Muscle Activity and Gait Analysis of Assistive Device for Rehabilitation Gait Abnormalities Patient

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Abstract. Gait abnormality is a muscle disorder that disabling the patient to walk properly. This is caused by several factors including genetic influence, accident history, health issue, and others. Some suffered from this illness could be cured but some cases only could be helped by rehabilitation. This work is an original initiative in developing an assistive device as part of patient’s recovery and rehabilitation in helping the patient to regain muscle, as well assisting patient in performing their activities. However, the effectiveness on the device’s performance to serve its purpose has not yet been confirmed. Therefore, an electrical tool known as surface Electromyography (EMG) is being used to obtain the information required. This research is analysing the patient's nerves system with and without the assistive device and demonstrate the effectiveness of the assistive device in reducing the muscle contraction, as well to increase the time-to-fatigue of the muscle. The findings of this research showed that the reduction in percent of average Root Mean Square (RMS) value of patient’s contraction muscle when using the device has increase the time-to-fatigue of the muscle. In conclusion, this assistive device assists the patient, minimise the muscle fatigue, and ease the patient in their daily chores.

1. Introduction

Gait is defined as a person's manner of walking, meanwhile abnormalities refer to irregularity of feature or occurrence. GA is when a person unable to walk in a normal pattern. They faced this complication due to several reasons such as underlying conditions, genetics, injuries, stroke, or problems with the legs and feet. One of genetic issue found in our respondent as having Para-myotonia Congenital (PC). PC is one of the health problems that contributes to the GA. However, physical rehabilitation therapy and intervention which able to help improving a person’s gait and reduce their uncomfortable symptoms. Numbers of work reported in focusing into intervention using technologies includes an assistive device produced in order to help in improving the gait abnormalities and capabilities of the GA as in recovery process [1]– [4]. Currently, in this earlier work, the Gait Abnormality Assistive Device (GUARD) is produced tool which developed to reduce the GA as in Figure 1 below. Technical detail is excluded in this paper as this paper emphasise on the functionality and muscle activities of the device. In general, this device is created to reduce the use of muscle stretch from the leg, using the force or muscle power from the hand of the user, at the same time increase the comfortability of the patient to walk in a normal
condition. But how far this assistive device could affect the muscle activity to reduce this issue has not been discovered. Thus, the functionality of EMG is used to detect muscle function or muscles activity through electrical stimulation. Consequently, the analysis of muscle of people or patient through EMG was proposed to detect the functionality of an application of current device.

Figure 1. Gait Abnormality Assistive Device (GUARD) for GA patient

This project covered the analysis the muscle activity of assistive device for rehabilitation GA patient. This project significantly has potential to help the resulted in confirming the usage of GUARD in reducing the muscle activities and improve fatigue level of the users. This project contributes to society in improving their capabilities and quality of life.

2. Methodology

The study starts with interview survey questions to assess the data and background of the respondents. The question consists 2 part which are part A and part B. Part A question regarding the demography meanwhile Part B question related to the respondent specification. Next, using anthropometric measurements data taken from the respondents to obtain the size of the body. The EMG used for this study was DELSYS Trigno Wireless EMG System that functions as a device in collecting electrical signal and filter software that interpreted the signal to a graph. In this arrangement, data were collected from normal people respondents and respondent with GA. The activities involved were the walking activity in three minutes and climbing stairs in one minute. Table 1 below show the illustration of experimental setup plan for the study.

| No. | Time of process (min) | Activity                          | Description                                      |
|-----|-----------------------|-----------------------------------|--------------------------------------------------|
| 1.  | 3                     | Walking without device (W0)       | Respondents with no assistive device and walk for 10 seconds. |
| 2.  | 3                     | Walking with device (W1)          | Respondents with the assistive device and walk for 10 seconds. |
| 3.  | 1                     | Climbing stairs without device (CS0) | Respondents with no assistive and climb stairs for 10 seconds. |
| 4.  | 1                     | Climbing stairs without device (CS1) | Respondents with no assistive and climb stairs for 10 seconds. |

