Analysis of handwriting task using electromyography

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Abstract. Writing is one of the most important medium for communication which can represent one of the easiest ways like symbols and sign. Handwriting is one of the most complex activities in human motions which results in major disorders. Handwriting disorder is one of the major problems in humans and hence it should be rectified before leading into major disorders like dyspraxia, dysgraphia and others. This work is a step to identify the writing disorder in early stage by using EMG sensor. It consists of EMG-sensor which measures the muscle potential from two important muscles extensor digitorum and flexor carpi radialis. The electrodes are placed in such a way that it pick up the muscle potential. The extensor digitorum helps in movements of the elbow and wrist where we obtain minimum potential compared to flexor carpi radialis which is just the flexor of the wrist only. So extensor digitorum is the most prominent muscle where we obtain maximum potential because it extents the metacarpophalangeal joint. The prototype is tested against people of two aged groups, one with people aged above 50 years and the other with adult age between 16-30 years including both the genders. They are allowed to write in their own speed of three types slow, normal, fast, of standard sentence at one stretch to obtain better muscle potential without any deviation. The acquired muscle potential shows good results about muscle potential with respect to age while writing. This prototype can be extended to the early diagnosis of handwriting disorder which helps to rectify the neurogenerative disorder before leading into severe complications.

1. Introduction.
Electromyography is the technique which is used to measure the electrical potential which is generated by muscle where these signals are analysed to obtain any abnormalities or the biomechanics of human. The development of the system or module is based upon the muscle biopotential which is being recorded through EMG sensor from two important muscle namely extensor digitorum and flexor carpi radialis. The subjects are chosen based upon their disorders like dysgraphia, dyspraxia. Therefore monitoring of handwriting pattern is very important. Several attempts are used to find out the neurogenerative disorder and one such work is the recognition of handwriting through EMG sensor and the signals are obtained from hand and forearm muscles [1]. Another approach is to find muscle activity in developing children in the upper extremity proximal and distal muscle during handwriting task and to increase the quality of writing [2]. The hand gesture recognition which is based upon the EMG sensor but mainly based upon the accelerometer to find out the intensity level of the signal [3]. The detection of the grasp pattern through electromyographic analysis where the static tripod group showed the significant change in the surface EMG [4]. Through inertial sensor which is being attached
on the fingertip which is used to recognise the handwriting [5]. Parkinson’s disease is one of the most frequent neurodegenerative disorders which is being analysed through fractional derivatives of online handwriting [6]. Another approach is the diagnosis and prognosis of the Parkinson’s disease through analysis of handwriting through electronic pen which gives good result for diagnostic [7]. And also analyses of electromyography signals are used for the classification of the handwritten Arabic characters [8]. Identify the performance of the cranio-cervical flexion through electromyography analysis where the muscle potential is obtained from different muscles [9]. And through EMG sensor the interventions to improve the handwriting [10]. All the approaches differ from one another by the sensing and nevertheless none of these approaches is to find out the abnormalities and difficulty in handwriting patterns through EMG sensor by measuring their muscle potentials. Moreover the measurement of quantitative feedback of the handwriting therapy given to the subject is mandatory to evaluate the progress of therapy adapted by them. In this proposed study muscle potential with respect to different writing speed with respect to various age is measured. The goal of the study is to diagnosis or to recognise the handwriting disorder in the early condition which is caused due to neurogenerative disorder or other writing disorder. This helps to give a quantitative feedback about the handwriting therapy given to the subject. This must be a promising tool to track the progression of the treatment. This study concludes that the muscle potential decreases when the age increases.

2. Materials and Methods

2.1 Work flow diagram

An EMG sensor (figure 1) monitors the electric potential generated by muscle cells and it produces an output signal (analog signal) that can be read using a microcontroller. This method of measuring the muscle activity is being used in medical research. The output voltage of the sensor increases as the target group of muscles flexes. The method of measuring any physical or electrical phenomenon such as temperature, pressure, current or voltage with the help of a computer is called as Data acquisition. It consists of sensors, measurement hardware and a computer with programmable software. The computer based DAQ system makes use of the productivity, display, and connectivity capacities of industry standard computers, providing better flexible and cost-effective measurement solutions, than the previously used measurement systems. The display unit means, the computer output of data and compilation of information from these outputs. All the information handling tasks needs a certain kind of display output. The most important task of the display unit is monitoring and control tasks. The display unit may be electronic displays, hardcopy printouts or signalling devices such as voice outputs.
3. Materials required

3.1 Participants

A total of 20 normal participants of both the sexes belonging to two different age categories (16 to 30 years and above 50 years) were chosen for performing this experiment. People with already existing neurological disorders and who have been diagnosed with the same were not considered for this experiment. The participants selected for this experiment do not show any signs of hand injuries or discomfort while writing.

| Characteristics | Young adults (Category 1) | Older adults (Category 2) |
|-----------------|--------------------------|--------------------------|
| Age (years)     | 16-30                    | >50                      |
| Male : Female   | 1:1                      | 3:2                      |

3.2 EMG sensor

Electromyography measures the muscle activity by analysing its electrical potential. However, with the advancement of better and powerful microcontrollers and integrated circuits, EMG sensors have made their presence into various kinds of control systems. The sensor used for this project is the V3 sensor and the electrical activity of the muscle is filtered and rectified (Figure 2). The sensor also amplifies the electrical activity of the muscle and also produces an analog output signal that can be easily processed by a microcontroller, enabling muscle-controlled interfaces. The operating voltage of EMG sensor is about ± 18V and the gain is adjustable.

