DEVELOPMENT OF WEARABLE GAIT ANALYSIS DEVICE BASED ON VERTICAL GROUND REACTION FORCES

By

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INTRODUCTION

- Gait analysis is the assessment of the walking pattern.
- Biomechanical analysis of a gait pattern employs various methods such as kinetic analysis, pressure measurement, dynamic electromyography, etc.
- **The purpose of gait analysis system development:**
  i. To measure the degree of pronation which the natural inward rolls act as a shock absorber for the leg and body by optimally disturbing the force of the impact when the heel hitting the ground
  ii. To analyse the gait variability for monitoring or analyzing the gait pattern that can be used for therapy
  iii. To detect any abnormalities of the gait cycle at early stage

Problem Statements

- In the field of biomedical engineering, gait analysis has been a fundamental method and assistive tool to characterize human locomotion.
- A standard gait analysis method has been successfully developed and applied in a number of gait laboratories – **requires specialized labs, expensive equipment, a long-time processing and a large area to perform the experiment**
- To overcome this problem, an alternative gait analysis method based on wearable sensors, which can be used outside the laboratory environment has been introduced in this study.

Objectives

1. To develop a wireless hardware and devices for a gait analysis system based on vertical GRFs.
2. To analyse the performance of the developed device by comparing the gait pattern obtained from the device with the standard gait data.

PROJECT DEVELOPMENT

This project consists of two main parts:

1) Hardware part

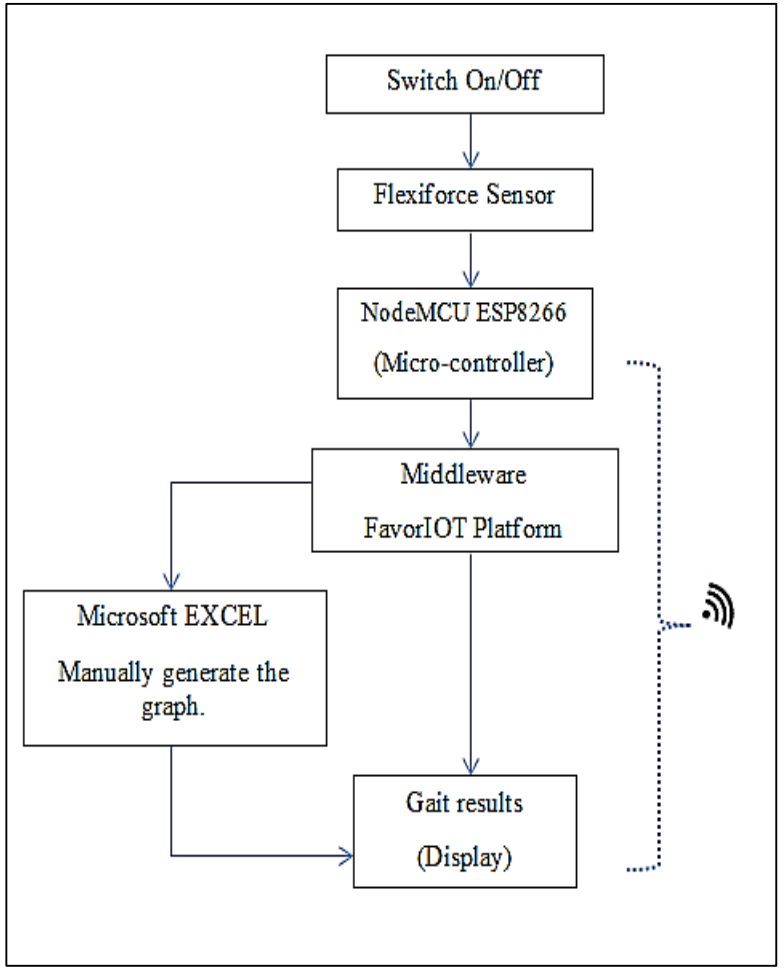
Sensor - Flexiforce Sensor (FFS):

- Used to record the pressure generated
- High durability, lightweight, small size and easy to embed on the shoes.

