Chapter 3
Muscle Fatigue Analysis of Radiculopathy Patients Under Cervical Traction Treatment Using EMG Data

3.1 Introduction

Neck pain is generally related to paraspinal neck muscle and cervical radiculopathy. Cervical radiculopathy (CR) is a disease that affects the cervical spinal nerve root. [Ellenberg, 1994]. This disease may cause pain that radiates into the shoulder, as well as muscle weakness and numbness that travels down toward the arm and into the hand [Robinson J. et al., 2014; Vernon H. et al., 2007; Bono et al., 2011].

The symptoms of radiculopathy depend on which nerves are affected. The main symptom of CR is pain that spreads into the arm, neck, chest, or shoulders.

(a) (b)

Figure 3.1 (a) Neck Pain **(b)** Cervical Radiculopathy

Medical specialists suggested that cervical traction therapy is the prominent solution for the treatment of neck pain. This therapy is also known as non-surgical spinal decompression therapy. It is described as the clinical method that applies force along the inferior-superior axis of the spine to extend the cervical spine vertebrae [Wong et al., 2017]. The traction machines include the manual adjustment of traction weight and timing of traction pull phases [Ojoawo et al., 2013].

Cervical traction can be applied to the neck according to type:-

- **Manual Cervical Traction**

Manual cervical traction is a part of conservative management and is effective in managing neck pain. The head and neck are held in the hands of the practitioner, and then the traction of a pulling force is applied. [Bukhari et al., 2016].

- **Mechanical Cervical Traction**

Mechanical cervical traction involves using a machine to provide the traction force to the neck. A harness on the machine is attached to the head and neck.

- **Gravitational Traction**

The distraction force is provided by gravity.

Many previous studies have been conducted to analyze neck muscle fatigue, which is described below.

Parker, (1978) reported that no significant change in muscle activity was observed during or after traction therapy. DeLacerda, (1980) showed that the electrical activity of the upper trapezius muscle increases as the angle of application of cervical traction increases. Jette et al. (1985) showed that no significant difference in muscle activity was observed during the six-time periods measured.

Martha (1989) presented a more accurate means to document the amount of power applied to an individual's cervical spine when manual cervical traction techniques are used. Moeti et al. (2001) described the clinical results of 15 patients with CR treated with mechanical cervical traction. This paper observed a reduction in the level of disability. Joghataei et al. (2004) observed that cervical traction, combined with physical therapy and exercise, produced an immediate improvement in the handgrip function in patients with CR.

Borman et al. (2008) observed no significant effect of traction over standard physical therapy. Ragonese (2009) indicated that when treating patients with CR, an approach that combines manual therapy and strengthening exercise is superior to a treatment that uses either intervention alone. Jellad et al. (2009) described their experiment in which group A was treated by conventional rehabilitation with manual traction, group B with conventional rehabilitation with mechanical traction, and group C with conventional rehabilitation alone. After treatment, cervical pain, radicular pain, and disability were significantly reduced in groups A and B compared with group C. The manual and mechanical cervical traction appeared to be a major factor in the rehabilitation of CR.

Dawood et al. (2013) observed that kinesio-taping and traction positions were similarly helpful in improving cervical curvature, pain strength, and function neck disability in patients with mechanical neck dysfunction more than the exercise program. Sharma and Patel (2014) concluded that TENS was more efficient in the management of CR along with isometric neck exercise in reducing both neck and arm pain. Bid et al. (2014) observed that conventional therapy is effective. Cervical traction provided better results in mechanical neck pain.

Hoseinpour et al. (2015) reported that physiotherapy with traction was more useful than needle therapy and strengthening exercise in patients with cervical disease. After some weeks, traction therapies were more effective in decreasing pain. Bukhari et al. (2016) stated that CR treated with mechanical traction, segmental mobilization, and exercise therapy will manage pain and disability more effectively than that treated with manual traction, segmental mobilization, and exercise therapy.

Khan et al. (2016) supported protocols that involve multiple interventions, stating that cervical traction is more useful when it is combined with a conventional active range of motion exercises and modalities in painful CR.

The above mentioned studies all discussed studies on neck pain under cervical traction treatment. However, for the effective planning of treatment schedule and protocol, a there is a need to do the quantitative analysis of paraspinal muscle strain during cervical traction is necessary.

