DEVELOPMENT OF A SYSTEM FOR MEASURING PEDAL FORCE IN ARM/LEG PEDAL EXERCISE

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DECLARATION

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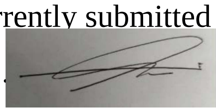
Signed…….  …….........(Mohammad Amirul Akmal Bin Mohd Najib)

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LIST OF ABBREVIATIONS

AE	Active Engage
AD	Active Disengage
SD	Standard Deviation
PE	Passive Engage
PD	Passive Disengage
LED	Light Emitting Diode
USM	Universiti Sains Malaysia

LIST OF APPENDICES

ABSTRAK

Isu strok kini menjadi tumpuan kepada para pengkaji dalam mencari cara yang paling berkesan untuk pesakit mendapat kesembuhan. Antara kaedah yang terkenal dalam menyembuhkan pesakit stroke adalah dengan melakukan aktiviti aerobik seperti berjalan, berbasikal dan berlari. Kaedah berbasikal telah digunakan dalam bidang perubatan bagi menyembuhkan peasakit strok yang mengalami hemiparesis. Reka bentuk terkini tidak mempunyai sistem tindak balas di mana pesakit tidak dapat melakukan terapi berbasikal dengan berkesan. Masalah yang berlaku adalah, masa yang diambil ketika melakukan terapi sanagat panjang di sebabkan hanya satu bahagian anggota badan sahaja yang dapat dirawat dalam satu masa. Tujuan kajian ini adalah untuk menetukan parameter yang ada pada mod aktif dan pasif serta keberkesanan sistem tindak balas kepada pesakit strok ketika melakukan terapi. Di akhir kajian ini, mod aktif dan pasif untuk angota badan bahagian atas dan bawah, nilai kelajuan bersudut, pecutan bersudut, kelajuan dan pecutan telah dikaji. Berdasarkan hasil kajian, nilai yang paling rendah untuk kelajuan bersudut, pecutan bersudut, kelajuan dan pecutan telah dikaji adalah -0.18482 deg/s bagi aktiviti aktif tidak bersambung pada anggota atas, -0.37149 deg/s^2 bagi aktiviti aktif bersambung pada anggota bawah, 0.127865 m/s dan -8.2759E-05 m/s^2 bagi aktiviti pasif bersambung pada anggota atas. Untuk melihat signifikan aktiviti aktif dan pasif, ujian-T dengan 95% selang keyakinan telah dijalankan. Hasilnya adalah, hanya nilai pecutan untuk anggota atas dan bawah sahaja yang mempunyai nilai signifikan. Berdasarkan hasil yang dikaji, ativiti aktif dan pasif mempunyai kesan yang hampir sama. Jadi, pesakit strok yang parah dapat melakukan terapi berbasikal dalam mod pasif dengan mempunyai kesan yang hampir sama dengan aktiviti aktif. Keberkesanan system tindak balas telah dinyatakan di dalam bahagian hasil. Bedasarkan gambar di bahagian hasil, LED akan menyala apabila nilai pecahan bagi perbezaan daya dengan keseluruhan daya melebihi 0.4 atau -0.4. LED akan berhenti menyala apbila perbezaan daya menjadi stabil. Ujian-T telah dialkuakan untuk kedua belah kaki di mod aktif dan pasif. Terdapat nilai signifikan bagi kedua-dua belah kaki untuk mod aktif dan pasif. Kesimpulannya, system tindak balas ini dapat memberikan amaran kepada pesakit jika perbezaan daya sangat besar di mana mereka dapat menstabilkan daya kedua-dua belah kaki.

ABSTRACT

Nowadays, stroke issues become important field which many researchers and scientist have work on how to get the best method for their recovery. For stroke patients, the most popular method to recover is through aerobic exercise like walking, cycling, or running. Rehabilitation cycle have been used in medication field for the hemiparesis patients. Current designs do not provide no feedback system to the patient. It is difficult to determine whether the patient perform effectively. The problem that occurs during the therapy is time consuming because only single limbs were treated at one time. The purpose of this study is to determine the parameters for both active and passive mode and the effectiveness of feedback system to the stroke patients during the therapy. At the end experiment the active and passive activity for both upper and lower limb in term of angular speed, angular acceleration, speed and acceleration have been study. From the result it can be shown that the average of angular speed, angular acceleration, speed and acceleration, the lowest are active disengage at upper limb with -0.18482 deg/s, active engage at lower limb with -0.37149 deg/s^2 and passive engage activity at upper limb which is 0.127865 m/s and -8.2759E-05 m/s^2 respectively. To see the significant of active and passive activities, the T-test with 95% confidence interval was conducted. The results are only speed for both limbs have significant difference while others have no significant value. From this study, it can be clearly observed that active and passive activity almost have same effect. So, the severe stroke patients can do the passive mode exercise with have almost same effect as active mode before they can move their own limbs. The feedback system to detect the force difference that too large have been shown in the result part. The figure show that when the force difference is too large which the fraction of difference and total force value exceed 0.4 or -0.4, the LED will start to be blinking until the force difference become stable. The T-test with 95% confidence interval was conducted between both legs at active and passive mode. It shows that there were significant different for both active and passive mode. So, the feedback system can notify the user if force difference is too big where they will be improving force between both legs.

CHAPTER 1

INTRODUCTION

1.1 Research background

Nowadays, advancements in the field of medical technology has improved the survival rate of stroke patients[1]. However, these survivors might encounter problems like hemiparesis, which resulted one side paralysis of the body that affects arm, leg or face. There are several types of rehabilitation exercise for stroke patients which are arm and leg interlimb cycling intervention in motor control improvement and balancing with stationary cycling therapy, body weight supported treadmill therapy and occupational therapy[2]. One of the treatments is rehabilitation cycling pedal. This treatment is very important to the stroke patient to restore their walking and moving ability. This rehabilitation cycling pedal treatment is going to help patient to move and train the affected body. Many studies suggest that by applying cycling in rehabilitation treatment might improve the affected body to functioning[1][3][4].

Cycling activity is similar to walking because both of legs, knees, ankles and hip would use[3]. The cycling activity have high potential to restore the muscles strength[1][3][4]. This cycling rehabilitation give advantage to stroke patients where they do not have to be in a standing position compare to body weight support therapy which need to standing on treadmill[2]. The study about benefit and efficacy of pedal cycling to improve stroke recovery have been conducted. This pilot study compared the effectiveness of traditional physiotherapy to aperitive cyclic movement training in improving (i) power during submaximal cyclic movement training of the lower limbs, (ii) cardiac fitness, (iii) balance and gait ability, and (iv) quality of life in stroke patients over a 4-week period[5].

There are some problems that the system had which the hemiparesis patients, they lack of activity of affected limb is often compensated by the unaffected limb[1]. After the treatment, the patients will not recover completely cause the unaffected limb not use fully during the rehabilitation cycling pedal exercise[1]. So, this study was conducted to measure the pedal forces that act at both pedals and arms then monitor and analyse the combined pedalling forces to evaluate the differences between the pedals and arms. After that, the system that can provide feedback was developed to user if the forces differences are too large.

1.2 Problem statement

The hemiparesis patients lack of activity of affected limb is often compensated by the unaffected limb when perform rehabilitation cycle therapy[1]. After the treatment, the patient will not heal completely because the affected limb does not use fully used during the rehabilitation cycling pedal exercises. The force that applied to the pedals will not balance in both sides.

1.3 Objectives

In order to solve these problems, there are two main objectives to achieve:

1. To measure, monitor and analyse the active and passive mode of pedalling parameters act at both pedals' legs and arms.
2. To develop the system that can provide feedback to the user if the force differences are too large.

1.4 Scope of work

The feedback system was created by using Arduino software version 1.8.12. to detect the force difference obtained from Canister load cell model MNC-200L. The load cell was located at each leg pedal only because chain and gear are connected between the leg and arm pedal. The load cell was calibrated by using another code to get the accurate result. The force value will be converted to Newton.

The feedback system was notifying the patient if the force difference is too large. It notified the patient through signal light. The patient can adjust the force if the force does not balance. The data obtained from the load cell were compared between with and without feedback system.

Both combine and separate pedalling parameters were analysed and monitor the speed, acceleration, and angle movement of limbs. From the data obtained were compare between the activities that being plan. The activities are, engage and disengage between upper and lower limbs. Those two activities also have another two sub-activities which are active and passive mode.To achieve these objectives, the functional test was performed in the lab and 4 different healthy students were perform the activities. The data and the feedback system were analysed.

