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THE REAL TIME GAIT PHASE DETECTION FOR LOWER LIMBSUSING IOT TECHNOLOGY

Nurul Aini Syazlin Binti Mohamad[1], Suryani Binti Ilias[2]

`1Electric Engineering Department,

Politeknik Sultan Salahuddin Abdul Aziz Shah, Shah Alam,Selangor,

syazlinmohamad99@gmail.com

2Electric Engineering Department,

Politeknik Sultan Salahuddin Abdul Aziz Shah, Shah Alam,Selangor,

suryani@psa.edu.my

ABSTRACT

Stroke has been recognized as a major public health concern, being the third most common cause of mortality and topping the nation's disability rate. Stroke patients have difficulty walking and moving to the point of endangering areas of the brain that control movement coordination when brain impulses become chaotic, and muscles may find it difficult to communicate effectively. The gait sensor function can measure various characteristics of the human gait with the movement signal recorded and used to perform the gait analysis. The goalof this product is to obtain real-time run phase performance using wearable sensors and IoT technology by tracking the number of steps generated by the patient. The movement signals recorded by these sensors are used to perform gait analysis and can be used as analytical data such as number of steps, cadence, and length of steps to obtain information about the level of progress achieved by stroke patients. Combining with a motorized walker will aid stroke patients' movement during treatment and can encourage them to walk at an appropriate speed. Based on the effectiveness of the tools that have been measured throughout, the patient can produce and display progress in graph form. From this study, several improvements can be made to improve the usability of the device in the future.

Keyword: Stroke patients, brain, gait sensor, walker, treatment.

I. INTRODUCTION

The Real time gait phase detection for lower limb using IOT technology is the project development for stroke patient that have difficulty walking and getting around. Strokes can harm the areas of your brain that control movement coordination(Alrabghi et al., 2018). Brain impulses get scrambled, and your brain and muscles may struggle to communicate effectively. Gait is an important human function that allows us to move freely in our surroundings. Gait is a demonstrated key metric of quality of life because of its consequences and being regarded the sixth vital sign, it is even a mortality risk(Alrabghi et al., 2018). One of the most common causes of acquired disability is stroke. It is believed that 80% of stroke survivors have difficulty walking(Nandy, 2019). Given this, enhancing a stroke patient's walking velocity and efficiency is a critical goal for improving overall functionality and quality of life. Other than that, a walker is a tool for disabled people, who need additional support to maintain balance or stability while walking(Brian et al., 2020). So, it can help and support the stroke patient in the treatment they receive. As we know, the gait sensor can stimulate the progress of a stroke patient, and it shows with graph results to present the progress. The goal of this product is to obtain real-time walking phase performance using wearable sensors and IoT technology.

Cerebrovascular accidents (stroke) is brain injury caused by disruption the supply of blood to a brain region, which could result in permanent neurological deficits or death(Yoshioka et al., 2022). One of the leading causes of morbidity and mortality is strokes (also known as cerebrovascular accidents CVA) attributing to significant negative consequences on the society. Strokes are defined by the World Health Organization (WHO) as an acute, focal, or diffuse, dysfunction of the brain, originating from vessels and lasting for a period longer than a day(Nonnekes et al., 2019). This definition, thus, will include intra-cerebral hemorrhages, subarachnoid hemorrhages, ischemic strokes, and cerebral venous sinus thrombosis. Post-stroke disability may involve mobility and stability of joints, muscle power, tone and reflexes, muscle endurance, control of movement, and gait pattern functions(Li et al., 2019). These impairments lead to problems with transferring, maintaining body position, mobility, balance, and walking. In the first 6 months post stroke, almost all patients experience at least some predictable degree of functional recovery(Wu & Li, 2020). Although most stroke patients learn to walk independently by 6 months after stroke, gait and balance problems persist through the chronic stage of the condition and have a significant impact on patients' quality life.