The objective of this study was to quantify the efficacy of cervical traction based on fatigue analysis using EMG data. The EMG signal was calculated using time domain and frequency domain parameters such as mean absolute value (MAV), root mean square (RMS), standard deviation (SD), mean frequency (MNF), and median frequency (MDF).

3.2 Methodology

EMG data were recorded from 12 neck pain patients during cervical traction treatment using a wireless EMG sensor. Two groups of patients, group A consisting of five neck pain patients with radiculopathy and group B consisting of seven neck pain patients without radiculopathy. EMG data recording was obtained from the upper trapezius muscle using a wireless EMG sensor.

3.2.1 Anatomy of the Cervical Spine

The cervical spine begins at the base of the skull. The seven vertebrae of the vertebral column in the neck region are known as the cervical vertebrae and are numbered C1, C2, C3, C4, C5, C6 and C7.

3.2.1.1 Cervical Vertebrae

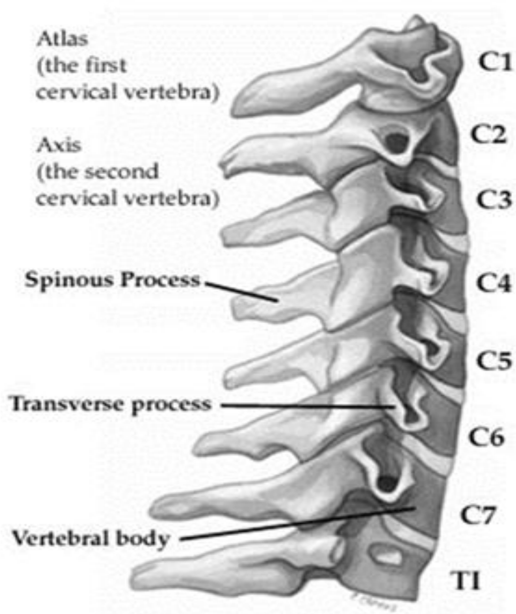

Figure 3.2 Cervical Vertebrae

The neck region of the spine is known as the cervical spine. The region consists of seven vertebrae, which are abbreviated C1 through C7 (top to bottom). The cervical spine can be divided into the upper cervical spine and the lower cervical spine. The vertebrae are named for their position in the neck, beginning at the top with C1, C2, C3, down to C7. Between the neck and bones are disc, which functions as shock absorbers, protecting each bone. As shown in Figure 2, the upper cervical spine includes the occiput, atlas (C1), and axis (C2).

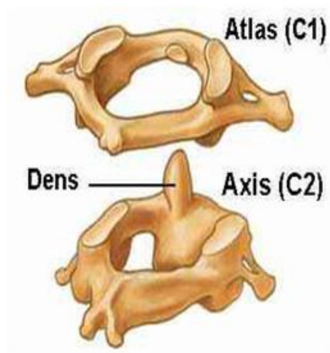

Figure 3.3 Cervical vertebrae (C1-C2)

The first two vertebrae are different because they perform functions not shared by other cervical vertebrae. The atlas (C1), which is ring-shaped and supports the skull and the axis (C2) are unique, bearing little resemblance to the rest of the vertebrae of the spinal column. According to [Magee 2008], the lower cervical spine consists of the third to the seventh cervical vertebrae (C3- C7). The cervical vertebrae (C3 to C7) are shaped like boxes with small spinous processes that extend from the back of the vertebrae. C3 - C4 are, two nerve roots that help regulate the diaphragm. The C4 nerve root can radiate pain to the lower neck and shoulder. Shoulder pain and weakness can be experienced in the upper arm.

C5 is relatively smaller and more flexible than other true or movable vertebrae. The C6 vertebra plays an important role in supporting and protecting the structure of the head and neck. C7 has a large spinous process that protrudes posteriority towards the skin at the back of the neck.

The wireless EMG sensor was placed on the neck muscle (C5 - C6) position to record the EMG data. The subjects were treated with 15 minutes of cervical traction at a force of 7 kg tension. The traction was applied to the subject in a sitting position, with withhold time (10 sec) and rest time (2sec) intervals for six working days in (BHU) hospital from January 2017 to April 2017. Prior approval from the ethical committee of IMS BHU was obtained.

