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Wireless Insole for Dynamic Foot Plantar Measurement in Standing Activity Using Force Sensitive Resistor Base on Android

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***Abstract* - The distribution of load on the soles of the feet depends on the position of the feet during the activity. Most of the human activities most often carried out by humans are standing activities. Pain in the soles of the feet appears not only because of the posture of the feet since birth, but can also be due to habits when doing activities. This study aims to analyze the distribution of foot load during standing activities. Useful information to improve your standing pattern. The research method involved a 21-year-old human sample, with a weight criterion of 81 kg using shoes between sizes 40. Load distribution measurements used 24 FSR-400 sensors (12 left and 12 right). The sensor is installed by sewing on a 3 mm thick silicon sole and inserted into a sports shoe. Sensor data is received by ESP-32 as a microcontroller and sent using Bluetooth wireless technology (HC-05) to an android smartphone. Load distribution sensor data is processed in Python Android (Pydroid) and then displayed in a color gradation concept (color mapping). This concept more easily describes the load on the soles of the feet. The smallest to largest loads are shown in blue to red. Based on 10 measurements, the results are validated by the measurement display on the tool that has been made. The load distribution data shown by the tool on users with normal feet can help change their habitual patterns of standing activities.**

Keywords: Disribusi, beban, FSR, sol, telapak kaki, wireless, pydroid.

I. INTRODUCTION

The distribution of load on the soles of the feet depends on the position of the feet during the activity. Previous research results show that when standing barefoot the heel and arch area bear a load of around 70% BW (BW: body weight), while the metatarsal area and toes bear 30% BW [1].

Measurement of the distribution of the load on the soles of the human feet during activities has been carried out in many countries for anthropometry, foot type (high arch, normal, or flat foot) [2], analyzing body stability [3], nerve death (neuropathy) [4], evaluates the development of treatment for diabetics both those with foot ulcers [5], as well as before and after leg amputation. know the development of the treatment of patients with inflammation of the bones and joints (osteoarthritis) in the hip, knee, or ankle [6].

In some activities, such as standing activities, the feet have different positions. In general, a normal human standing position should have almost the same pattern of weight distribution on the soles of the feet. Foot disorders experienced by humans vary. The causes can be birth defects, diabetes or an accident which can reduce or change the structure of the human foot.

The results of measuring the load distribution on the soles of the feet are also used as a basis for designing sports shoes and orthotic shoe soles [7]. When walking or running in the heel strike phase the load on the heel can reach 2.0 to 4.0 times the BW. Meanwhile, in the mid stance phase, which represents 30 percent of the cycle, BW passes through the legs as the body advances. During this time the foot will support the weight of the body and the arch of the foot provides the necessary shock absorption for the foot during the walking phase.

There are two types of scanning of the soles of the feet, namely unloading and loading. The results of an unloaded scan using a 3D scanner can include the contour of the soles of the feet [8]. This type of scan aims to design a contour-shaped shoe insole, evaluate the type of foot (flat foot or high arch), estimate the deformation of the sole when standing [1] and evaluate the ground reaction force (GRF) when walking [1,9]. The scan result can be an image in the form of colors representing differences in voltage, capacity, resistance, load or deformation (deflection or displacement). Color mapping can be called an algorithm that produces a mapping function or an algorithm that changes the color of an image. This color grouping is called color mapping. Color changes are usually

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symbolized by blue representing the lowest load and red representing the largest load. Other results can be three-dimensional (3D) contours. The resulting difference represents the contour of the concavity or convexity of the contour of the sole of the foot.

The data transfer system for measurements using an insole has developed. The use of wireless technology such as Bluetooth [10] and WiFi[11] replaces USB serial cables [12]. to increase patient comfort during measurements. Several studies combine wireless systems packaged in an application to monitor patients from home using a smartphone [13,14]. In this research, we will discuss the analysis of the load distribution on the soles of the human feet using Android-based wireless shoe soles for standing and walking activities, which is a development of the results of testing the loads on the soles of the feet using a number of force sensing resistor (FSR) sensors communicated using a USB serial cable (Universal Serial Bus).