A walker is a type of mobility aid used to help people who are still able to walk (e.g., don't require a wheelchair) yet need assistance. It is a four-legged frame that allows a person to lean on it for balance, support, and rest (Morone et al., 2016). Basic spatiotemporal gait parameters (e.g., step and stride length, step and stride time, cadence, speed) can be computed with minimal equipment, while more advanced measurement techniques can be used to determine kinematic (e.g., joint angles, angular velocity) and kinetic (e.g., ground reaction force, joint moments, joint power) variables(Zhang et al., 2020). This not only limits the accessibility to these advanced gait analysis systems to select clinical and research facilities, but gait analyses conducted in this manner do not necessarily capture how an individual walks or runs in a real-world setting (Yeo & Park, 2020). In fact, future development for patient treatment should include the device portability to increase the potential applications. The preliminary results have highlighted the robot-assisted therapy currently works hand in hand rather than a replacement of traditional therapy(Cabanas-Valdés et al., 2020). Therapies and rehabilitation strategies should be not only more effective but also more cost-efficient.

Therefore, the research on product development was put to good use there, serving its own aims. In the first place, to design the portable device using gait walking phase for stroke patient by using the motorize walker and gait sensor. The second objective is to develop real-time software mechanization for walking treatment using IOT technology application called blynk. Finally, for the purpose of analysis, to analyze the gait phases using wearable sensor for show the patient progress along the treatment they do.

II. METHODOLOGY

This paragraph of the study discusses the development of a product based on first and second objectives that is aimed at providing the real time gait phase detection for lower limbs that can be controlled remotely using user's smartphone.

a. Design Process of the real time gait phase detection for lower limb

A 3D design of the product was drawn by using tinker cad based on different angle to enhance and realizing the idea of this project from different angle. Figure 1 is the back and front view of the product which consist of two-wheel motor, gait sensor on shoe and include push button controller.

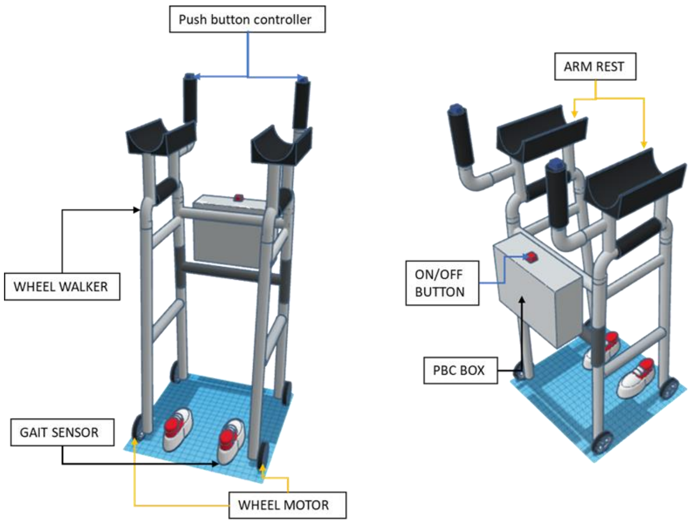

Figure 1: back and front view

b. Developed the real time gait phase detection of lower limb

Products from this project have been successfully developed (Figure 2). The real time gait phase detection for lower limb is provided a comfy arm rest that focus for upper limbs comfortable and support when use. Apart from that, there is also a motor system that can help the patient in pushing them to walk which is accompanied by a speed that can be adjusted according to the suitability and ability of the patient to help to walk. Finally, with a combination of force sensors that function as detecting the number of step counts can calculate how many steps can be achieved by the patient during rehabilitation is carried out.