Figure 3.4 Wireless EMG system with the sensor

Figure 3.5 Clinical photograph of cervical traction

Figure 3.6 Clinical photograph during cervical traction application of the sensor

The EMG signal was analyzed to gain information about various features of muscle activity. It is a biosignal that records the electrical activity of the muscle. It contains substantial information about the muscular system and neuromuscular disorder [Bajaj et al., 2015; Kaur et al., 2016]. The EMG signal is described by its amplitude, frequency, and phase as a function of time [Goen et al., 2013].

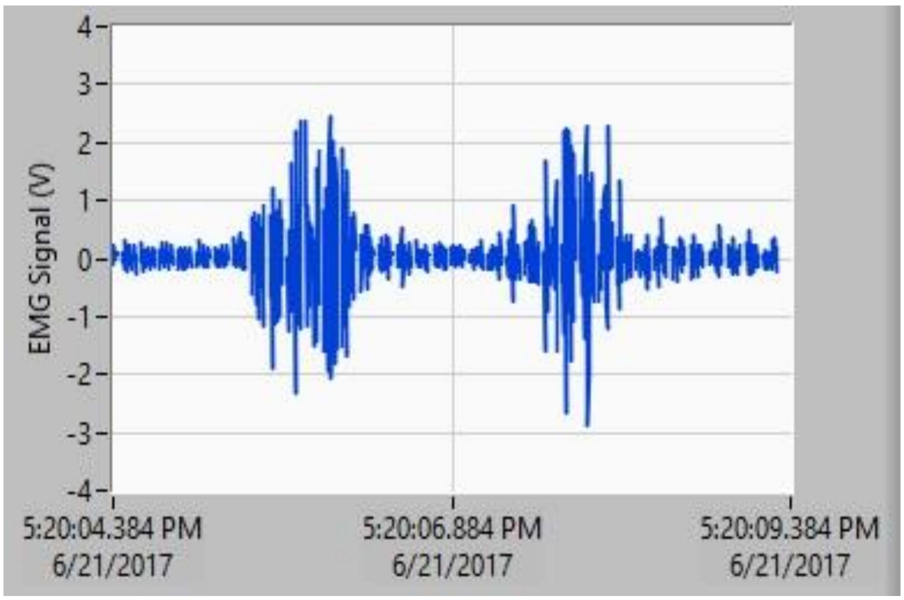

Figure 3.7 Raw EMG signal

In EMG processing, the acquired EMG signal was band-pass filtered between 0.5Hz and 500 Hz. With a 50 Hz Notch filter to remove power line noise). Subsequently, various time and frequency features such as MAV, RMS, SD, MNF, and MDF were used to extract the main information from the EMG data. MF and MDF are two useful features to detect muscle fatigue.

To determine the changes that occurred in the muscle activity of both groups during traction treatment, the EMG data were recorded for 15 minutes of traction and were divided into intervals of pre 5 minutes and post 5 minutes. From the recorded EMG data, various parameters in the time domain and frequency domain features were extracted for the assessment of muscle fatigue.

3.2.2 Time Domain Parameters

Time domain features have been generally used in both medical and engineering fields. These features are calculated based on the raw EMG signal [Tkach et al., 2010] and have been used as follows.

a. Mean Absolute Value

MAV is defined as the average distance between each data value and the mean. It can be given by

$$\text{MAV} = \frac{1}{N}\sum_{n=1}^{N} |x_n| \qquad \text{(i)}$$

where N denotes the length of the signal, and x_n represents the EMG signal in a segment.

b. Root Mean Square

RMS is defined as the square root of the mean value of the squared function of the instantaneous value. It can be calculated by

$$X_R = \sqrt{\frac{1}{N}\sum_{n=1}^{N} |x_n|^2} \qquad \text{(ii)}$$

Where N represents the length of the signal, and x_n represents the EMG signal in a segment [Ahsan et al., 2011].

(c) Standard Deviation

SD can be used to find the threshold level of muscle contraction activity. It can be defined as

$$\mathrm{SD} = \sqrt{\frac{1}{N-1}\sum_{n=1}^{N}(x_n - \bar{x})^2} \quad \text{(iii)}$$

where N represents the length of the signal, x_n corresponds to the values of the segment and $\bar{x}$ is the mean value of the EMG signal. [Ahsan et al., 2011; Phinyomark et al., 2012].

