PEDAL EXERCISE MACHINE FOR PHYSICAL REHABILITATION OF STROKE PATIENTS

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MAY 2019

This dissertation is submitted to
Universiti Sains Malaysia
As partial fulfillment of the requirement to graduate with honors degree in
BACHELOR OF ENGINEERING (MECHANICAL ENGINEERING)

School of Mechanical Engineering
Engineering Campus
Universiti Sains Malaysia

DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

Signed………………………………………………………………. (Ahmad Bulya)
29 May 2018
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STATEMENT 1
This thesis is the result of my own investigations, except where otherwise stated.
Other sources are acknowledged by giving explicit references.
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ACKNOWLEDGEMENT

The successful of this project is not possible without the assistance from many people. First of all, I would like to express my sincere gratitude towards the School of Mechanical Engineering of Universiti Sains Malaysia (USM) for providing the golden opportunity to complete this four-year course in Mechanical Engineering as well as to conduct Final Year Project (FYP) individually. All the acquired knowledge and skills would definitely equip me for my future undertakings as an engineer.

Besides, I would like to extend my appreciation towards my project supervisor, Dr. Mohamad Ikhwan Zaini Ridzwan, for providing me with his expertise and guidance throughout this research. Since this research is concerning on the study of stroke rehabilitation, thus I have encountered lots of challenges as it was very hard for me to finish this project. However, the help and guidance from my supervisor and the patience and enthusiastic encouragement from my supervisor have always motivated me to putting more efforts to overcome the problems faced in this research.

I would also like to express my gratitude to the staffs of the USM's Mechanical staff, Mr Abdul Halim Che Aat for helping me during the fabrication process, Mr Baharom , Mr Norijas and Mr Latif for guiding me through the fabrication and assembly process, Mr Mohd Sani and Mr Mohd Zafril for helping me during the welding process and finally thanks to Mr Mohd Nawawi from USM Health Campus for helping me during EMG experiment . In addition, I am grateful to the coordinator of this course, as well as the lecturers from the School of Mechanical Engineering in conducting seminar talks. The contents from these seminars have indeed helped me a lot in completing my research work, for instance the effective method in presenting literature review as well as the techniques in writing a good thesis.

Finally, I take this opportunity to express my sincere gratitude to my dearest family and friends for their continuous support throughout the completion of this project.

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ABSTRAK

Pemulihan strok telah menjadi perkara penting dalam dunia moden, dan banyak penyelidik dan ahli sains berusaha keras untuk mendapatkan kaedah pemulihan terbaik. Salah satu kaedah yang paling biasa untuk pemulihan stroke adalah melalui senaman aerobik seperti berjalan, berlari, berenang, atau berbasikal. Dalam kajian ini tumpuan pemulihan stroke adalah tumpuan kepada latihan berbasikal, produk senaman berbasikal biasa yang terdapat di pasaran biasanya hanya untuk anggota tunggal. Masalah dengan produk ini yang terdapat di pasaran adalah ketika pemulihan hanya satu anggota tunggal yang dapat berlatih untuk pemulihan pada satu masa. Ini menyebabkan kesabaran untuk menghabiskan masa tambahan untuk merawat anggota badan lain dengan merancang produk yang dapat menampung kedua anggota pada masa yang sama akan meningkatkan masa yang diperlukan untuk proses pemulihan. Masalah seterusnya yang dihadapi pesakit strok adalah masalah keletihan, semasa pemulihan pesakit cenderung menjadi keletihan apabila proses pemulihan semakin lama, maka produk yang dirancang juga dapat mengakomodasi aktivitas pasif dimana motor digunakan untuk menjalankan produk yang dirancang supaya jumlah aktiviti otot mengekalkan sepanjang proses pemulihan.

Percubaan dilakukan pada dua sampel yang sihat menggunakan produk yang direka dan produk pasaran. Pengiraan T-test berpasangan digunakan untuk mengukur perbezaan penting antara kedua-dua produk dalam bacaan EMG. Pada akhir eksperimen, nilai penting antara produk pasaran dan produk yang direka adalah apabila fabrikasi dalam mod aktif dengan melibatkan kedua-dua anggota badan yang terlibat dan nilai P yang diperoleh adalah 0.003 untuk sebelah kanan dan 0.032 untuk sebelah kiri yang bermaksud signifikannya lebih baik apabila menggunakan produk fabrikasi. Bacaan purata tertinggi juga diperolehi daripada menggunakan produk fabrikasi dalam mod aktif semasa melibatkan kedua-dua anggota badan dengan purata tertinggi bahagian kanan sebelah atas 43.94 μV dan bahagian bawah kanan 38,19 μV. Oleh itu dari penyelidikan ini, dapat disimpulkan bahawa dengan menggunakan produk yang direka, pesakit stroke dapat memiliki output otot yang lebih tinggi daripada yang tersedia di pasar. Untuk kerja-kerja masa hadapan, lebih banyak sampel harus dipilih untuk menghasilkan hasil yang lebih tepat dan untuk mengesahkan kebolehpercayaan produk yang direka.

ABSTRACT

Stroke recovery is an important field in modern world, and many researcher and scientist have worked hard to obtain the best recovery method. One of the most common method for stroke recovery is through aerobic exercise such as walking, running, swimming, or cycling. In this research the focus of stroke recovery is focus on cycling exercise. The common cycling exercise product that is available in the market is usually only for a single limb. The problem with this product is that during rehabilitation only a single limb that can train for recovery at a time. This causes a patient to spend extra hours to rehab the other limb therefore by designing a product that could accommodate both limbs at the same time would greatly improve the time needed for recovery process. The next problem that the stroke patient face is the problem of fatigue, whenever during the rehab the patient tends to be fatigued due to longer rehab process, hence the designed product also able to accommodate passive activity where a motor is used to run the designed product so that the amount of muscle activity is maintain throughout the rehabilitation process.

An experiment is carried out on two healthy subjects using a fabricated product and a market product. A paired T-test calculation is used to measure the difference between the two products in EMG reading. At the end of the experiment the significant value between the market product and the fabricated product when the fabricated in active mode with of both limbs being engaged and the P-value obtained is 0.003 for the right side and 0.032 for the left side which are significantly better compare to market product. The highest average reading is also obtained when using the fabricated product in active mode while engage both limbs with the highest average of the right side upper limb is 43.94 μV and right side lower limb is 38.19 μV. hence from the research it can be deduced that by using the fabricated product, the stroke patient can have higher muscle output than the one available in the market. For future work, more number of subjects should be choose in order to have accurate results and to validate the reliability of the fabricated product.