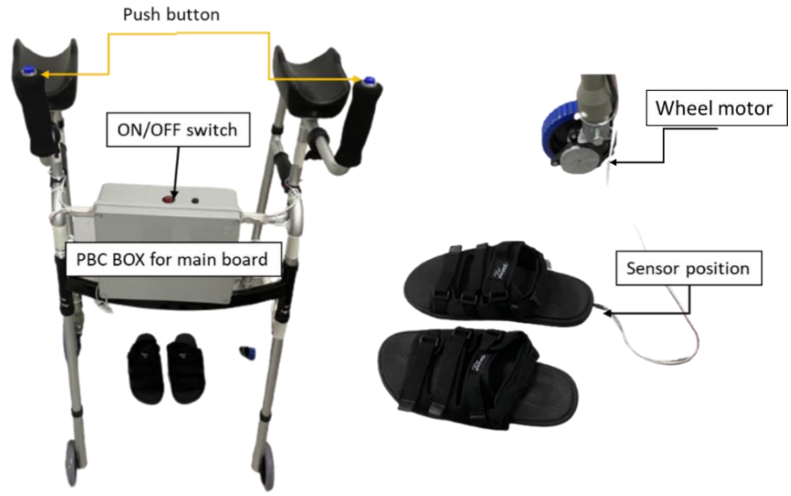

Figure 2: Developed product of the real time gait phase detection for lower limb

As been shown in the block diagram in figure 3 for the real time gait phase detection using gait sensor which includes three parts which is input, process, and output. And the diagram block has two main parts which the wheel walker part and the gait sensor part. For wheel walker part consists of input (switch and battery) works for on/off device system and battery as a power supplier while in the process part includes ESP32 (IOT connection), 30A DC motor, wheel motor he which in this part is the controlling part movement (ESP32) and the component that drives the moving device. and on the gait sensor uses a force sensor where the function of the sensor is to calculate the patient's step when stepping on it and it is connected to ESP 32 (IOT connection) for transmission between wheel walker part and gait sensor part to send a signal to the application that is 'blink' application on the output side of the system and output the gait phase result.

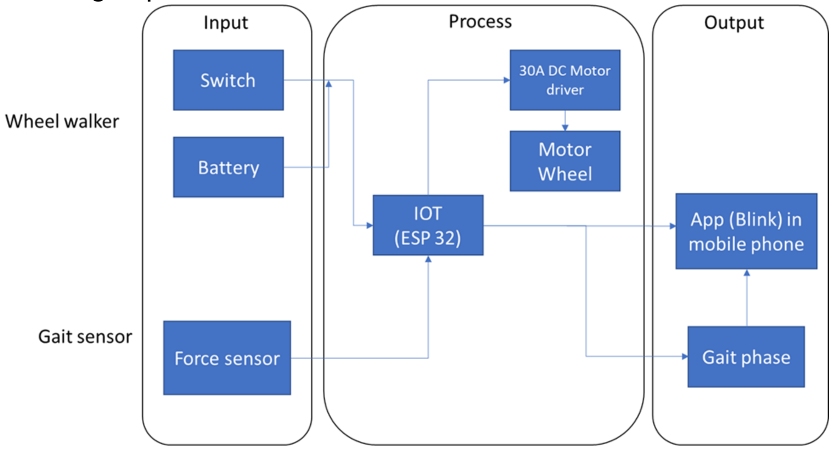

Figure 3: Block diagram of project development

c. Standard operation procedure

In figure 4 below demonstrate the usage of the real time gait phase detection for lower limb using IOT technology. The real time gait phase detection for lower limb supports the lower part of stroke patient. The wheel walker can adjust the speed of motor base on suitable of patient situation and also for the shoes that provide the adjustable strap for suitable on patient's size. By using the 'blynk' application software on smartphones, user can control the level of speed, mode of treatment and on off device when they want to do the treatment.

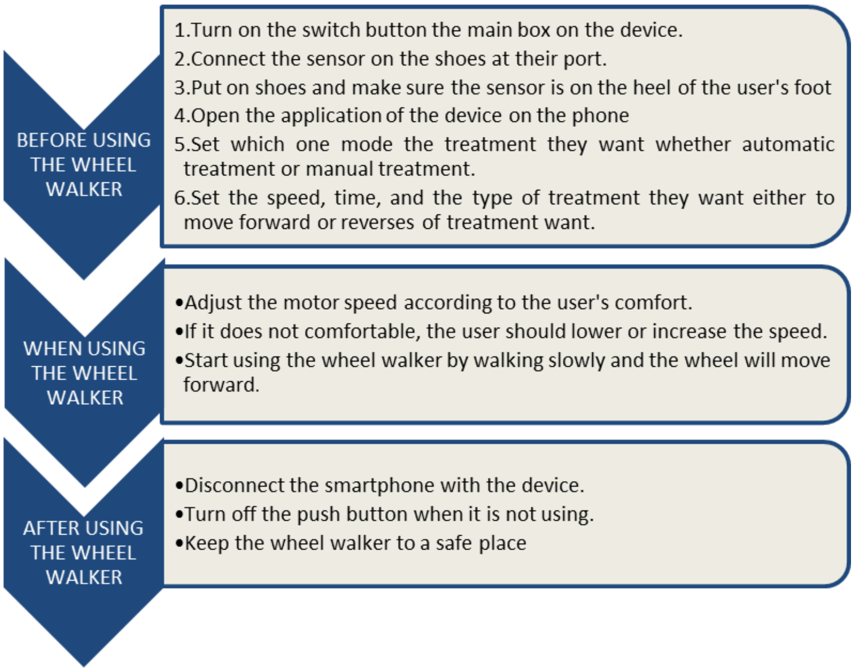

Figure 4: standard operation procedure of the real time gait phase detection for lower limb