3.2.3 Frequency Domain Parameters

Frequency domain features are generally used to study muscle fatigue. These features include such as the mean frequency and median frequency; the median frequency requires more computed time than time domain (TD) features [Thongpanja et al., 2013].

a. Mean Frequency

MF calculated as the sum of the product of the EMG power spectrum and the frequency divided by the total sum of the power spectrum. Mean power frequency is also called mean frequency. It can be defined as

$$\mathrm{MNF} = \frac{\sum_{j=1}^{M} f_j p_j}{\sum_{j=1}^{M} p_j} \quad \text{(iv)}$$

Where f_j is the frequency value of the EMG power spectrum at the frequency bin j, P_j is the EMG power spectrum at the frequency bin j, and M is the length of frequency bin. [Thongpanja S. et al., 2013].

b. Median Frequency

MDF is a frequency value at which the EMG power spectrum is divided into two regions with equal integrated power. It can be expressed as

$$MDF = \sum_{j=1}^{MDF} P_j = \sum_{j=MDF}^{M} P_j = \frac{1}{2}\sum_{j=1}^{M} P_j \qquad \text{(v)}$$

where P_j is the EMG power spectrum at a frequency bin j and M is the length of frequency bin [Thongpanja et al., 2013; Oskoei et al., 2008].

3.3 Results

Twelve neck pain and radiculopathy patients who participated in the study were clinically assessed. The recorded EMG data of these patients during cervical traction treatment were analyzed. During clinical testing, each patient was treated in the sitting position 15 minutes per day for one week. The data analysis of pre 5 minutes and post 5 minutes of the first day (Fd) and last day (Ld) of the week.

Table 3.1 shows that the acquired EMG data were used further to extract various features of neck muscles in the time domain features (MAV, RMS, and SD) and in the frequency domain (MNF and MDF) to evaluate muscle fatigue.

The changes in muscle activity during the one week of traction are shown in Tables 3.1 and 3.2. This result shows some significant differences in the calculated parameters. The extracted features were found to increase in the frequency domain parameter and decrease in the time domain value.

Table 3.1 Time and frequency domain features during traction in the sitting position

Subjects	Time Domain Features						Frequency Domain Features			
	MAV		RMS		SD		MNF		MDF	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1. Fd	2.182	2.170	2.285	2.195	5.190	3.296	0.055	0.066	2.533	7.356
Ld	1.676	1.662	1.877	1.783	9.043	6.964	0.024	0.036	8.484	9.363
2.Fd	2.201	2.197	2.296	2.273	6.584	5.875	0.016	0.019	7.734	7.805
Ld	1.582	1.425	1.985	1.476	3.839	1.409	0.017	0.055	0.013	0.712
3.Fd	8.842	3.578	6.158	4.943	4.710	1.145	0.186	0.204	0.094	0.099
Ld	9.372	2.933	3.686	1.224	3.218	1.215	0.236	0.239	0.093	0.151
4.Fd	1.689	1.448	2.987	1.612	7.393	2.602	0.064	0.069	9.04	9.104
Ld	1.693	1.688	1.917	1.885	9.670	8.588	0.031	0.032	9.072	9.642
5.Fd	6.709	6.414	8.445	8.114	8.314	7.933	0.136	0.137	0.087	0.091
Ld	2.196	1.598	7.847	2.074	7.692	1.492	0.120	0.670	0.014	0.069