Micro-controller - NodeMCU (ESP8266):

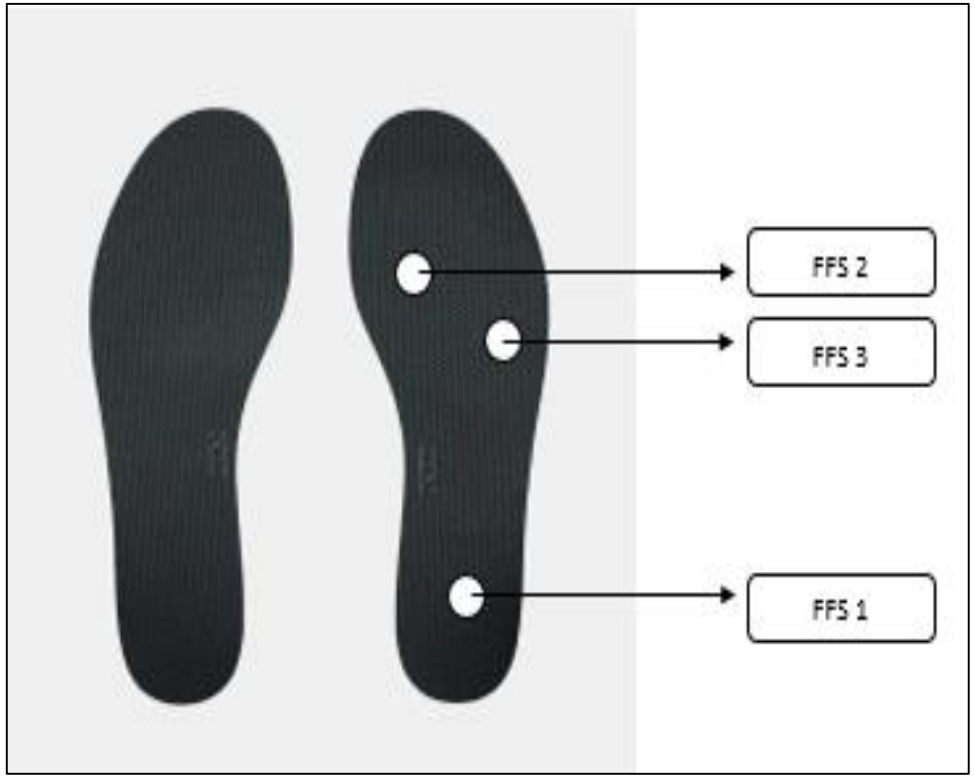
- Wireless capability and small size

2) Software part – Arduino IDE

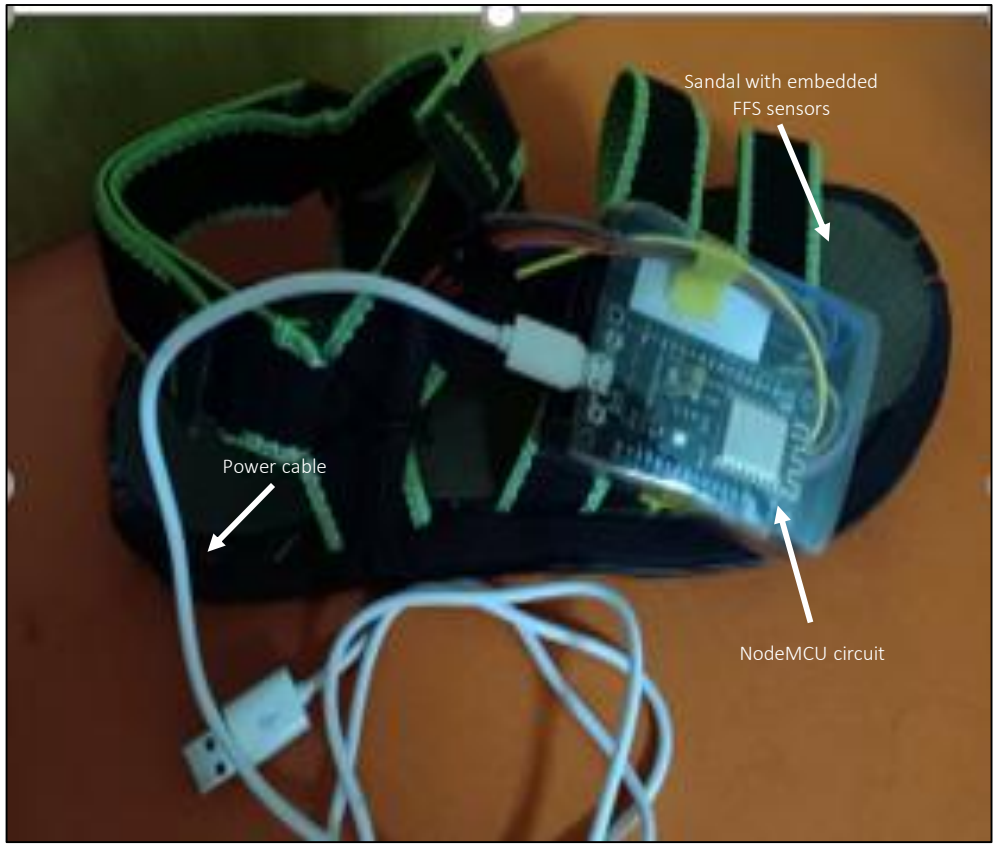


Block diagram of the project

PROJECT DEVELOPMENT



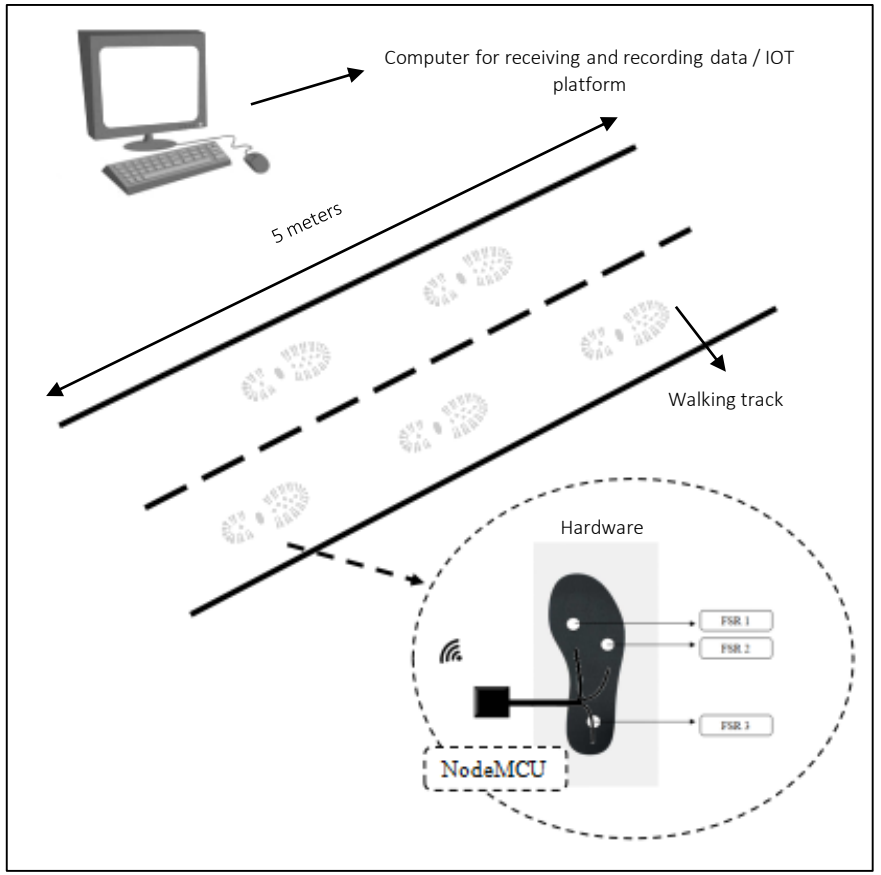
Pressure sensor locations



Hardware final design

EXPERIMENTAL SETUP

1. The analysis was conducted based on the designated walking track.
