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Study of Flexor Carpi Ulnaris (FCU) Muscle Strength in Dominant and Non-Dominant Hands in Various Hand Postures

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Abstract--- *Human hand is a versatile organ that adapts to various environments in day to day life. Hand muscles provide stability to the joints to deal objects of various sizes and shapes in position. The main aim of this research is to identify the posture and the hand (dominant/non-dominant) which extracts maximum effort from the FCU muscle. Further, it was hypothesized that, If a particular posture demands a comparatively greater effort from the muscle, it will drive the participants to hold it for a longer period time compared to the other postures. Flexor Carpi Ulnaris (FCU) Muscle strength was determined by subjecting the wrists of both dominant and non-dominant hands (DH and NDH) to prolonged flexion and extension. The maximum duration sustained by the participants for each posture is the direct measure of the FCU muscle strength in terms of amplitude (voltage) and time (milliseconds). The postures were: tight fist; tight fist combined with wrist flexion; palm stretch combined with wrist flexion. The effort exerted by FCU muscle varied individually for all the postures. The outcomes showed that the tight fist combined with wrist flexion posture was tougher compared to the remaining postures since the participants felt it difficult to hold the posture for a longer period of time.*

Keywords--- *Flexor Carpi Ulnaris (FCU), Muscle Strength.*

I. INTRODUCTION

FCU is one of the superficial flexor muscles responsible for wrist flexion and adduction of hand. It origins from the medial epicondyle of the humerus and has an additional point of attachment on the ulnar head. The pisiform and the hook of the hamate bone are the points of insertion along with the little finger

Across the literature, it was observed that exclusive analysis of FCU muscle strength was less in number. One of the methods to determine muscle strength is to perform endurance training exercises. It is done by focusing on a

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single or a set of muscles to strengthen it.

The muscle which is flexed shortens due to contraction. The contraction depends upon the nature of the posture performed by the individual. On the contrary, the muscle which undergoes extension is stretched. This is the antagonistic and agonistic principle of muscle action where one set of muscles is stretched when the other set is extended. During wrist flexion, FCU is shortened and EDC (Extensor Digitorum Communis), the extensor responsible for extension of fingers [1].

The muscle synergy for hand motions for both dominant and non-dominant hands were studied. sEMG from both the hands for brachioradialis (BRA), flexor carpi ulnaris (FCU), flexor carpi radialis (FCR), extensor digitorum communis (EDC), flexor digitorum superficialis (FDS), abductor pollicis brevis (APB), first dorsal interosseous (FDI) and abductor digiti minimi (ADM) of both the hands were recorded. Results showed that both the muscles had similar muscle synergies for all the six motions [2].

A study was conducted with the main objective to reduce the cross talk between the electrodes during sEMG recording. Branched electrode (BE) configuration was adapted with a conventional EMG device to record the EMG signal from 5 forearm muscles. The configuration was successful in removing a considerable amount of cross talk between FDS and FCU. This paper proves to be helpful in noise reduction while placement of surface electrodes on muscles for recording [3].

The relationship between the forearm muscle activity and wrist joint angles/position was studied while hand grip force was varied. At various levels of grip strength the variation of EMG signals with respect to wrist joint angle was studied. The results of this study would be helpful in controlling the movements of a prosthetic arm in the form of a control algorithm [4].

Muscle strength can be studied in terms of amplitude and time. To obtain the equivalent force a particular amplitude, neural network algorithms are required. With an objective to determine the muscle force from EMG signal, Back Propagation Neural Network (BPNN) was developed to overcome the shortcomings of hill-type muscle model. The former was successful in estimating the force of any of the four muscle of the fore arm under study [5].

The muscle activities of the forearm was evaluated by using hand postures and object property. 4 objects of varying sizes and weights were chosen for the study. They were handled by various postures to determine the variations in muscle activity. The results showed that among the 5 levels of posture, 2 fingers pinch extracted a larger forearm muscle activity compared to the others for sustaining a stable pinch. Hand posture and property of an object to be dealt with are an integral property that determines the activity of forearm muscles [6].

The importance of the flexor and abductors for writing posture was studied. The results reported that the flexor muscles FCR and FCU acted as stabilizers whereas the Abductor Pollicis Brevis (APB), the thumb muscle actively involved in during the writing process. There was no signal variability observed among the flexors and abductors while writing scripts in both upper case and lower case letters [7].

A four input, two output wrist muscle model with Hammerstein structure was proposed to realize wrist movements in 2 degrees of freedom. The main aim of this research is to address tremor issues of people with

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neurodegenerative disorders and/or injuries. The algorithm was compared to recursive least squares identification algorithm for determining the parameters of previously existing four input and one output system [8].

