Asian Journal of Electrical Sciences
ISSN: 2249-6297 (P); 2583-7923 (E)
Vol.13 No.1, 2024, pp.1-18

www.crijournals.org
DOI: https://doi.org/10.70112/ajes-2024.13.1.4242

Time-Domain Statistical Analysis of EMG Signals for Muscular Dysfunction Detection

Shubha V. Patel*, G. H. Kiran Kumar, I. K. Ali, Mahendrachari, G. C. Jyothi, K. L. Banumathi and Bhagya Shanthakumar
Department of Electronics and Communication Engineering,
Bapuji Institute of Engineering and Technology, Davangere, Karnataka, India
E-mail: kiran.gungiganur@gmail.com, parveenali6@gmail.com, mahendracharimc1@gmail.com, jyothigkiran@gmail.com, klbanu01@gmail.com, bhagyashantakumar@gmail.com
*Corresponding Author: shubhapatel678@gmail.com
(Received 6 August 2024; Revised 25 August 2024, Accepted 28 September 2024; Available online 5 October 2024)

***Abstract* - Electromyogram (EMG) signals provide a visual representation of the electrical activity of muscles and serve as a key tool for analyzing muscular activity in subjects with paralysis and neuromuscular diseases. This study focuses on the analysis of EMG signals in individuals with amyotrophic lateral sclerosis (ALS), myopathy, and healthy subjects. Twelve statistical features in the time domain are extracted from the EMG signals of these subjects, and the significance of these features is tested using an F-test. The results show that all twelve features are statistically significant ($p < 0.05$) in distinguishing between normal, ALS, and myopathy conditions. These findings suggest that time-domain statistical features can be effectively used to analyze paralysis conditions, potentially aiding in the development of better treatment options. Since biomedical signals are continuous by nature, graphical representations of these signals, such as time-amplitude plots, are essential for the analysis of time-series data. The analysis of EMG signals in the time domain reveals important information about the variations in amplitude over time, providing insights into muscular dysfunction in various paralysis conditions.**
Keywords: **Electromyogram (EMG) Signals, Time-Domain Statistical Features, Amyotrophic Lateral Sclerosis (ALS), Neuromuscular Diseases, Muscular Activity Analysis**

I. INTRODUCTION

Paralysis is a neuromuscular condition that describes the loss of muscle function, which can occur in one or more parts of the body. Paralysis results from damage to the nervous system [1]. The nervous system consists of the central nervous system (CNS) and the peripheral nervous system (PNS). The CNS includes the brain and spinal cord, while the PNS comprises nerves outside the CNS. The peripheral nervous system performs numerous functions; motor neurons control muscle actions, and sensory neurons activated by environmental input send information to the CNS [2].

Damage to the nerves, spinal cord, or brain interrupts the transmission of nerve signals, leading to paralysis. The severity of paralysis depends on the extent of muscle function loss. Paresis, also called partial paralysis, causes muscle weakness and impaired movement. In complete paralysis, movement in the affected body part is restricted. Permanent paralysis often results from head or neck injuries or neuromuscular disorders. Localized paralysis affects a small part of the body, while generalized paralysis impacts a larger area [3].

Different types of paralysis include monoplegia, hemiplegia, paraplegia, and quadriplegia. Monoplegia affects a single arm or leg, hemiplegia impacts an arm and leg on the same side of the body, and paraplegia affects both legs, sometimes involving the hips and lower abdominal organs. Spinal cord injury is the most common cause of paraplegia. Quadriplegia affects the arms, legs, and trunk muscles.

Flaccid paralysis causes lower motor neuron damage, muscle shrinking, and deterioration. The PNS is affected by autoimmune disorders, Guillain-Barre syndrome, and inflammation of the spinal cord, known as myelitis [4].

Muscle stiffness, spasms, and muscle weakness are caused by spastic paralysis. Spastic paralysis results from spinal cord injuries, myopathy, amyotrophic lateral sclerosis (ALS), stroke, or hereditary spastic paraplegia [5].

Information signals are transmitted between the brain and other parts of the body through a healthy nervous system. Signals from the brain are transmitted to the PNS via the spinal cord. The peripheral nerves regulate muscle movements and sensory functions. Damage to any part of the nervous system affects health and quality of life [6].

Diagnosing paralysis involves assessing damage to the muscles and nerves, and the functioning of muscles and nerves is evaluated through EMG signal analysis. Other testing modalities, such as MRI scans, CT scans, or X-rays, can also be used for assessment. The nerve function test, performed using EMG, measures responses to muscle stimulation [7]. Medical treatments, physical therapy, mobility devices, and management strategies can improve quality of life.

Paralysis can lead to difficulty in breathing, deep vein thrombosis, speech difficulty, difficulty in swallowing, urinary incontinence, loss of bowel control, and heart problems. Analyzing the paralyzed condition aids in the diagnosis of impaired muscular activities, which can lead to better treatment options. A visual representation of muscle electrical activity is called an electromyogram (EMG). Electromyography is a device used to capture the electrical potential generated when a muscle cell is electrically or neurologically stimulated.

To analyze muscular activity and determine the degree of recruitment or activation, EMG signals can be examined. EMG is related to the activity of voluntary muscular contractions. The functional element of muscular contraction is the motor unit, which consists of a single alpha motor neuron and all the muscle fibers it innervates [8].

When action potentials exceed the depolarization threshold, the muscle fiber contracts. The motor unit action potential comprises the sum of individual muscle fiber action potentials. The EMG signal is formed by the motor unit action potentials within the electrode's pick-up zone, which are algebraically summed. Multiple motor units are generally present in the electrode's pick-up zone. Muscles that govern fine movements have fewer muscle fibers per motor unit, whereas muscles used for large, gross movements have more muscle fibers per motor unit.

The current produced by ionic flow across the muscle fiber membranes travels through auxiliary tissues to the detection surface, constituting the EMG. Groups of innervated muscle fibers form motor units. Motor unit activation is controlled by signals from the nervous system and generates Motor Unit Action Potentials (MUAPs). The CNS generates MUAPs to produce force and action from the muscles. The EMG signal is composed of these MUAPs from simultaneously active motor units [8]. A schematic representation of the generation of MUAPs is presented in Figure 1. Figure 2 shows the action potential from a muscle fiber.

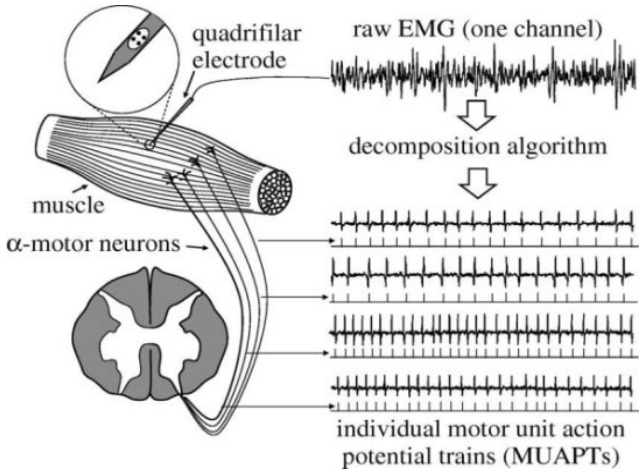

Fig. 1 Origin of EMG [9]

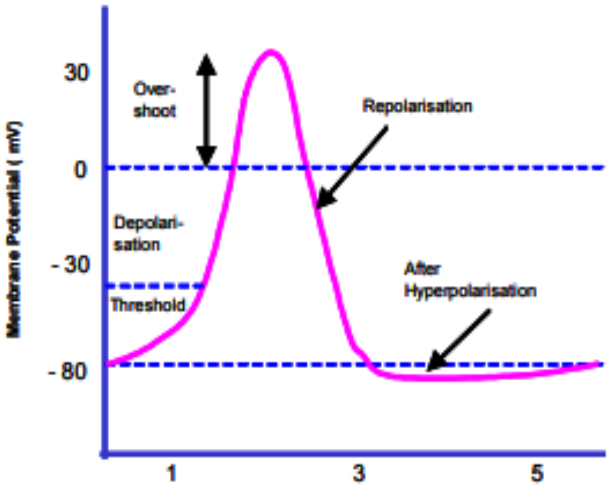

Fig. 2 Action potential from muscle fiber [8]

For the diagnosis of neuromuscular pathology using diagnostic EMG, the properties of motor unit action potentials, such as duration and amplitude, are analyzed [10]. Muscle activity in relation to movement is analyzed using kinesiological EMG [10].

The measure of electrical potential present on the skin with respect to muscle contractions is called EMG. The voltages are detected by electrodes placed on the skin, and the measured voltage corresponds to the activity of the muscle. As the muscle is activated, the signal amplitude increases from zero to tenths or hundreds of microvolts over time.

Surface EMG (sEMG), a non-invasive method, has been used for motion analysis and muscle function assessment. sEMG has applications in sports, ergonomics, occupational health, and rehabilitation medicine. It is used to investigate muscle activation and physiological characteristics [11]. A limitation of sEMG is that individual motor units cannot be reliably distinguished. Using percutaneous needle EMG, the electrical activity of individual motor units can be visualized, allowing for the evaluation of neurological diseases.

The needle EMG method is used to acquire and analyze electrical signals from individual motor unit muscle fibers. EMG signal recording is performed during voluntary contraction and at rest, using clinically recommended needle electrodes.

The needle electrodes are inserted into the muscle to record muscle fiber activity during contraction and at rest, and the acquired signal is amplified for analysis. Precautions should be taken in selecting needle electrodes, amplifiers, and filters for noise removal. The possible risks associated with the needle EMG method include muscle pain, muscle bleeding, and pneumothorax [12].

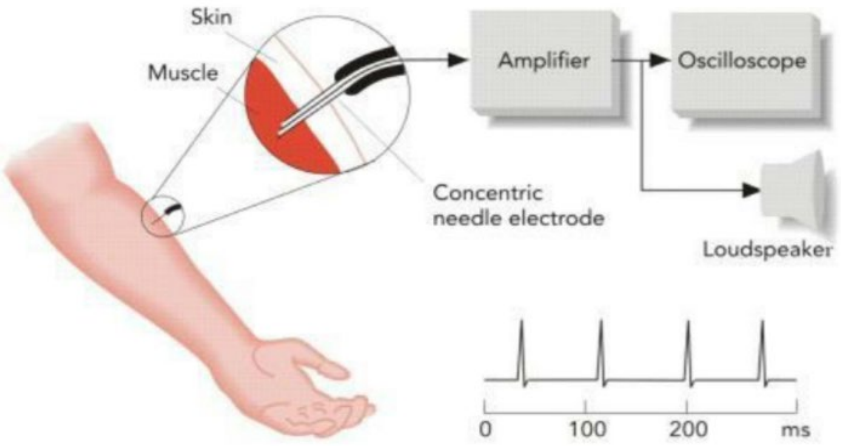

Fig. 3 Needle EMG Instrumentation [13]

The clinically recommended needle electrodes are inserted into the muscle, as shown in Figure 3. The acquired signals are further processed using appropriate methods and displayed on electronic devices.

There are two types of needle electrodes: monopolar and concentric. The insertion tube serves as the reference electrode, while the concentric needle electrode consists of a thin wire that passes through the shaft to act as the recording electrode. In the monopolar needle electrode, the shaft is coated with Teflon, leaving the tip as the recording electrode, and a separate reference electrode is needed. A monopolar needle electrode is low-cost and causes less insertion pain. However, electrode impedance mismatch can increase electrical noise. The clinical history and the findings of neurologic examinations can be used to choose the muscle to be tested [14].