d. Data analysis

Figure 5 below is the method of the data collection of the real time gait phase detection for lower limb. That provide of 3 method which is based on the questionnaire, experimental of design and test on patient.

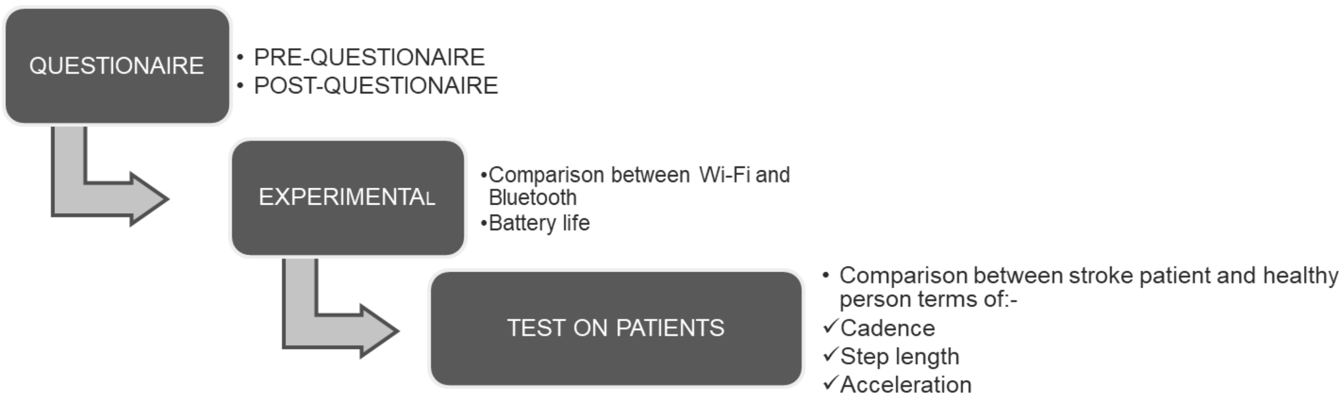

Figure 5: Method of data collection

For questionnaire we provide 2 types of questionnaires, namely pre- and post-questionnaire. For the pre-questionnaire we focus on the introduction device to get approval to develop this device. for the post-questionnaire, the focus is on the effectiveness of the device for stroke patients. After that, In the experimental part of the design, we tested several components such as the difference stimulation between Wi-Fi and Bluetooth (using thinker cad) in figure 6 and the durability of the battery in figure 7 for use during the treatment. And finally, about the test on patient method in figure 8, where in this method we have done testimonials on 2 categories, which are stroke patient and healthy person. In this method, 4-meter track and 10m/s speed are used and tested in terms of increasing the value of cadence produced, the value of step length and the value of acceleration that can be produced by the subject to see the differences produced by these 2 subjects and 4 trial tested is taken of see the progress.

