EMG Signal Measurement of Flexor Carpi Radialis Muscle in Post Stroke Patients and Normal Individuals Using Time Domain and Frequency Domain Feature Extraction

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Abstract. Stroke patient increase with 50% motor deficit disability. Therapists identify muscle conditions conventionally with a subjective approach, especially in post-stroke patients by measuring the flexor carpi radialis muscles. There has been no measurement of the flexor carpi radialis muscle in the intervention during rehabilitation. Study to quantify the flexor carpi radialis muscle strength in grasping movements between post-stroke patients and normal individuals needed. EMG signals measure using Bitalino tools. Measurements of the flexor carpi radialis muscle in post-stroke patients and normal individuals involve 18 subjects. Palm muscle grip strength using a hand grip dynamometer and flexor carpi radialis muscle tension utilizing EMG signal amplitude with Bitalino. Muscle tension is measured based on the time domain and frequency domain. EMG Signal measure through raw signal acquisition stage, signal pre-processing includes filtering, windowing, rectification and smoothing. The EMG signal extraction stage use Matlab software with a bandpass filter at a cut-off frequency below 30 Hz and above 600 Hz, a sampling rate of 1000 Hz. Savitz-Golay statistics on the smoothing stage to get more precise signals. Comparison between post-stroke patients and normal individuals to grip strength obtained range 3,1 - 11,5 kg (27,8 - 35,0 kg). EMG signal measurements in time domains include IEMG 43.236 – 90.574 μV (139.434 - 525.172 μV), MAV 4,323 - 9,056 μV (13,942 – 52,512 μV), SSI 587.520 – 1.275.884 μV (2.805.717 – 33.917.112 μV), VAR 58,752 – 127,588 (280,571 – 3.391,711), RMS 7,664 – 11,294 μV (16,749 – 58,235 μV), WL 1.984 – 5.204 μV (155 – 1.449 μV), COV 0,745 – 1,519 μV (0,479 – 0,781 μV), AE 58,746 – 127,575 μV (280,543 – 3.391,372). Frequency domain includes MNF 0.035 – 0.051 μV (0.010 μV), MDF 0.001 – 0.017 μV (0,001 – 0,003 μV). There is a difference in grip strength between post-stroke patients and normal individuals. Bitalino can measure EMG signals on the flexor carpi radialis muscle with precision.

Keywords: Stroke Patient, Flexor Carpi Radialis Muscle, EMG Signals

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1 Introduction

Stroke sufferers are prediction increase with a stroke disability rate of 65% [1]. Half of stroke patients experience unilateral motor deficit disorder impact in a significant reduction in upper limb function [2]. Post-stroke rehabilitation/therapy is needed as the number of sufferers and disabilities due to stroke increases. Conventional rehabilitation relies on the direction of the therapist. The therapist provides stimulation in the form of holding, pinching, or other activities to assess the patient's condition. Assessment of the patient's condition is measured subjectively. The response of post-stroke patients becomes a reference for therapists in carrying out rehabilitation. This method requires a long time and high effort so that it has an impact on reducing patient motivation [3]. There has been no measurement of the flexor carpi radialis muscle in the intervention during rehabilitation. It is necessary to measure the patient's condition precisely and quantitatively/objectively. The results of measuring muscle strength become a reference for therapists in providing rehabilitation so that development is measurable and the rehabilitation time for post-stroke patients is short.

Measuring the level of muscle strength can be identified through the strength of the EMG signal. Electromyography (EMG) is an important part used to support post-stroke rehabilitation. Active patient involvement in post-stroke rehabilitation provides better results. EMG is a biomedical signal obtained by detecting muscle activity, EMG signals are detected from muscle contractions [4]. Contractions in normal muscles generate a voltage of 0.1 mV – 5 mV. Muscle contractions in the frequency range between 100 Hz-500 Hz produce a force of 1 mV and muscle contractions in the frequency range between 500 Hz-2000 Hz produce a force of 0.5 mV [5]. Furthermore, the muscle strength of post-stroke patients was measured to be compared with normal subjects. Comparison of muscle strength as a reference for rehabilitation and monitoring the development of post-stroke patients.