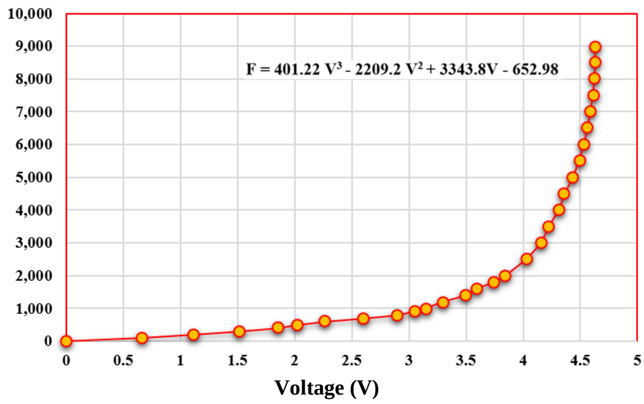
The aim of the research is to create a tool in the form of a shoe sole that can display the pressure distribution of the human foot. The measurement results can be a reference for the condition of the feet when carrying out standing activities based on differences in pressure distribution in the sole area of the feet. After being able to see the results of the load distribution, the patient is expected to be able to improve his habitual patterns during standing activities. Improvements in habit patterns can be seen in the distribution of load on the soles of the feet shown by the tool when carrying out activities.

II. MATERIAL AND METHODS

The research involved a human sample aged 21 years, with a body weight criterion of 81 kg using shoe soles with a size between 40. Measurement of load distribution used 24 FSR-400 sensors (12 left and 12 right). The sensor is installed by sewing on a silicone sole with a thickness of 3 mm. Before installation, the FSR undergoes a calibration process. This process is very important to determine the incoming voltage as input and continue with the data processing process to convert it into a load. The test was carried out 30 times with a maximum load of 9000 gr (see Table 1). The relationship between load and voltage can be seen in Figure 1.

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

No	Load (gr)	Voltage (Volt)	No	Load (gr)	Voltage (Volt)	No	Load (gr)	Voltage (Volt)
1	0	0	11	1000	3.15	21	4500	4.36
2	100	0.66	12	1200	3.3	22	5000	4.43
3	200	1.11	13	1400	3.5	23	5500	4.49
4	300	1.52	14	1600	3.59	24	6000	4.53
5	400	1.85	15	1800	3.74	25	6500	4.56
6	500	2.02	16	2000	3.84	26	7000	4.59
7	600	2.26	17	2500	4.03	27	7500	4.61
8	700	2.6	18	3000	4.16	28	8000	4.62
9	800	2.9	19	3500	4.22	29	8500	4.63
10	900	3.05	20	4000	4.31	30	9000	4.63



F(load) = 401.22 V^3 – 2209.2 V^2 + 3343.8 V – 652.98

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

The shoe soles that have been installed with sensors will later be installed into sports shoes. Sensor data is received by ESP-32 as a microcontroller and sent using Bluetooth wireless technology (HC-05) to an android smartphone. The hardware design can be seen in Figure 2.

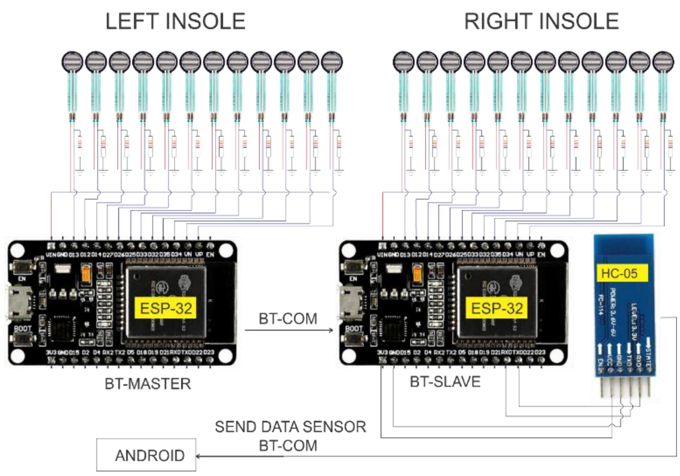


Figure 2: Hardware Design

The FSR sensor is then installed at predetermined coordinate points. The coordinates serve as layout input to describe the level of loading on the sole of the foot. Coordinate determination is done in CAD software. The placement of the 24 FSR sensors can be seen in Figure 3. The sensor coordinates can be seen in Table 2.