CHAPTER 1: INTRODUCTION

1.1 Research Background

This project requires to design and develop a machine exerciser to accommodate reciprocal movement of both upper and lower limbs with and without using motor. This machine will help for stroke rehabilitation, Stroke contributes to major morbidity and mortality in both developed and developing countries. The cases are increasing annually. With the right recovery programs that prioritise exercise for rehabilitation, stroke survivors can 'relearn' crucial motors skills to regain a high quality of life. During the rehabilitation period, the patients will have to undergo a set of training exercises to improve and restore the limbs function. One of the training is by using a pedal exerciser to stimulate coordination and muscle strength. The pedal exerciser has variable resistance adjustment knob and is compact and light. However, it only allows for one set of limbs at a time while in operation. This will then increase the time that the patients will have to spend for another limbs (upper or lower) function.

From the past, a number of studies about stroke recovery using a pedal exerciser have been carried out to study the recovery rate of a patient. Recently, a group of researcher have conducted a study on a stroke patient with residual neurological deficits to assess the patient cardiopulmonary exercise by exercise stress testing using a combined upper and lower-limb ergometer called the Power Trainer (Denise C.Hill. 2005). The research outcome was measured using the data collected from rate-Pressure product (RPP) and age-predicted maximal heart rate (APMHR) in percentage. However, this past work focusses only on Power Trainer a pedal exerciser that accommodate upper and lower limb simultaneously and in active, but it does not compare using passive training.

1.2 Problem Statement

The problem that we are facing are the absent of pedal machine exerciser in the market that could help stroke to rehab their upper and lower limbs simultaneously. In Malaysia the most common pedal machine exerciser that could be found in most rehabilitation centre is the one that accommodate only single limb at a time. The problem with single limb pedal exerciser is that it is time consuming for the patient that require to exercise both of their limbs in order to have speedy recovery.

There is also another problem with the pedal machine exerciser available in market which is the machines could only function as a motorized or non-motorized. The one in the market is not able to accommodate motorized function and non-motorized function in a single machine. A motorized pedal exerciser also is very expensive. Therefore, in this project the fabrication will be focused on trying to eliminate the problem of pedal exercisers that are available in the market while trying to reduce cost of the machine. Previous researcher used age-predicted maximal heart rate (APMHR) in percentage as the focus on measure parameter which only focus on the heart rate and not the muscle activity of the patient that could potentially show the crucial part of the human recovery system for a stroke.

1.3 Objective (s)

In order to solve the stated problems, two main objectives have been identified that are stated below:

1. To quantify between the effect of passive-active movement training on muscle activity by using Electromyography (EMG).
2. To quantify between the effect of upper and/or lower limbs exertion on muscle activity by using Electromyography (EMG).

1.4 Scope of Research

A machine will be fabricated to accommodate reciprocal movement of both upper and lower limbs design for stroke rehabilitation. A stroke is a "brain attack". stroke can happen to anyone at any given time. stroke will occur when the blood flow to an area is stop. When blood flow is cut off, the brain cells oxygen will be deprived and begin to die. So, when brain cells die, this will cause an area on the brain to malfunction and hence causing loss of muscle control. Each person who is affected by stroke may have different effect depending on where and how the brain is damaged. For minor case of stroke body will face temporary weakness of a leg or an arm. Some worst-case scenario is people may be permanently paralyzed on one side of the body and lose the ability to speak. there are chances for people to recover from strokes, but more than 66% of survivors will have some type of disability.

Stroke rehabilitation is a very important part of recovery once stroke is detected, the main goal of stroke rehabilitation is to help the patient to relearn skills which are lost when stroke affecte the part of the brain and help in regain brain motor capabilities. Stroke rehabilitation can help in improving patient’s lifestyle and help in regaining independence ability. In this project a pedal exerciser machine will be developed that is able to accommodate upper and lower limbs simultaneously. The machine will move in contralateral movement because when stroke occur, it usually affects a part of the brain, therefore by using contralateral movement, the brain motor would have better recovery.

In this research, the focuses are on the type of training using a pedal exerciser to understand which training would give the highest muscle training compare to the baseline product that is currently being used in most rehab centre. The data of the muscle output from the experiment will show which training is the best for stroke recovery.

The contralateral exercise was chosen in this research because it mimics the normal human behaviour such as walking, running, swimming and other activities. Table 1.1 below shows that the contralateral movement is the suitable method for stroke recovery.

Table 1.1 : Difference between Contralateral and Ipsilateral

Contralateral	Ipsilateral / homolateral
On the opposite side of the body. * Each hand is controlled by the contralateral motor cortex. (That is, the right hand is controlled by the left side of the brain, and vice versa.)	on the same side of the body. "The stroke was characterised by ipsilateral paralysis.
Contralateral movement exercise is better than ipsilateral exercise because the other body part can help to coordinate the brain coordination	Therefore, for rehabilitation exercise using ipsilateral movement is not suitable for passive stroke patience due to motor of one side of the brain need help to coordinate once again

CHAPTER 2: LITERATURE REVIEW

2.1 Stroke

Stroke is a major cause of disability, which can be related with abnormal function of a body area. This altered function is due to weaker function of the brain, spinal cord, muscles, or nerves [1]. It also results in great physical deconditioning that will cause even higher cardiovascular risk and disability [2]. Sixty percent of stroke patients have disabilities in the arm or leg, and more than thirty percent have to be taken care of in a nursing home and needed assistant device or these patients will have to be dependent on others [3, 4]. The physiotherapy that is currently being implement focus primarily on restoring motor and postural control so that the quality life of the stroke patients can be improved [5].

2.2 Stroke Recovery

Repetitive practice of goal-directed, skilled functional tasks, such as walking, enhances the brain changes that underly recovery of motor function after stroke [6, 7]. The problem is that the people who are unable to walk due to their brain motor skills are not at the required conditions, will have problem practicing on how to walk and hence cannot benefit from practising the task. Therefore, this people will not be able to have a good recovery process by walking, due to current rehabilitation procedure[8]. Identification and practice of better methods of walking rehabilitation are in the top-ten research priorities set by stroke survivors [9].

Body-weight support treadmill training (BWSTT) has been proposed as another alternative to perform the task but could not provide benefit over over-ground walking training [10]. Using Robotic systems and exoskeletons has also been considered as another possible alternative for walking practice after stroke, but research findings are preliminary and, recently it was recommended that using electromechanical gait training for stroke patient who cannot walk independently [11], but such devices are expensive and to be able to adapt the rehabilitation program in rehab places or people's home will be challenging.

Cycling is a beneficial activity that has potential to benefit patients when used as an addition to therapy after stroke[12]. It requires that antagonist and agonist muscles are contracted reciprocally that mimics the similar contraction while walking [13]. Hence, it is a repetitive muscle activity that could have been beneficial to train gait [14]. Indeed, pedalling may facilitate phasic, co-ordinated muscle activity even in patients with severe hemiparesis [15]. While stroke survivors is well known that reciprocal pedalling is likely to require re-acquisition of motor skill following the onset of hemiparesis.