1.5 Thesis outlines

This thesis contains five chapters and references that consists of:

Chapter 1: Introduction to overview and background of the project, problem statement, research objectives, scopes of project and the thesis outline.

Chapter 2: In-depth literature reviews on stroke, stroke rehabilitation therapy and cycling exercise for stroke rehabilitation.

Chapter 3: Detailed explanation regarding the methodology uses in conducting the research project.

Chapter 4: Precise explanation on the findings based on the experiment conducted and the discussions based on the results obtained.

Chapter 5: A brief conclusion of the whole project work and the short summary for the future research of the project.

References: The list of references that have been used in this research.

CHAPTER 2

LITERATURE REVIEW

2.1 Stroke

Stroke is a disease that cause disability to do work normally. According to World Health Organization WHO stroke can be defined : ‘ a syndrome of rapidly developing clinical sign of local (or global) disturbance of cerebral function, with symptoms lasting 24 hours or longer or leading to death, with no apparent cause other than of vascular origin’ [6]. It is estimated that approximately 30% of all ischemic stroke patients will deteriorate in the first 24 hours regardless of pharmacologic and/or mechanical intervention[7]. Figure 2.1 shows the example of ischemic stroke where the blood vessel at brain were blocked by blood clotting[8]. It will affect the muscle to do work and cause the part of the body cannot function properly. They cannot do activity properly like normal person like walking, running and carry something. Most of the stroke patient’s disability involve the arms and legs. This stroke patient may be survived from the disease but may face hemiparesis which half of the body cannot function very well.

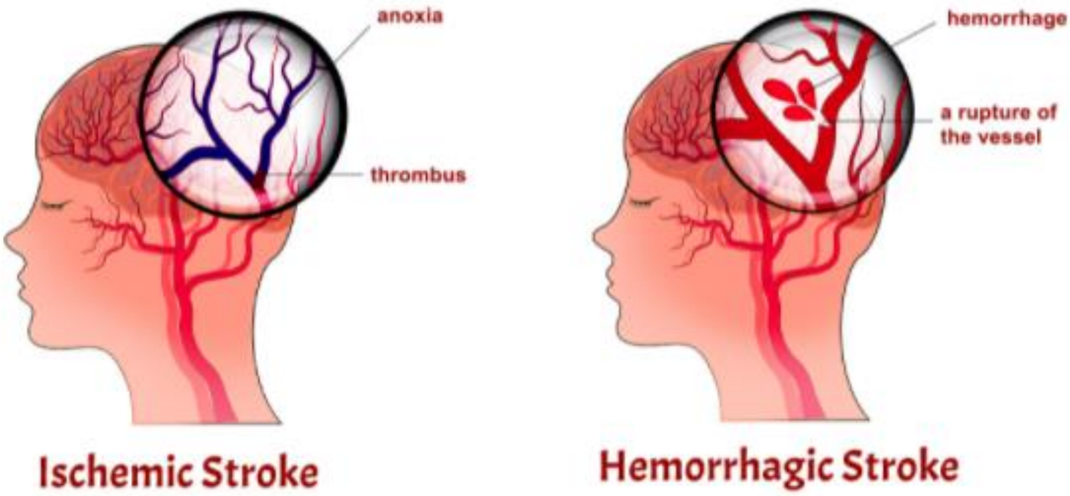

Figure 2.1: Types of strokes[8]

Stroke is a primary cause of long-term disability include hemiparesis, inability to walk without assistance, and reliance on others to perform ADLs[9]. Paralysis (hemiplegia) and weakness (hemiparesis) on the contralateral side of the afflicted hemisphere of the brain characterize motor impairments[10]. In hemiparetic individuals, postural instability, muscle weakness (paresis), spasticity, asymmetrical lower-limb motions, aberrant movement synergy, lack of mobility, loss of interjoin coordination, and loss of feeling are all common[10][11]. For hemiparetic stroke patients, performing continuous and smooth reciprocal movements, such as walking, is a challenging task[12].

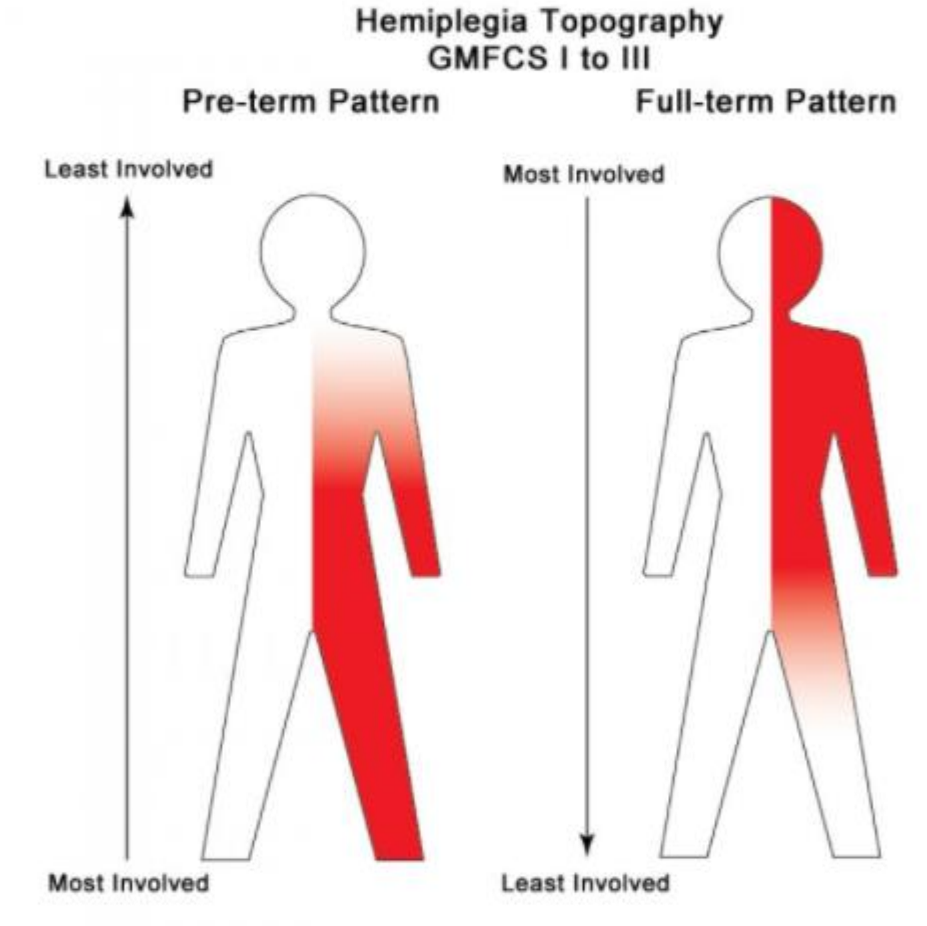

Figure 2.2: Hemiplegia topography[13]

The primary goal of lower limb rehabilitation after a stroke is to regain walking abilities[14]. The degree of recovery is determined by various factors, including the location and severity of the lesion, as well as the potential for adaptation through training, and is greatest in the first month following a stroke[10]. As soon as the patient is medically stable, rehabilitation can begin during the acute phase of a stroke (usually between 3 and 7 days)[3]. Early mobilization promotes functional reorganization and the use of the hemiparetic side to prevent and lessen the consequences of deconditioning and potential later deficits[3]. In the subacute (usually 7 days to 6 months) and chronic (more than 6 months poststroke) stages, patients with disabilities continue their therapy.

Stroke rehabilitation programs currently emphasize task-specific training combined with intensive practice of functional tasks[10]. To overcome unequal lower limb function and decreased postural control, treadmill gait training with or without suspension, supporting reciprocal stepping, and muscular strength exercises have been used[15][16]. However, depending on the severity of the impairments, these therapies may not be appropriate for some stroke patients. Typically, these therapies must be carried out in a gym or clinical setting[3].