The measurements of muscle activity were conducted based on the real-time monitoring. All electrodes that attached on muscles were connected to the data logger and electromyography signals from the data logger were monitored through the laptop screen using wireless networking. Figure 2 illustrates the muscle selected and Table 2 shows details descriptions about the muscle involve, function of each muscle and the activity can be done related to the muscles, adapted from previous work with the suitability of the experimental work (5).
Table 2. Function of Each Muscle and Activity Related to the Muscles

| Muscles                              | Function                                      | Activity     |
|--------------------------------------|-----------------------------------------------|--------------|
| Tibialis anterior (TA)               | Flexes foot upward and inward, support arch of foot | Standing     |
|                                      |                                               | Walking      |
|                                      |                                               | Running      |
|                                      |                                               | Climbing     |
| Rectus Femoris (RF)                  | Flexes thigh at hip with other quadriceps muscles, extend knee | Walking |
|                                      |                                               | Running      |
|                                      |                                               | Climbing     |
| Peroneus Longus (PL)                 | Flexes foot downward, turns it outward         | Running      |
|                                      |                                               | Climbing     |
| Gastrocnemius Lateral Head (GLH)     | Flexes ankle and pulls up heel, flexes knee    | Running      |
|                                      |                                               | Climbing     |

Next, is the analysis section of EMG data. This section calculated the RMS value of EMG signal based on activity done by the respondents which been used to compute the electric signal receives and reflects any physiological activity of human body, during contraction. The RMS graph indicates the muscle activity includes the muscle behaviour and time-to-fatigue of the connected muscles. In other words, to simplify and focus on result output, the amplitude of the EMG signal was an average based on the subject's muscles, Root Mean Square (RMS) of the muscles. RMS used as the main analysis tool in the project, where RMS reported as the easiest method to analyse the data obtained from the EMG.

3. Results and discussion
The respondents involved in this work were 3 normal people (NP) and 1 GA patient. The age of four respondents is between 14-16 years old. The respondents were female. The GA patient was a 14 years old girl with the disease of Para-myotonia Congenital (PC) for more than 10 years. This section discussed the muscle activity of the normal people and GA patient while walking and climbing stairs. The muscle contraction was identified through this analysis. The muscles involved in this section were right rectus femoris (RF), right tibialis anterior (TA), right peroneus longus (PL), and left gastrocnemius lateral head (GLH). This section also consists of 2 main subsections, the comparison of muscle behaviour between normal people versus GA patient and the muscle analysis of GA patient with assistive device versus without assistive device. All of the subsections contain 2 results representing 2
activities, walking and climbing stairs. Each of the subsection, samples were taken with 3 times of reading and calculate the average.

Figure 3 below shows example of the graph results from the experiment of 3 reading, at 1 respondent, at 1 activity and 1 type of muscle. All of the sample are in rest condition before the experiment commenced. The figure demonstrates the average RMS value of tibialis anterior (TA) muscle from EMG Delsys sensor 13, 3 reading altogether produced an average amount of value during walking. The duration for the sample to each activity is 10 seconds. From here results of RMS values were taken and discussed.

**Figure 3.** Graph of average RMS value TA muscle of NP

### 3.1. Muscle Activity Analysis Normal People versus GA Patient in Walking and Climbing Activity

**Figure 4.** Graph of comparison RMS value of four muscles between NP and GA patient in walking activity

Figure 4 above illustrates the comparison of average RMS (µV) value between normal people versus GA patient during walking. The average from 3 sample of normal people, sample 1, sample 2 and sample 3 is being calculated. Thus, the average of RMS value of normal people is being compared with the data gained from GA patient. In the graph, green bar representing the average RMS of normal people
meanwhile the blue bar representing the RMS value of GA patient. The RMS value is basically the value of muscle contractions produced during the activity (walking). For rectus femoris (RF) muscle, RMS value of normal people is 45% smaller compared to GA patient. For tibialis anterior (TA) muscle, RMS value of normal people is 35% smaller compared to GA patient. For peroneus longus (PL) muscle, RMS value of normal people is 73% smaller compared to GA patient. For gastrocnemius lateral head (GLH) muscle, RMS value of normal people is 89% smaller compared to GA patient.