EMG signal acquire using Bitalino device and OpenSignals software [6]. Bitalino has reliable signal recording feature that can be used for evaluation of muscles, physical condition, and fitness [7]. Signals acquired from muscle activity were analyzed using MATLAB software for extraction [8]. Signal information processed through signal processing steps and selection of appropriate EMG signal extraction features [9]. Signal processing is carried out by signal acquisition, signal preparation, namely Visualization, Filtering, Rectification, and Normalization then signal extraction, Integrated EMG (IEMG), Mean Absolute Value (MAV), Simple Square Integral (SSI), Variance (VAR), Root Mean Square (RMS), Wave Length (WL), Coefficient of Variance (COV), Average Energy (AE), Mean Frequency (MNF), Median Frequency (MDF). EMG signals store information from muscle activation and are captured by electrodes placed on the skin surface. This study provides a reference for how to determine grip strength and measure flexor carpi radialis muscle strength in normal individuals and post-stroke patients utilizing EMG signals using Bitalino so that muscle strength measurements are more quantitatively measurable and can be used as a reference in rehabilitation.

This paper is development of previous study by Pamungkas (2019). Adding the number of subjects and feature extraction, the flexor carpi radialis muscle's EMG strength was measured using a dynamometer and Bitalino to map the muscle conditions between healthy people and post-stroke patients. This test serves as a guide and aids therapists in objectively defining post-stroke patient conditions and quantifying muscular strength.

2 Method

2.1 Study Participant

The study was conducted in the Jajar, Laweyan District, Surakarta City as shown in Fig. 1 by taking normal individual subjects and post-stroke patients meeting the inclusion criteria and excluding post-stroke subjects with exclusion criteria. 9 subjects of post-stroke and 9 subjects of normal individual involved in this study.

Fig. 1. Location for subject (Source: https://id.wikipedia.org/wiki/Jajar, Laweyan,_Surakarta#/media/Berkas:Jajar.jpg)

Normal individuals and post-stroke patients are willing to be involved in research, approved and proven in filling out the informed consent form [10]. Informed consent is an act of agreeing that something will happen to a person involved in research by knowing and understanding the facts, risks, and benefits of conducting research. The risks and benefits for research participants are explained in easy-to-understand language and explained before filling out the informed consent form in the study. In addition, it is also supported by ethical clearance, namely a statement of written permission that scientific activity meets moral principles, values and standards of ethical behavior, so that psychology research or services can be declared feasible to carry out.

The characteristics of research participants are ascertained by considering the elements that influence the EMG signal's strength, such as age, weight, height, and circumferences. The subsequent criteria (inclusion criteria) were used to choose three healthy people and three stroke survivors. BMI falls within the category of normal, with an acceptable range of 18.5 to 25 kg/m^2. [11], circumferences of 16 cm – 26 cm [12] on the strongest arm possible to demonstrate the flexor carpi radialis muscle's strength as well as the difference between post-stroke patients who are 50–65 years old and healthy persons. Subject characteristics shown in Table 1.

Table 1. Subject characteristics

Subject	Name	Gender	BMI (Kg/m^2)	Age (Years)	Circumferences (Cm)
Post-stroke	Subject 1 (A1)	Male	24,14	63	23,00
	Subject 2 (A2)	Male	24,25	62	23,40
	Subject 3 (A3)	Male	24,51	61	23,50
	Subject 4 (A4)	Male	24,29	63	25,10
	Subject 5 (A5)	Male	23,99	64	24,50
	Subject 6 (A6)	Male	24,10	65	24,80
	Subject 7 (A7)	Male	21,05	64	23,50
	Subject 8 (A8)	Male	22,00	60	23,80
	Subject 9 (A9)	Male	21,15	59	24,30
Normal Individuals	Subject 1 (B1)	Male	23,22	50	24,20
	Subject 2 (B2)	Male	23,43	55	22,70
	Subject 3 (B3)	Male	23,10	57	22,40
	Subject 4 (B4)	Male	22,98	64	26,00
	Subject 5 (B5)	Male	23,00	61	25,30
	Subject 6 (B6)	Male	22,76	62	24,30
	Subject 7 (B7)	Male	23,56	65	26,00
	Subject 8 (B8)	Male	23,78	63	25,20
	Subject 9 (B9)	Male	23,89	61	23,70

Determining the number of research subjects using the Colton calculation, where Colton in 1974 [13] formulated a statistical method in health research as follows:

$$n = \left\{\frac{(Z_\alpha - Z_b)\sigma}{u_1 - u_0}\right\}^2 \tag{1}$$

2.2 Electronic Hand Dynamometer EH101

The Electronic Hand Dynamometer EH101 measures the strength of the hand grip in order to monitor strength gains throughout rehabilitation. Test your grip strength quickly, easily, and safely to receive accurate measurements. It has specifications, where units measure in Kg or lb, max capacity measure is 90 Kg/198 lb, with smallest unit measure/ scale accuracy 0.1 Kg/ 0.2 lb, power supply needed 2 x 1.5 V battery type AAA, tolerance in measurement is 0.5 Kg/1 lb.