Electromyography (EMG) is a test used to assess the health of muscles and nerve cells. The acquired EMG data is used to examine muscle function, nerve function, or disturbances in nerve-to-muscle signal transmission. EMG results aid in the proper diagnosis of neuromuscular disorders, including amyotrophic lateral sclerosis, peripheral neuropathies, muscular dystrophy, myasthenia gravis, and myopathy. EMG is performed with low risk; however, potential risks during the EMG procedure include bleeding, nerve injury, infection, and pneumothorax [15].

Needle EMG is used in the field of sports, as it can assess dynamic situations. EMG recordings of muscle activity during athletic performance provide valuable insights related to performance requirements and injury prevention [16].

An EMG test may be used to assess neuromuscular disorders and aids in the diagnosis of degenerative conditions, motor tissue issues, nerve damage, and neuromuscular diseases. Neuromuscular illnesses such as amyotrophic lateral sclerosis, peripheral neuropathies, myopathies, muscular dystrophy, and myasthenia gravis can be evaluated and managed using electromyography [17].

II. LITERATURE SURVEY

Most neuromuscular disorders, including ALS and myopathy, result in paralysis [27]. Amyotrophic lateral sclerosis (ALS), also known as Lou Gehrig's disease, is a degenerative neuromuscular condition characterized by the loss of motor nerve cells in the brain and spinal cord. Muscular weakness occurs due to the loss of muscle function, which results when motor neurons are unable to transmit signals to the muscles. ALS does not negatively affect a person's intelligence, vision, hearing, or sense of taste, smell, or touch [18].

ALS is considered a unique condition as it strikes suddenly and is relatively rare. The illness most frequently affects individuals between the ages of 40 and 70. Due to intensive research and advancements in understanding the primary causes, prevention, and treatment of ALS, many patients can live longer. Timely and accurate diagnosis can significantly increase the life expectancy of individuals with ALS.

1. Causes of ALS: ALS is a unique and unpredictable disease, with its main cause often linked to genetic history. It is a degenerative neurological illness characterized by the loss of muscle control as it destroys nerve cells in the brain and spinal cord.

2. Symptoms of ALS: The symptoms of ALS include muscle twitching and cramping, loss of motor function in the hands and arms, weakness and fatigue, frequent falls and dropping objects, difficulty projecting one's voice, shortness of breath, breathing difficulties, swallowing difficulties, and paralysis. The symptoms of ALS are illustrated in Fig. 4.

3. ALS Diagnosis: ALS is diagnosed based on medical history and physical examinations. Laboratory tests, including blood, urine, and thyroid function tests, are conducted. Additionally, muscle and nerve examinations, cerebrospinal fluid analysis, X-ray, and MRI techniques are employed for diagnosis.

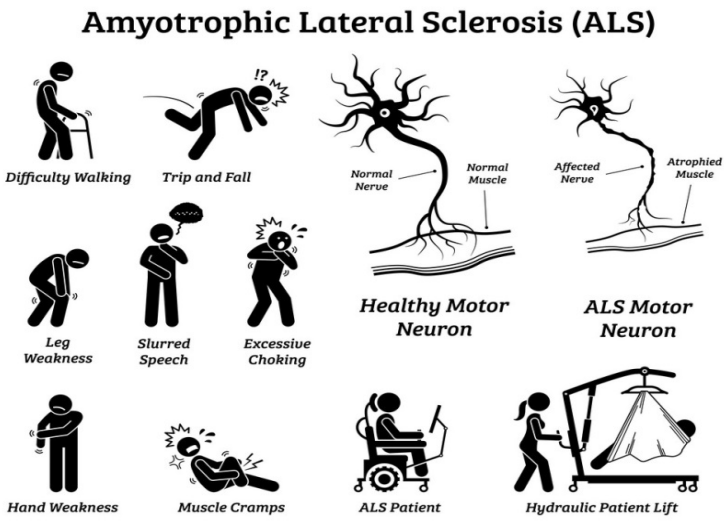

Fig. 4 Symptoms of ALS [19]

The procedures used in the examination to evaluate and identify anomalies in the muscles and motor neurons include electromyography (EMG) and nerve conduction velocity (NCV). Electrodes are inserted into the muscle or placed on the skin to monitor electrical activity and muscle response.

The term "myopathy" is used to describe diseases related to muscles. In individuals with myopathy, the muscles function less effectively than normal, which may be due to abnormal muscle development, muscle damage, or a deficiency of important components in the muscle system [20]. Proteins and other structural elements work together to contract a muscle. Myopathy may result from a deficiency in one of these components.

4. Myopathy Symptoms: Myopathy typically results in muscular weakness, with proximal weakness being the most common type. This means that the muscles of the upper arms and upper legs are more noticeably weaker than the muscles of the hands or feet. In some cases, myopathy can also cause deterioration of the respiratory muscles. This leads to muscle wasting, further weakening the muscles. Myopathy is often associated with abnormal bone formation. Additional symptoms include fatigue, general weakness throughout the day, or gradual weakness with exertion.

5. Myopathy Diagnosis: Diagnosis is based on medical history, physical examination, muscular strength, and balance assessments. Various tests are performed depending on the medical history and physical examination. Blood tests and electrolyte analysis are among these tests. Electromyography (EMG), an electrical test that evaluates muscle function by using needles to detect different aspects of muscle movement and structure, is another diagnostic tool. Certain types of myopathy may be diagnosed with the help of special tests, including muscle biopsies and genetic analysis [20].

6. EMG for Muscle Analysis: A significant portion of the examination of patients with neuromuscular diseases involves electrodiagnostic tests. The main purpose of electromyography (EMG) is to supplement clinical examinations. EMG is used to diagnose peripheral nervous system problems. The muscles, primary motor neurons, primary sensory neurons, nerve roots, brachial and lumbosacral plexuses, peripheral nerves, and neuromuscular junctions are among the structures affected. These investigations also provide helpful diagnostic information for central nervous system diseases [21]. EMG records the electrical activity of muscles and is used to determine abnormalities related to neuromuscular activity. The EMG is acquired using surface electrodes or needle electrodes, which are placed or inserted into specific muscles under investigation.

EMG analysis of amyotrophic lateral sclerosis (ALS) and myopathy conditions provides insights into the performance of muscular activity in subjects with paralysis [28]. Features are the distinctive pattern representations of reduced-dimensional signals. The goal of feature extraction is to identify traits that are exceptionally distinctive and informative. Time-domain (TD), frequency-domain (FD), and time-frequency-domain (TFD) features are used to study the EMG characteristics. TD represents signal characteristics as a function of time. FD represents the signal characteristics as a function of frequency, and the frequency spectrum of the signal indicates the frequencies contained in the signal. TFD features provide information about both the temporal and spectral characteristics of the signal. Several aspects are considered for EMG signal classification, including features taken individually and the number of features in groups analyzed in TD, FD, and TFD domains [22], [29].

The initial characteristics considered are TD features based on EMG signal amplitude. These characteristics are the best option from a computational standpoint, as they can be extracted directly without the need for extensive

mathematical processing. The following twelve common TD characteristics are evaluated: mean, mean absolute value (MAV), variance, variance absolute value (VAV), waveform length (WL), zero crossing (ZC), root mean square (RMS), log detector (LD), average amplitude change (AAC), difference absolute standard deviation value (DASDV), kurtosis, and skewness.

The most significant explanation for muscular movement depends on the fluctuation of energy over time. Higher levels of muscular activity often result in the recruitment of more motor units and the subsequent release of more motor unit action potentials (MUAPs) for EMG detection [21]. The classification of EMG is achieved using neural network models. Various types of neural network models include artificial neural networks (ANN), recurrent neural networks (RNN), and convolutional neural networks (CNN).

III. METHODOLOGY

EMG signal analysis is based on a better understanding of the characteristics of the EMG signal. Understanding the characteristics of EMG in normal, amyotrophic lateral sclerosis (ALS), and myopathy conditions aids in the analysis of both normal and paralyzed states.

EMG signals are generated by action potentials at the muscle fiber membrane resulting from depolarization and repolarization processes. The amplitude of the EMG signal can range from -5000 microvolts to +5000 microvolts.

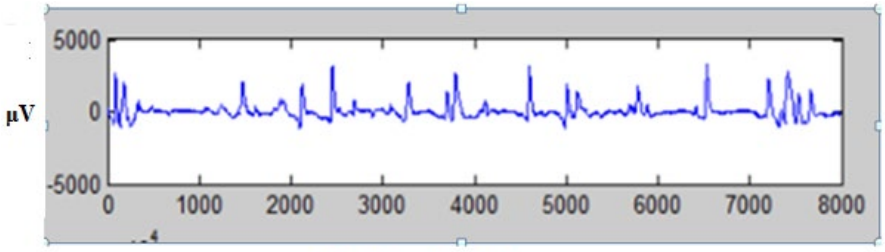

Fig. 5 (a) EMG signal pattern of normal condition [23]

The frequency content ranges between 1 Hz and 10 kHz. The sampling rate is selected to be greater than or equal to the Nyquist rate of the signal. This sampling rate ensures that the processing unit fully captures the signal's frequency spectrum. Figure 5 (a) shows the EMG signal pattern under normal conditions. EMG in amyotrophic lateral sclerosis (ALS) shows the presence of fasciculations. Additionally, fibrillations and positive sharp waves are observed.

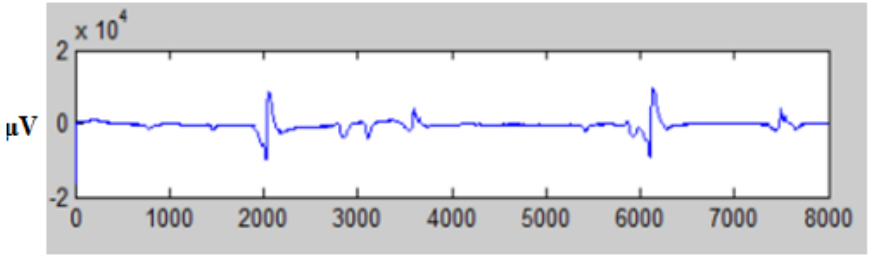

Fig. 5 (b) EMG signal pattern of ALS condition [23]

ALS data also show decreased conduction velocity, extended distal motor delay, and decreased compound muscle action potential (CMAP) [24]. Figure 5 (b) depicts the EMG signal pattern in ALS. In myopathy conditions, the presence of abnormal spontaneous activity is observed. As a result, each motor unit action potential (MUAP) is generated by fewer motor fibers.

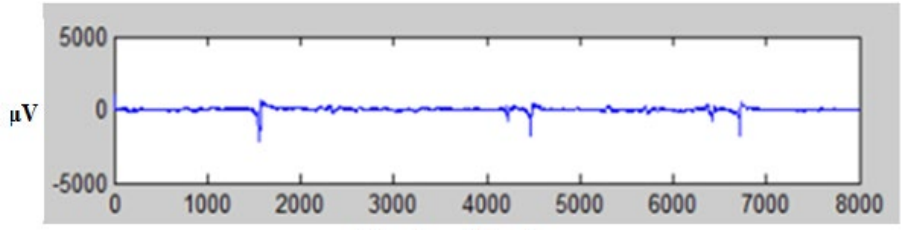

Fig. 6 EMG signal pattern of myopathy condition [23]

MUAPs become polyphasic, short in duration, and low in amplitude [25]. Figure 6 shows the EMG signal pattern in myopathy conditions. In the present work, the dataset [26] used consists of EMG signals recorded from needle electrodes. The electrode insertion levels are low, medium, and deep. The recordings were performed during steady isometric contractions. The sampling frequency of the EMG signals is set to 23.435 kHz. The block diagram for the method used is shown in Figure 7. The amplitude of the EMG lies between -5 mV and +5 mV. The EMG has a sampling rate of 23.435 kHz.