In terms of medical recovery, therefore it is potential to use static cycling for repetitive, co-ordinated exercise training as part of stroke rehabilitation programmes to improve motor function. However, the evidence in support of cycling interventions is preliminary. The early findings from a systematic review are that, whilst research into aerobic capacity after stroke has often incorporated a cycling pattern [16-18], there has been a number of trials that have been specifically evaluated to observe the effect of cycling on motor function for early stroke patient. Some of it indicate that cycling activity may have a positive effect on reciprocal activation of antagonistic muscle groups, strength improvement and balance in stroke survivors in the chronic stages and sub-acute stages, but cautious interpretation of these results is required for a number of reasons: subject sizes were relatively small (n = 24[19] ; n = 17[15]; n = 8[20]), exact time since stroke onset was not specified [19] and findings related to a single session which was not repeated over time [15].

Furthermore, most of these works used a recumbent position and with using a standard leg cycle ergometer for cycling exercise [15, 17, 19, 20]. Although suitable for cardiovascular training, this position does not replicate the upright posture needed for walking. So, in order to replicate the upright posture, it is proposed that cycling that provide beneficial potential for the lower limb is when it is done in upright posture, in order to maximise potential for activity in major lower limb muscle groups, in a posture similar to walking. Indeed, muscle activation patterns during pedalling are not fixed and are modified according to body position [21, 22] and heightened levels of activity in quadriceps and hamstrings have been demonstrated in more upright pedalling postures [21].

2.3 Experiment Result

In article about Exercise Stress Testing in Subacute Stroke Patients Using a Combined Upper- and Lower-Limb Ergometer [20]] has shown beneficial result on stroke patient using a combined upper- and lower-limb ergometer which is called The Power Trainer.

Figure 2. 1: Show the Power Trainer Ergometer[20]

The result that have recorded has shown a positive feedback that the aerobic exercise is beneficial for patient recovering from stroke. For instance, when a patient involves in an aerobic exercise it has shown to increase in cardiopulmonary exercise capacity for chronic hemiparesis [23-26] hence it will improve the conditioning and stroke-related impairments have on overall physical fitness. Aerobic exercise will benefit in the subacute period after stroke were shown by Katz-Leurer et al,[27] who has been involving in training the subject for 8 weeks, and the result show that aerobic parameters and some functional measures of mobility has improved after the training period. In a recent study evaluating a standard stroke rehabilitation program [28] we can see that such programs does not incorporate enough aerobic training although its beneficial effects and also that the patients enjoys aerobic exercise, referring to the questionnaire results in article about exercise stress testing in subacute stroke patients using a combined upper- and lower-limb ergometer by Hill DC, [20]. By using the Power Trainer to evaluate exercise tolerance during subacute stroke rehabilitation, they were able to prescribe appropriate and safely individualized the limitations on exercise therapy. Exercise testing thus can help the embodiment of aerobic exercise into the stroke recovery program during a time [29] when cardiac comorbidity has been shown to negatively influence functional recovery.

The next benefit that is found in Power Trainer exercise stress testing study of poststroke study patients was that the value of diagnostic test for coronary artery disease (CAD), these was reflected by the 66% of common CAD in stroke population. based on Mcneer et al, [30] ST-segment interpretation and exercise duration, followed by maximal heart rate, all yield important clinical information about the likelihood of CAD in the patient undergoing an exercise stress test (EST). These data were successfully obtained in our study on patients with neurologic deficits resulting from stroke.

1864 **NOVEL POSTSTROKE EXERCISE STRESS TEST, Hill**

Table 3: Comparison of Our Study Protocol With Published EST Protocols

Study	No. of Subjects	Exercise Modality	Mean Age (y)	Time of Testing After CVA	% of APMHR	No. of Subjects ≥85% of APMHR	Mean Peak Exercise RPP	No. of Subjects on β-Blocker Therapy
Current study	30	Power Trainer	62.8	7.3wk	75	10	197	12
Moldover et al[18]	10	Supine bicycle ergometer	71.5	9.5wk	66.5	2	184	2
King et al[17]	70	Adapted Schwinn Air-Dyne ergometer	62.9	NR	76	18	201	0
Kelly et al[20]	17	Semirecumbent leg ergometer	61	≤7wk	77	2	142	0
MacKay-Lyons and Makrides[1]	29	BWS treadmill	64.9	26d	84.9*	NR†	224	15

Abbreviations: CVA, cerebrovascular accidents; NR, not reported.
*Maximum heart rate (HR) for those subjects on β-blocker was adjusted according to the formula HRmax=85%(220−age [in years]).
†Twenty-two of 29 subjects attained at least 1 of 4 criteria for the attainment of $\dot{V}O_2$max.

Figure 2.2: Percentage of age-predicted maximal heart rate (APMHR) pressure product (RPP)[20]

There are many advantages of using a combined arm-leg ergometer such as the Power Trainer to test to patient with hemiplegia based on stress testing. The power trainer is designed specifically to be used a wheelchair, hence it can reduce the poor balance effect and motor control on maximal exercise, performance. In comparison, because of poor limb coordination, an inability to follow directions, poor endurance, and lack of attention treadmill testing is not really possible for many post stroke patients [31]. Although using a BWS harness reduces the effect of the above limitations, but the equipment is very expensive. the next advantages of using Power Trainer is the ability to used 3 or 4 limbs during exercise will have more higher to enhance the evaluation of peak aerobic exercise capacity in people with hemiplegia while reducing the likelihood that testing will be limited by limb fatigue. it is needed that at least 50% of total muscle mass, to ensure that the exercise is limited by the capabilities of the cardiovascular system [32].

Thus, we can conclude from Hill DC [20], the subjects that involve in the exercise stress testing post-stroke using the Power Trainer have enraged a significant cardiopulmonary response. Using the Power Trainer, the patients were able to exercise while seated in wheelchair comfortably and safely with 3 or 4 limbs. All the subjects were able to complete the exercise test because of the problems related to balance or motor impairments. By objectively describing exercise tolerance, appropriate exercise limits were prescribed and diagnostic information about CAD was yielded. By making stress testing feasible and available, perhaps stroke rehabilitation programs would more likely include aerobic exercise of sufficient intensity to promote cardiac conditioning. The Power Trainer has been adapted for people with hemiparesis, therefore no modification is needed before it is use. Plus, the Power Trainer is not considered as expensive as the BWS treadmill, with the cost of $1300, the Power Trainer is considered affordable. The results of Hill DC [20] study suggest that using the Power Trainer for exercise stress testing is an appropriate consideration for those with neurologic deficits after stroke, precluding the use of more conventional devices.