2.3 Bitalino

EMG strength measurements in this study used OneDot Ag/AgCl electrode materials and Bitalino tools to record Normal individuals and post-stroke patient flexor carpi radialis muscles both exhibit EMG signals. A total of 3 electrodes are needed to record the EMG signal of a subject. The electrodes are attached to the surface of the skin in the area where the EMG signal is recorded. The electrodes connected to the 3-lead electrode cable and the EMG sensor on the Bitalino tools are shown in Fig. 2.

Fig. 2. Bitalino EMG signal acquisition tools

The BITalino(r)evolution kit is a complete board with every component that can be connected with different sensors (ECG, EEG, EMG, ACC, etc.) and outfitted with Bluetooth low energy (BLE) communication possible to integrated with other devices. The EMG sensor has a specific use for surface EMG. The bipolar design is ideal for low-noise data collecting, and the raw data output makes it suitable for biomedical and projects involving human-computer interaction. The most recent wireless toolbox for gathering and analysis accurate biosignal data is called Biosignalsplux [14]. A selection of wired sensors available from Biosignalplux and can be utilized with different biosignal sensors. A high-performance, low-noise bipolar sensor for acquiring muscle signal data is the electromyography (EMG) sensor. The bipolar arrangement of the sensors, which are intended to track muscle activity, is perfect for data collection. Biomechanics and sports-related studies can benefit from the highly accurate signal capture results provided by raw data output. High signal-to-noise ratio, analogue preconditioning, bipolar differential measurement, and medical grade raw data output are among the features. This gadget has real-time display and capture capabilities for signals. The EMG sensor features a single integrated channel that includes a triaxial acceleration sensor and magnetometer for the Bluetooth module to use for real-time gathering of muscle activity and motion data. This sensor can acquire data at sampling rates of up to 1000 Hz with a resolution of up to 16 bits, and it has an inbuilt battery that can sustain continuous data streaming.

2.4 Experiment Protocol

Assessing muscle strength in normal individuals and post-stroke patients by measuring grip strength with a hand grip dynamometer. The test was conducted while taking into account the gender, BMI, circumferences, body positions, and ages of healthy people and stroke survivors. Set the subject's age and gender on the dynamometer. In a seated position, subjects were instructed to hold firmly. The dynamometer is held by the thumb, while the dynamometer lever is held by the position of the index finger, middle finger, little finger, and ring finger. The power grip exercise was performed by the subjects as forcefully as feasible. Keep track of the grip strength of normal individual and post-stroke patient.

Measurements based on EMG signals are used to determine muscular strength. The flexor carpi radialis muscle's EMG signal was measured. Measurements of signal strength are made by focusing on the forearm's anterior flexor carpi radialis muscle. The superficial layer flexor carpi radialis muscle, which controls movement of the index and middle fingers, arises from the medial epicondyle of the humerus, travels obliquely to the side of the forearm, and inserts at the base of the second and third metacarpal bones [15]. The placement of electrode put and targeting flexor carpi radialis muscle.

The process of measuring EMG signals includes subject preparation, acquisition/recording of EMG signals using Bitalino tools and opensignals software, signal preprocessing (such as filtering, windowing, rectification, smoothing, and extracting EMG signals based on time domain and frequency domain), and analysis of the signals. This process is shown in Fig. 3. employing MATLAB program for signal preprocessing and extraction. Filtering is the process of removing undesired signal components. The signal is suppressed by the bandpass filter at a frequency inside the permitted range. A bandpass filter with a frequency range of 30 Hz–600 Hz is used in this study. Signal windowing is the practice of only viewing a portion of the signal at once. Data were collected from each of the 18 respondents in this investigation over the course of 10 seconds. Each individual underwent one cycle of gripping and relaxing movements. Rectification is the process of adding the values and making them integrative in order to transform all of these negative values into positive ones. In order to obtain modest fluctuations in value and make it simpler to detect trends in our data, smoothing involves identifying significant patterns in our data while omitting irrelevant elements (i.e., noise). When analyzing input data, it may occasionally be necessary to smooth the data in order to detect a signal trend.