2.2 Stroke rehabilitation

The rehabilitation of a stroke typically involves a cyclic process[17], which involves: (1) evaluating, assessing and quantifying the patient's needs; (2) setting goals, setting realistic and achievable improving goals; (3) intervention to help achieve goals; and (4) re-evaluating the progress towards the agreed objectives. Motor impairment that limits muscle motion or mobility is the most widely accepted impairment caused by a stroke[18]. Speech and language, swallowing, vision, sensation and understanding also have common impairments[19]. Even if a substantial non-linear relationship seems to be established between impairment and function, evidence of impairment-centric treatments which increase real logical neuro healing in the human brain is still rare for motor disability[20][21][22]. On the other hand, significant evidence suggests that task orientated training promotes the natural pattern of functional rehabilitation, which supports the notion that functional rehabilitation is largely supported by adaptive mechanisms that offset damaged functions[20][22][23]. Most rehabilitation procedures therefore appear to be best suited to the level that they are targeted[20]. There are several types of rehabilitation exercise for stroke patients which are arm and leg interlimb cycling intervention in motor control improvement and balancing with stationary cycling therapy, body weight supported treadmill therapy and occupational therapy[2].

Figure 2.3: Arm and limb interlimb cycling therapy[2]

Figure 2.4: Stationary cycling therapy with ergometer[2]

Figure 2.5: Body weight supported treadmill therapy[2]

The current treatments involve physical, occupational, rehabilitation and mental health therapy. According to WHO, rehabilitation is a set of measure to optimize functional and reduce the disability of individual in interacting with their environment[24]. The purpose of rehabilitation is to treating disorder affecting the nervous and neuromuscular system, known as neurorehabilitation[25]. There is phase model of rehabilitation for stroke patients being use in Germany. Figure 2.3 shows the time course of susceptibility to complications and functional recovery during rehabilitation after stroke. Phase A consist of emergency care in a stroke unit. Phase B is early neurological rehabilitation which still need medical treatment. In phase C which post-stroke rehabilitation, patients can involve in their therapy but still under medical treatment and nursing assistant. After early mobilization which in phase D, the rehabilitation is narrower definition of after hospital curative treatment. Occupational reintegration in phase E and phase F is continue measure for support, maintain or improve function[26]. Some of stroke patients cannot perform rehabilitation walking because the lowest limb cannot support their bodies. One of the solutions of this problem is rehabilitation cycle. In this treatment, the patients can sit on the wheelchair and perform the treatment continuously.

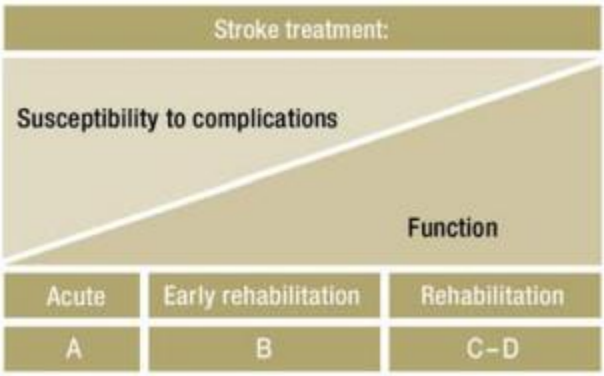

Figure 2.6: A simplified graphic depicting the progression of vulnerability to problems and functional recovery during stroke therapy[26]

2.3 Cycling exercise for stroke rehabilitation

Cycling share an identical kinematic pattern with walking, since it required reciprocal flexion and extension motions of hip, knee and ankle; it provide an alternating and synchronised antagonist muscle activation[3]. Moreover, cycling does not need balancing body because the patient just needs to sit on the wheelchair and it safe. In order to counter consequences of immobility, cycling is a best method to perform[4]. It will improve aerobic capacity, strength and cardiopulmonary function. The patient can perform the rehabilitation cycling continuously or prolonged, in contrast the capacity of training can be altered according to patient's health status, physiological response and rehabilitation evolution[27]. During the exercise, it will allow reversing patient's muscular weakness that have half affected side because the unaffected side help the affected side through pedalling. This affected side will be use and the muscle control the limbs, so the affected leg can support more weight while standing[28].

Two main modes that exist during this rehabilitation cycle which are active and passive mode[3]. Figure 2.4 and Figure 2.5 shows both active and passive mode of rehabilitation cycle. For active mode, the patient will use their own energy to move their limbs which similar to normal cycling. Passive mode, the pedals were connected to the motor to drive it which the patient's movement will assist by the motor. This active mode will give active contraction limb muscles while passive activity will trigger the sensory inputs of patients[3]. Passive mode usually suitable for patients who cannot perform the active activity which their limbs are too weak to do work[29]. Cycling exercise has been researched for its impact on many diseases such as multiple sclerosis[30], Parkinson disease (motor function[31], executive function[32], tremor, and bradykinesia[33]), in older people, gait dysfunction (hip abductor weakness[34]), and stroke[35].

Figure 2.7: Active mode rehabilitation cycle

Figure 2.8: Passive mode rehabilitation cycle

Table 2.1 summarize a major characteristic of publish cycling studies applied in stroke patients. In the study, it includes subacute and chronic phase patients. Majority of this study consider the patients after the stoke. Only three studies include ischemic stroke while the others consider ischemic and haemorrhage type and no information about stroke. They are divided into two groups in the experiment which are control and experimental groups. Some of the study use healthy person as a control group to find the expected result in using rehabilitation cycling. Some also consider healthy elderly as a control group to determine the expected result for stroke patients who have same age. Other study only have experimental group or case study[3]

Table 2.1: Major characteristics of the published cycling studies, applied in stroke patients[3]

	Therapy		Population					
Study	Aim	Length	N	Age (years ± SD)	Years after stroke (± SD)	Ischemic/ hemorrhagic stroke	Groups (E, C, H, EH)	RCT
Kamps et al[3]	RT	16 weeks	31	C: 65.8 (10.7) E: 63.1 (8.1)	C: 1.28 (1) E: 1 (.79)	31/0	E, C	
Katz-Leurer et al [40]	RT	3 weeks (5 seconds/week)	24	63 (9)	NS	24/0	E, C	x
Seki et al[43]	RT	8 r (sg)	10	69	.19	6/4	E, H	
Fujiwara et al[44]	RT	5 minutes (sg)	17	55.1 (10.9)	.44 (.16)	5/12	E	
Potempa et al[30]	ARC	10 w (3 seconds/w, 30 minutes)	42	21 to 77	>0.5	NS	E, C	x
Tang et al[45]	ARC	3 seconds/w (30 minutes)	23	64.7	.05	17/5	E, C	
Holt et al[46]	ARC	8 w (2/3 seconds/w, 30 minutes)	1	55	1.5	0/1	SC	
Quaney et al[47]	ARC	8 weeks (3 seconds/week)	38	C: 58.96 (14.7) E: 64.10 (12.3)	4.9 (3.3)	NS	E, C	x
Lennon et al[48]	ARC	10 weeks (2 seconds/week, 30 minutes)	48	C: 60.5 (10) E: 59 (10.3)	C: 4.72 (3.26) E: 4.56 (2.13)	48/0	E, C	x
Katz-Leurer et al [49]	ARC	5 weeks (3/5 seconds/week, 30 minutes)	92	63 (11)	NS	80/12	E, C	x
Lee et al[50]	ARC	10/12 weeks (3 seconds/week, 30 minutes)	52	63.2 (9)	4.75 (4.5)	33/9	E, C	x
Chen et al[26]	AST	5 minutes (sg)	10	58.9 (13.5)	2.11 (1.61)	NS	E, EH	
Brown et al[27]	AST	3 minutes (sg)	15	65.3 (5.8)	3.53 (3.59)	NS	E, EH	
Kautz et al[31]	AST	3 minutes (sg)	15	65.3 (5.8)	3.53 (3.59)	NS	E, EH	
Brown et al[29]	AST	3 minutes (sg)	15	65.3 (5.8)	3.53 (3.59)	NS	E, EH	
Rosecrance et al[51]	AST	4.5 minutes (sg)	13	58.7 (8.9)	4.8 (3.5)	NS	E, EH	
Brown et al[52]	AST	120 minutes (sg)	17	63.1 (5.0)	1.67 (.43)	NS	E, EH	

Abbreviations: ARC, aerobic; AST, assessment; C, control; E, experimental; EH, elderly healthy; H, healthy; min, minutes; NS, not stated; r, wheel revolutions; RCT, randomized controlled trial; RT, rehabilitation; N, sample size; SC, single case; sg, single session; s/w, sessions per week; w, weeks.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this study, a pedal exerciser was design for stroke patients from mild, moderate, and severe stroke. It also has two modes of exercise which is active and passive activities. The efficiency between both modes will be compared in the experiment. Besides, each mode also has another two sub-activities which are engaged and disengaged between upper and lower limbs. This research will show the parameters like speeds, accelerations, and angles.