An electronic circuit was developed for amplification and filtering of high frequency EMG signal acquired from FDS. The participants were asked to apply grips of various levels on a hand gripper. The resulting EMG signal was fed to the device to test and validate the performance. This could be used in hand rehabilitation device to estimate appropriate level of resistance to be offered to the patients during their rehabilitation sessions [9].

Regression models developed for wrist torque estimation using sEMG signals drive the robotic arms worn by the patients. These models disturb the accuracy of the model when the limb postures are varied by them. To overcome this problem, a regression model unaffected by varying arm posture and joint angles was formulated [10].

A study was conducted to identify the type of contraction weak, medium, strong. Electrodes were connected to a PIC microprocessor with a printed circuit board (PCB) to acquire and process the EMG signals. Based on the strength of contraction, powered vehicles namely wheelchair could be moved at varying accelerations [11].

A study conducted on 10 volunteers proved that proper placement of sEMG electrodes would result in a high quality EMG signal. Power spectral density and signal –to-noise ratio were applied on the signal to identify the most accurate location for positioning the electrodes. The optimal signal and optimal position from FCR and ECR were respectively presented at 90% of the electrode position over the forearm length. This was suggested as an important step in sEMG applications to ensure the quality of the signal [12].

Tremor amplitude suppression Parkinson's disease (PD) was one of the challenges for researchers. Resting tremor on these patients were recorded using sEMG technique on biceps, triceps, FDS, Extensor Digitorum (ED), FCU and extensor carpi radialis (ECR) muscles. Transcutaneous electrical stimulation (TES) applied on dorsal hand skin of PD patients resulted in instant tremor suppression and the EMG signals showed a quick recovery from tremor [13].

Individual mechanical properties of the muscle could be determined by varying the amplitude, frequency and pulse width of the signal during stimulation. Varying these parameters would alter the muscle fiber pennation angle, muscle fascicle length, tendon length which could be studied by ultrasonography using in-vivo and non-invasive method [14].

II. MATERIALS AND METHODS

6 young healthy volunteers participated in the study. The informed consent forms were obtained from them prior to the study. All of them were right dominant. They were made to sit comfortably in the arm chair while performing all the 3 postures. The region from which the EMG signal was acquired was prepared in before the start of the experiment. The forearm and hand was wiped with the gel to ensure proper conductivity. The postures were: tight fist; tight fist combined with wrist flexion; wrist flexion combined with palm stretch. sEMG electrodes were placed on the point of origin and insertion of the FCU. The FCU muscle response for all the three postures were recorded. The duration of the posture was set the same to observe the variation of amplitude in the muscle activity. It was ensured that none of them had histories of undergoing metal implant surgery, fracture and/or neurodegenerative

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disorders associated to hands. The response of FCU muscle was recorded using BIOPAC kit designed by BIOPAC SYSTEMS, Inc., an opensource software for acquisition of various biosignals. The EMG signals acquired were set in the frequency range from 5 to 500 Hz. The maximum amplitude attained due to MVC for the posture was recorded for each participant in both dominant and non-dominant hands.

Fig. 1: BIOPAC Systems, Inc.

Tight Fist

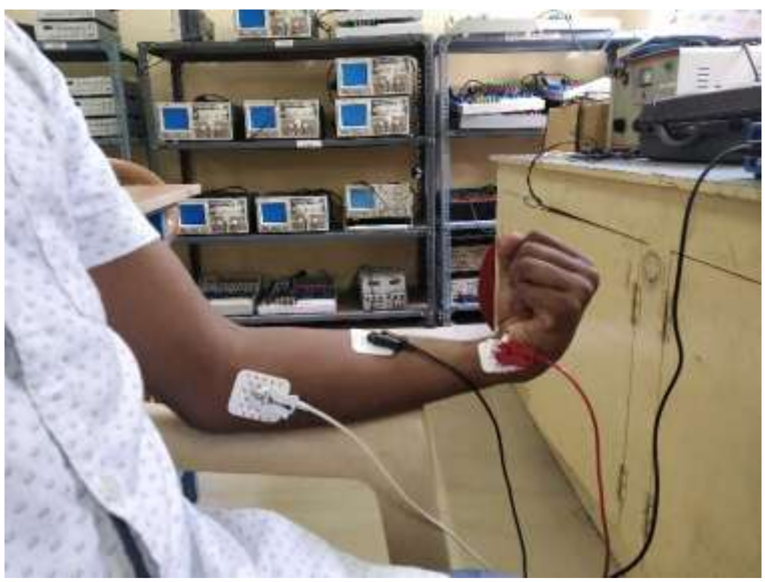

Fig. 2: Tight Fist of NDH

The participants were allowed to sit comfortably on an arm chair. In prior to starting the experiment, they were asked to make tight fists for 5, 10 and 15 seconds. It was found that 10 seconds was the comfortable period for them to sustain the tight fist after which the hands started to jitter. It seemed to disturb the EMG readings. So, 10 seconds was set as the standard time period for the study. The mean amplitude for all the six participants were calculated.