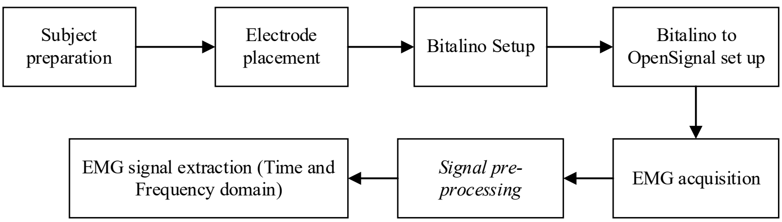

Fig. 3. EMG signal acquisition steps

3 Result and Discussion

3.1 Hand Grip

The results of hand grip strength measurements showed that post-stroke patients had low grip strength and the value of grip strength between post-stroke patients had small differences. Meanwhile, normal individual's grip strength is stronger and has a small difference in grip strength value compared to normal individuals. The difference in the value of grip strength is different between normal individuals and post-stroke patients. Hand grip measurement show in Table 2.

Table 2. Hand grip strength result

Subject	Name	Gender	Hand grip strength (Kg)
Post-stroke	Subject 1 (A1)	Male	3,10
	Subject 2 (A2)	Male	3,20
	Subject 3 (A3)	Male	3,40
	Subject 4 (A4)	Male	3,50
	Subject 5 (A5)	Male	3,70
	Subject 6 (A6)	Male	3,50
	Subject 7 (A7)	Male	11,40
	Subject 8 (A8)	Male	11,30
	Subject 9 (A9)	Male	11,50
Normal Individuals	Subject 1 (B1)	Male	34,70
	Subject 2 (B2)	Male	35,00
	Subject 3 (B3)	Male	33,00
	Subject 4 (B4)	Male	28,00
	Subject 5 (B5)	Male	27,80
	Subject 6 (B6)	Male	29,00
	Subject 7 (B7)	Male	32,00
	Subject 8 (B8)	Male	31,50
	Subject 9 (B9)	Male	31,70

Comparison between post-stroke patients and normal individuals to grip strength obtained range 3,1 - 11,5 kg and 27,8 - 35,0 kg. Post-stroke patients showed the results of the measurement of subject A1-A6's grip strength of 3.10-3.70 Kg, not more than 4 Kg, while subjects A7-A9 showed grip strength of 11.30-11.50 Kg. Comparison of grip strength between post-stroke patients has a gap of 7-8 Kg. Normal individual subjects B1-B3 showed grip strength of 33.00-35.00 Kg, B3-B6 of 27.80-29.00 Kg, B7-B9 of 31.50-32.00 Kg. Comparison of normal individual grip strength there is a gap of 4-7 kg. The grip strength discrepancy between post-stroke patients and normal individual is around 7-8 kg, which is a significant difference.

3.2 EMG strength

EMG signal measurements in time domains between post-stroke (A1-A9) and normal individual's (B1-B9) include IEMG 43.236 – 90.574 µV and 139.434 - 525.172 µV. MAV 4,323 - 9,056 µV and 13,942 – 52,512 µV. SSI 587.520 – 1.275.884 µV and 2.805.717 – 33.917.112 µV. VAR 58,752 – 127,588 µV and 280,571 – 3.391,711 µV. RMS 7,664 – 11,294 µV and 16,749 – 58,235 µV. WL 1.984 – 5.204 µV and 155 – 1.449 µV. COV 0,745 – 1,519 µV and 0,479 – 0,781 µV. AE 58,746 – 127,575 µV and 280,543 – 3.391,372 µV. Frequency domain includes MNF 0.035 – 0.051 µV and 0.010 µV. MDF 0.001 – 0.017 µV and 0,001 – 0,003 µV. EMG strength varies concerning post-stroke patients and normal individual. EMG measurement show in Table 3.

Measurement of EMG signal strength in post-stroke patients showed that subjects A1-A3 had the strongest EMG signal strength in the time domain extraction feature IEMG, MAV, SSI, VAR, RMS, and WL while in the feature extraction COV and AE showed subjects A4-A9 showed a the bigger one. The frequency domain feature with MDF extraction shows uniform EMG signal strength for subjects A1-A9 with a range of 0.035-0.051 µV. The MNF feature showed that the EMG signal strength of subjects A1-A3 is 0.001 µV, while subjects A4-A9 showed stronger results, between 0.007-0.017 µV.