2.4 Research Background

From the literature review, it can be seen that stroke recovery machine is not something new and many researches have used it for stroke rehabilitation [20, 26]. From the literature review, it is found that activity that involve cycling movement is a supplementary therapy after stroke [12] because the pattern that require during walking can also be found when cycling, human requires the agonist and antagonist muscles that are also used during walking [13]. From Hill DC [20] using the Power Trainer for stroke patient benefit drastically for cardiopulmonary response, the patient using the Power Trainer were able to complete the exercise comfortably and safely with 3 or 4 of their limbs. The exercise was done while the patient is seated on a chair to provide safety, it is found that all the patient was able to complete the exercise test although with balance or motor impairment. From the testing Hill DC state that stroke recovery should likely include aerobic exercise of sufficient intensity because this can help improve the cardiac conditioning and the result of the study using Power Trainer is suitable for neurologic deficits after stroke.

Based on the literature review there are pros and cons on the rehabilitation machine used during the stroke recovery. Most of the machine used such as Power Trainer in Figure 2.1 is low cost and can be fabricated easily. The downside of the machine is that the machine has limited functionality. For instance, the Power Trainer has the ability to accommodate upper and lower limb, but the power trainer is unable to perform function for passive patient only for active patient which require the patient to cycle without using any motorise functionality. For the current project the objective is to design and develop the machine that is not only capable to accommodate the upper and lower limbs but also have the capabilities to run in passive and active modes. The result of the project is to understand the efficacy of active and passive exerciser when using upper and lower limb simultaneously or separately.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

This research focuses on a new design of a pedal exerciser that have various functionality for stroke patient recovery and to compare the efficacy of a passive activity and active activity exercise. The target audiences of this research are stroke patient range from mild stroke, moderate stroke and severe stroke. That is why the design of the pedal exerciser will be able to accommodate various type of exerciser such as active activity for upper limb, lower limb and combined limbs and for passive activity upper limb, lower limbs and combined limb. In order to have better comparison the design product will be compare to the one that is available in the market. The research work is meant to have better understanding the human muscle activity during aerobic exercise such as pedalling and the benefit of aerobic exercise from active activity compare to passive activity. The research also focusses on certain human muscle that are important during pedalling exercise.

3.2 Design of The Product

In this research it is required to design a new reciprocal machine that is able to accommodate upper and lower limb for passive and active patient, therefore the scope of work needed is to design using a computer-aided design (CAD) software such as Solidworks and choose the best design in term of weight, manufacturability, stability and aesthetic for fabrication. Fabricated product is the one that was fabricated in the workshop that is powered by RS 224-3625 DC gear motor with an output speed of 73 rotation per minute and maximum output torque of 5Nm. while market product, is the pedal exerciser that is available in the market. Figure 3.1 show the CAD version of the fabricated product; Figure 3.2 show the actual Fabricated product and Figure 3.3 show the market product that was bought online. The testing and experimenting the machine can be done once the fabrication process is complete. In the experiment the patient muscle electrical activity will be tested using electromyography (EMG), therefore from the experiment the discussion about the effectiveness of the machine can will be analyse.

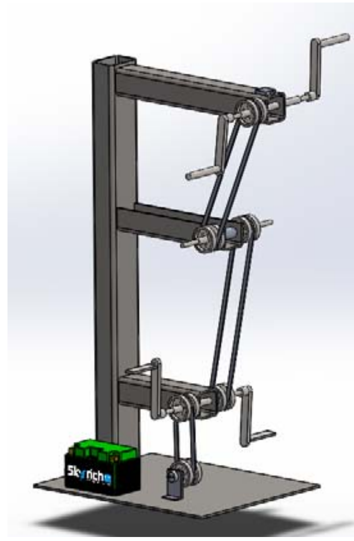


Figure 3.1: Final Design

Figure 3.2: Fabricated Product

Figure 3.3: Market Product

3.3 Machine Functionality

The design of the product is capable to accommodate two main function of activity which is the passive activity and the active activity. Each of the activity also has a its own subset of activities that require different limb either upper, lower or combined upper and lower limb. For each of the functionality of the pedal exerciser is focus on certain condition of patients. Figure 3.4 shows briefly the overall machine functionality. Figure 3.5,3.6 and 3.7 show the position of a subject when conducting the experiment using a fabricated product and Figure 3.8 and Figure 3.9 show when using market product.