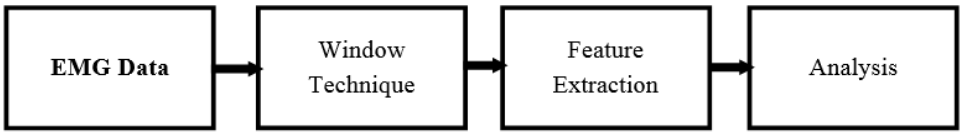

Fig. 7 Time Domain Feature Extraction and Classification of EMG Data

Rectangular windows of 300.37 ms with a 99.84 ms overlap are utilized for feature extraction. A total of 110 segments were produced from 11.20 seconds of data using the window approach. Each segment consists of a sample size of 7040 sample values and an overlapping sample size of 2340 sample values. Features in the time domain are extracted from each segment of the EMG dataset. In this work, twelve features are considered. The EMG features considered in this work include the mean value, variance, mean absolute value, root mean square, waveform length, zero crossing, log detector, difference absolute standard deviation value, average amplitude change, variance absolute value, kurtosis of the signal, and skewness of the signal. The features obtained are used for analysis.

The EMG features are described as follows:

1. Mean: The mean EMG value provides the overall innervation input of a chosen muscle for a specified task or work. EMG activity is a measure of the amount of muscle contraction and the number of contracted muscles.

2. Variance: Variance of EMG signal (VAR) gives the signal power. The calculation of variance is shown in equation (1).

$$VAR = \frac{1}{L-1}\sum_{i=1}^{L}(x_i)^2 \qquad (1)$$

3. Mean Absolute Value: The mean absolute value (MAV) is the average of the summation of absolute value of signal. The MAV is calculated using equation (2).

$$MAV = \frac{1}{L}\sum_{i=1}^{L}|x_i| \qquad (2)$$

4. Root Mean Square: The root mean square (RMS) value is the square root of average power of the signal for a specified time interval. RMS value describes the muscle information. The RMS is calculated using equation (3).

$$RMS = \sqrt{\frac{1}{L}\sum_{i=1}^{L}(x)_i^2} \qquad (3)$$

5. Waveform Length: The waveform length (WL) is the cumulative length of the waveform over the segment. WL value represents the amplitude, frequency, and duration. WL is a measure of complexity of the EMG signal. WL is calculated using equation (4).

$$WL = \sum_{i=2}^{L}|x_i - x_{i-1}| \qquad (4)$$

6. Zero Crossing: The zero crossing (ZC) measures the frequency information. The number of times the sign of the signal value changes divided by the length of the segment. ZC is calculated using equation (5).

$$ZC = \sum_{n=1}^{N-1}\left[\text{sgn}(x_n \times x_{n+1}) \cap |x_n - x_{n+1}| \geq threshold\right]; \quad (5)$$

$$\text{sgn}(x) = \begin{cases} 1, & \text{if } x \geq \text{threshold} \\ 0, & \text{otherwise} \end{cases}$$

7. Log Detector: The log detector (LD) estimates the exerted force. LD is calculated using equation (6).

$$LD = \exp\left(\frac{1}{L}\sum_{i=1}^{L}\log(|x_i|)\right) \qquad (6)$$

8. Difference Absolute Standard Deviation Value: The difference absolute standard deviation value (DASDV) can be expressed as in Equation (7).

$$DASDV = \sqrt{\frac{\sum_{i=1}^{L-1}(x_{i+1} - x_i)^2}{L-1}} \qquad (7)$$

9. Average Amplitude Change: The average amplitude change (AAC) can be formulated as in Equation (8)

$$AAC = \frac{1}{L}\sum_{i=1}^{L-1}|x_{i+1} - x_i| \qquad (8)$$

10. Variance Absolute Value: The variance absolute value can be expressed as in Equation (9).

$$VAV = \frac{1}{L-1}\sum_{i=1}^{L}(|x_i|)^2 \qquad (9)$$

11. Kurtosis: Indicates the peakedness of the signal and describe the contraction of the muscles. Kurtosis is obtained using equation 10.

$$\text{Kurtosis} = ((\text{Fourth Moment}) / (\text{Second Moment})^2) \quad (10)$$

12. Skewness: Distribution symmetry is measured by skewness. Skewness is obtained using equation (11).

$$\text{Skewness} = ((3*(\text{mean}-\text{median})) / (\text{standard deviation})) \quad (11)$$

IV. RESULTS AND DISCUSSION

The time domain features extracted in the present work are analyzed statistically using statistical F-test.

TABLE I STATISTICAL F-TEST ANALYSIS FOR TIME DOMAIN FEATURES

Sl. No.	Time Domain EMG Features	Data Sets compared in the Test	p - Value
1	Mean	normal, ALS	0.03667
		normal, myopathy	0.04674
		ALS, myopathy	0.00005857
2	Variance	normal, ALS	2.22e-16
		normal, myopathy	<0.05
		ALS, myopathy	<0.05
3	MAV	normal, ALS	6.661e-16
		normal, myopathy	3.007e-8
		ALS, myopathy	<0.05
4	RMS	normal, ALS	<0.05
		normal, myopathy	1.194e-9
		ALS, myopathy	<0.05
5	WL	normal, ALS	2.22e-16
		normal, myopathy	4.441e-16
		ALS, myopathy	<0.05
6	ZC	normal, ALS	1.67e-9
		normal, myopathy	<0.05
		ALS, myopathy	7.772e-15
7	LD	normal, ALS	-4.441e-16
		normal, myopathy	2.767e-10
		ALS, myopathy	0.002471
8	DASDV	normal, ALS	6.661e-16
		normal, myopathy	6.66e-16
		ALS, myopathy	<0.05
9	AAC	normal, ALS	2.22e-16
		normal, myopathy	4.441e-16
		ALS, myopathy	<0.05
10	VAV	normal, ALS	4.441e-16
		normal, myopathy	0.4953
		ALS, myopathy	<0.05
11	Kurtosis	normal, ALS	2.22e-15
		normal, myopathy	-1.332e-15
		ALS, myopathy	<0.05
12	Skewness	normal, ALS	<0.05
		normal, myopathy	1.533e-9
		ALS, myopathy	<0.05

The features are found to be statistically significant with p <0.5, for analysis. Table I show the p-values obtained from F-test.

The figures 8(a), 8(b), and 8(c) show the mean value extracted in time domain for ALS, myopathy, and Normal data.

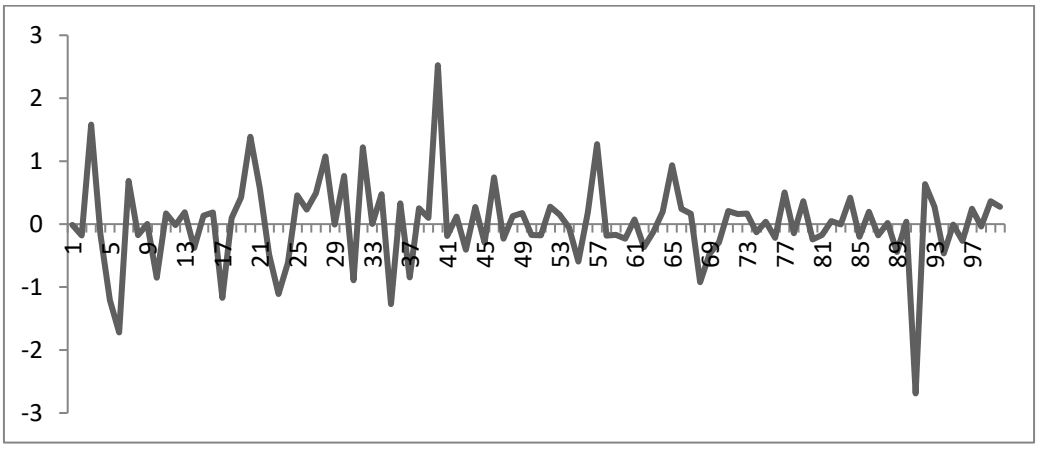

Fig. 8(a) Mean value of ALS Data

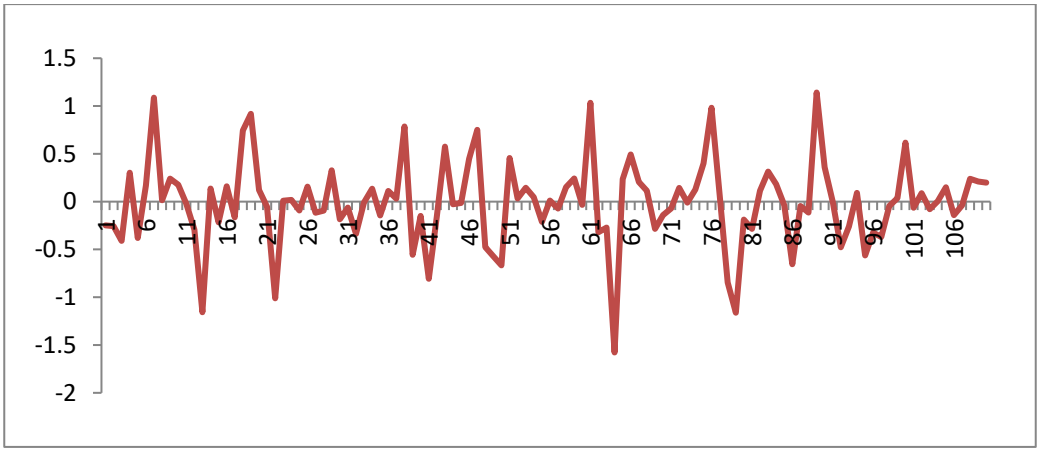

Fig. 8(b) Mean value of Myopathy Data

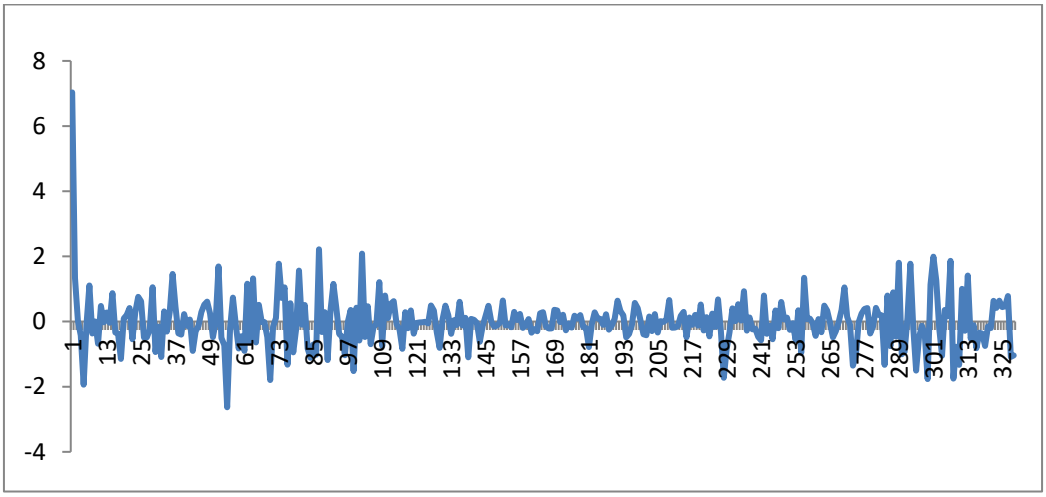

Fig. 8(c) Mean value of Normal Data

Figures 8(a), 8(b), and 8(c) show that ALS and myopathy data have greater mean peak values than normal data. Muscle fatigue is higher in ALS and myopathy subjects.