3.3 Disposable electrodes

Disposable electrodes are used for this experiment since they can be used once and can be thrown away after using it on each participant. This prevents the occurrence of infections for the participants. The disposable electrodes are at fairly reasonable cost and they are non-invasive (Figure 3).
4. Experimental procedure

Participants belonging to two different age categories (16-30 years and above 50 years) of both the sexes were considered for this project. Participants suffering from various neurological disorders were not taken for this experiment. Each participant was made to sit at their comfort. Two EMG sensors having three electrodes each (figure 4) were connected using disposable electrodes to the participant’s hand. The electrodes are placed at muscle extensor digitorum and flexor carpi radialis. The reference electrodes were placed where the bone was prominent because it is the area where there is considerably lower potential. The EMG sensors were connected to the NI DAQ (Data Acquisition Unit) in order to record the signals obtained from the muscles.

Each participant was given a standard sentence in his/her mother tongue and were made to write in three different speeds: participant’s normal speed, fast speed and slow speed. The given sentence was made to write at a single stretch to obtain better muscle potential without any deviation or error. 20 participants were considered as subjects for this experiment and the same procedure was asked to follow by all of them.

After performing the experiment by all the participants, the values were obtained by the help of NI DAQ. The recorded values were saved in the excel sheet and the average was obtained for all of them. The obtained average values were then plotted as graphs and the results were obtained through Biomedical Workbench software.

5. Discussion

The muscle which is responsible for writing is identified and designated as A and B and it is mentioned in Table 2.
**Table 2.** Muscles employed

|   |   |
|---|---|
| A | Extensor digitorum |
| B | Flexor carpi radialis |

The category 1 subjects are instructed to write a sentence with their maximum writing speed. The corresponding muscle potential is recorded and tabulated in table 3

**Table 3.** Category-1 fast writing

| S.NO | AGE | A      | B      |
|------|-----|--------|--------|
| 1    | 18  | 1.52749| 0.72263|
| 2    | 33  | 1.40445| 0.70204|
| 3    | 21  | 1.44246| 0.74192|
| 4    | 22  | 1.46012| 0.79255|
| 5    | 28  | 1.41978| 0.7877 |
| 6    | 23  | 1.42075| 0.76203|
| 7    | 22  | 1.46987| 0.72047|
| 8    | 21  | 1.47529| 0.70608|
| 9    | 21  | 1.47741| 0.76489|
| 10   | 20  | 1.56789| 0.75488|

**Figure 5.** The above graph shows the category 1 fast Writing between the two muscles.

The charted values (figure 5) show that muscle A is having greater value than B.

The category 1 subjects are instructed to write a sentence with slow writing speed. The corresponding muscle potential is recorded and tabulated in table 4
Table 4. Category-1 slow writing

| S.NO | AGE | A    | B    |
|------|-----|------|------|
| 1    | 18  | 0.84227 | 0.53944 |
| 2    | 33  | 0.85854 | 0.55199 |
| 3    | 21  | 0.81987 | 0.55977 |
| 4    | 22  | 0.89549 | 0.56418 |
| 5    | 28  | 0.80376 | 0.52964 |
| 6    | 23  | 0.88915 | 0.59367 |
| 7    | 22  | 0.81017 | 0.54116 |
| 8    | 21  | 0.86438 | 0.56049 |
| 9    | 21  | 0.86127 | 0.5631  |
| 10   | 20  | 0.82176 | 0.55631 |

Figure 6. The above graph shows the Category 1 slow writing between the two muscles.

Bar graph in Figure 6 shows Extensor digitorum is having maximum EMG.

The category 1 subjects are instructed to write a sentence with their normal writing speed. The corresponding muscle potential is recorded and tabulated in table 5

Table 5. Category-1 normal writing

| S.NO | AGE | A    | B    |
|------|-----|------|------|
| 1    | 18  | 0.940168 | 0.652865 |
| 2    | 33  | 0.941472 | 0.63722 |
| 3    | 21  | 0.993057 | 0.662316 |
| 4    | 22  | 0.926123 | 0.644257 |
| 5    | 28  | 0.884761 | 0.669664 |
| 6    | 23  | 0.883486 | 0.592345 |
| 7    | 22  | 0.849768 | 0.539428 |
| 8    | 21  | 0.841176 | 0.561146 |
| 9    | 21  | 0.852035 | 0.50644 |
| 10   | 20  | 0.812183 | 0.565718 |
Figure 7. The above graph shows the Category 1 normal writing between the two muscles.