**Figure 5.** Graph of comparison RMS value of four muscles between NP and GA patient in climbing activity

Figure 5 above illustrates the comparison of average RMS (µV) value between normal people versus GA patient during climbing stairs activity. The average from 3 sample of normal people, sample 1, sample 2 and sample 3 is being calculated. Thus, the average of RMS value of NP is being compared with the data gained from GA patient. In the graph, blue bar representing the average RMS of NP meanwhile the red bar representing the RMS value of GA patient. The RMS value is basically the value of muscle contractions produced during the activity (climbing). For rectus femoris (RF) muscle, average RMS value of GA patient is 53% higher compared to normal people. For tibialis anterior (TA) muscle, average RMS value of GA patient is 54% higher compared to normal people. For peroneus longus (PL) muscle, average RMS value of GA patient is 54% higher compared to normal people. For gastrocnemius lateral head (GLH) muscle, average RMS value of GA patient is 47% higher compared to normal people.

Based on these two graphs, data indicates GA patient has a higher muscle contraction than NP, where NP consider as the baseline benchmark as compared to GA muscles. These results shown predictable hypothesis as GA patient’s muscle has muscle activity and fatigue influence to the function of other physiological systems of the body due to disease and GA nerves systems. GA patient’s muscle more sensitive and easier to fatigue compared to normal people’s muscle [6], [7]. Thus, the main aim of the assistive device is to reduce the muscle contraction in order to attain it closer to the normal people. The results of muscle activity comparison on GA patient with device versus without device will be analysed in later sub-section.
3.2. Muscle Activity Analysis of GA patient without device versus with device in Walking and Climbing Activity

Figure 6. Graph of comparison RMS value of four muscles of GA patient without and with device in walking activity

Figure 6 above shows the comparison of average RMS (µV) value of GA patient with device versus without the assistive device during walking activity. Based on the Figure above, purple bar is representing the GA patient without device, meanwhile the brown bar is representing the result of GA patient with device. From this graph, the reduction of percentage in RMS value with the assistive device has reduced by 66%. The result for the tibialis anterior (TA) muscle, the reduction of percentage in RMS value with the assistive device has reduced by 73 %. For rectus peroneus longus (PL) muscle, the reduction of percentage in RMS value with the assistive device has reduced by 77%. The result for the gastrocnemius lateral head (GLH) muscle, the reduction of percentage in RMS value with the assistive device has reduced by 86%.

Figure 7. Graph of comparison RMS value of four muscles of GA patient without and with device in climbing activity

Figure 7 above shows the comparison of average RMS (µV) value of GA patient with device versus without the assistive device during climbing activity. Based on the Figure above, red bar is representing
the GA patient without device, meanwhile the green bar is representing the result of GA patient with device. From this graph, the reduction of percentage in RMS value with the assistive device has reduced by 61%. The result for the tibialis anterior (TA) muscle, the reduction of percentage in RMS value with the assistive device has reduced by 69%. For rectus peroneus longus (PL) muscle, the reduction of percentage in RMS value with the assistive device has reduced by 33%. The result for the gastrocnemius lateral head (GLH) muscle, the reduction of percentage in RMS value with the assistive device has reduced by 84%.

These data indicates that the amount of muscle contraction reduces when the GA patient with the device compared without the device. When the muscles contraction reduces, time-to-fatigue of muscles increase as the muscle contraction is inversely proportional to time-to-fatigue. In order word, the muscle took a longer time to fatigue and in this case the muscle of GA patient could be used longer. This shown significant reduction of muscle, where in walking activity, all muscles reduce by above 50%. For climbing stairs activity, PL muscle reduce below 50 % while the three muscle reduce more than 50%. This prove that the usage of assistive device could help and assist the user in their daily life activities and increase their quality of life.

4. Conclusion
In conclusion, the muscle and gait activity of GA patient using an assistive device is completely analysed using DELSYS Trigno Wireless EMG system. Comparing NP and GA, data indicates GA patient has a higher muscle contraction than NP. This is due to the sensitivity muscle of GA patient where the GA has fatigue influenced on the function of other physiological systems of the body in regards with GA nerves systems This analysis was an acceptable tool to be used to measure and compare the muscle activity of the respondents. In addition, the usage of assistive device shown major contribution in assisting the user to improve muscle activity usage in their daily life activities and increase their quality of life. This analysis is an excellent work in order to improve the rehabilitation assistive device product in the future.

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