**The task in the above figure was performed using both DH and NDH. The image of the participant performing* *the task using NDH is displayed*

Tight fist combined with wrist flexion

Fig. 3: Tight Fist Combined with Wrist Flexion of DH

With an idea to extract extra effort from the muscle, the study was stepped up. The participants were asked to make a tight fist combined with wrist flexion. With the same window (10 s) as reference, they performed the posture. As reported by the participants reported this was considered tougher compared to the former. At the same time, the amplitude was relatively higher for each participant to the one obtained from holding a tight fist alone. The mean amplitude for all the six participants were calculated.

**The posture in the above figure was carried out for both DH and NDH. The image of the participant performing the task using DH is displayed.*

Palm stretch combined with wrist flexion

Fig. 4: Palm Stretch Combined with Wrist Flexion of NDH

To increase the flexion angle of the wrist and to observe the corresponding variation in the level of amplitude, the second posture was modified. This was done to study the variation in the muscle activity provided, the duration

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of the posture remained the same for all the participants. Initially, it was hypothesized that increasing the flexion angle would shoot up the level of amplitude. It was observed that the amplitude was lesser compared to posture 1 where the participants were making a tight fist in neutral position. The mean amplitude for all the six participants were calculated.

**The posture in the* above *figure was carried out for both DH and NDH. The image of the participant performing the task using NDH is displayed.*

III. RESULTS

FCU strength of both dominant and non-dominant hands were compared for all the 3 postures. The following observations are reported. (A) Maximum amplitude of FCU for both the hands of the same participant (B) Mean amplitude of FCU for the DH and NDH individually for all the postures.

The FCU muscle activity for one of the participant is chosen and represented below individually for all the postures. The maximum contraction of FCU exerted using both DH and NDH for each posture is a direct measure of the strength of FCU.

Maximum Amplitude of FCU for both the Hands of the Same Participant

The tight fist held by the participant using his DH and NDH was determined. The EMG readings showed that FCU of DH exerted maximum contraction compared to FCU of NDH.