From Figure 5, 6 and 7, we can interpret the muscle potential is getting varied with respect to writing speed. The Extensor digitorum muscle is having maximum EMG signal, this shows that compared to Flexor carpi radialis, Extensor digitorum is actively involving in a writing task.

With the above conclusion category 2 subjects are allowed to write a sentence with different writing speeds. The results are recorded and analysed, that are listed further.

The category 2 subjects are instructed to write with their maximum speed and corresponding EMG signals are recorder and tabulated in Table 6

| S.NO | AGE | A     | B     |
|------|-----|-------|-------|
| 1    | 53  | 0.769872 | 0.539428 |
| 2    | 50  | 0.775294 | 0.561146 |
| 3    | 55  | 0.777413 | 0.564406 |
| 4    | 58  | 0.756789 | 0.565772 |
| 5    | 53  | 0.765487 | 0.556732 |
| 6    | 58  | 0.754098 | 0.550128 |
| 7    | 52  | 0.759251 | 0.537815 |
| 8    | 60  | 0.720492 | 0.573019 |
| 9    | 62  | 0.702754 | 0.591457 |
| 10   | 51  | 0.787123 | 0.525174 |
Figure 8. The above graph represents Category 2 fast writing between the two muscles.

The category 2 subjects are instructed to write with slow speed and corresponding EMG signals are recorded and tabulated in Table 7.

Table 7. Category 2 slow writing

| S.NO | AGE | A       | B       |
|------|-----|---------|---------|
| 1    | 53  | 0.449768| 0.060465|
| 2    | 50  | 0.441176| 0.06082 |
| 3    | 55  | 0.452035| 0.064894|
| 4    | 58  | 0.442183| 0.054876|
| 5    | 53  | 0.454719| 0.066025|
| 6    | 58  | 0.402356| 0.065729|
| 7    | 52  | 0.419564| 0.061485|
| 8    | 60  | 0.489356| 0.068935|
| 9    | 62  | 0.428394| 0.063756|
| 10   | 51  | 0.481576| 0.063674|
The category 2 subjects are instructed to write with their normal writing speed and corresponding EMG signals are recorded and tabulated in Table 8.

**Table 8.** Category-2 normal writing

| S.NO | AGE | A     | B     |
|------|-----|-------|-------|
| 1    | 53  | 0.610168 | 0.341161 |
| 2    | 50  | 0.664376 | 0.351987 |
| 3    | 55  | 0.661265 | 0.363102 |
| 4    | 58  | 0.621765 | 0.356309 |
| 5    | 53  | 0.593571 | 0.304569 |
| 6    | 58  | 0.603891 | 0.334901 |
| 7    | 52  | 0.659082 | 0.321896 |
| 8    | 60  | 0.609374 | 0.319087 |
| 9    | 62  | 0.634198 | 0.386453 |
| 10   | 51  | 0.612598 | 0.361039 |

**Figure 9.** The above graph shows the Category 2 slow writing between the two muscles.

**Figure 10.** The above graph shows the Category 2 normal writing between the two muscles.
By looking at the above graphs (figure 8, 9 & 10), it can be clearly understood that the muscle potential of A (Extensor digitorum) is prominently risen higher than the muscle potential of B (flexor carpi radialis). And also, in both the categories, the average potential is greater during fast writing, followed by normal writing and slow writing.

For further understanding, the potential of muscle A from both the categories is plotted in the form of graphs (figure 11 & 12) for comparison.

![Graph 11](image1.png)

**Figure 11.** The above line graph shows the comparison of category 1 and category 2 of the same muscle A (extensor digitorum).

![Graph 12](image2.png)

**Figure 12.** The above line graph shows the comparison of category 1 and category 2 of the same muscle B (flexor carpi radialis).

From the above tabulations and their corresponding graphs, it can be concluded that as the age of a person increases, their EMG potential decreases. And also, muscle Extensor digitorum produces more EMG potential than that of muscle Flexor carpi radialis [1].
6. Conclusion and future work

The analysis of EMG while writing using EMG sensor to measure the muscle potential has been discussed in this paper. From the result, it is observed that as the age increases, the muscle potential of extensor digitorum and flexor carpi radialis decreases. The muscle potential of writing task is highly dependent to writing speed of individual. This study act as a potential tool to evaluate the progression of the therapy given to the subject. This is only performed for the people who are normal and without any handwriting disorders or neurological disorders. For future reference, this prototype acts as the proof of concept, which helps to diagnose the writing disorder in a quantitative manner. Furthermore, the device can be made more compact and wireless and that also can be implemented and evaluated.

7. References

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