Measurement of EMG signal strength in normal individuals showed subjects B1-B3, followed by subjects B7-B9, and subjects B4-B6 with the lowest EMG signal strength in the time domain extraction feature IEMG, MAV, SSI, VAR, RMS, WL and AE, whereas in The COV extraction feature shows that subjects B1-B3 show the weakest value. The frequency domain feature with MDF and MNF extraction showed that the EMG signal strength of subjects B1-B3 and B5-B9 is 0.001 µV, while subject B4 showed higher results 0.003 µV.

4 Conclusion

The flexor carpi radialis muscle's strength to evaluate grip strength using EMG signals revealed that normal individuals tended to be stronger. Identification of grip strength is used as a reference in comparing the EMG signal strength of post-stroke patients and normal individuals, as a reference for whether grip strength has a linear effect on EMG signal strength. The difference strength in grip between post-stroke patients and normal individuals indicates the possibility of increasing the grip strength of post-stroke subjects to be improved grip strength of normal individual. Bitalino and Matlab can detect and process EMG signals precisely. The flexor carpi radialis muscle's strength to evaluate grip strength using EMG signals revealed that normal individual looked to have stronger. A robust EMG signal is produced by the flexor carpi radialis muscle in normal individual, as shown by the time domain feature extraction, compared to post-stroke patients.

Table 3. EMG signal extraction

Feature Extraction											
		Time Domain (μV)								Frequency Domain (μV)	
Condition	**Subject**	**IEMG**	**MAV**	**SSI**	**VAR**	**RMS**	**WL**	**COV**	**AE**	**MNF**	**MDF**
Post-stroke	A1	71.691,031	7,168	1.003.108,262	100,310	10,015	2.870,417	0,976	100,300	0,035	0,001
	A2	90.574,428	9,056	1.275.884,390	127,588	11,294	5.204,634	0,745	127,575	0,040	0,001
	A3	84.564,811	8,455	1.200.455,955	120,045	10,956	3.952,076	0,824	120,033	0,036	0,001
	A4	43.421,766	4,341	587.520,644	58,752	7,664	2.022,645	1,454	58,746	0,051	0,014
	A5	43.236,319	4,323	604.765,742	60,476	7,776	1.984,955	1,495	60,470	0,049	0,017
	A6	43.267,247	4,326	592.661,456	59,266	7,698	2.093,031	1,471	59,260	0,051	0,017
	A7	44.382,945	4,437	651.693,906	65,169	8,072	2.155,197	1,519	65,162	0,046	0,012
	A8	50.577,772	5,057	684.268,338	68,426	8,271	2.403,069	1,294	68,420	0,046	0,007
	A9	50.337,232	5,033	700.693,997	70,069	8,370	2.373,527	1,328	70,062	0,045	0,011
	Average	58.005,950	5,800	811.228,077	81,122	8,902	2.784,395	1,234	81,114	0,044	0,009
Normal Individual	B1	525.172,072	52,512	33.917.112,586	3.391,711	58,235	1.449,819	0,479	3.391,372	0,001	0,001
	B2	356.638,625	35,660	17.543.335,221	1.754,333	41,882	384,420	0,616	1.754,158	0,001	0,001
	B3	416.983,256	41,694	23.326.154,127	2.332,615	48,294	471,839	0,584	2.332,382	0,001	0,001
	B4	139.434,143	13,942	2.805.717,385	280,571	16,749	1.094,833	0,665	280,543	0,001	0,003
	B5	148.552,354	14,853	3.067.716,991	306,771	17,514	155,551	0,624	306,741	0,001	0,001
	B6	148.409,916	14,839	3.066.852,909	306,685	17,511	183,348	0,636	306,654	0,001	0,001
	B7	350.850,616	35,081	19.032.810,205	1.903,281	43,624	391,605	0,739	1.903,090	0,001	0,001
	B8	349.428,817	34,939	19.661.837,516	1.966,183	44,339	478,714	0,781	1.965,987	0,001	0,001
	B9	331.365,040	33,133	16.754.165,860	1.675,416	40,929	462,798	0,725	1.675,249	0,001	0,001
	Average	307.426,093	30,739	15.463.966,978	1.546,396	36,564	563,659	0,650	1.546,242	0,001	0,001

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