3.2 Design of product

This device was fabricated and improved from previous works (Refs from Bulya and Chin Ze Yi, theses)[2][36]. The device contains both upper and lower pedal exercisers (Figure 3.1). It was connected by a single rod that the length can be adjusted. Both upper and lower pedals are connected by the chain system to make sure that it can move simultaneously. The cycling device is placed permanently on a stainless-steel plate with four caster wheels, this will give mobility to the device. A 12V DC motor was connected to the lower sprocket to move the upper and lower pedal automatically.

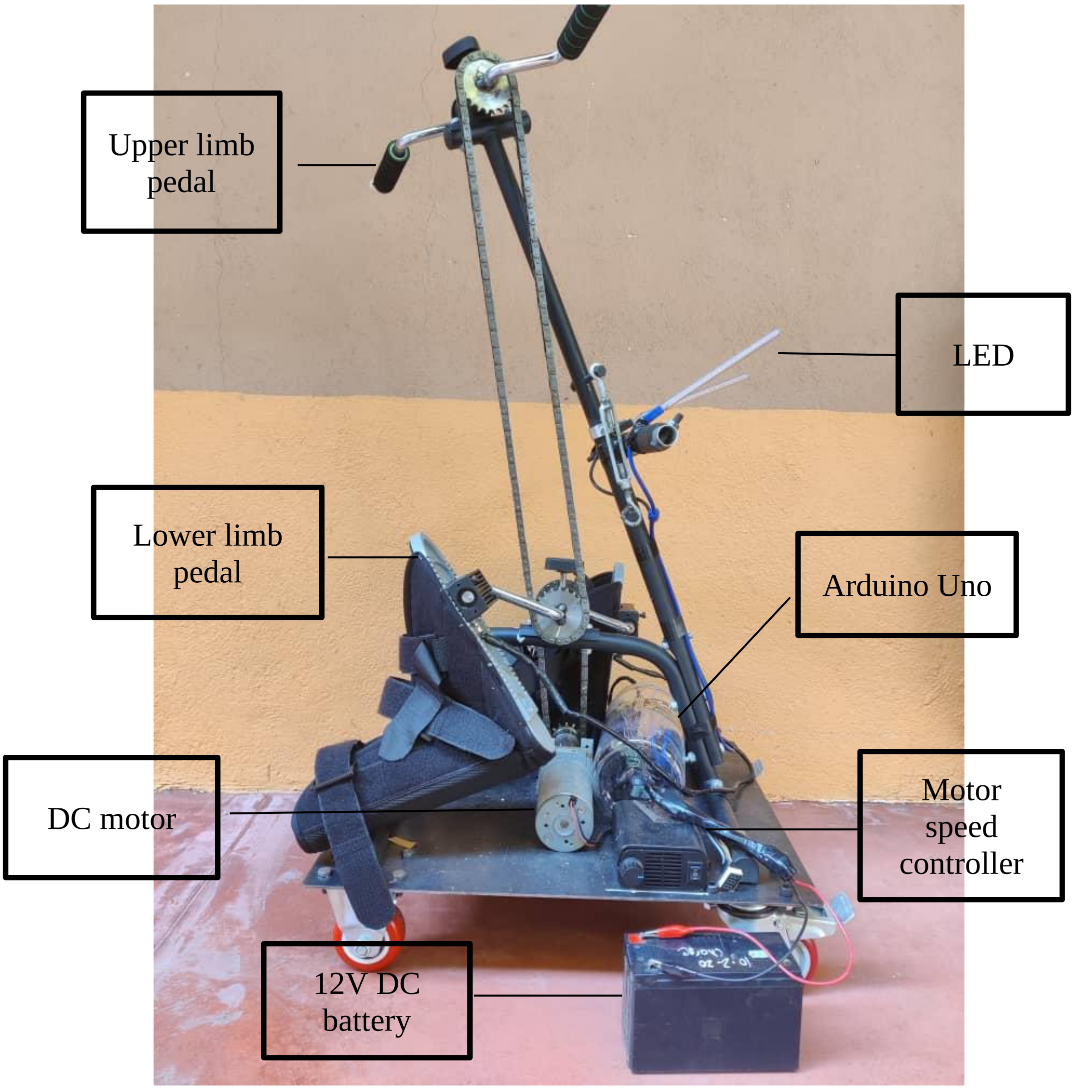

Figure 3.1: Rehabilitation cycle

3.3 Machine functionality

This cycling device can be operated to perform either active or passive activities. Active activity is the pedal exercise does not attach to DC motor while passive activity, the pedal was attached to motor. Passive mode is usually for severe and moderate stroke patients because the motor assists the movement of pedals. The patients may not use their own energy to do the exercise. This will give the patients move their limbs even they do not have enough energy to move, and it will help the patient to recover. If the patients can move their limbs by its own, they can move to active mode.

Active mode is use when the patients can use their own energy to perform the cycling exercise. This mode use for mild and moderate stroke patients. Each patient will show different result cause of pace that they perform.

3.3.1 Passive mode

During passive mode, both arm and leg pedals are operated by a DC motor (RS 224-3625) with speed and maximum torque of 73 rpm and 5 Nm respectively. In this study, the speed was set at 50% from the maximum speed, which it produces 36-37 rpm. There also have another two sub-activity which are engage and disengage between both upper and lower limbs.

The arm and leg pedals will be engaged when both are connected by the chain system. Both pedals will move simultaneously. While for disengage activity, both limbs will do separately which if the leg pedal is connected to the motor the arm pedal will remain stationary. Figure 3.2 shows the functionality of this mode.

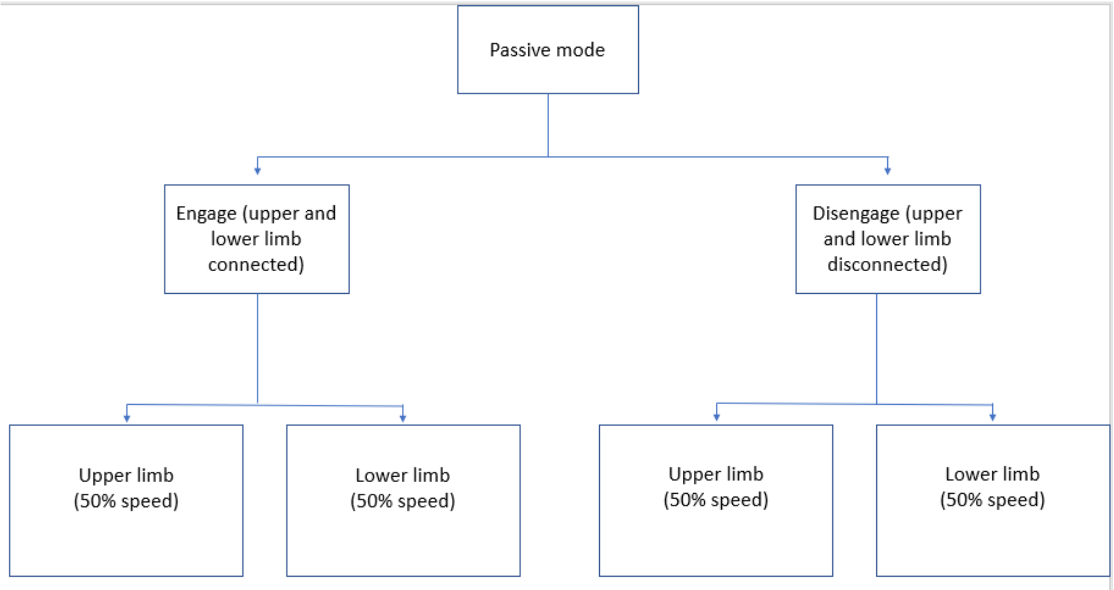

Figure 3.2: Passive mode

3.3.2 Active mode

During active mode, the patients will use their own energy to operate the rehabilitation cycle. This also have another two sub-activity which engage and disengage. Engage activity represent for the fabricated product while disengage represent the market product. The concept also same as the passive mode but the difference is it does not have motor to move the pedals. The engage activity, both limbs connected to chain and disengage both activities will do separately. Figure 3.3 shows the active mode activities.