2. The walking track was set to 5-meter in length – considered the limited space on the lab and the subject able to produce at least two complete gait cycle (1.5 m per stride).
3. The subject was asked to walk in a normal working pace.



Experimental setup (walking track)

EXPERIMENT PROCEDURE

Step 1: The subject need to read and fill in the consent form.

Step 2: Record the name and weight of the subject.

Step 3: Prepare the insole to the subject. The insole must be properly worn by the subject.

Step 4: Check the walking track and make sure it is clear from any hazards.

Step 5: The subject walk on the track provided for every step in 2 minutes.

Step 6: The data obtain saved and displayed in the computer.

Step 7: Analyse the results.

DEMOGRAPHIC INFORMATION

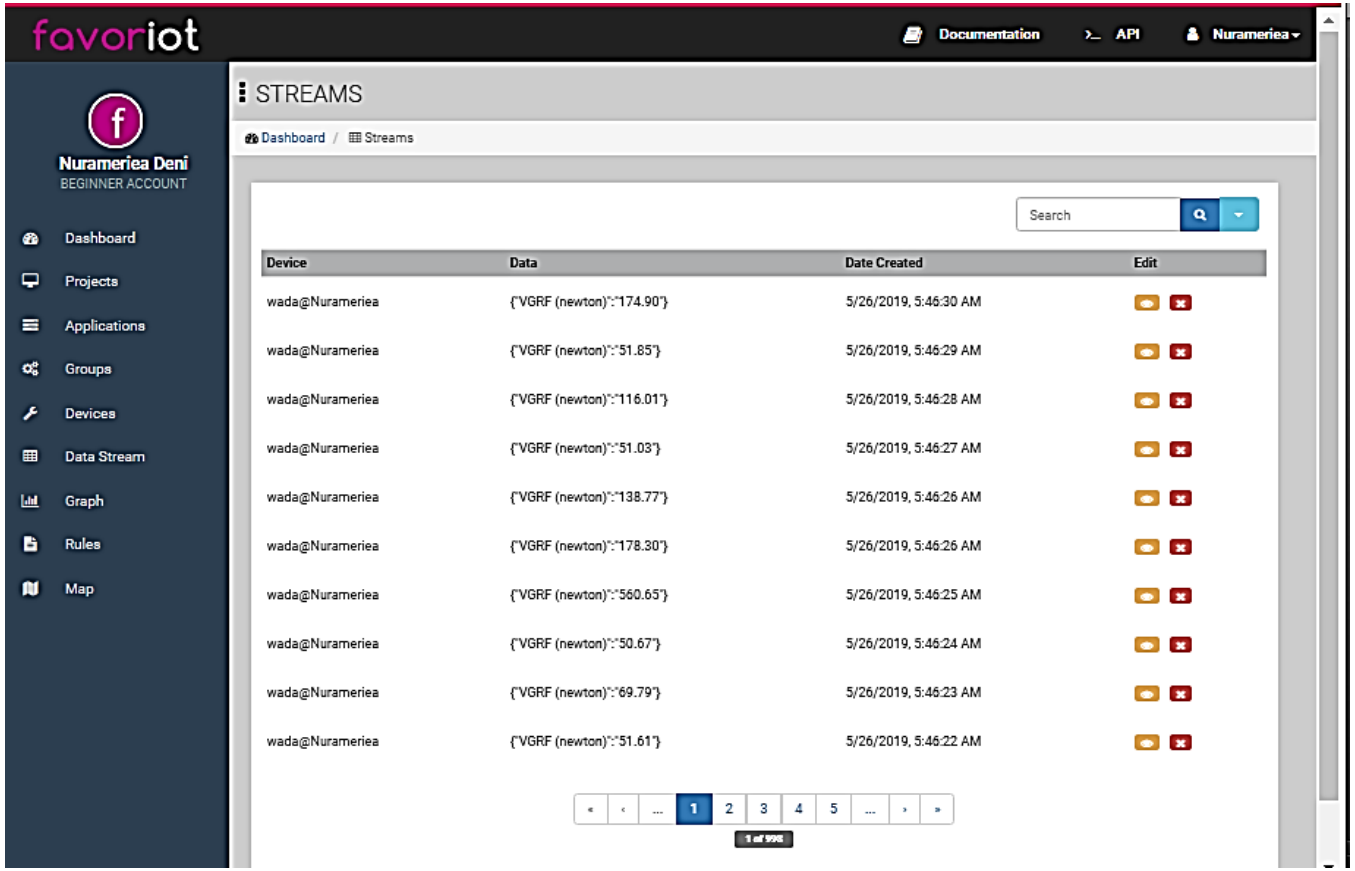
- The difference in the subjects' body weights can greatly influence the force and gait pattern during walking – the criterion can be used to validate the results of the study.