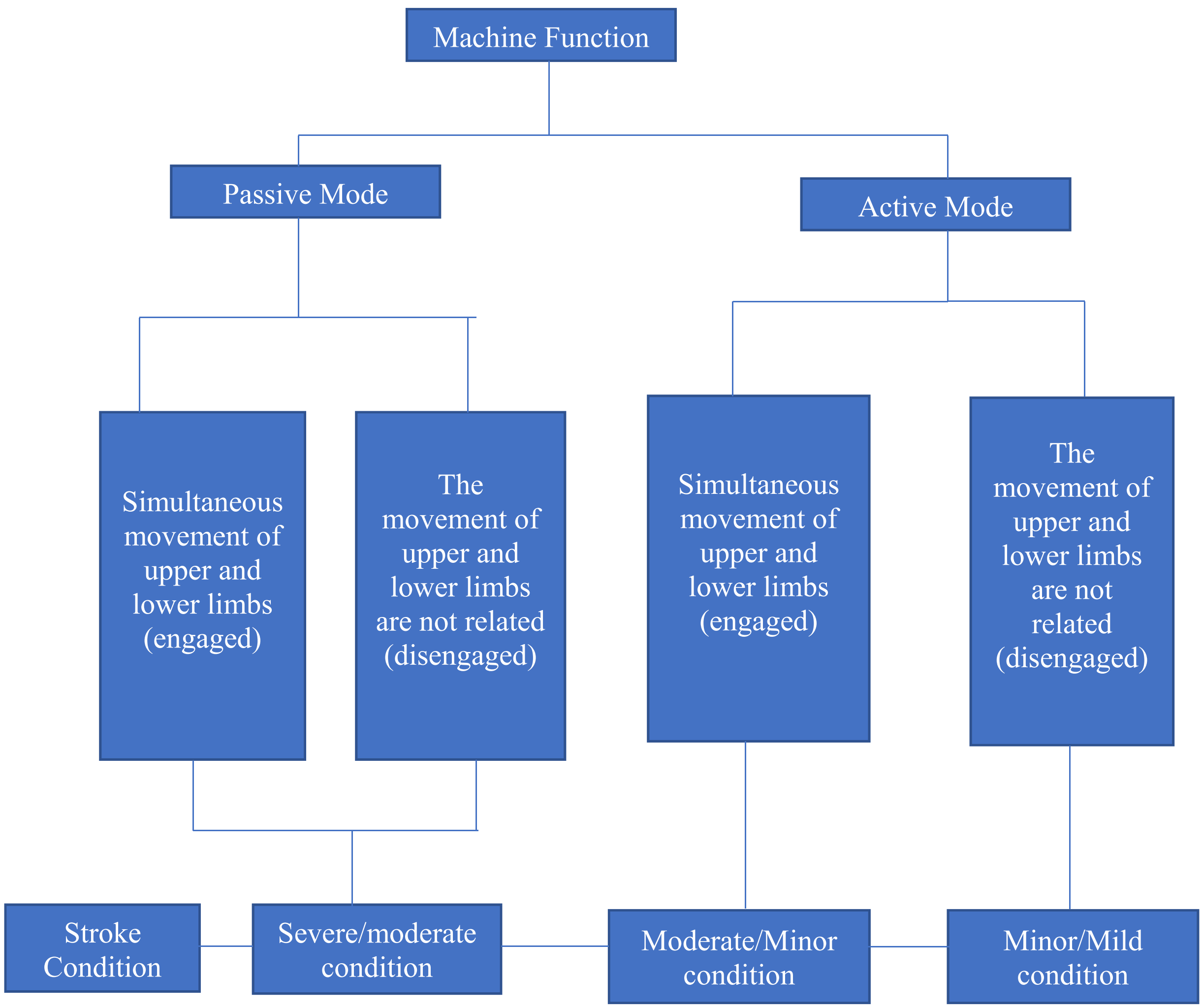


Figure 3.4: Fabricated Machine Functions

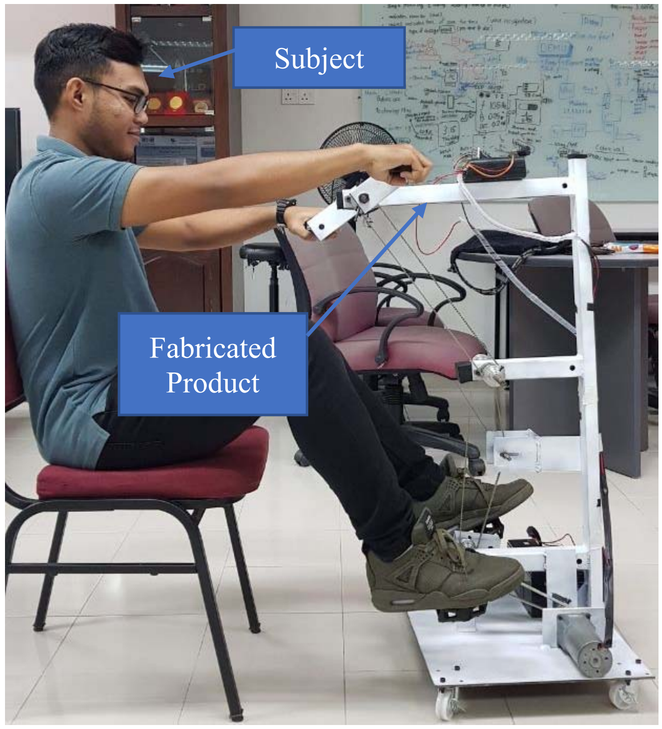


Figure 3.5: Engaging of both limbs

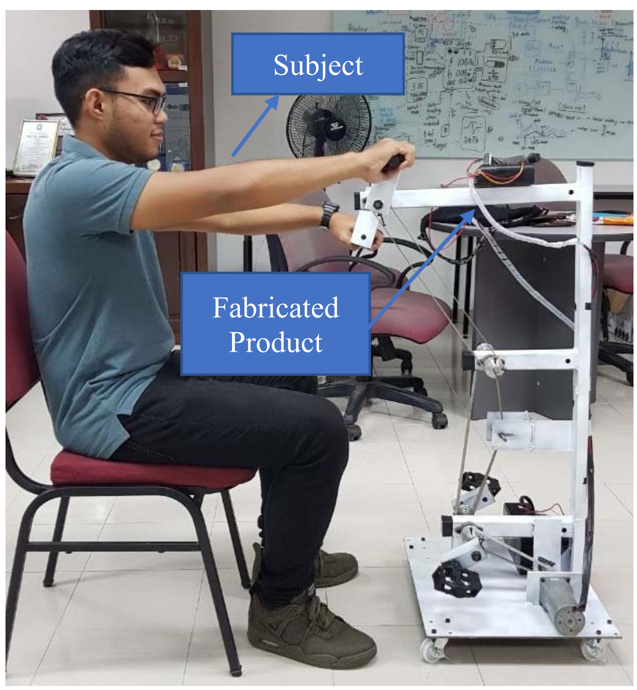


Figure 3.6: Engaging of only upper limbs

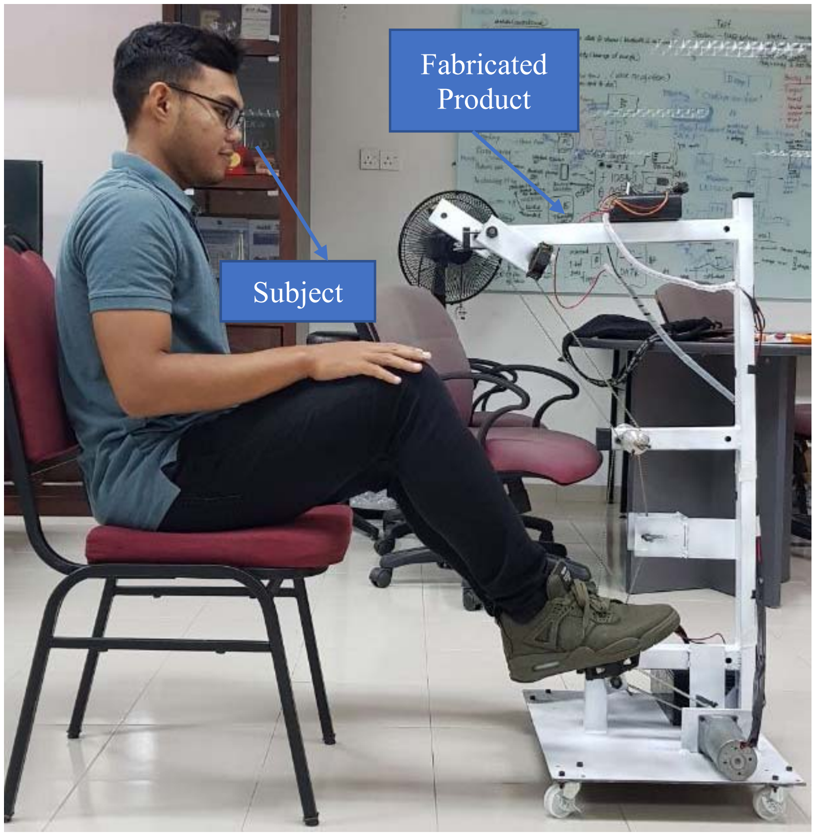


Figure 3.7: Engaging of only lower limb

Figure 3.8: Upper limb for market product

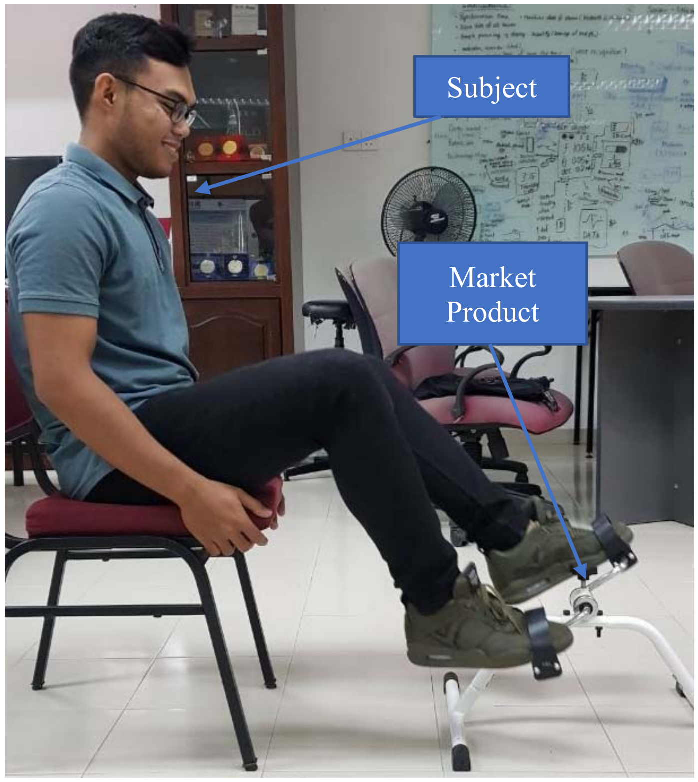


Figure 3.9: Lower limb for market product

Passive mode is the activity where the patient with severe or moderate stroke condition is assisted by a motor in order to perform the aerobic exercise that is needed for stroke recovery. In this mode the patient may and may not have used their own energy to perform the exercise, meaning the patient are able to perform the exercise although they are incapable of moving their body with their own.

Active mode is the activity where the patient is using his/her own energy in order to perform the aerobic exercise that is needed for stroke recovery. In this mode the patient will continuously cycle and at certain point when the patient fatigues the cycle will tend to get slower hence making the rotation per minute produce by the patient varies differently for each patient.