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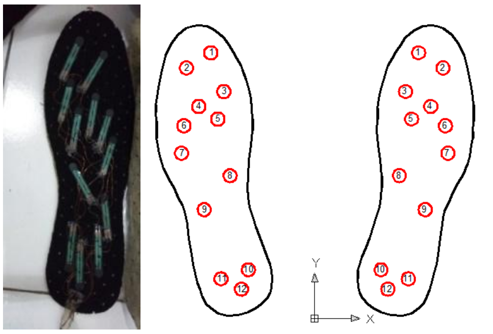

(a) (b)

Figure 3: (a) Simple Insole for Dynamic Foot Plantar Measurement; (b) Location FSR placement

Table 2: Coordinate of FSR Placement

	X	Y		X	Y
Sensor 1	-9.45	24.19	Sensor 1	9.45	24.19
Sensor 2	-11.67	22.8	Sensor 2	11.67	22.8
Sensor 3	-8.26	20.65	Sensor 3	8.26	20.65
Sensor 4	-10.55	19.3	Sensor 4	10.55	19.3
Sensor 5	-8.82	18.15	Sensor 5	8.82	18.15
Sensor 6	-11.9	17.53	Sensor 6	11.9	17.53
Sensor 7	-12.13	15.03	Sensor 7	12.13	15.03
Sensor 8	-7.7	12.98	Sensor 8	7.7	12.98
Sensor 9	-10.05	9.89	Sensor 9	10.05	9.89
Sensor 10	-6.03	4.4	Sensor 10	6.03	4.4
Sensor 11	-8.52	3.58	Sensor 11	8.52	3.58
Sensor 12	-6.66	2.64	Sensor 12	6.66	2.64

The incoming voltage is used as input to acquire data. Data acquisition was performed using python android. The form of data visualization is in the form of an image of the soles of the soles of the feet. Data from 24 FSRs can be monitored on an Android smartphone and can be viewed using the color gradation concept (color mapping). This concept more easily describes the load on the sole of the foot. The smallest to the largest loads are shown in blue to red. The data reader will be able to easily find out the level of the loading area that occurs in the entire area of the soles of the feet. The Android Measurement (IAM) Insole GUI display on a smartphone can be seen in Figure 4.

Figure 4: Graphyc User Interface (GUI) on Android Smartphone

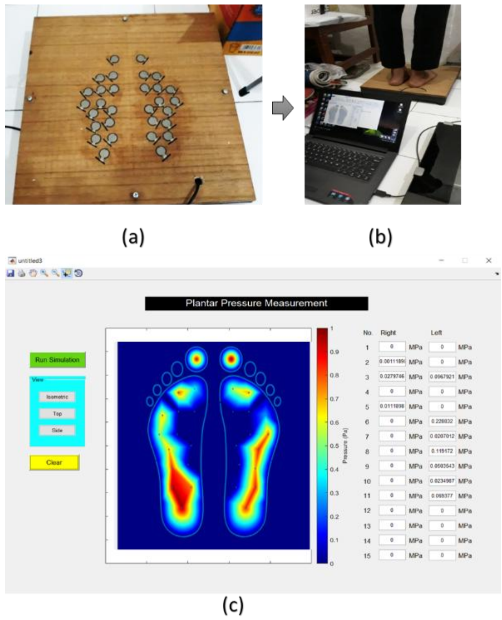

Figure 4: Plantar Pressure Measurement (PPM)

The results of the data visualization are then compared with existing foot weight measurement tools. The tool used to validate measurement results uses a platform as a base. This tool has been used on previous research. Image validation tool can be seen in Figure 5.