Figures 9(a), 9(b), and 9(c) show the variance values extracted in the time domain for ALS, myopathy, and normal data.

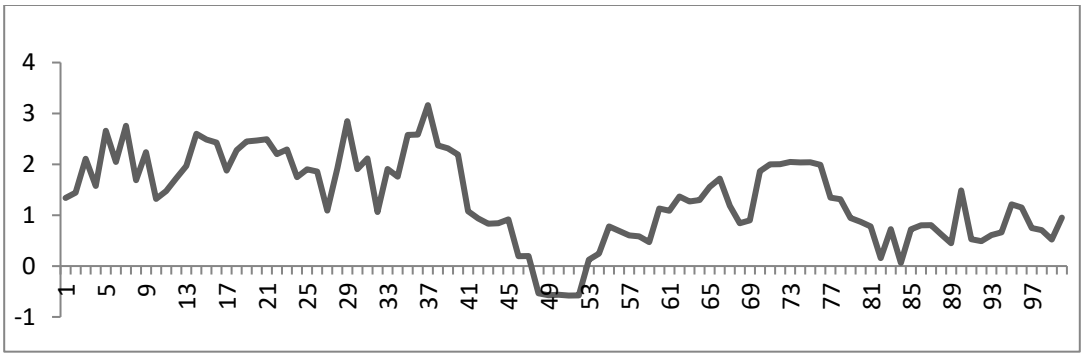

Fig. 9(a) VAR value of ALS Data

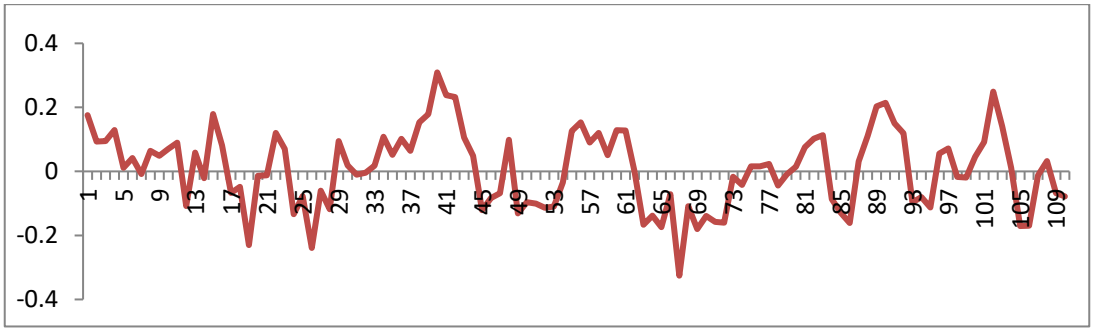

Fig. 9(b) VAR value of Myopathy Data

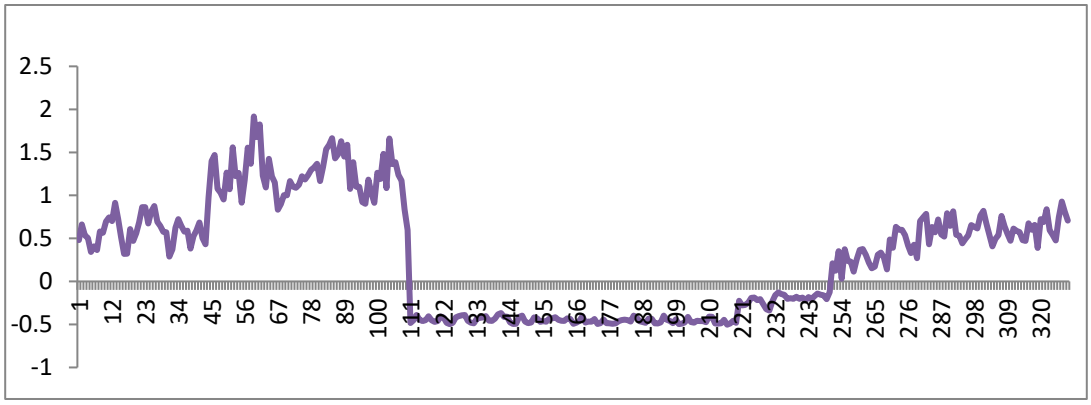

Fig. 9(c) VAR value of Normal Data

Figures 9(a), 9(b), and 9(c) show that ALS data have a higher variance peak than normal data. Myopathy data have a lower variance peak than normal data. Figures 10(a), 10(b), and 10(c) show the mean absolute value (MAV) extracted in the time domain for ALS, myopathy, and normal data.

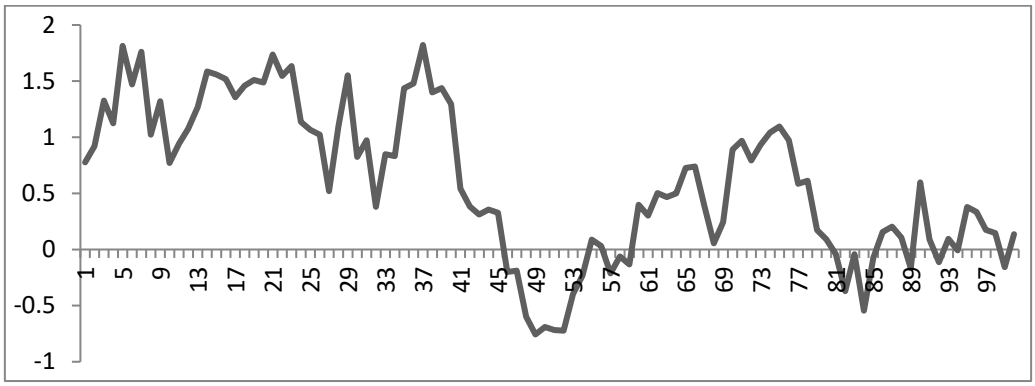

Fig. 10(a) MAV value of ALS Data

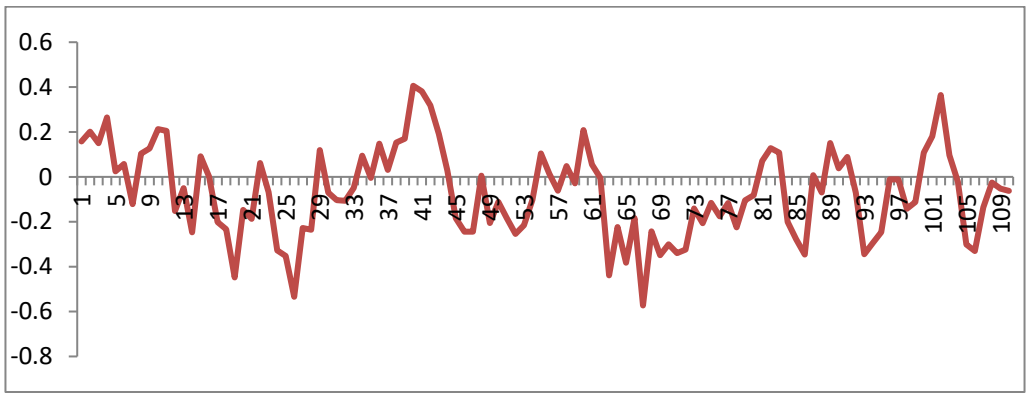

Fig. 10(b) MAV value of Myopathy Data

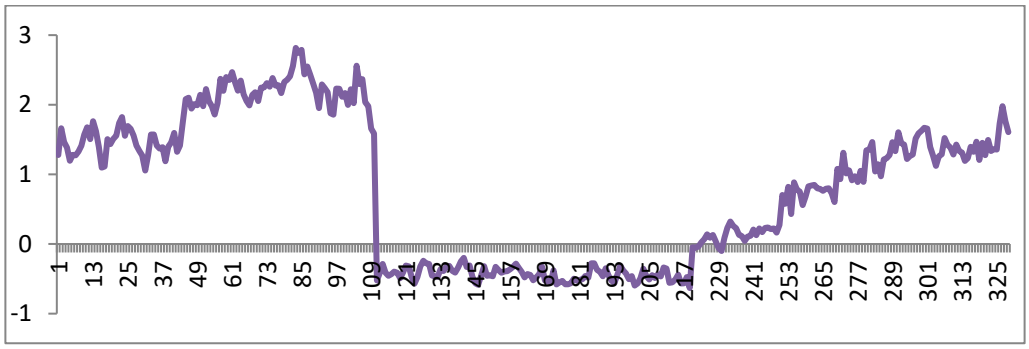

Fig. 10(c) MAV value of Normal Data

Figures 10(a), 10(b), and 10(c) show that MAV values in ALS and myopathy subjects indicate increased motor recruitment to produce constant muscle force during isometric contractions. Figures 11(a), 11(b), and 11(c) show the root mean square (RMS) values extracted in the time domain for ALS, myopathy, and normal data.