In both active and passive activity, the engage and disengaged of the limb were taken into consideration to study the difference output produce for each engagement and disengagement. Engage is simultaneous movements of upper and lower limbs while disengage is the movements of upper and lower limbs are not related.

3.3.1 Passive Mode

Figure 3.10 below shows the various training for passive mode training. For passive mode the training was done using two different speed 50% speed which is around 35 rpm and at 100% speed is 73 rpm.

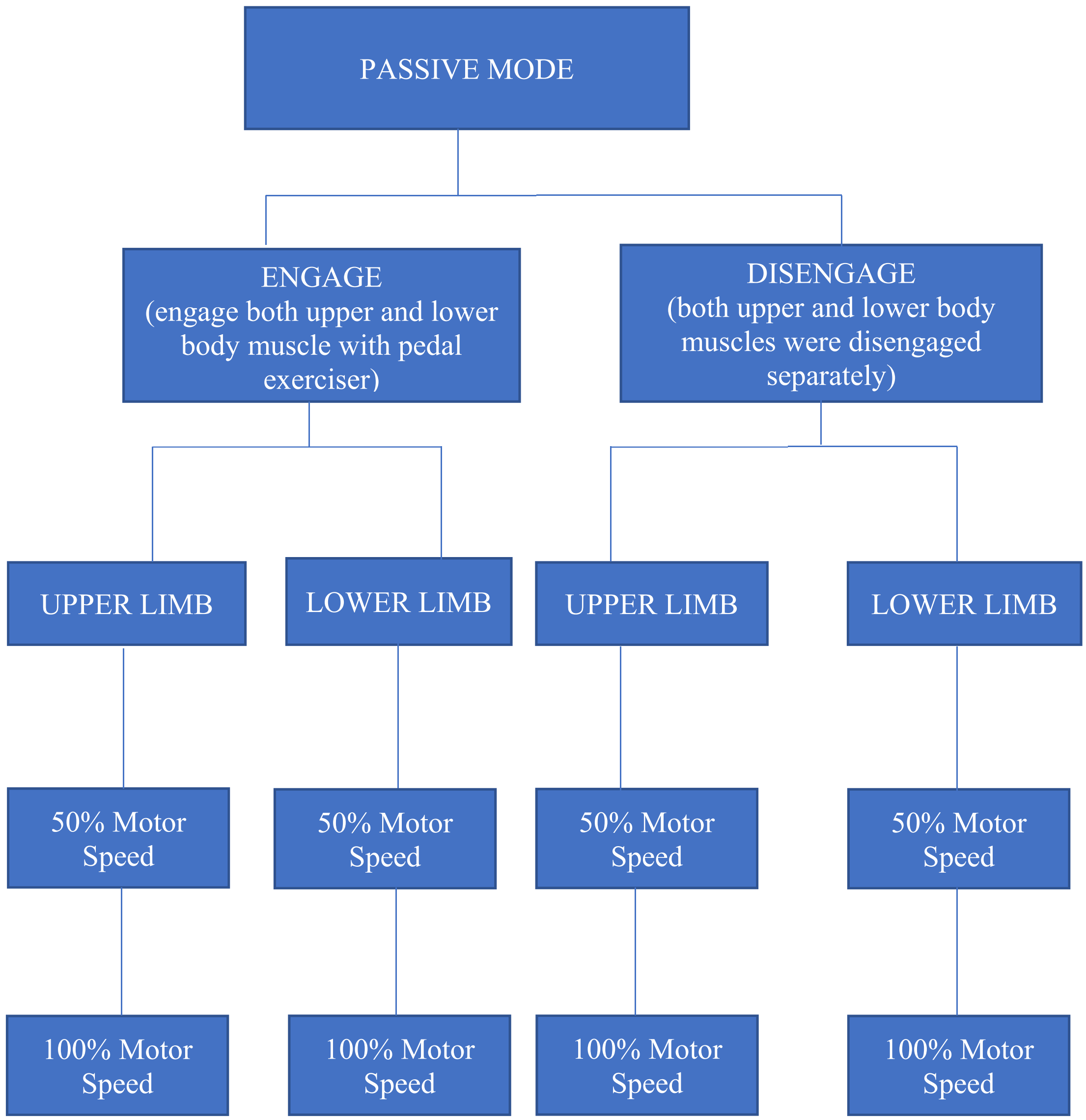


Figure 3.10: Passive Mode

In the passive mode, the pedal that was used was pedal exerciser A, which is the one fabricated in the workshop, the pedal exerciser A was power with RS 224-3625 DC gear motor with an output speed of 73 rotation per minute and maximum output torque of 5Nm. At 50% of motor speed the machine produces 36-37 rotation per minute and while at 100% the pedal exerciser will produce around 73 rotation per minute. For passive activity, there were two subset of activity in passive which are engaged and disengage, for engage activity the upper and lower limb were engage to the pedal exerciser and while for disengage activity either the upper or the lower part of the limb are engage to the pedal exerciser while the other limb remains stationary. Figure 3.10 shows the functionality of the passive mode.