Table 3: Result of Measurement with IAM 10 times

	Measurement - (gram)									
	1		2		3		4		5	
	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
1	17.35	0	57.35	0	0	0	0	0	0	0
2	153.02	0	156.28	0	0	0	0	0	0	0
3	302.62	75.69	325.71	209.46	159.46	0	269.14	0	156.57	115.16
4	1662.72	461.57	1915.73	603.36	1247.94	237.51	2251.7	255.08	1650.27	386.6
5	449.43	450.32	496.74	680.4	400.14	308.81	569.49	368.18	518.6	338.99
6	470.1	0	499.52	0	535.3	0	558.36	0	575.45	1787.15
7	0	795.61	0	1 581.04	0	558.94	0	789.35	16.75	1635.28
8	2.35	0	4.24	33.21	0	0	0	0	0	0
9	623.32	466.99	637.69	582.18	590.76	238.51	656.36	337.05	644.87	604.55
10	3753.2	3646.92	3355.02	3021.12	2401.02	3735.06	3529.22	3400.12	3201.55	3254.69
11	3215.6	2167.69	2569.61	1554.69	3593.18	1978.28	4293.76	2980.44	2783.42	2023.05
12	2506.74	4412.7	2199.38	3707.58	1964.34	4412.7	2600.76	3309.39	2593.52	3093.71

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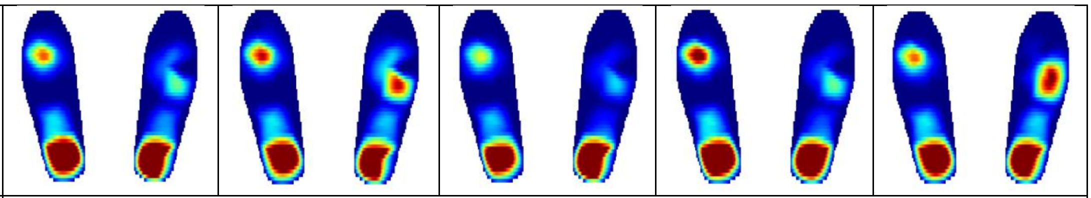
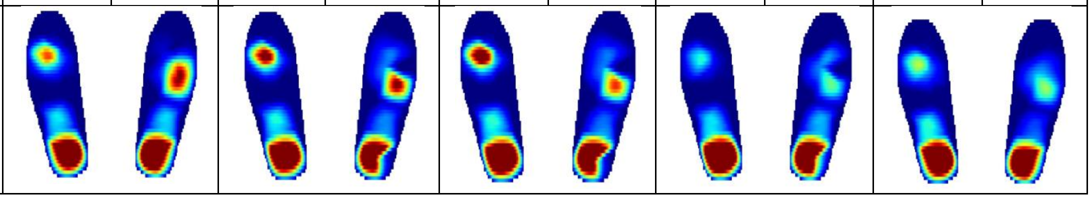
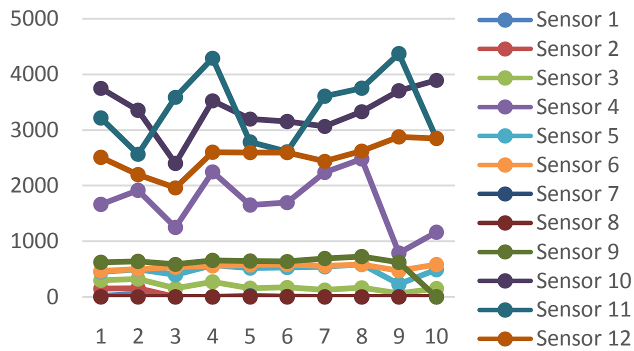
Sensor	Measurement - (gram)									
Visualization										
	6		7		8		9		10	
	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
1	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0
3	175.62	1 14.03	130.6	268.4	171	303.77	66.13	0	151.95	24.83
4	1700.05	388.31	2239.26	445.71	2479.83	423.01	787.07	562.24	1160.83	410.59
5	531.32	368.18	544.05	472.09	586.58	475.56	232.38	472.09	491.17	479.02
6	581.41	1721.22	561.54	0	583.8	0	472.09	0	580.22	499.15
7	6.83	1651.55	0	1722.06	3.1	1461.71	0	783.72	11 .17	865.06
8	0	0	0	0	0	0	0	0	0	0
9	641.52	604.55	692.27	452.24	723.87	404.1 6	619.97	545.05	71 5.73	326.57
10	3151.77	3479.45	3068.82	3069.6	3334.28	3444.19	3703.43	3338.43	3898.38	3038.75
11	2615.1	2384.66	3606.83	760.3	3752.4	755.14	4371.09	1306.74	2856.21	2388.1
12	2593.52	3184.96	2441.65	2674.78	2626.07	2753.59	2875.57	3089.56	2846.65	3392.35
Visualization										