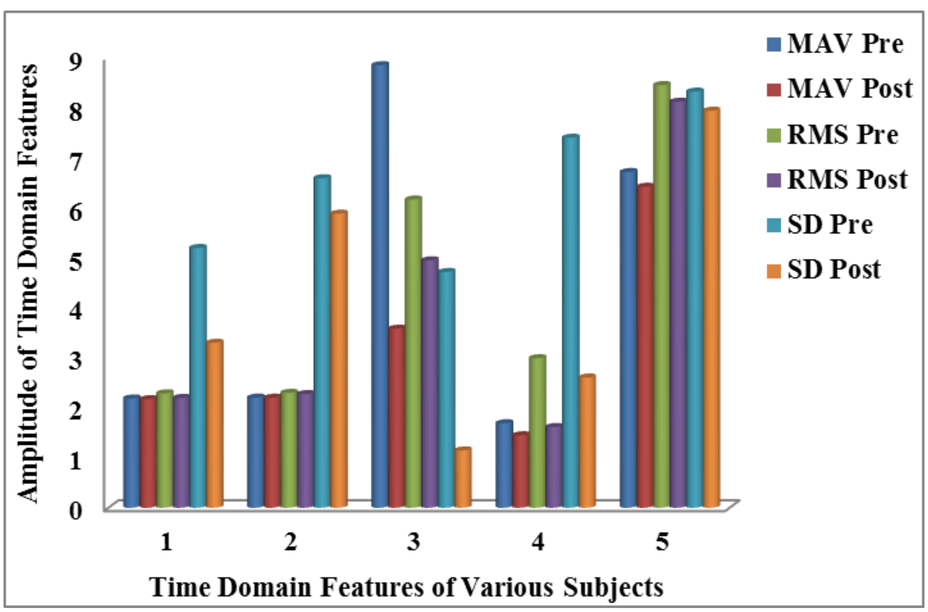

Figure 3.8 (a) Time domain features during traction in the sitting position for the first day

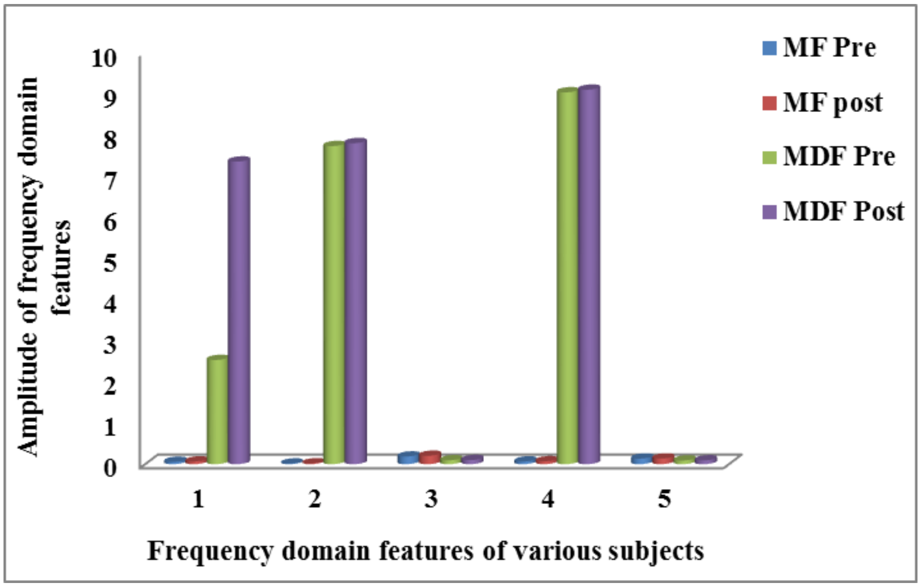

Figure 3.8 (b) Frequency domain features during traction in the sitting position for the first day

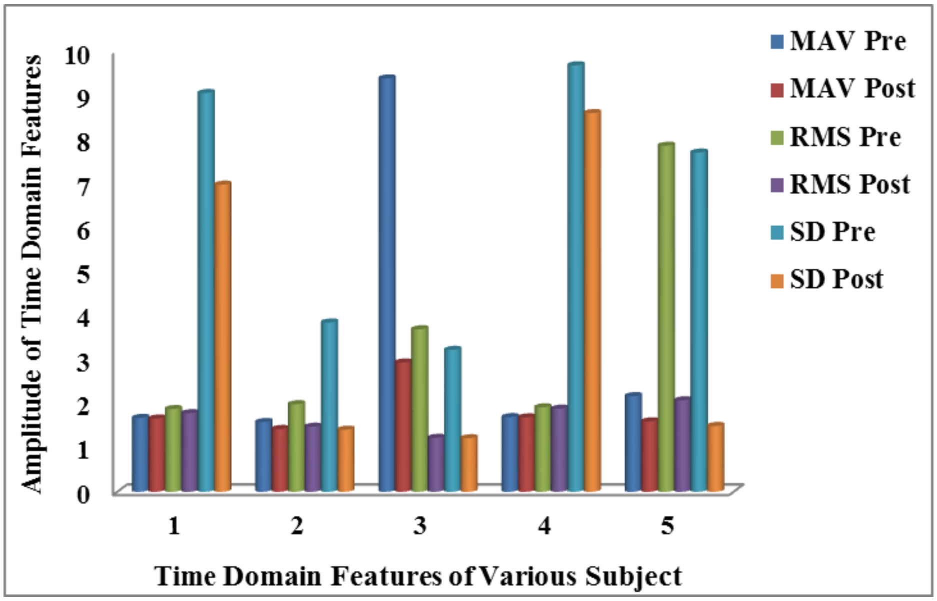

Figure 3.8 (c) Time domain features during traction in the sitting position for the last day