3.3.2 Active Mode

Figure 3.11 shows the training that were done on active mode.

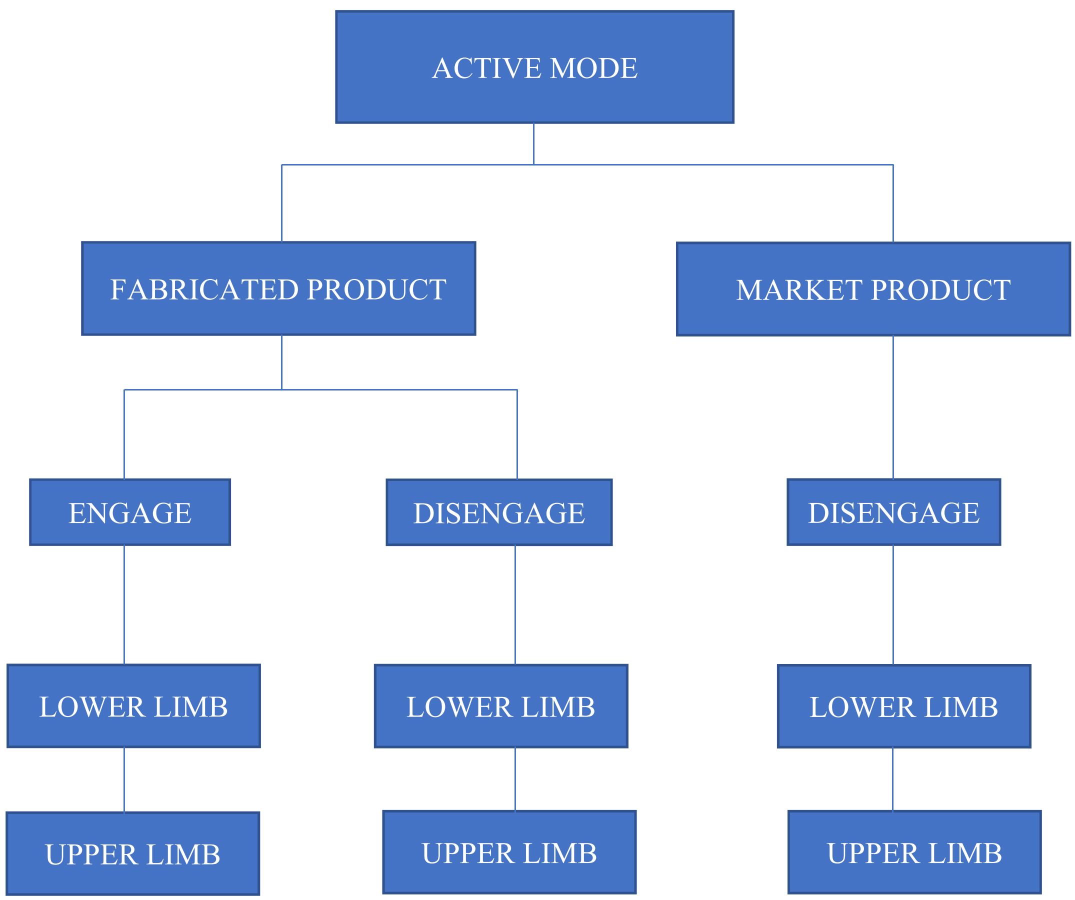


Figure 3.11: Active Mode

In the active mode, from Figure 3.11 the pedal that was used was pedal exerciser from fabricated product and pedal exerciser from market product. For fabricated product the activity is separated for engage and disengage activity and for each of it is the engage and disengagement of upper and lower limb. For pedal exerciser from market there is only the disengage of lower limb or upper limb activity due to the product unable to perform to limb at once.

3.4 Experimental Procedure

The experiment was conducted in Sports Science Lab Universiti Sains Malaysia (USM) Health Campus Kubang Kerian, Kelantan. The main purpose to conduct the experiment was to collect data on the muscle activity during pedalling fabricated product and market product. Two male students were selected. The average height was 1.68 m ± 0.03, weight in at 72 kg ± 9.5 and BMI of 23.9 ± 3.68. Figure 3.12 the participants sat in a chair and the distance was around 1.5 m ± 0.6 from the camera.

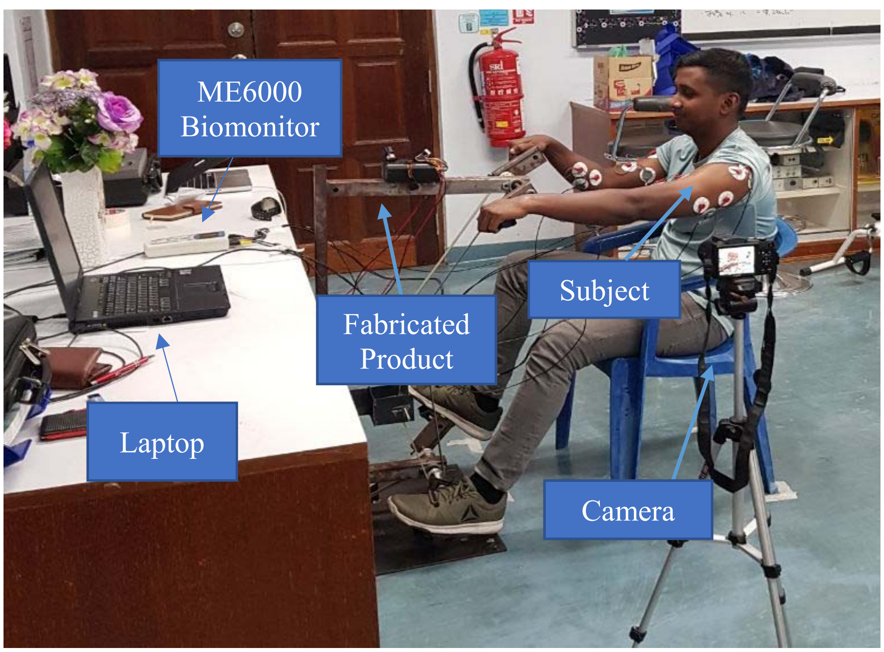


Figure 3.12: Example of setup during experiment

Once the electrodes were placed on the surface of the skin at the wanted muscle, the EMG can be connected to the electrodes using the sensor cable as shown in Figure 3.13 and Figure 3.14.

For each experiment activity the software will take reading for 95 seconds therefore during the period the subject student will proceed pedalling until the measurement is done and take rest for 30 seconds before proceeding the same activity for three repetitive cycle. This process is repeated until all the activity for active and passive activity were carried out, Figure 3.13 show the image when the Fabricated Product was used and Figure 3.14 shows the image when market product was used.