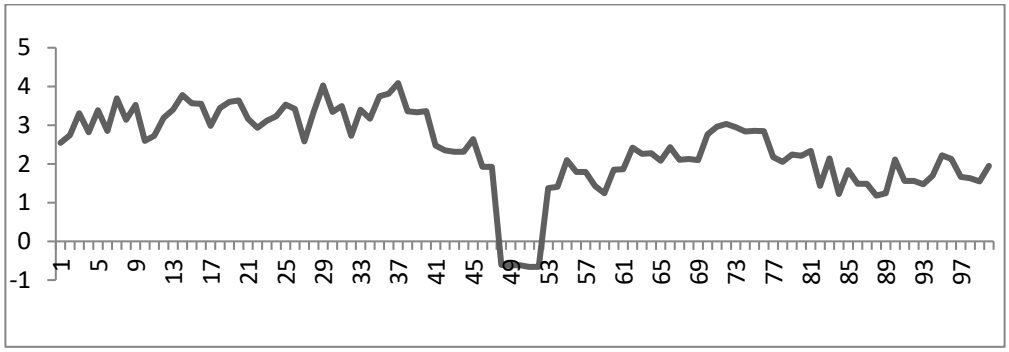

Fig. 11(a) RMS value of ALS Data

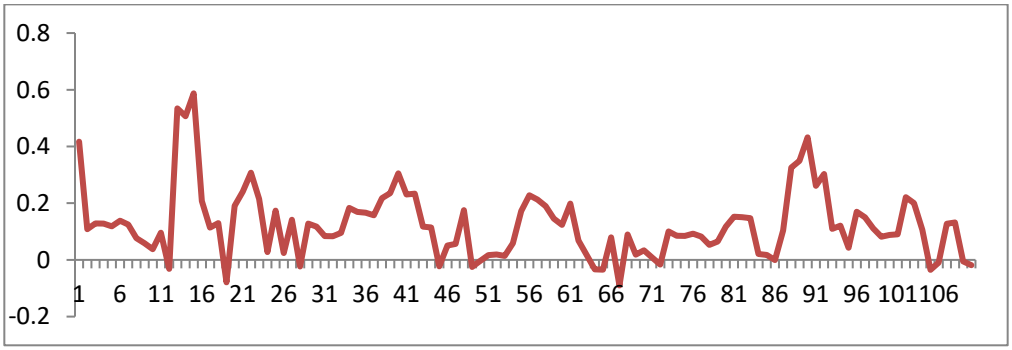

Fig. 11(b) RMS value of Myopathy Data

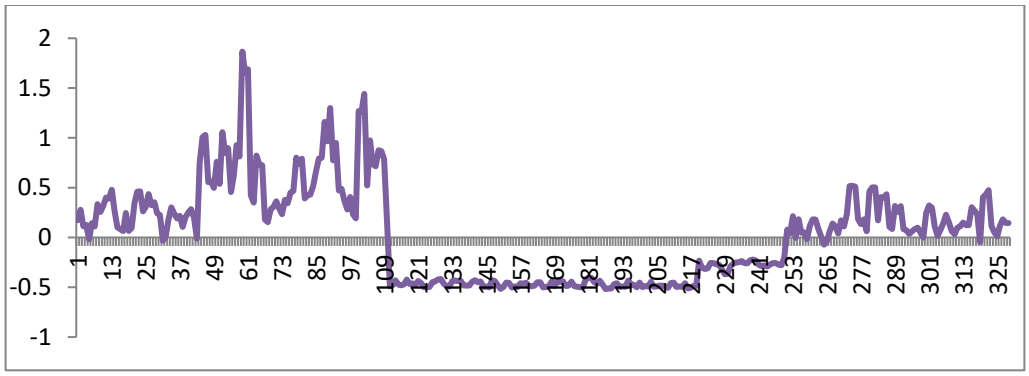

Fig. 11(c) RMS value of Normal Data

Figures 11(a), 11(b), and 11(c) show that the root mean square values describe the force or torque produced by the muscles. To maintain the isometric position, the torque produced in ALS and myopathy subjects is greater compared to normal subjects. Figures 12(a), 12(b), and 12(c) show the waveform length (WL) values extracted in the time domain for ALS, myopathy, and normal data.

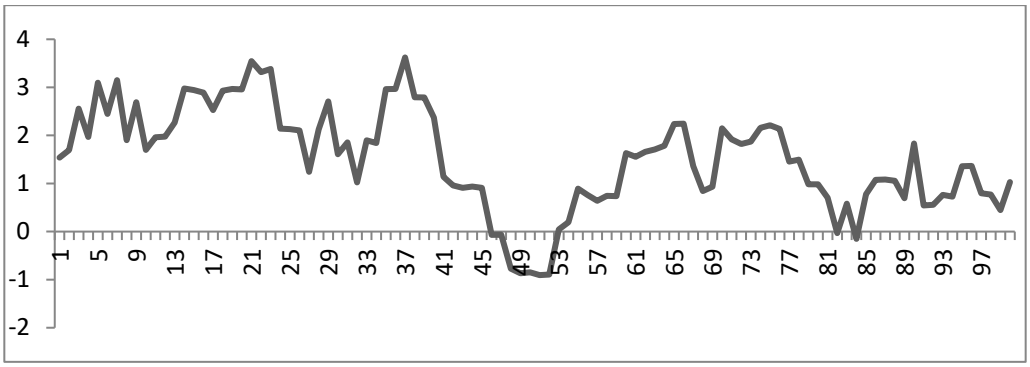

Fig. 12(a) WL value of ALS Data

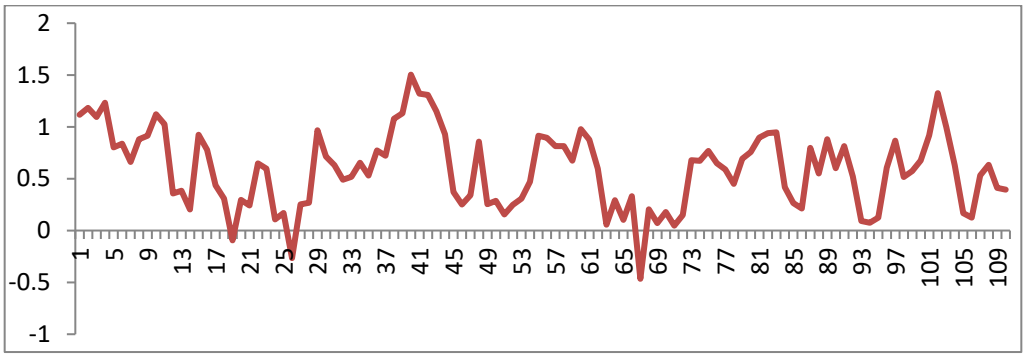

Fig. 12(b) WL value of Myopathy Data

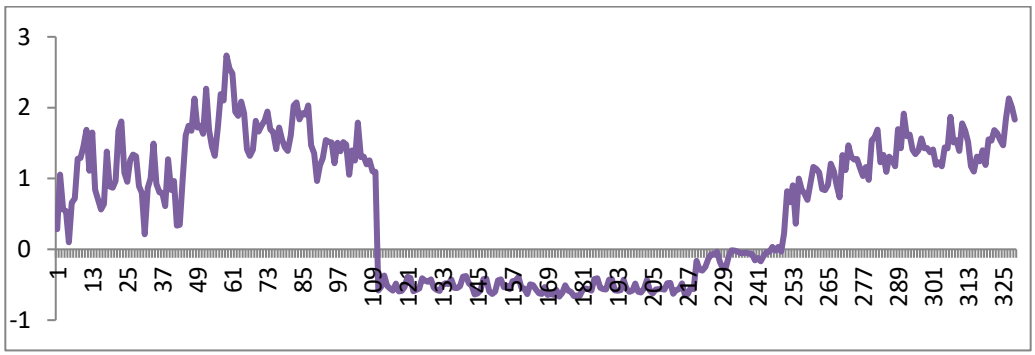

Fig. 12(c) WL value of Normal Data

Figures 12(a), 12(b), and 12(c) describe the increased complexity due to higher cumulative values. Figures 13(a), 13(b), and 13(c) show the zero crossing (ZC) values extracted in the time domain for ALS, myopathy, and normal data.

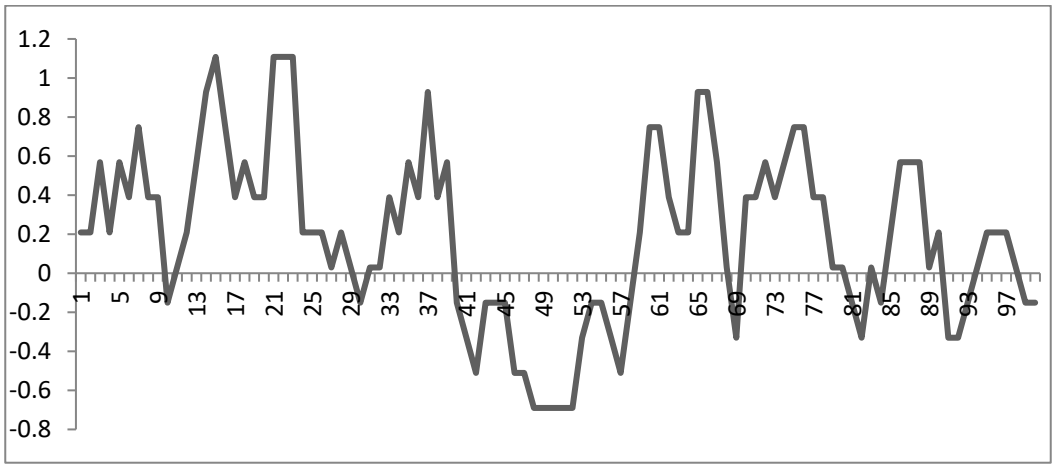

Fig. 13(a) ZC value of ALS Data

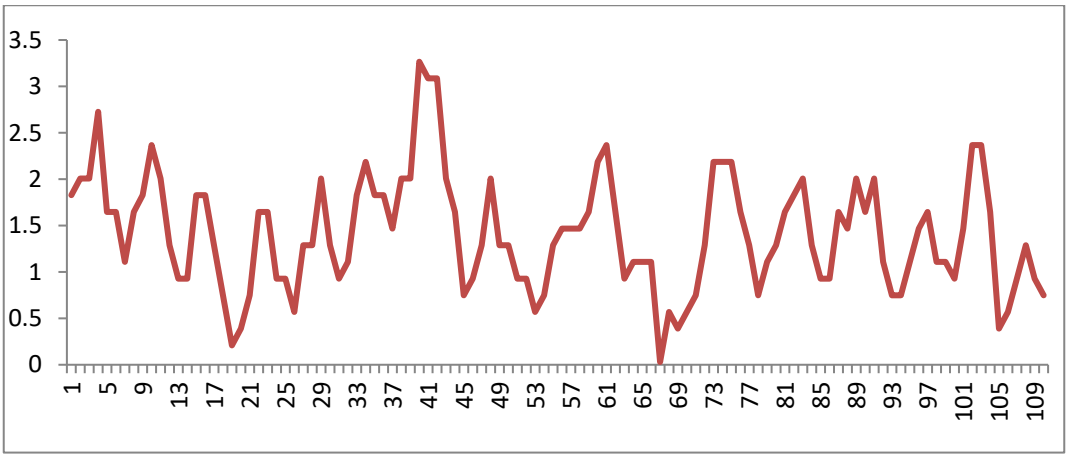

Fig. 13(b) ZC value of Myopathy Data

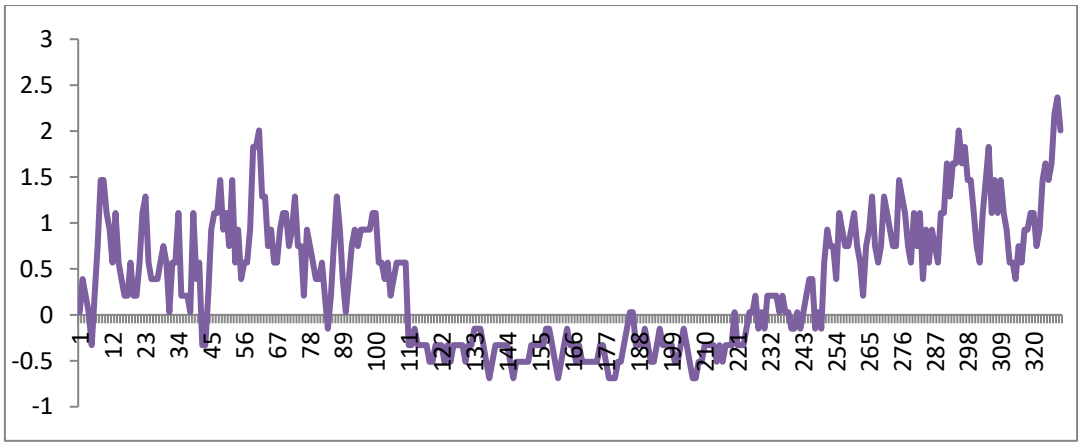

Fig. 13(c) ZC value of Normal Data

Figures 13(a), 13(b), and 13(c) show that ALS and myopathy data have higher ZC rates than normal data. Figures 14(a), 14(b), and 14(c) show the largest deviation (LD) values extracted in the time domain for ALS, myopathy, and normal data.