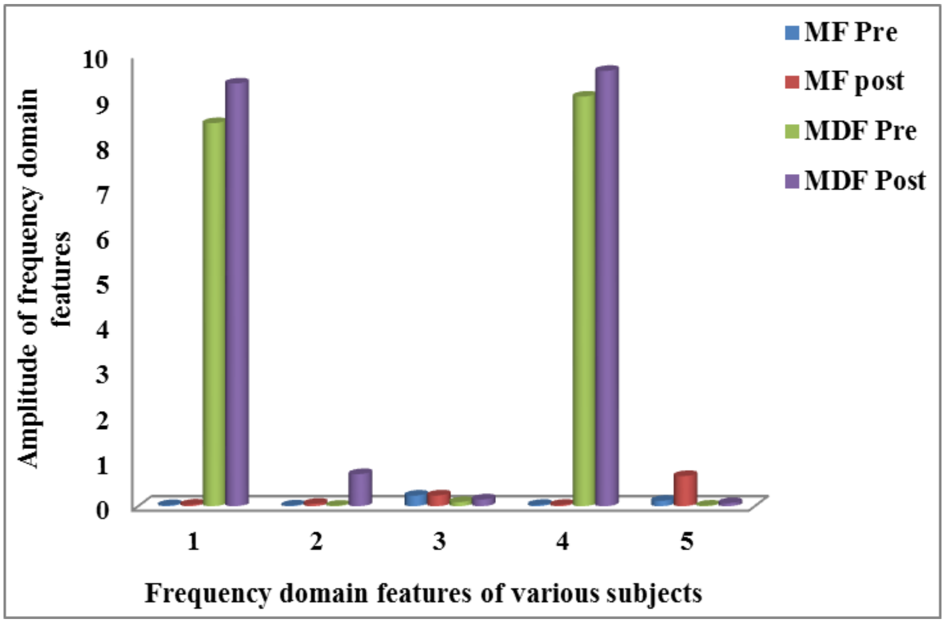

Figure 3.8 (d) Frequency domain features during traction in the sitting position for the last day

In this group, EMG data were recorded for 15 minutes during traction using a wireless EMG sensor. This group consisted of patients with neck and arm pain complaint in the therapy unit. Table 3.1 shows the data measured in the first 5 minutes and the last 5 minutes during traction in the sitting position for 15 minutes on the first day and last day of the week. The recorded EMG data were used further to extract various features of neck muscles. The time domain features were gradually decreased, and the frequency domain features were increased after traction.

Table 3.2 Time and frequency domain feature during traction in the sitting (without radiculopathy) position.

Subjects	Time Domain Features						Frequency Domain Features			
	MAV		RMS		SD		MNF		MDF	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1. Fd	2.254	2.202	2.346	2.262	7.163	5.652	0.008	0.013	7.669	7.930
Ld	1.396	1.357	1.924	1.753	1.389	1.371	0.066	0.072	0.005	1.228
2.Fd	1.700	1.658	2.395	2.111	1.925	1.568	0.055	0.062	0.030	0.042
Ld	2.217	2.206	2.266	2.251	4.706	4.520	0.011	0.013	7.492	7.514
3.Fd	1.420	1.410	1.500	1.478	4.884	4.119	0.017	0.023	7.795	8.042
Ld	1.549	1.433	1.642	1.575	6.505	5.422	0.021	0.031	8.070	8.669
4.Fd	1.421	1.398	1.553	1.486	6.704	5.051	0.025	0.034	8.129	8.837
Ld	1.449	1.442	1.490	1.478	3.446	3.259	0.010	0.012	7.557	7.597
5.Fd	1.990	1.445	2.654	1.572	6.852	2.246	0.040	0.086	8.054	8.876
Ld	1.690	1.411	2.104	1.532	3.045	1.564	0.047	0.083	8.031	8.516
6. Fd	3.760	2.829	4.841	3.506	4.311	2.720	0.069	0.089	0.044	0.059
Ld	2.317	2.277	2.458	2.380	8.910	7.185	0.021	0.028	7.911	8.278
7.Fd	1.721	1.718	1.849	1.792	6.896	5.107	0.015	0.027	2.608	2.784
Ld	1.590	1.320	1.543	1.483	3.343	2.405	0.037	0.046	2.183	2.186