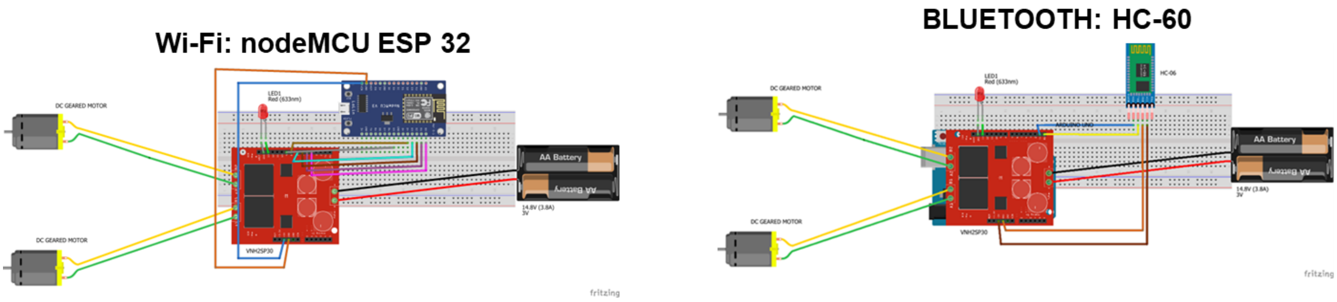

Figure 6: Network connection testing

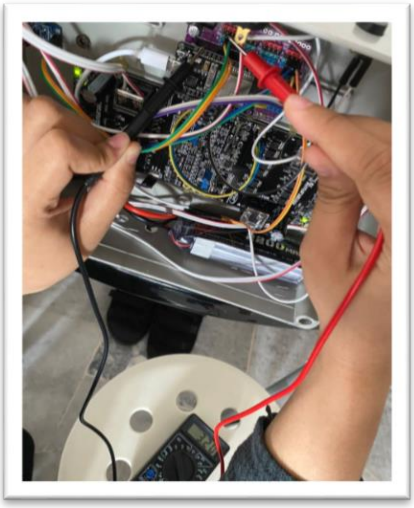

Figure 7: Voltage drop testing

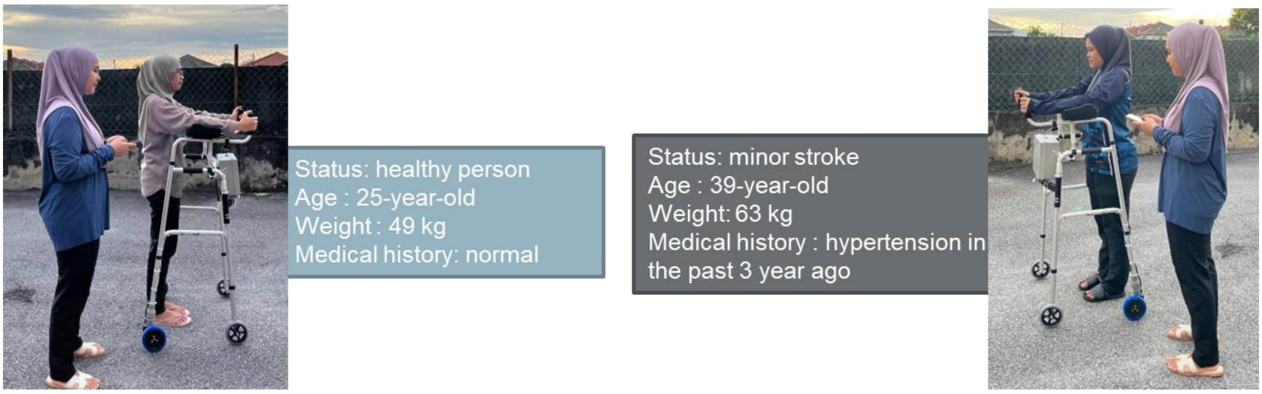

Figure 8: Testing on subject

III. RESULT AND FINDING

In this section, the result of an analysis based on testing on subject using the application which involves several parameters such as the number of step count and time taken. Where with the presence of both parameters can measure progress based on cadence, step length and acceleration.

A. Analysis on cadence

Figure 9 and table 1 displays comparison of cadence between stroke patient and healthy patient. The graph shows that, the cadence for stroke patient and healthy person is different. The cadence for healthy person is higher than the stroke person for all trials. Then, from Trial no. 1 to Trial no. 4, the cadence is increasing for healthy person. And for stroke patient, from trial 1 to trial no.3 is increased. However, at Trial no 4, the cadence for stroke patient is slightly decreased with the number from 10.24 step/min to 9.8 step/min. This may be due to the step length of stroke patients being slightly longer than the previous one and resulting in a reduced number of steps. With the conclusion that can be seen through the result graph, the frequent of the experiment value produces the cadence value produced, while the increase in step value produced along the 4 meter track the less time it takes, doing 4 attempts to get progress in cadence where the objective for experiment this is to analyze the cadence in stroke patients for a certain speed in the application.