Tight Fist

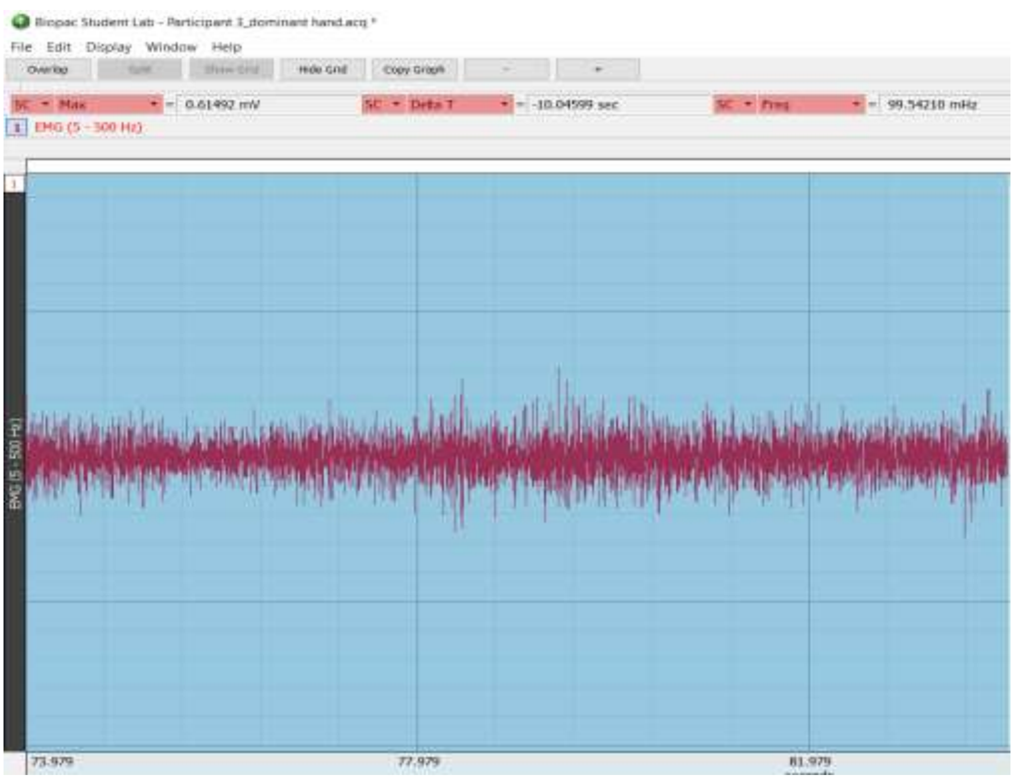

Fig. 5: The Maximum Amplitude of DH for Posture 1

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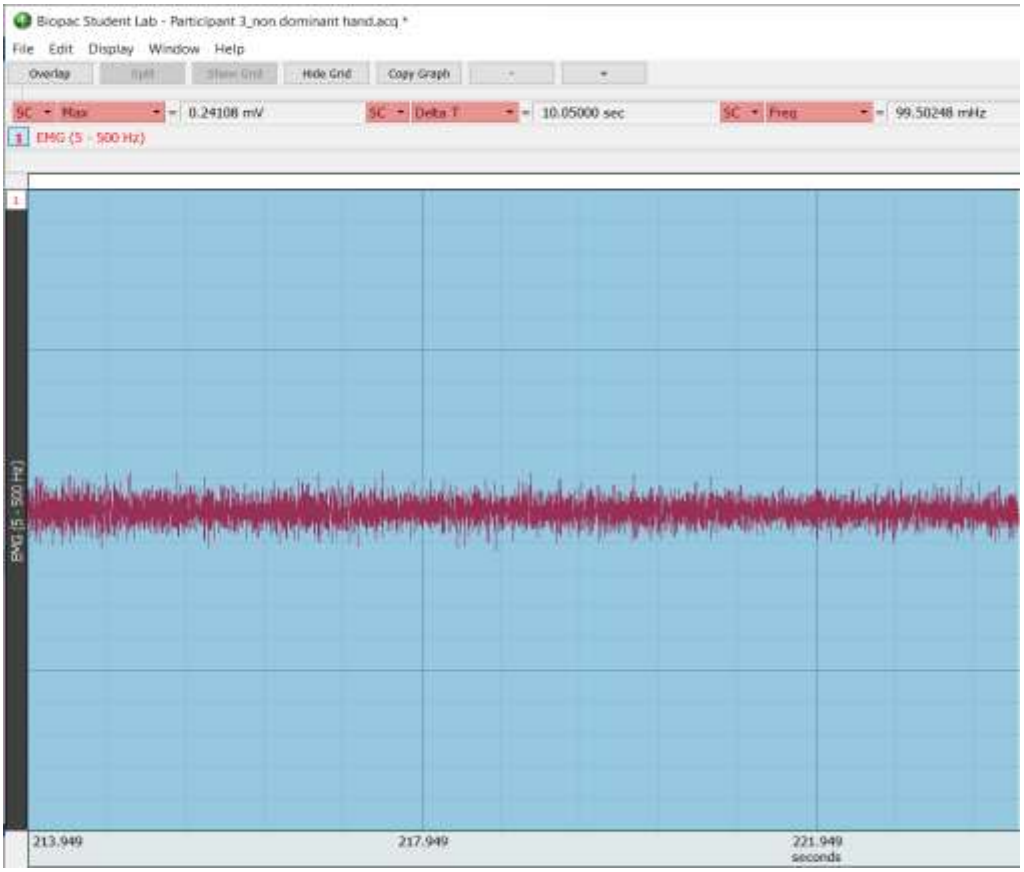