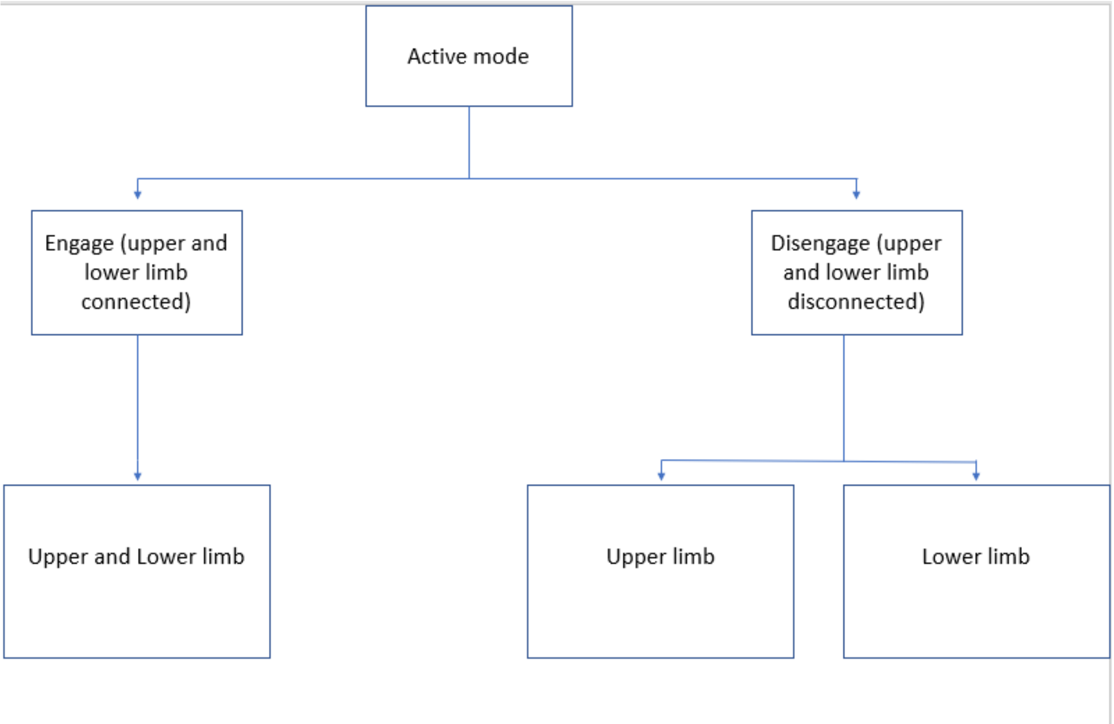

Figure 3.3: Active mode

3.4 Electrical components for feedback system

This feedback system was used to give alertness to stroke patients when the value of difference force between two load cells were too big. There are several electrical components that exist in this feedback system. The components are Arduino Uno, wire jumper, LED, HX711, PCB board, and canister load cell. The Arduino software 1.8.12 is used to run the calibration and system coding. The electrical components were connected on PCB board and being solder. The full overview of the system will be shown in the schematic (Figure 3.4). Arduino Uno is act as a microprocessor which it will display the force that act at sensors that connected to it.

HX711 is use as an interface between the load cell and Arduino Uno because it is 24-bit analog to digital (ADC) for weighing scale like load cell. It specially made to amplify signal from cell and report to another microcontroller which Arduino Uno. Canister load cell model MNC-200L and LEDs are used to detect force and give signal to the user.

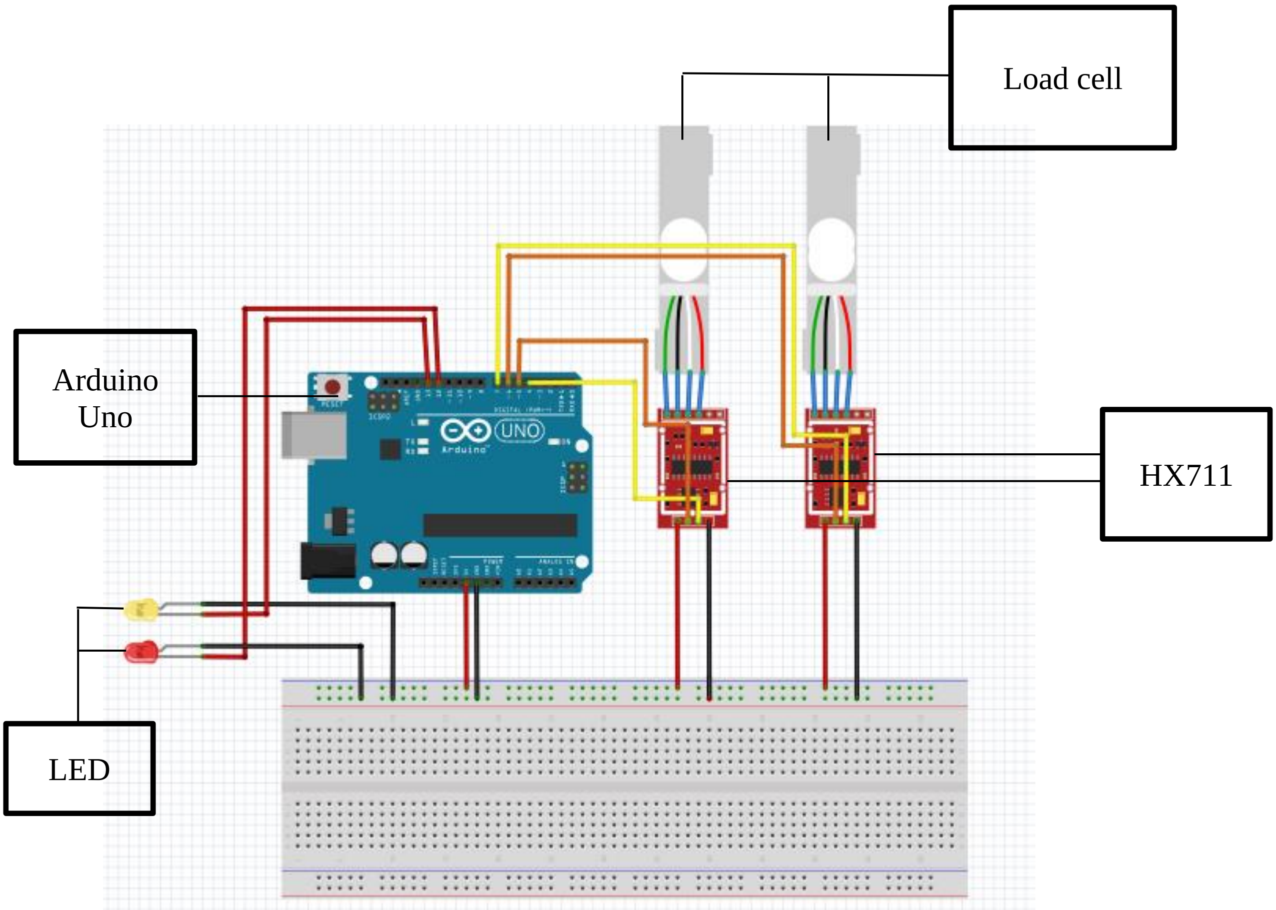

Figure 3.4: Schematic diagram for electrical components

3.5 Force measurement and real time notification system

The main sensor that uses in this project is Canister load cell that can detect load up to 200kgf. The quantity is two units to detect both left and right legs force that act to it. This load cell contains strain gauge that arrange in Wheatstone bridge which it detect the mechanical force and then converted to electrical voltage for the display of the force.

The calibration of the load cell and it interface which is HX711 is need in this project to get the most accurate values and to get the calibration factor which will insert into the coding. The 2500 grams of mass was placed on the load cell and the calibration code is run in Arduino software. The Figure 3.5 shows on how the mass is place on load cell and Figure 3.6 calibration process.