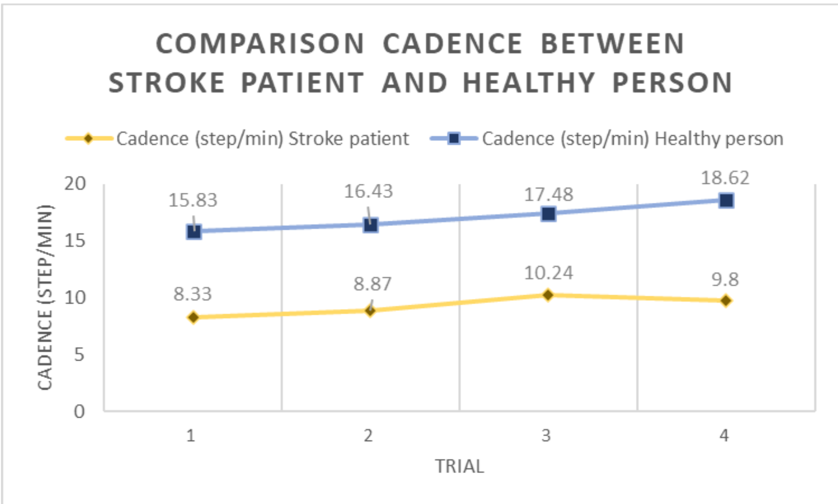

Figure 9: Comparison of cadence between stroke patient and normal patient

Stroke patient

Trial	No. of steps (step)	Time treatment (sec)	Cadence (step/min)
1	10	85	8.33
2	11	87	8.87
3	13	84	10.24
4	12	80	9.88

Healthy person

Trial	No. of steps (step)	Time treatment (sec)	Cadence (step/min)
1	22	103	15.83
2	23	105	16.43
3	25	100	17.48
4	27	99	18.62

Table 1: Data collection of cadences

B. Analysis on step length

Figure 10 and table 2 displays the comparison of step length for stroke patient and healthy person. The graph shows that, the step length of stroke patient and healthy person are different caused by their condition. The step length of healthy person is higher than stroke patient for all trial. Then, from trial no. 1 to trial no.4 the step length is increased for healthy person. And for stroke patient, from trial no.1 to trial no.3 is increased. However, stroke patient at the trial no.4 the step length is slightly decreased with the number from 18.18 cm to 17.39 cm. That is dependent of the cadence value for stroke patient at figure 9 decreased that can affect the step length value. The finding that we can see based on the objective which is to analyze the step length on stroke patients for given through the graph of results, the higher the trial value the higher the step length value produced, whereas the increasing the value of the cadence produced along the 4m track the increasing the step length taken.

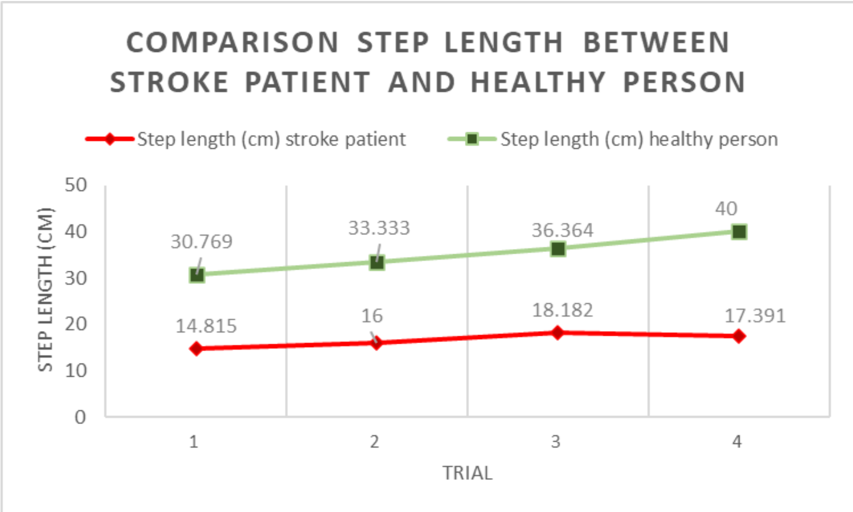

Figure 10: comparison of step length for stroke patient and healthy person

Trial	Stroke patient		Healthy person	
	Cadence (step/min)	Step length (cm)	Cadence (step/min)	Step length (cm)
1	8.33	14.815	15.83	30.769
2	8.87	16	16.43	33.333
3	10.24	18.182	17.48	36.364
4	9.88	17.391	18.62	40

