., 2008, "The effect of foot type on in-shoe plantar pressure during walking and running". Gait & Posture 28 405–411, Elsevier Boehm, Raphael. The foot & the shoe: Measurement & size. DARCO (Europe) GmbH. June 2015.
- [5] Crompton, R.H., Pataky, T.C., et al., 2012, "Human-like external function of the foot, and fully upright gait, confirmed in the 3.66 million year old Laetolihominin footprints by topographic statistics, experimental footprint-formation and computer simulation", J. R. Soc. Interface 9, 707-719.
- [6] Albion, T. Plantar Force Distribution for Increasing Heel Height within Women’s Shoes. The College of Wooster 2011.
- [7] Haryadi, G.D.; Wibowo, D.B.; Ariyanto, M.; Suprihanto, A. Digital Scanning Method for Evaluation of Dimensional Parameters and Identification of Foot Type. Patent No. IDS000002253, 2 April 2019.

AUTHORS BIOGRAPHY



Muhammad Abdul Wahid, Student, Mechanical Engineering Department, Diponegoro University, Indonesia.



Scharta Saragih, Student, Mechanical Engineering Department, Diponegoro University, Indonesia.



Dwi Basuki Wibowo, Lecturer,
Mechanical Engineering Department,
Diponegoro University, Indonesia.



Ismoyo Haryanto, Lecturer, Mechanical
Engineering Department, Diponegoro
University, Indonesia.

Citation of this Article:

Muhammad Abdul Wahid, Scharita Saragih, Dwi Basuki Wibowo, Ismoyo Haryanto, “Simple Insole for Dynamic Foot Plantar Measurement in Walking Gait Analysis Using Force Sensitive Resistor” Published in *International Research Journal of Innovations in Engineering and Technology - IRJIET*, Volume 5, Issue 11, pp 57-61, November 2021. Article DOI <https://doi.org/10.47001/IRJIET/2021.511010>