No	Name	Age	Gender	Weight (kg)
1.	Subject 1	26	Female	38
2.	Subject 2	26	Female	47
3.	Subject 3	27	Male	83
4.	Subject 4	27	Male	80
5.	Subject 5	26	Female	56
6.	Subject 6	27	Male	72
7.	Subject 7	27	Female	96
8.	Subject 8	26	Female	43
9.	Subject 9	26	Female	85
10.	Subject 10	24	Female	45

Demographic information of the subjects

DATA STREAM ON FAVORIOT

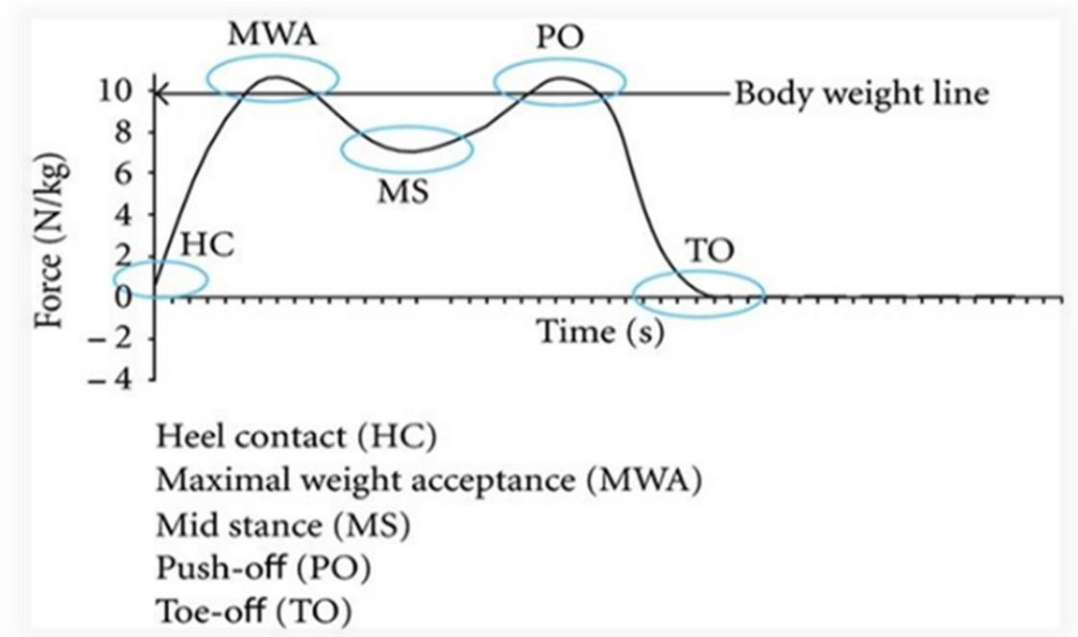
- The data obtained from the force sensors was sent wirelessly to the computer.
- The FavorIOT platform allows user to directly access the data without requiring manual data transfer from a memory card.