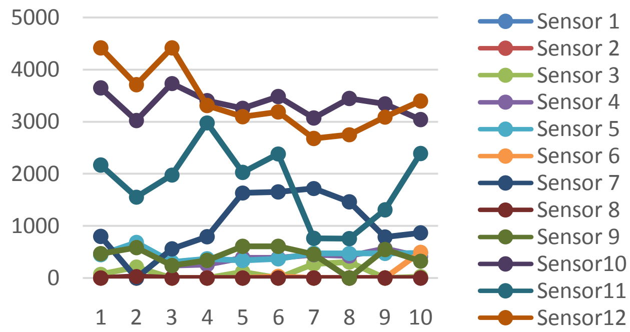
III. RESULTS AND DISCUSSIONS

This section describes the results and discussion during testing the pressure distribution of the soles of the feet in standing activities. Data collection was carried out using an insole that had 12 FSR sensors installed on each sole of the foot which had been installed at certain coordinates to detect the amount of load on the soles of the feet during standing activities. As validation, data was collected on the distribution of foot load during standing activities using a Plantar Pressure Measurement (PPM) tool which uses 15 FSR sensors on each sole of the foot. Foot pressure measurements were taken from 10 measurements.

The measurement results are expected to provide results that are not too far away so as to provide accurate information. The sample was a human who had the criteria for a foot type with a shoe size of 40. After testing 10 times, it was found that the heels of both feet experienced the greatest pressure. In the LFF (Lateral Fore Foot) section, the soles of the feet are also under pressure. The results of the application display show that there is a stable pressure distribution value (see Table 3).



Number of Measurement
(a)



Number of Measurement
(b)

Figure 5: Graphyc of Measurement with IAM 10 times
(a) Left Foot; (b) Right Foot

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If you look at Figure 5, the load on a number of sensors fluctuates quite a bit. It is possible that each foot position measurement is placed on the sole of the shoe in a position that is not where the previous measurement was. This means that there is a shift in the position of the foot relative to the sole of the shoe each time a measurement occurs, causing the measurement values of several sensors to fluctuate.

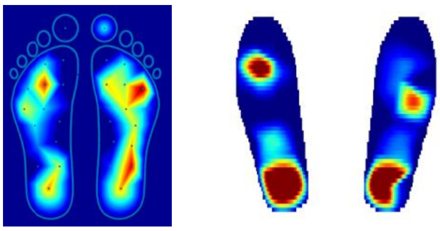

Figure 6: Comparison of PPM and IAM visualization

Based on Figure 6, the results of testing the distribution of loads on the soles of the feet during standing activities carried out on PPM and IAM, there is a slight difference because there are differences in the number of sensors installed on PPM (15 per foot) and IAM (12 per foot). It can be seen that the stress areas shown in PPM and IAM have almost the same phenomena. The distribution of load on the sole of the right foot has slight differences in the middle and front of the foot. This may be due to the position when standing there is a slight shift and a slight difference in alignment so that the sensor that receives the pressure also shifts slightly. Overall, the results of foot pressure distribution tests carried out using IAM and PPM have similar results.

The results obtained from measuring 10 times were quite consistent. There are several sensor values that have fluctuating values because the position of the foot on the sole of the foot is not exactly the position of the previous measurements or has shifted slightly.

IV. CONCLUSION

The insoles that are made can help analyze the pressure distribution of the soles of the feet during standing activities. The results obtained from measuring 10 times were quite consistent. There are several sensor values that have fluctuating values because the position of the foot on the sole of the foot is not exactly the position of the previous measurements or has shifted slightly. The greatest load is on the back of the foot (heel), namely on sensors 10,11 and 12 of the 12 sensors per insole.

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