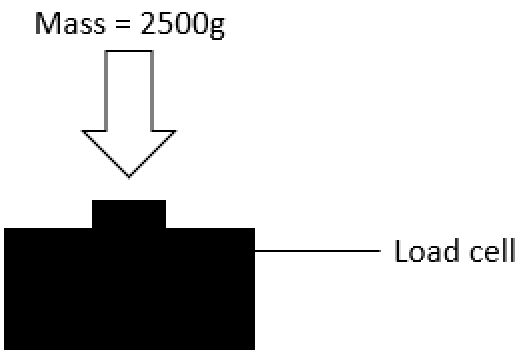

Figure 3.5: 2500g mass place on lad cell

```
02:22:27.205 -> Startup is complete
02:22:27.252 -> ***
02:22:27.252 -> Start calibration:
02:22:27.252 -> Place the load cell an a level stable surface.
02:22:27.252 -> Remove any load applied to the load cell.
02:22:27.252 -> Send 't' from serial monitor to set the tare offset.
02:22:33.349 -> Tare complete
02:22:33.349 -> Now, place your known mass on the loadcell.
02:22:33.396 -> Then send the weight of this mass (i.e. 100.0) from serial monitor.
02:22:45.225 -> Known mass is: 2500.00
02:22:47.211 -> New calibration value has been set to: 2.80, use this as calibration value (calFactor) in your project
02:22:47.211 -> Save this value to EEPROM adress 0? y/n
02:24:01.199 -> Load_cell output val: 2491.06
02:24:01.292 -> Load_cell output val: 2482.48
02:24:01.385 -> Load_cell output val: 2464.96
02:24:01.479 -> Load_cell output val: 2446.72
02:24:01.573 -> Load_cell output val: 2429.20
02:24:01.670 -> Load_cell output val: 2423.13
02:24:01.761 -> Load_cell output val: 2425.63
02:24:01.855 -> Load_cell output val: 2425.99
02:24:01.948 -> Load_cell output val: 2427.06
02:24:02.040 -> Load_cell output val: 2428.13
02:24:02.132 -> Load_cell output val: 2428.85
02:24:02.225 -> Load_cell output val: 2430.28
02:24:02.319 -> Load_cell output val: 2429.92
```

Figure 3.6: Calibration process

Then, the load cell is used to detect the force that act by the stroke patients. Bedside, the load cell also uses to measure the different force that act for both legs. This system can detect which load cell will shows the lowest value base on the difference that will calculate by the code. Equation (3.1) below will explain how the value is calculated. If the value of fraction between difference and total force is positive, so it means the load cell 2 value is lower and vice versa. The threshold value also being set to trigger whether the difference is too big which is more than value of 0.4 or -0.4.

$$Fraction\ of\ difference\ and\ total\ force = \frac{(\,Load\ cell\ 1 - Load\ cell\ 2)}{(Load\ cell\ 1 + Load\ cell\ 2)} \qquad (3.1)$$

The percentage performance of the constraint leg is determine based on below equation (3.2).

Percentage performance of constraint leg= $\frac{force\ at\ constarint\ leg}{total\ force\ of\ both\ load\ cell}\ x\ 100\%$

(3.2)

This fraction of difference and total force value will notify the other sensor which is LED. Each LED will pair with the load cell, which if the value of load cell is reach the threshold value the LED will be blink. This will notify the stroke patients which leg that they lack in activities. So, the patients will struggle to fix the error and they will improve their limbs.

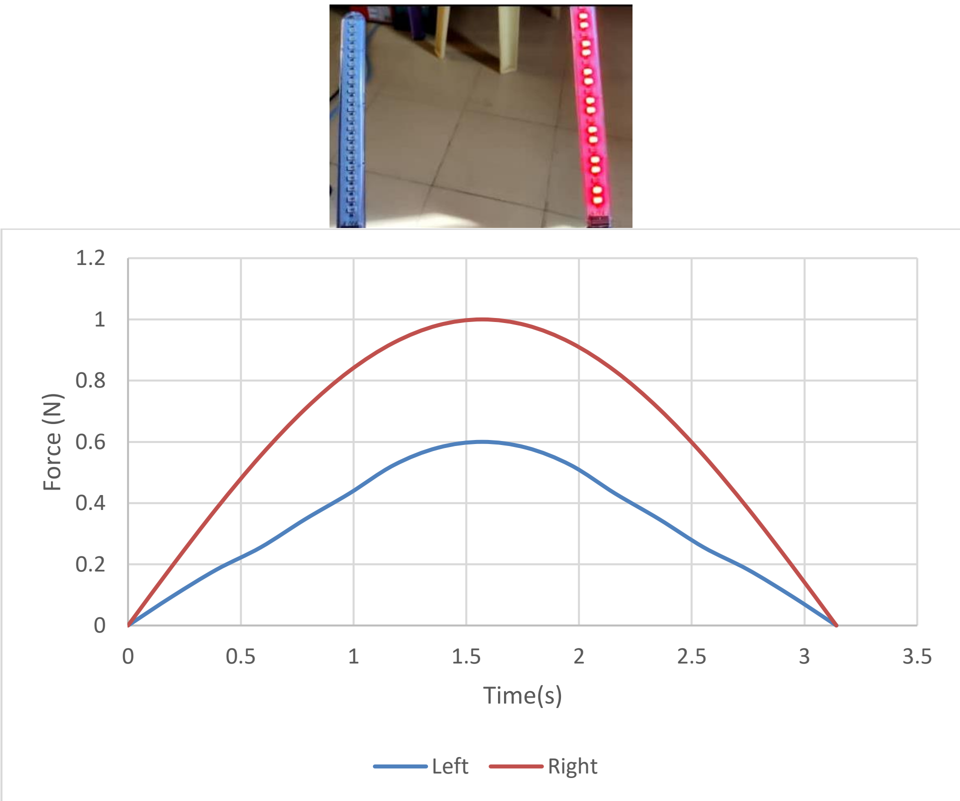

Figure 3.7: Right LED blinking

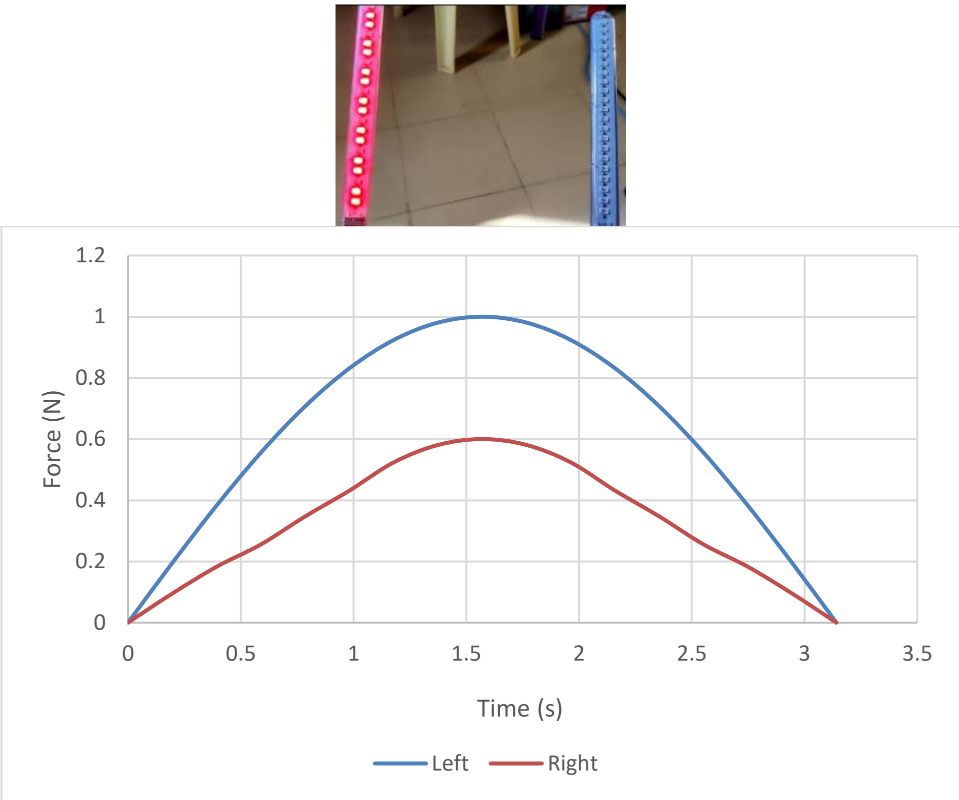

Figure 3.8: Left LED Blinking

3.6 Experimental procedure

Before starting the experiment, the problems statement and objectives were determined. The problem is the hemiparesis patients lack activity of affected limb is often compensated by the unaffected limb when perform rehabilitation cycle therapy. The objectives were to measure, monitor and analyse the active and passive mode of pedalling parameters act at both pedals' legs and arms and to develop the system that can provide feedback to the user if the force differences are too large.

The feedback system was developed by using several electrical components which are load cell, LED, Arduino Uno and HX711 interface. These components were connected in a printed circuit board (PCB) and being solder. Then, the load cell was calibrated, and the calibration value was insert into main coding. The coding was created in Arduino software.