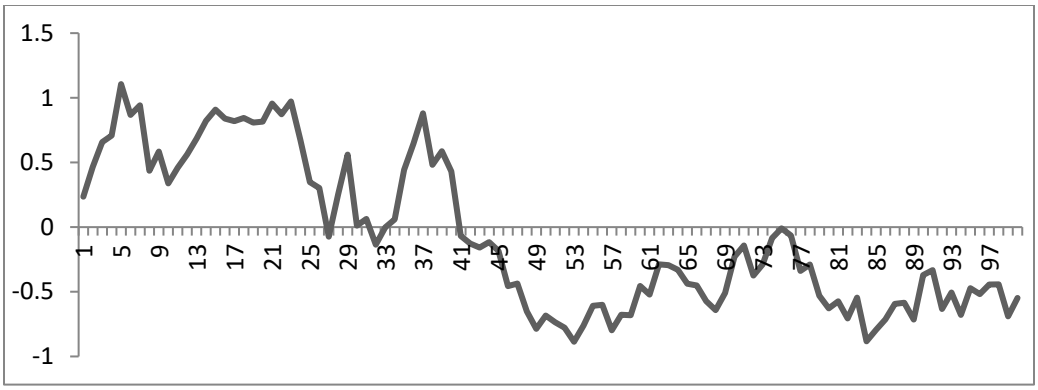

Fig. 14(a) LD value of ALS Data

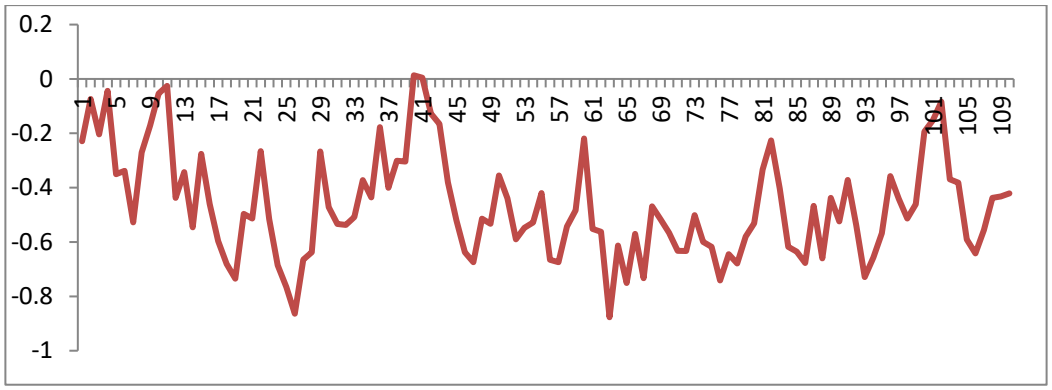

Fig. 14(b) LD value of Myopathy Data

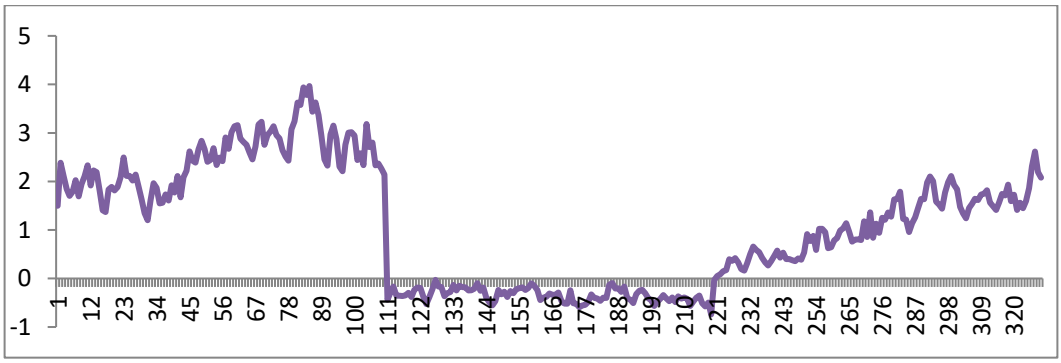

Fig. 14(c) LD value of Normal Data

Figures 14(a), 14(b), and 14(c) show the LD values, which describe the exerted muscle force. Figures 15(a), 15(b), and 15(c) show the difference absolute standard deviation value (DASDV) extracted in the time domain for ALS, myopathy, and normal data.

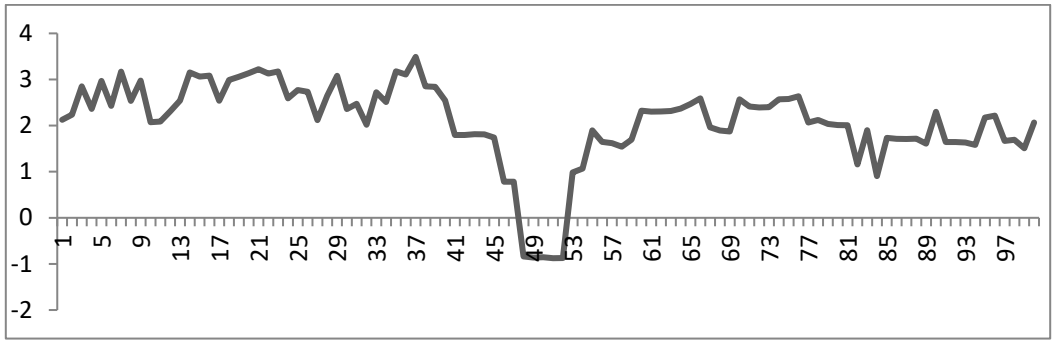

Fig. 15(a) DASDV value of ALS Data

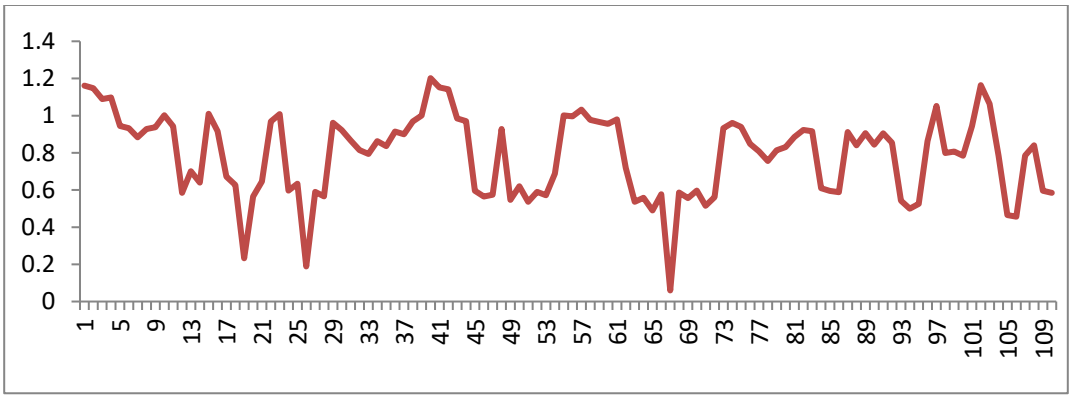

Fig. 15(b) DASDV value of Myopathy Data

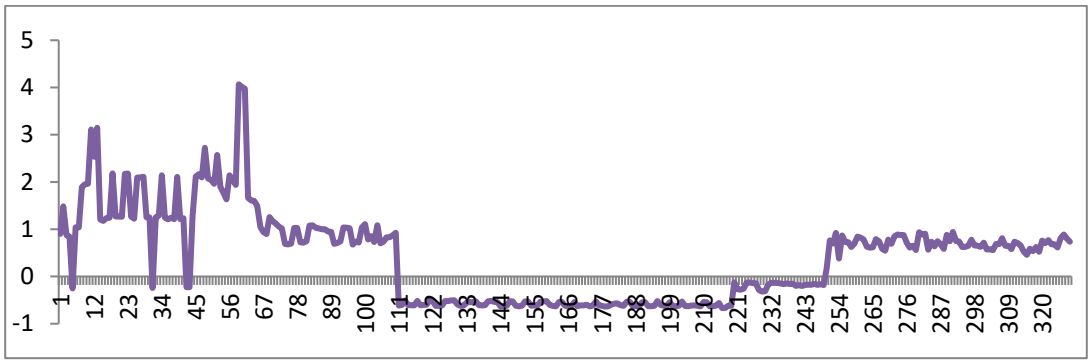

Fig. 15(c) DASDV value of Normal Data

Figures 15(a), 15(b), and 15(c) show the range of DASDV values in ALS, myopathy, and normal data. Figures 16(a), 16(b), and 16(c) show the average amplitude change (AAC) value extracted in the time domain for ALS, myopathy, and normal data.

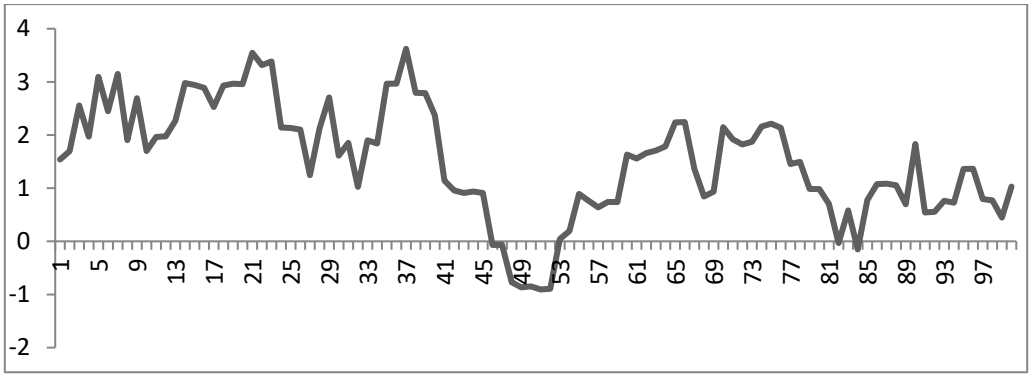

Fig. 16(a) AAC value of ALS Data

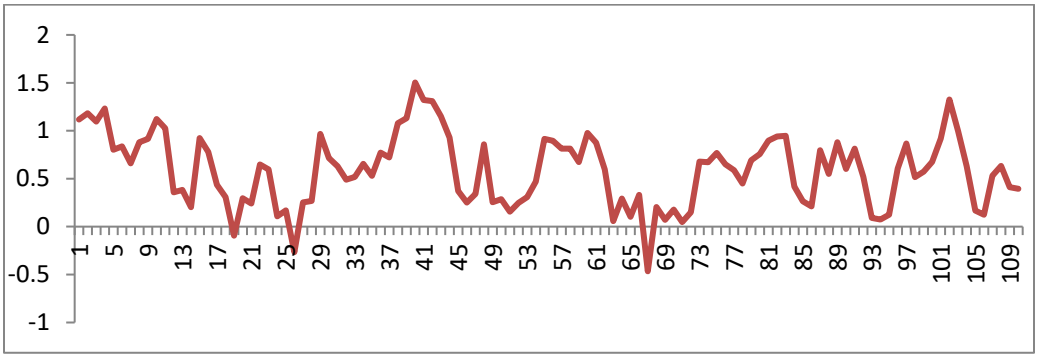

Fig. 16(b) AAC value of Myopathy Data

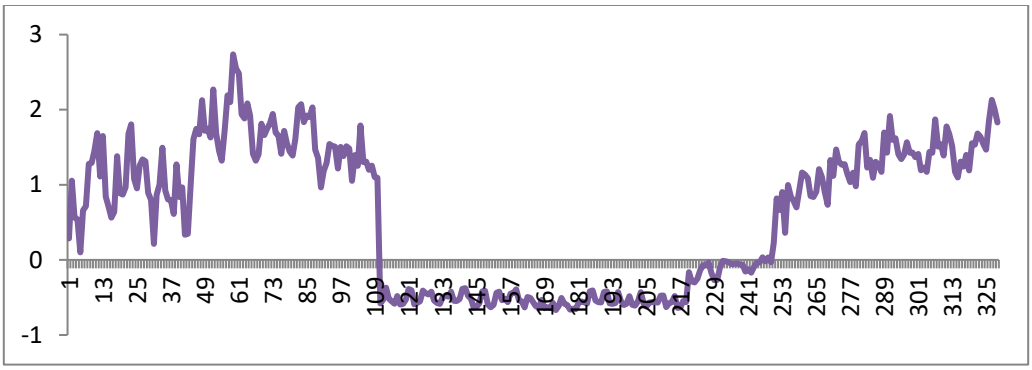

Fig. 16(c) AAC value of Normal Data

Figures 16(a), 16(b), and 16(c) show the range of AAC values in ALS, myopathy, and normal data. Figures 17(a), 17(b), and 17(c) show the variance absolute value (VAV) extracted in the time domain for ALS, myopathy, and normal data.