Fig. 6: The Maximum Amplitude of NDH for Tight Fist

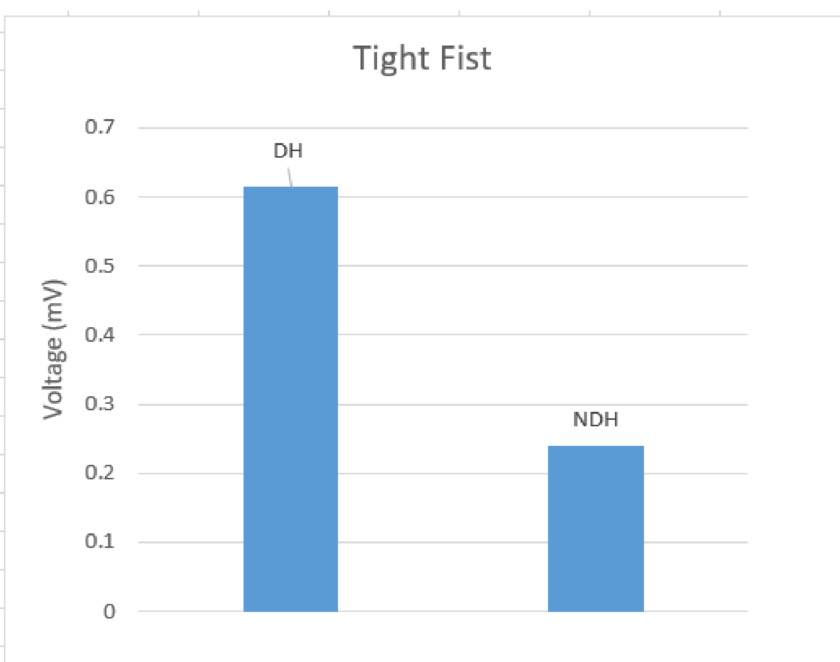

Fig. 7: Maximum Amplitude of DH and NDH for Tight Fist

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Tight Fist Combined with Wrist Flexion

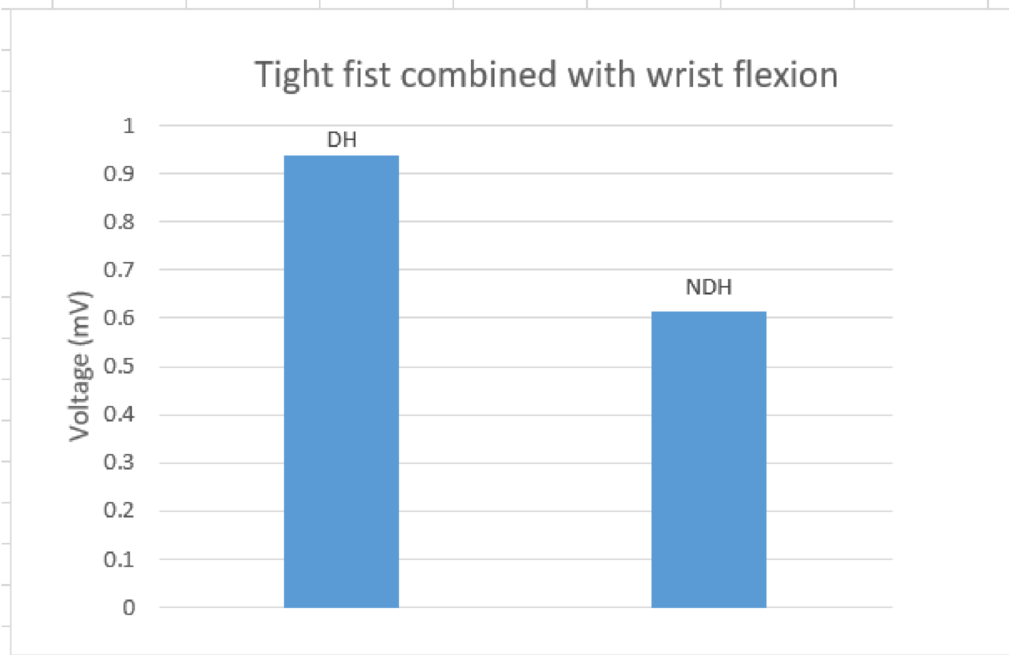

Fig. 8: Maximum Amplitude of DH and NDH for Tight Fist Combined with Wrist Flexion