Data stream on FavorIOT platform

STANDARD VGRF DIAGRAM

- The results were evaluated by referring to the standard diagram of VGRF for normal gait, Bouffard et al.
- Five significant events of gait – heel contact (HC), maximal weight acceptance (MWA), mid stance (MS), push-off (PO) and toe-off (TO).
- To determining and assessing the gait pattern of individual.



Vertical ground reaction force (GRF), Bouffard et al.

GAIT DATA ANALYSIS

- The vGRF value and percentage of gait cycle was calculated using the formula in equation (1) and (2):

$$V_{grf} = \frac{Output\ value\ (N)}{weight\ of\ subject\ (kg)} \qquad (1)$$

$$\%\ gait\ cycle = \left(\frac{time(s)}{total\ time\ (s)}\right) \times 100 \qquad (2)$$

RESULTS – GAIT DATA

Time (s)	Subject 1 (N)	% Gait Cycle	vGRF (N/Kg)
0	63.05	0.0	1.66
1	407.32	16.7	10.72
2	311.9	33.3	8.21
3	260.76	50.0	6.86
4	388.71	66.7	10.23
5	58.42	83.3	1.54
6	0	100.0	0.00

Complete gait cycle data of Subject 1

Subject	Standard value (N/kg)	Device reading (N/kg)	Percentage difference (%)
1	1	1.05	5
2	1	1.09	9
3	1	0.98	2
4	1	1.06	6
5	1	0.92	8
6	1	1.03	3
7	1	0.96	4
8	1	0.92	8
9	1	0.96	4
10	1	1.03	3

Heel contact reading for all subjects

RESULTS – GAIT DATA

Subject	Standard value (N/kg)	Reading value (N/kg)	Percentage difference (%)
1	11	10.16	8
2	11	10.08	8
3	11	9.96	9
4	11	10.02	10
5	11	10.77	2
6	11	10.43	5
7	11	10.72	3
8	11	10.17	8
9	11	10.28	7
10	11	10.37	6

Maximum weight acceptance data

Subject	Standard value (N/kg)	Reading value (N/kg)	Percentage difference (%)
1	7	6.86	2
2	7	6.97	0
3	7	5.7	9
4	7	6.37	9
5	7	7.34	5
6	7	7.54	8
7	7	6.94	1
8	7	7.06	1
9	7	7.16	2
10	7	7.28	4