Figure 3.13: Measuring Process of Fabricated Product

Figure 3.14: Measuring Process of Market Product

3.5 Data Acquisition

The EMG data were recorded during each test using Biomonitor ME6000 Console with MegaWin 2.3a3 software, with sampling frequency of 1000 Hz in microvolts.

Raw data were recorded and processed by MegaWin 2.3a3 on windows XP operating system with Intel Pentium 1.85 GHz, 504 MB RAM. The data were processed with standard root-mean-square (RMS) amplitude calculation and converted to a mean amplitude and used for EMG analysis.

The electrodes were placed on the upper and lower limb of the student, for every limb four main muscles was chosen for measurement, the muscle that were chosen were the main muscles that human used in daily life. For upper limb the muscle that was used to measure were deltoid muscle, flexor of the wrist, triceps brachii muscle and bicep brachii muscle as shown in Table 3.1 and Table 3.2. For lower limb the muscle that was used to measure were quadriceps femoris muscle, semitendinosus muscle, gastrocnemius muscle and tibialis anterior muscle as shown in Table 3.3 and Table 3.4.

Table 3.1: Electrode placement for deltoid muscle and flexor of the wrist

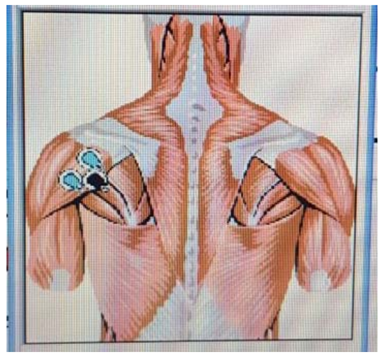
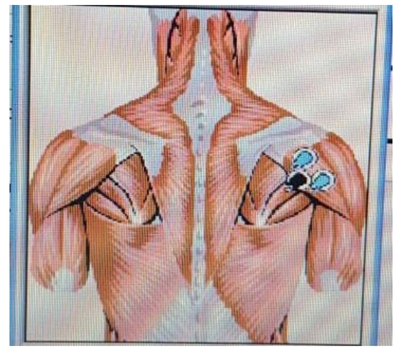
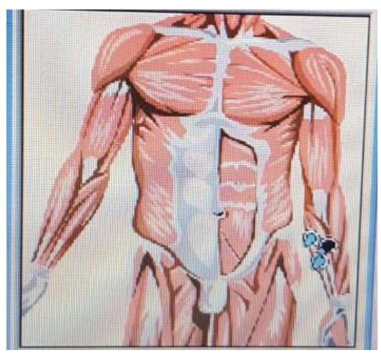
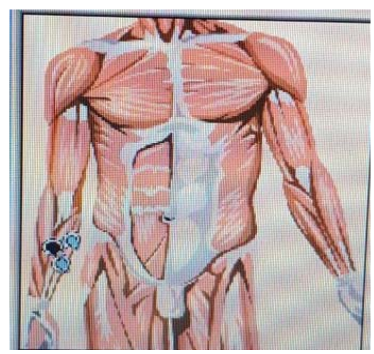
Type of Muscle	Left Side	Right Side
Deltoid Muscle		
Flexor of The Wrist Muscle		

Table 3.2: Electrode placement for bicep brachii muscle and triceps brachii muscle

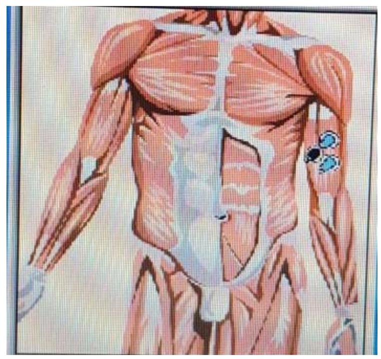
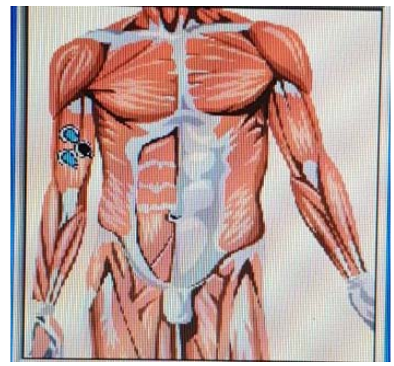
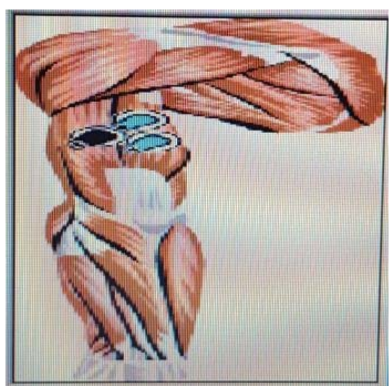
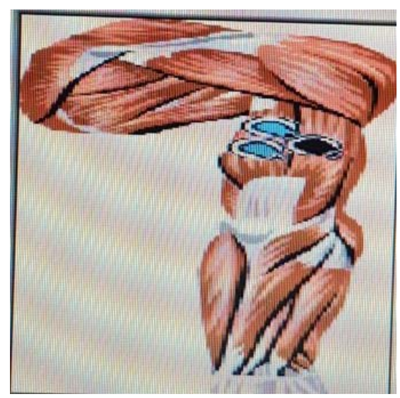
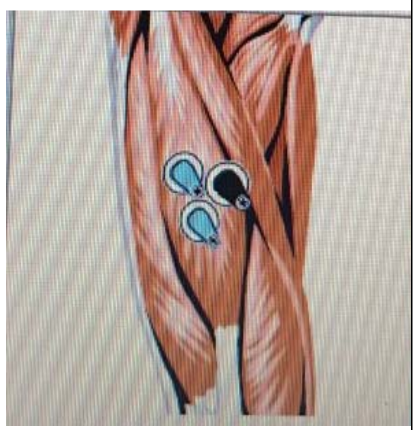
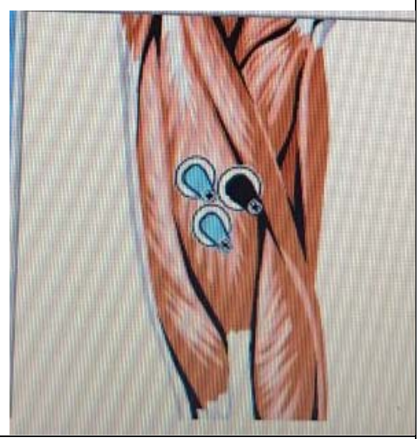
Type of Muscle	Left Side	Right Side
Bicep Brachii Muscle		
Triceps Brachii Muscle		

Table 3.3: Electrode placement for quadriceps femoris muscle and semitendinosus muscle

Type of Muscle	Left Side	Right Side
Quadriceps Femoris Muscle		
Semitendinosus Muscle