Palm Stretch Combined with Wrist Flexion

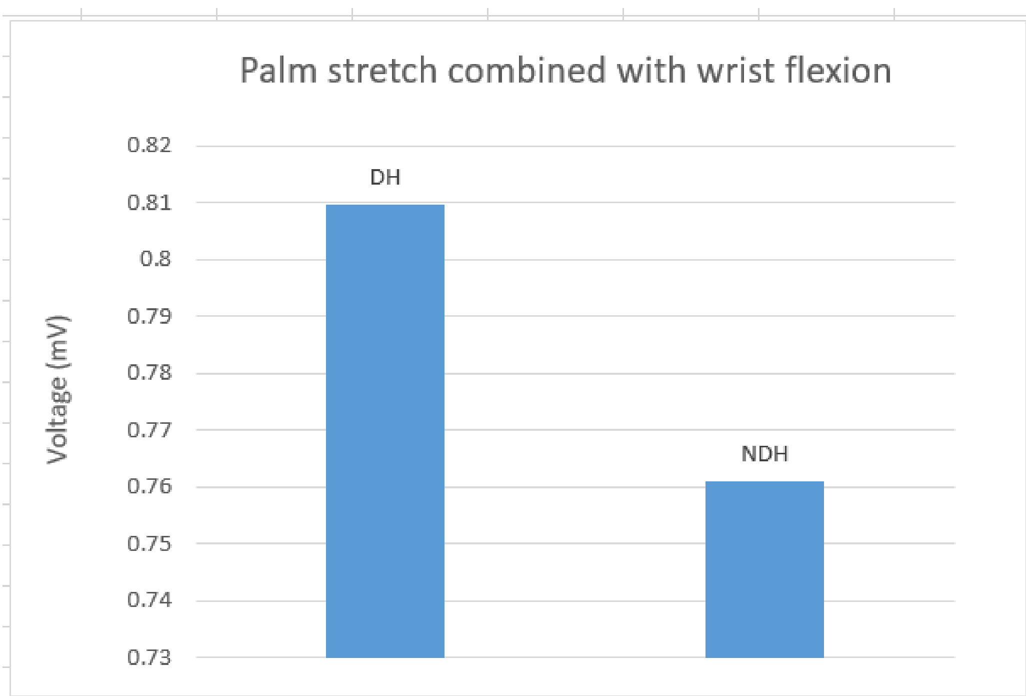

Fig. 9: Maximum Amplitude of DH and NDH for Palm Stretch Combined with Wrist Flexion

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Mean Amplitude of FCU for the DH and NDH Individually for all the Postures