The experiments activities were plan before executing them. The activities are active engage (AE), active disengage (AD), passive engage (PE) and passive disengage (PD). The experiment was conducted in Desasiswa Jaya, Universiti Sains Malaysia

(USM) Engineering Campus, Nibong Tebal, Penang. The purpose of this experiment was to measure, monitor and analyze the combine and separate pedaling parameters act at both legs and arms with the feedback system if the difference is too big. Four health male subjects were selected for this study. The average height was 1.69 m ± 0.05 m, weight 73 kg ± 9.5 kg, and BMI of 23.7 ± 3.68. The subjects were sat in a chair and the distance between the camera is approximately 1.5 m ± 0.6 m The mobile phone camera with 32 MP was used to record the video (Figure 3.9 and Figure 3.10).

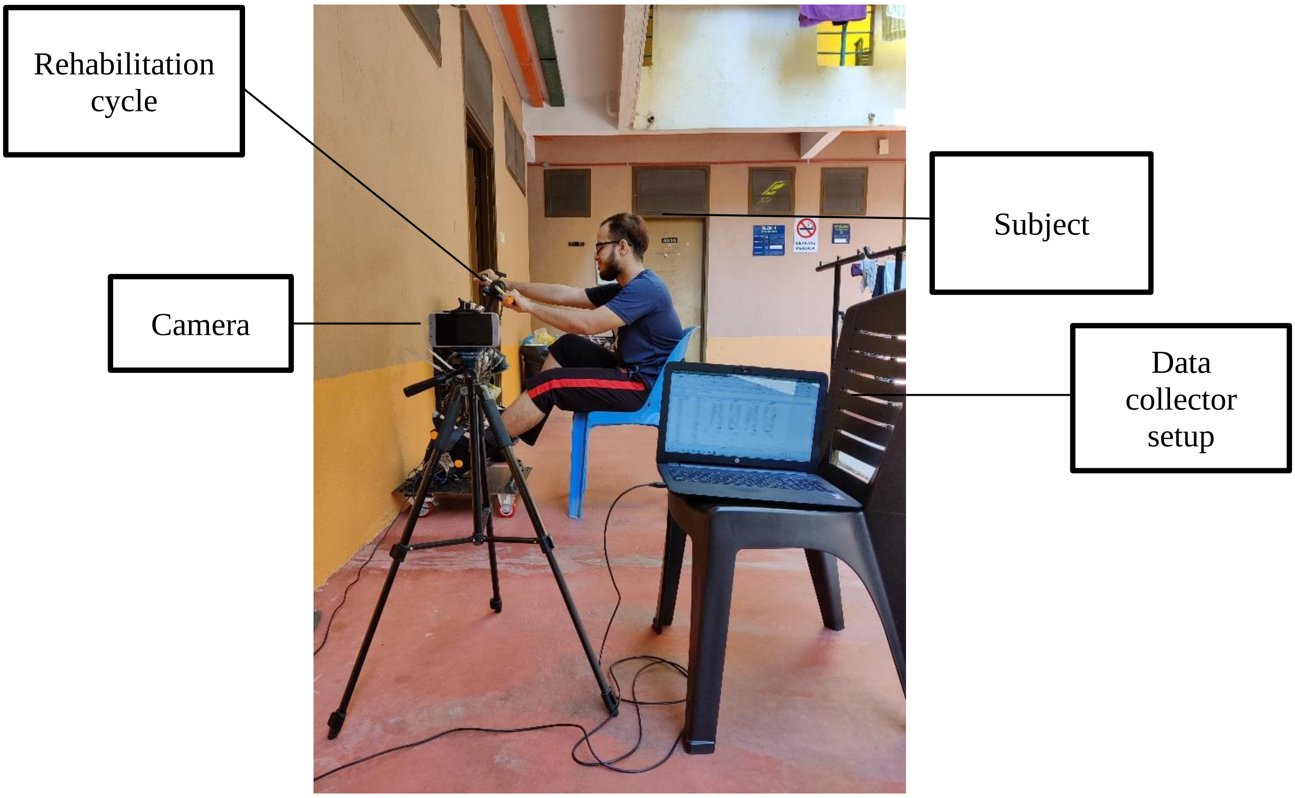

Figure 3.9: Experiment setup side view

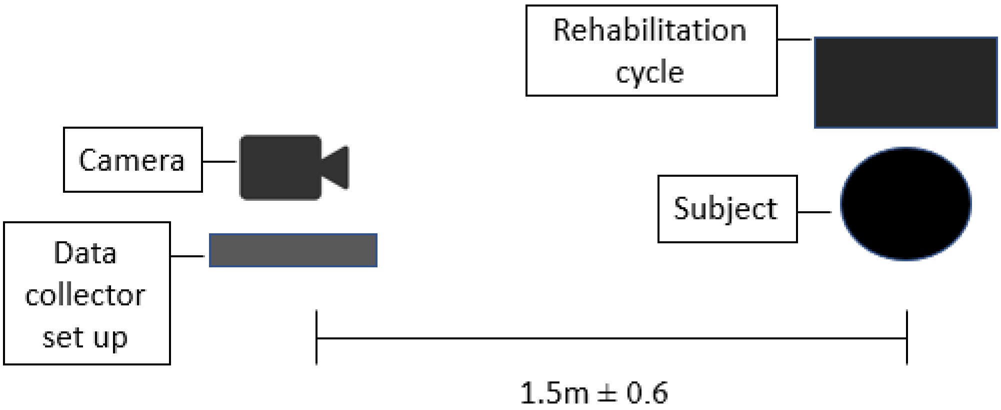

Figure 3.10: schematic diagram of experiment set up from top view

The participant will be wearing sticker to specific joints at both upper and lower and upper limbs. The purpose of this sticker to detect the movement of the joints in the Kinovea software version 0.8.15, available download at https://www.kinovea.org/. Figure 3.11 and Figure 3.12 will show the stickers that attach to specific joint at both lower and upper limbs.

Figure 3.11: Point markers were located at the main joints at the upper limb

Figure 3.12: Point markers were located at the main joints at the lower limb

There are several activities that the subjects need to perform. They need to cycle the fabricated rehabilitation cycle in active and passive mode. In active mode, the motor is used to move the pedal automatically while active mode is without motor attached. Both modes have their sub-activities which are, engage and disengage between upper and lower limbs, and feedback system is on. The engage and disengage limbs is not use the feedback system and the subject will cycle freely. They need to cycle about 2 minutes. While if feedback system is on, one of the participant legs need to be constraint which the right leg. It shown in Figure 3.13. In this activities, 5 minutes is required for the participant to perform the rehabilitation cycle to see the effectiveness of the feedback system. Finally, the data were analyzed and insert into report.

Figure 3.13: One side of the leg was constrained because simulate as stroke patient

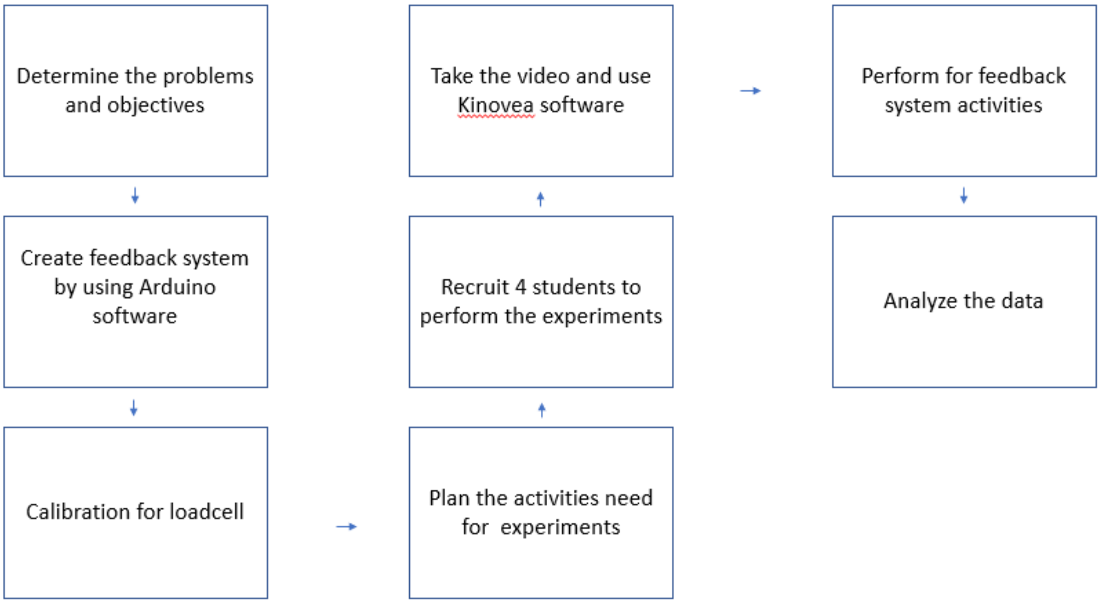

Figure 3.14: Overall flow chart of experimental procedure

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

The objectives of this project are to measure, monitor and analyse the active and passive mode of pedalling parameters act at both pedals' legs and arms and to develop the system that can provide feedback to the user if the force differences are too large. These activities involved active and passive mode for comparing both methods will have significant difference which could give effect to the rehabilitation activities through T-test. Then, the effectiveness of feedback system to the stroke patients through experiment on healthy person that simulate as stroke patients.