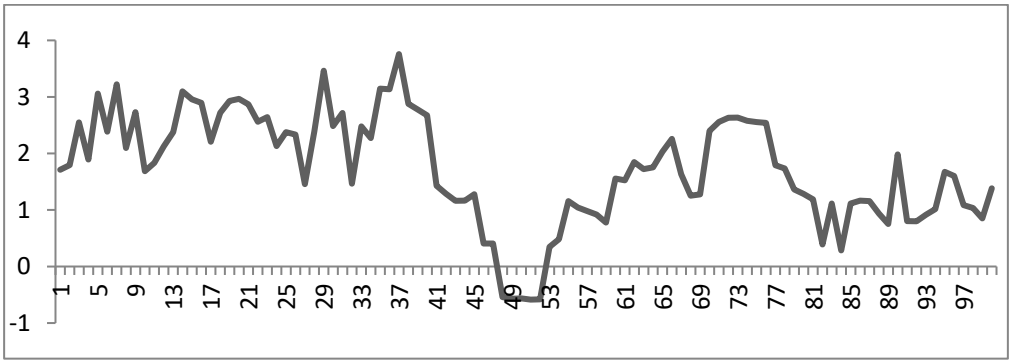

Fig. 17(a) VAV value of ALS Data

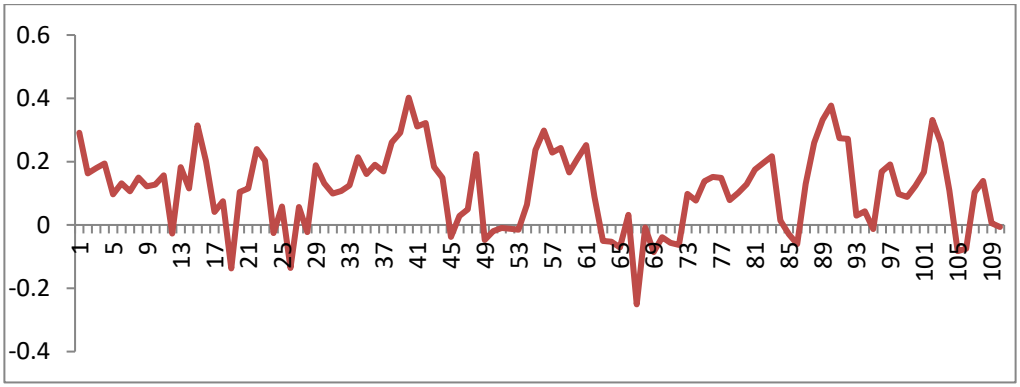

Fig. 17(b) VAV value of Myopathy Data

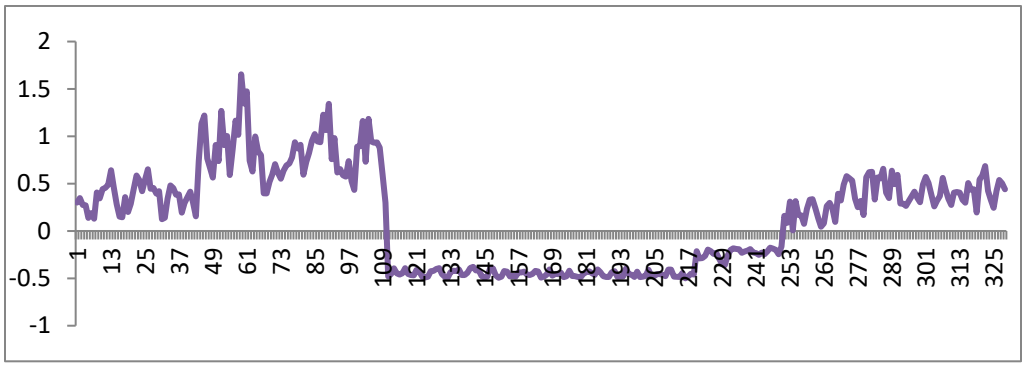

Fig. 17(c) VAV value of Normal Data

Figures 17(a), 17(b), and 17(c) show that ALS data have a higher VAV peak than normal data. Myopathy data have a lower VAV peak than normal data. Figures 18(a), 18(b), and 18(c) show the kurtosis values extracted in the time domain for ALS, myopathy, and normal data.

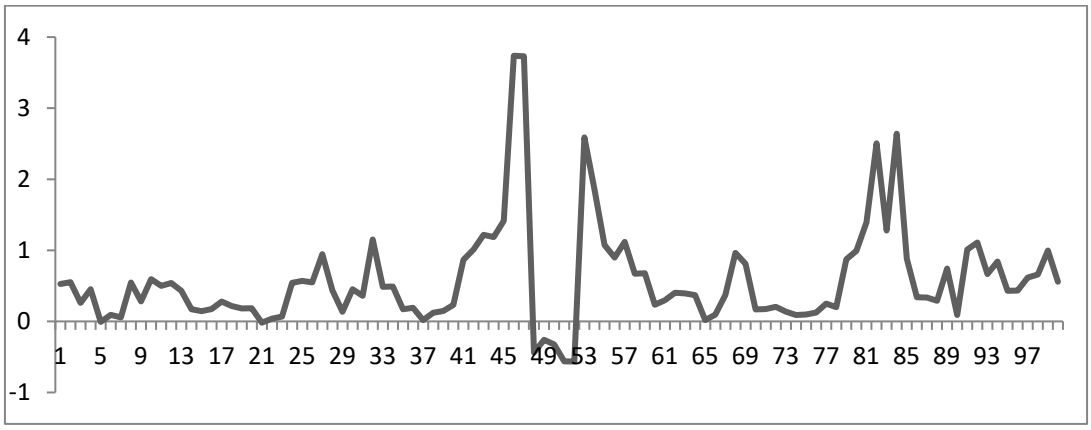

Fig. 18(a) Kurtosis value of ALS Data

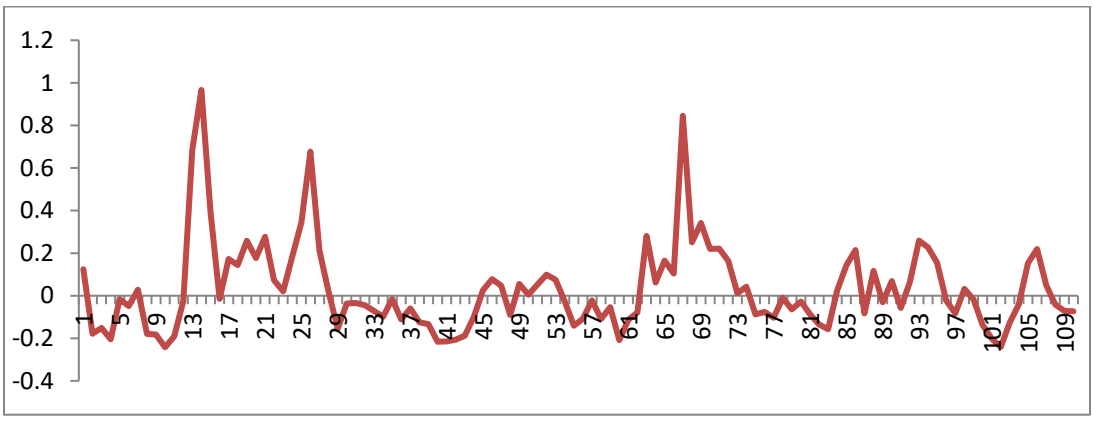

Fig. 18(b) Kurtosis value of Myopathy Data

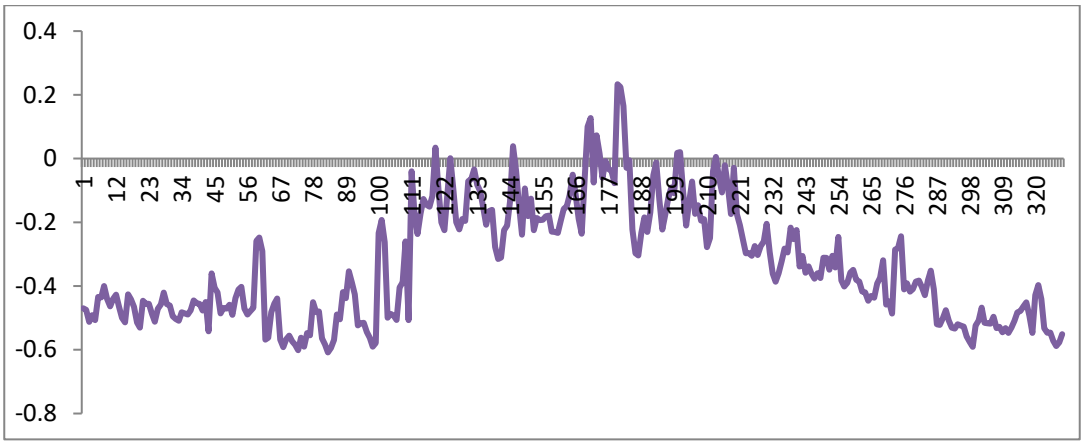

Fig. 18(c) Kurtosis value of Normal Data

Figures 18(a), 18(b), and 18(c) show that ALS and myopathy data have higher kurtosis peak values than normal data. The decrease in muscle contractions yields an increase in kurtosis values. ALS and myopathy subjects, possessing muscle weakness, show decreased muscle contractions. Figures 19(a), 19(b), and 19(c) show the skewness values extracted in the time domain for ALS, myopathy, and normal data.