Tight Fist

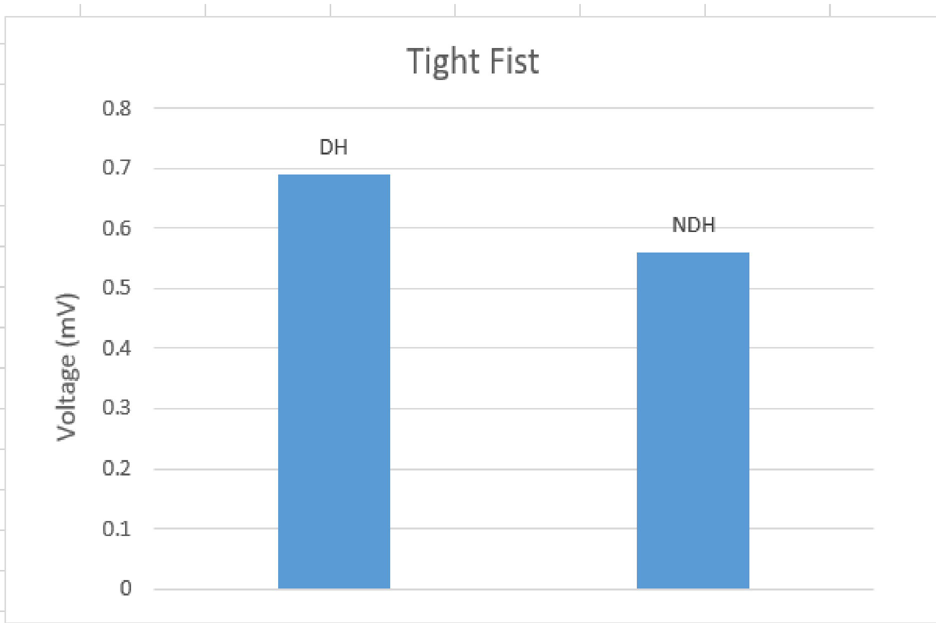

Fig. 10: Mean Amplitude of FCU for Tight Fist

Tight Fist Combined with Wrist Flexion

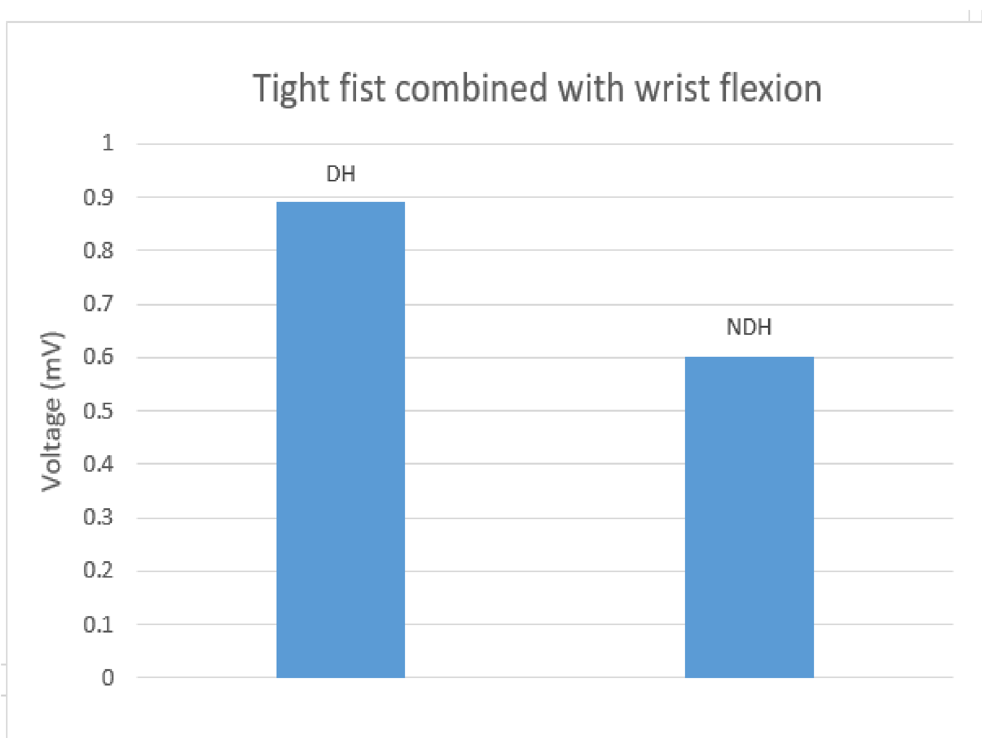

Fig. 11: Mean Amplitude of FCU for Tight Fist Combined with Wrist Flexion

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Palm Stretch Combined with Wrist Flexion

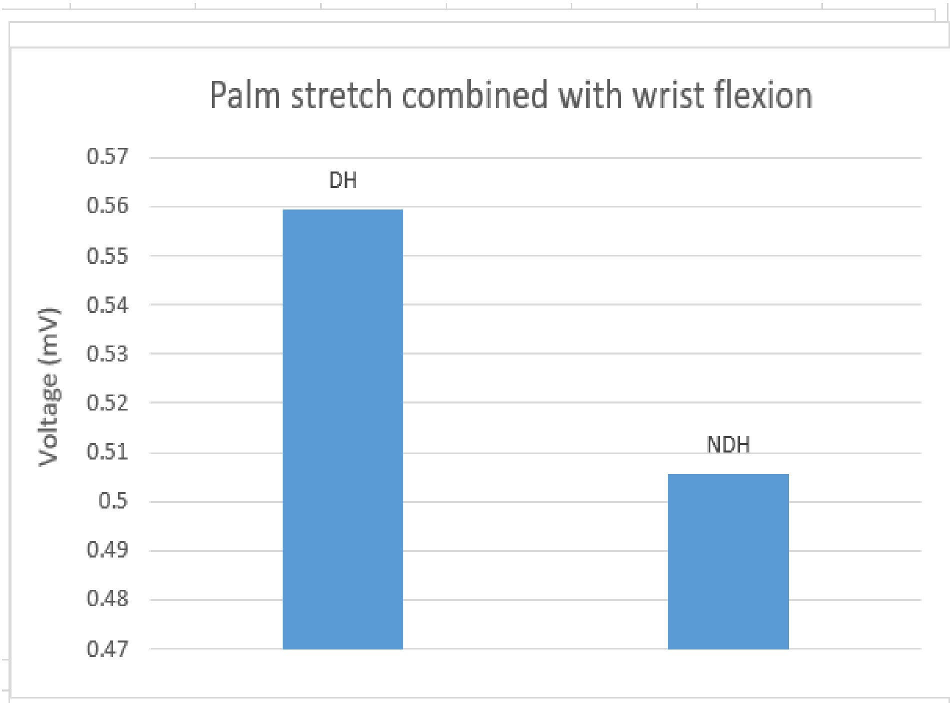

Fig. 12: Mean Amplitude of FCU for Palm Stretch Combined with Wrist Flexion

Overall FCU Muscle Activity of DH and NDH

Table 1: FCU Muscle Activity of all the Participants

	Dominant			Non Dominant		
	Posture 1	Posture 2	Posture 3	Posture 1	Posture 2	Posture 3
Participant 1	0.5853	0.9885	0.3759	0.7	0.8542	0.4122
Participant 2	0.8789	0.9311	0.8096	0.7543	0.6146	0.7611
Participant 3	0.6149	0.7443	0.5187	0.241	0.5358	0.4883
Participant 4	0.6734	0.4452	0.4406	0.5224	0.4292	0.3875
Participant 5	0.6643	1.3623	0.5684	0.5543	0.436	0.4189
Participant 6	0.7683	0.8694	0.6432	0.6342	0.7453	0.5648
Mean	***0.6975***	***0.8901***	***0.5594***	***0.5677***	***0.6025***	***0.5055***

*all units are in mV

Posture 1 - Tight Fist, Posture 2 - Tight fist combined with wrist flexion, Posture 3 - Palm stretch combined with wrist flexion.