Table 2: Data collection of step length

C. Analysis on acceleration

Figure 11 and table 3 shows the comparison of acceleration between stroke patient and healthy person. The graph shows that, graph of acceleration (m/s^2) against final velocity (m/s). Where from graph shows acceleration for stoke patient and healthy person is different. The acceleration for healthy person is higher than stroke patient for all the specified final velocity which are 10 m/s, 20 m/s, 30 m/s, 40 m/s, 50 m/s, 60 m/s, 70 m/s, 80 m/s. then, from trial no.1 to trial no.4, the acceleration is increased for both stroke patient and healthy person. However, at the final velocity 60 m/s to 80 m/s for healthy person sharply increased from 3.53 m/s^2 to 10 m/s^2. That is because the time taken by healthy person is so short with that speed and produces high acceleration. For the conclusion that can see through the graph of results, the higher the final velocity value the higher the acceleration value produced, whereas the decreasing the value of the times produced along the 4m track the increasing the final velocity taken. With this, through the experiment the objective is achieved that is from this experiment can measure the acceleration on stroke patients for given speed in application.

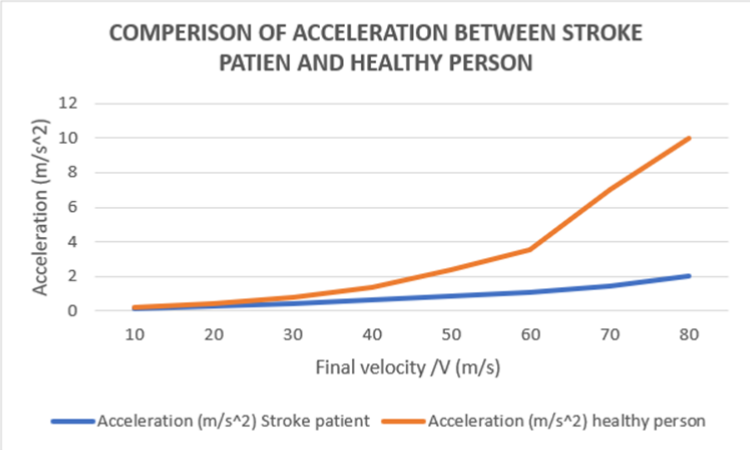

Figure 11: comparison of acceleration between stroke patient and healthy person

Final velocity /V (m/s)	Stroke patient		Healthy person	
	Acceleration (m/s^2)	Times taken (s)	Acceleration (m/s^2)	Times taken (s)
10	0.137	73	0.2	50
20	0.282	71	0.435	46
30	0.441	68	0.811	37
40	0.635	63	1.379	29
50	0.877	57	2.381	21
60	1.091	55	3.529	17
70	1.458	48	7	10
80	2	40	10	8

Table 3: Data collection of acceleration

IV. CONCLUSION

These studies had three distinct purposes. First, to design the portable device using gait walking phase for stroke patient. Where we have developed a device that combines the wheel walker and the gait sensor by using IoT technology. And the real-time gait phase-detection for lower limbs using IOT technology has been designed and developed for effective therapy devices. Second, to develop real-time software mechanization for walking treatment using IOT technology. Where an application that has, various functions is created to collect patient data throughout the treatment to find out the progress they have achieved. And from this objective we get the effectiveness of this device has been analyzed through 3 testing on subjects which is a healthy people and stroke patients: cadence, step length, and acceleration. IoT is successfully implemented in the project using the Blynk application. Lastly, to analyze the gait phases using wearable sensor. On the objective we use a force sensor where the sensor can detect the number of step counts and with that value, we can measure readings such as cadence and step length. with the availability of such data, it helps users in getting data easily and can help in treating patients in walking when using this walker. then the last object is reached. Some improvements will be done in the future in terms of the design of the wheel walker which in this section does not have an adjustment function to suit the user's height. other than that improvement in terms of IOT system.

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