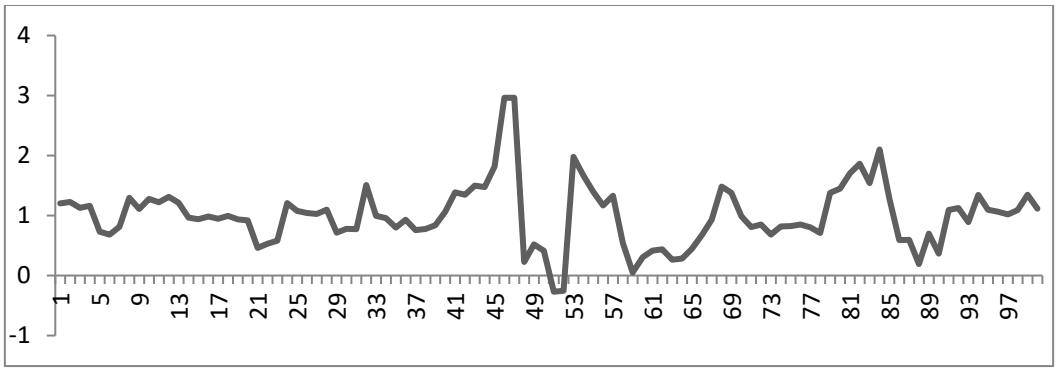

Fig. 19(a) Skewness value of ALS Data

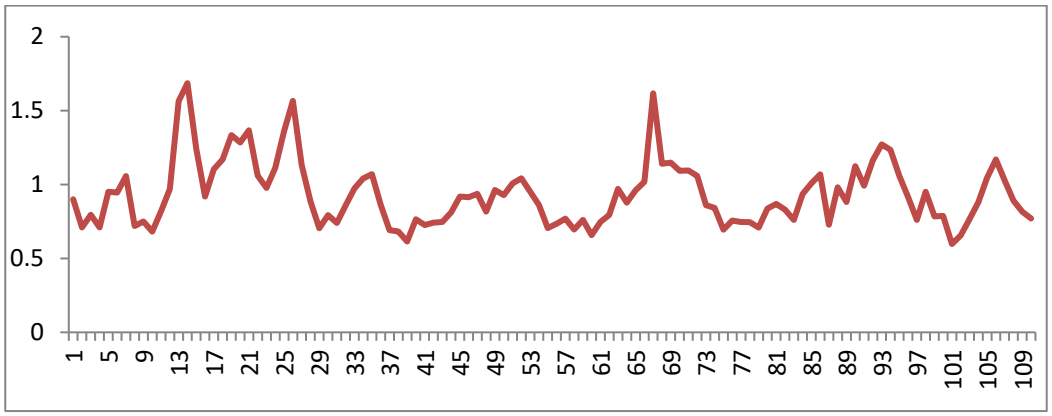

Fig. 19(b) Skewness value of Myopathy Data

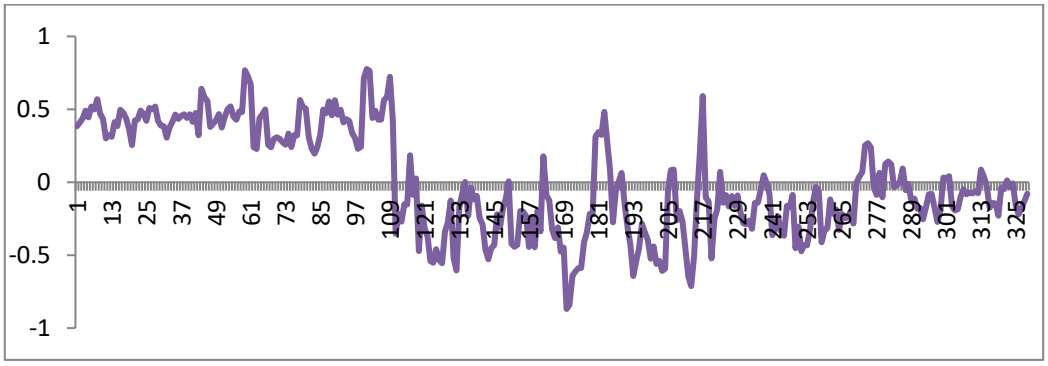

Fig. 19(c) Skewness value of Normal Data

Figures 19(a), 19(b), and 19(c) show that ALS and myopathy data have higher skewness peak values than normal data. The range of skewness values is greater in ALS and myopathy data compared to normal data.

V. CONCLUSION

The major characteristics of biomedical signals are continuous in nature. The graphical representation of these signals concerning some function of the time parameter is required to analyze these time-series signals. The general plot typically has amplitude along the time axis. Almost all signals in their natural form are in the time domain; hence, the signals are represented with a time-amplitude plot. The analysis of the EMG signal in the time domain provides information regarding variations in amplitude with respect to time. Twelve statistical features are considered for the analysis of paralysis diseases. From the statistical F-test analysis, all 12 features are found to be significant in differentiating normal data from ALS and myopathy data, thus distinguishing paralysis data with $p < 0.05$.

REFERENCES

[1] S. Chopra, A. K. Tripathy, A. Alphonso, M. Carvalho, and C. Sancia, "Brain computer interface and electro stimulation of muscles to assist paralyzed patients in limited movement of hands," *2017 International Conference on Nascent Technologies in Engineering (ICNTE)*, 2017, pp. 1-6, doi: 10.1109/ICNTE.2017.7947950.

[2] J. Chawla and A. S. Sahni, "Peripheral Nervous System Anatomy," *Medscape*, 2016. [Online]. Available: https://emedicine.medscape.com/article/1948687-overview

[3] A. H. Ropper and R. H. Brown, *Adams and Victor's Principles of Neurology*, 8th ed., Chapter 3, McGraw-Hill Medical Publishing Division.

[4] B. S. C. Beh, B. M. Greenberg, T. Frohman, and E. M. Frohman, "Transverse myelitis," *Neurol. Clin.*, vol. 31, no. 1, pp. 79-138, Feb. 2013, doi: 10.1016/j.ncl.2012.09.008. [PubMed] PMID: 23186897; [PMC] PMCID: PMC7132741.

[5] L. Wijesekera and N. Leigh, "Amyotrophic lateral sclerosis," *Orphanet J. Rare Dis.*, vol. 4, p. 3, 2009, doi: 10.1186/1750-1172-4-3.

[6] J. Eske, "Paralysis," *Medical News Today*, 2020. [Online]. Available: https://www.medicalnewstoday.com/articles/paralysis

[7] H. Stubblefield, "Paralysis," *Healthline*, 2018. [Online]. Available: https://www.healthline.com/health/paralysis#diagnosis

[8] P. Konrad, *The ABC of EMG: A Practical Introduction to Kinesiological Electromyography*, ver. 1.0, Apr. 2005. [Online]. Available: https://hermanwallace.com/download/The_ABC_of_EMG_by_Peter_Konrad.pdf

[9] R. Merletti and D. Farina, "Analysis of intramuscular electromyogram signals," *Phil. Trans. R. Soc. A*, vol. 367, pp. 357-368, 2009, doi: 10.1098/rsta.2008.0235.

[10] D. H. Sutherland, "The evolution of clinical gait analysis part I: Kinesiological EMG," *Gait Posture*, vol. 14, pp. 61-70, 2001. [Online]. Available: https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.501.2507&rep=rep1&type=pdf

[11] V. Medved and M. Cifrek, "Kinesiological electromyography," in *Biomechanics in Applications*, V. Klika, Ed. Rijeka, Croatia: InTech, 2009. [Online]. Available: https://books.google.co.in/books?id=ai-aDwAAQBAJ&lpg=PA349&ots=TIbKn6GzVe&dq=Clinical%20Or%20Diagnostic%20EMG%20and%20Kinesiological%20EMG&lr&pg=PA349#v=onepage&q&f=false

[12] D. I. Rubin, "Needle electromyography: Basic concepts," in *Handbook of Clinical Neurology*, vol. 160, P. H. Levin and P. Chauvel, Eds., Elsevier, 2019, pp. 243-256, doi: 10.1016/B978-0-444-64032-1.00016-3. [Online]. Available: https://www.sciencedirect.com/science/article/pii/B9780444640321000163

[13] *Slideplayer*, "Image Source," [Online]. Available: https://slideplayer.com/slide/12264889/

[14] J. E. Kim et al., "Basic concepts of needle electromyography," *Ann. Clin. Neurophysiol.*, vol. 21, no. 1, pp. 7-12, Jan. 2019, doi: 10.14253/acn.2019.21.1.7.

[15] *Mayo Clinic*, "EMG Test," [Online]. Available: https://www.mayoclinic.org/tests-procedures/emg/about/pac-20393913?p=1.

[16] D. R. Moynes et al., "Electromyography and motion analysis of the upper extremity in sports," *Phys. Ther.*, vol. 66, no. 12, pp. 1212-1219, Dec. 1986. [Online]. Available: https://citeseerx.ist.psu.edu/viewdoc/download?Doi=10.1.1.909.2233&rep=rep1&type=pdf

[17] *Brigham and Women's Hospital*, "EMG Test," [Online]. Available: https://www.brighamandwomens.org/medical-resources/emg-test

[18] *Medical News Today*, "Who gets paralysis?" [Online]. Available: https://www.medicalnewstoday.com/articles/281472#who-gets-it

[19] *iStockphoto*, "Amyotrophic lateral sclerosis (ALS) disease signs and symptoms," [Online]. Available: https://www.istockphoto.com/vector/amyotrophic-lateral-sclerosis-als-disease-signs-and-symptoms-gm1129371731-298309042

[20] *Cleveland Clinic*, "Myopathy," [Online]. Available: https://my.clevelandclinic.org/health/diseases/17256-myopathy

[21] D. C. Preston and B. E. Shapiro, *Electromyography and Neuromuscular Disorders: Clinical-Electrophysiologic Correlations*, 3rd ed., Elsevier Inc., 2013.

[22] C. S. MdRasedul I and M. H. R. Mohammad, "A comprehensive study on EMG feature extraction and classifiers," *Op. Acc. J. Bio Eng & Bio Sci*, vol. 1, no. 1, pp. 17-26, 2018. [Online]. Available: https://lupinepublishers.com/biomedical-sciences-journal/fulltext/a-comprehensive-study-on-eMG-feature-extraction-and-classifiers.ID.000104.php

[23] A. Krishna V and P. Thomas, "Classification of EMG signals using spectral features extracted from dominant motor unit action potential," *International Journal of Engineering and Advanced Technology*, vol. 4, no. 5, pp. 196–200, 2015.

[24] N. C. Joyce and G. T. Carter, "Electrodiagnosis in persons with amyotrophic lateral sclerosis," *PM R*, vol. 5, no. 5 Suppl., pp. S89–S95, May 2013, doi: 10.1016/j.pmrj.2013.03.020.

[25] S. Paganoni and A. Amato, "Electrodiagnostic evaluation of myopathies," *Physical Medicine and Rehabilitation Clinics of North America*, vol. 24, no. 1, pp. 193–207, Feb. 2013, doi: 10.1016/j.pmr.2012.08.017.

[26] M. Nikolic, *Database of Clinical Signals*, Rigshospitalet, Copenhagen, DK, dataset N2001. [Online]. Available: http://www.emglab.net.

[27] S. V. Patel and S. S. L, "Prediction and analysis of muscular paralysis disease using Daubechies wavelet approach," *Asian Journal of Electrical Sciences*, vol. 10, no. 2, pp. 6-15, Jul.-Dec. 2021, doi: 10.51983/ajes-2021.10.2.3036.

[28] S. V. Patel and S. S. L, "Performance analysis of paralysis disease using machine learning," *Asian Journal of Computer Science and Technology*, vol. 11, no. 1, pp. 21-34, 2022, doi: 10.51983/ajcst-2022.11.1.3242.

[29] S. V. Patel and S. S. L, "Analysis of muscular paralysis using EMG signal with wavelet decomposition approach," *Asian Journal of Computer Science and Technology*, vol. 11, no. 1, pp. 5-16, 2022, doi: 10.51983/ajcst-2022.11.1.3241.