For simplicity, the activities were assigned the names above.

Strength Analysis in Percentage for Each Posture

	Posture 1	
Hand	**Dominant**	**Non Dominant**
Voltage (mV)	0.6975	0.5677
Percentage (%)	19	

Fig. 13:Strength Analysis of DH and NDH for Posture 1

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	Posture 2	
Hand	Dominant	Non Dominant
Voltage (mV)	0.8901	0.6075
Percentage (%)	32	

Fig. 14: Strength Analysis of DH and NDH for Posture 2

	Posture 3	
Hand	Dominant	Non Dominant
Voltage (mV)	0.5594	0.5055
Percentage (%)	10	

Fig. 15: Strength Analysis of DH and NDH for Posture 3

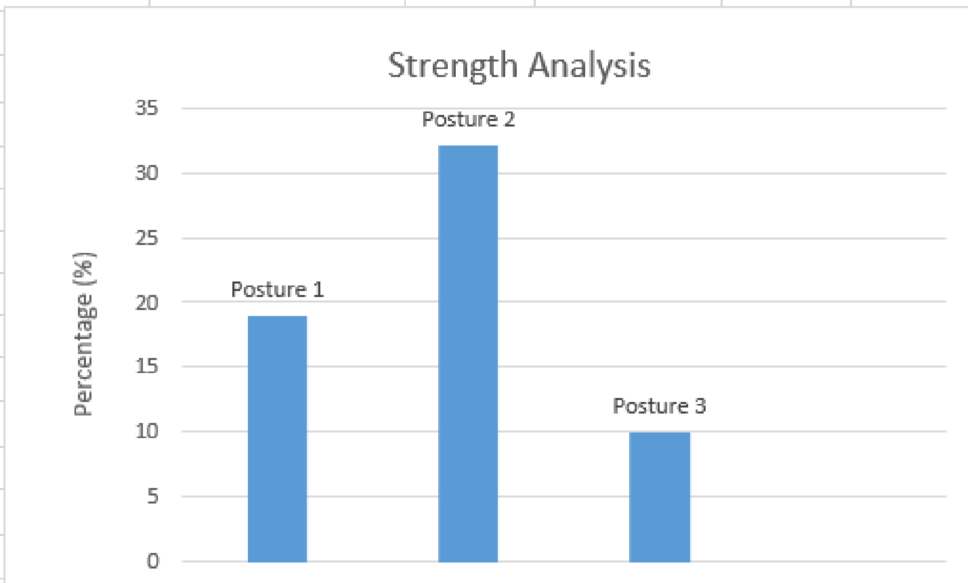

Fig. 16: Comparison of FCU Strength (%)

IV. DISCUSSION

Almost 90% of the world population are right dominant. The individual forearm muscle activity of right dominant people was higher compared to left dominant. For all the three postures, results were in favor of FCU muscle of the DH. The mean amplitude was determined individually for each posture in the DH and NDH of all the participants. The mean amplitude of posture 1 using DH was greater compared to using NDH for the same. The same pattern followed for the other two postures. The mean amplitude of posture 2 performed using both DH and NDH was greatest among the three postures whereas posture 3 was the least. The muscle contraction increases when tight fist is accompanied by flexion. Posture 3 did not contribute much to the muscle contraction compared to mere posture 1.Posture 2 produced maximum muscle contraction as it was tougher compared to the remaining postures. Experimental trials and corresponding results report the following outcomes: FCU of DH is 19% stronger than FCU of NDH for posture 1; FCU of DH is 32% stronger than FCU of NDH for posture 2 and FCU of DH is 10% stronger than FCU of NDH for posture 3. Further, the results were in favor of the hypothesis proposed. Posture 2 was

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comparatively tougher for the participants to hold for the insisted time. This increased the resistance of the participants to hold it beyond the insisted time period. Research on the response of FCU muscle would help in facilitating easier wrist motion in two degrees of freedom in humanoid robotic arms.

V. CONCLUSION

FCU muscle responsible for wrist flexion and ulnar deviation is a vital flexor muscle for wrist motion. Analyzing the strength and weakness of FCU will be a valuable guide for roboticists and prosthetists in rehabilitating hand amputees. Stimulating it with appropriate voltage would drive a prosthetic arm attached to a hand amputee. FCU muscle compensates for the function of extensors and flexors in case of severe hand injuries. Studies on understanding the biomechanical aspects of FCU will be performed in future.

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