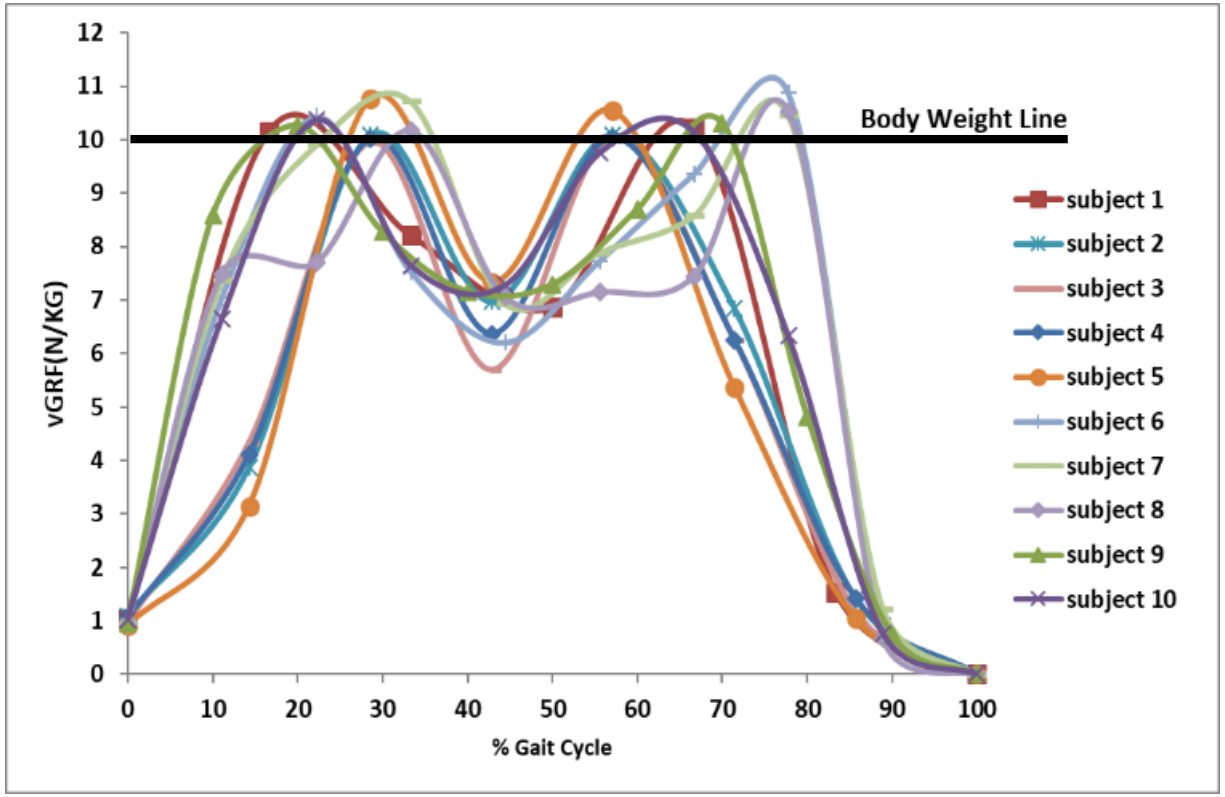
Mid-stance data

RESULTS – GAIT DATA

Subject	Standard value (N/kg)	Reading value (N/kg)	Percentage difference (%)
1	11	10.23	7
2	11	10.09	7
3	11	10.04	9
4	11	10.05	9
5	11	10.55	4
6	11	10.88	1
7	11	10.46	5
8	11	10.53	4
9	11	10.31	6
10	11	10.14	8

Push-off Data

RESULTS – vGRF Data



VGRF graph of 10 different subjects

DISCUSSION

- In general the vGRF patterns for all subjects exhibited the similar curve pattern as the standard vGRF.
- For each of the gait events showed a significant different but still in the acceptable range - based on the fact that the percentage difference between the measured and the standard gait data is less than 10% for each of the observed gait event.
- In average the percentage difference is 5.5%, thus, this device is 94.5% accurate.
- Factors that can affect the accuracy of the device:
  i. The variability of the style of walking between the subjects.
  ii. The style of walking of an individual is greatly influenced by the body mass index (BMI), walking speed, stride length.

CONCLUSION

- The development of the gait analysis device based on vGRF - shown a great potential to be further expanded in order to develop more accurate and cost effective device.
- This device has achieved 94.5% accuracy and shown a good repeatability.
- The accuracy of the device has been validated by comparing the result obtained from the experiment with standard gait pattern.
- In addition, all of the gait data can be transferred wirelessly and can be further analyzed to examine the performance of the gait.

FUTURE WORK

i. The analysis on longitudinal and lateral ground reaction forces.

ii. Improved the performance of the device by conducting an experiment involving subject from different BMI – overweight and obese subjects; different types of activities – stairs ascending and descending.

iii. Substitute manual computation that is believed can reduce the computation time and error in analyzing the gait data.

Thank You