For section 4.2, the study on Active-Passive movement based on their speed and acceleration. The average of angular speed, angular acceleration, speed and acceleration for this both activities will be shown in the table. Then, T-test analysis with 95% confidence interval will determine the significant different between active and passive mode.

Then, in section 4.3, the effectiveness of feedback system will be proven for the experiment data that perform by four healthy subjects. The comparison between active and active activities also being analyze but in engage form.

4.2 Active-Passive activity movement

These results were obtained from Kinovea software version 0.8.15, where the subjects perform the exercise being attached stickers to their joints to calculate the angular speed, angular acceleration, speed and acceleration. Besides, each of the mode will have another sub-activity which are engage and disengage. The activities are Active Engage (AE), Active Disengage (AD), Passive Engage (PE), and Passive Disengage (PD). Each of the result will divide into upper and lower limbs with the angular speed, angular acceleration, speed and acceleration. The T-test with 95% confidence interval were used to determine the significant difference between active and passive activity. Figure 4.1 shows the data collected from Kinovea software.

Figure 4.1: Data from Kinovea software that measure the joint angles of upper and lower limbs

4.2.1 Postural analysis of upper and lower limbs

The T-test with 95% confidence interval is conducted. The null hypothesis is passive activity have better angular speed or angular acceleration. To reject this hypothesis, the P-value must less than 0.05.

4.2.1(a) Angular speed

The value of the P-value for upper limb is greater than 0.05 which mean, there was no significant difference between the activities. The passive disengage show the highest mean value of angular speed while the lowest is active disengage.

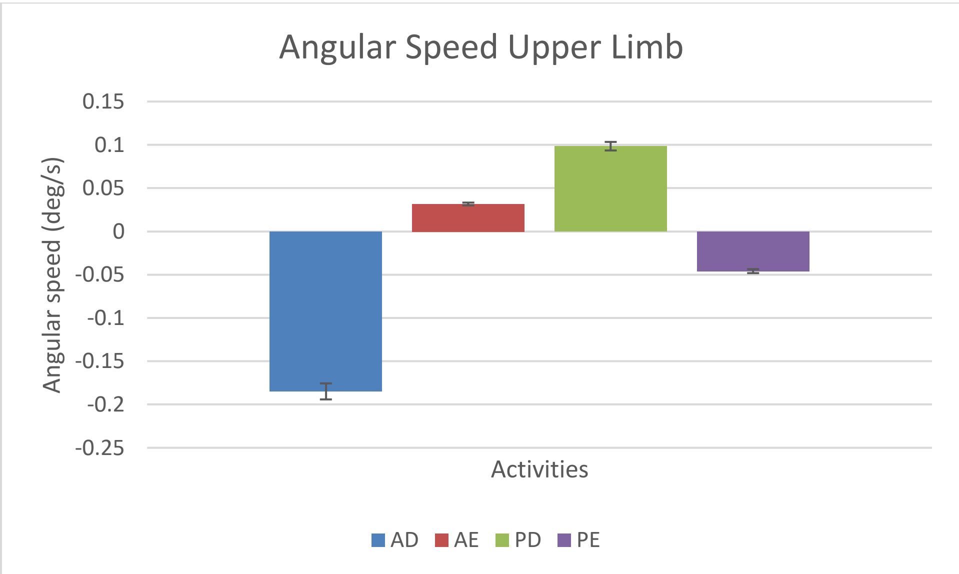

Figure 4.2: Angular speed for upper limb

The value of the P-value for lower limb is greater than 0.05 which mean, there was no significant difference between the activities. The active engage show the highest mean value of angular speed while the lowest is passive engage.

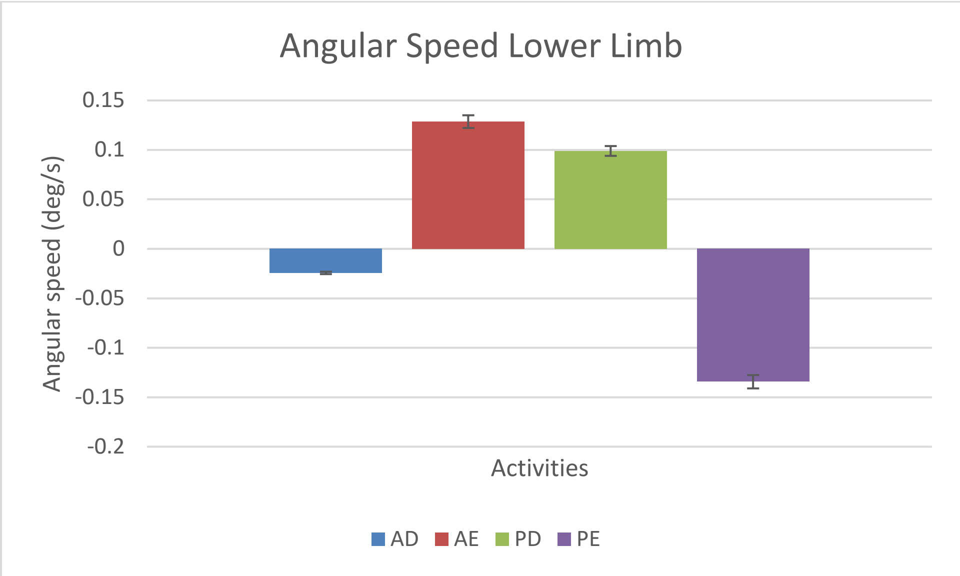

Figure 4.3: Angular speed for lower limb

4.2.1(b) Angular acceleration

The value of the P-value for upper limb is greater than 0.05 which mean, there was no significant difference between the activities. The active engage show the highest mean value of angular acceleration while the lowest is active disengage.

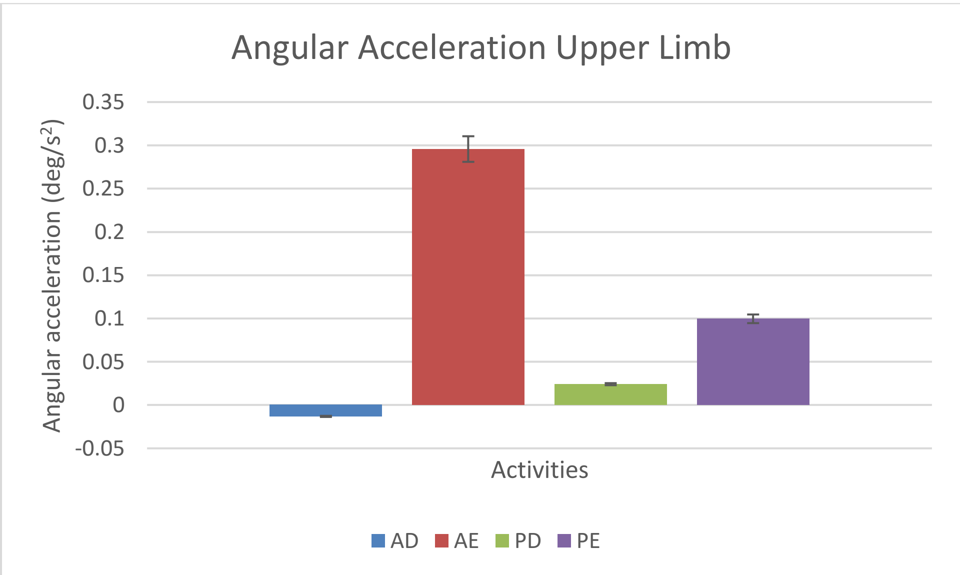

Figure 4.4: Angular acceleration for lower limb