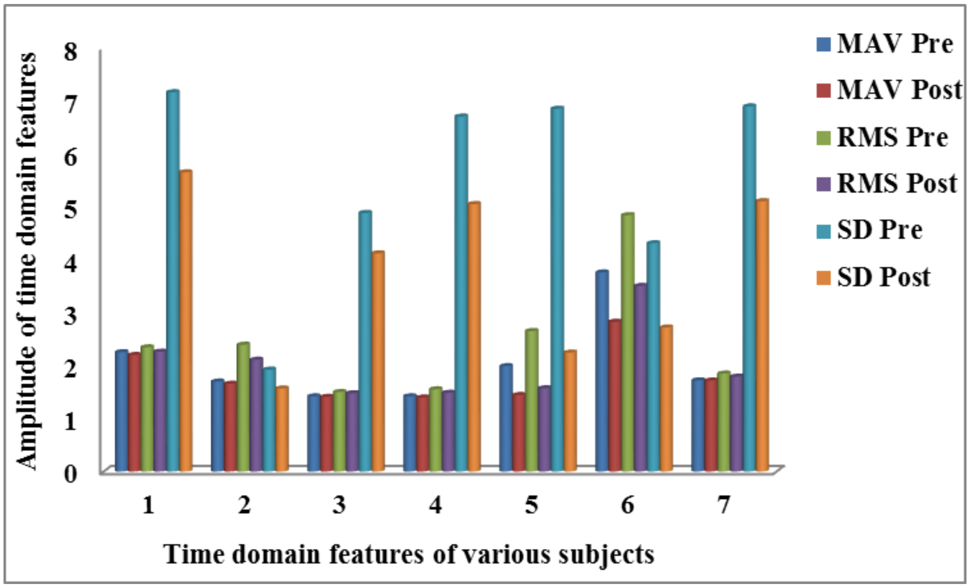

Figure 3.9 (a) Time domain features during traction in the sitting position for the first day

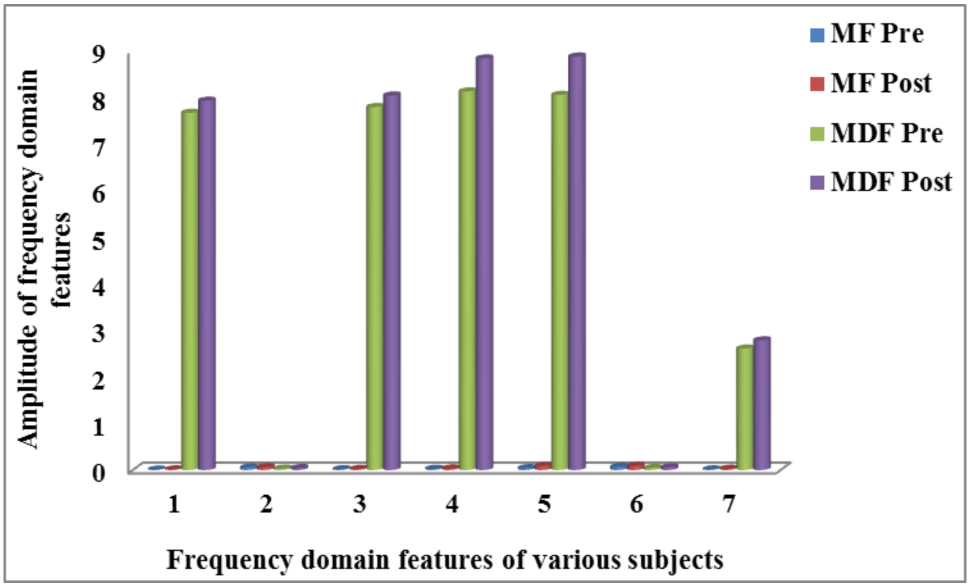

Figure 3.9 (b) Frequency domain features during traction in the sitting position for the first day

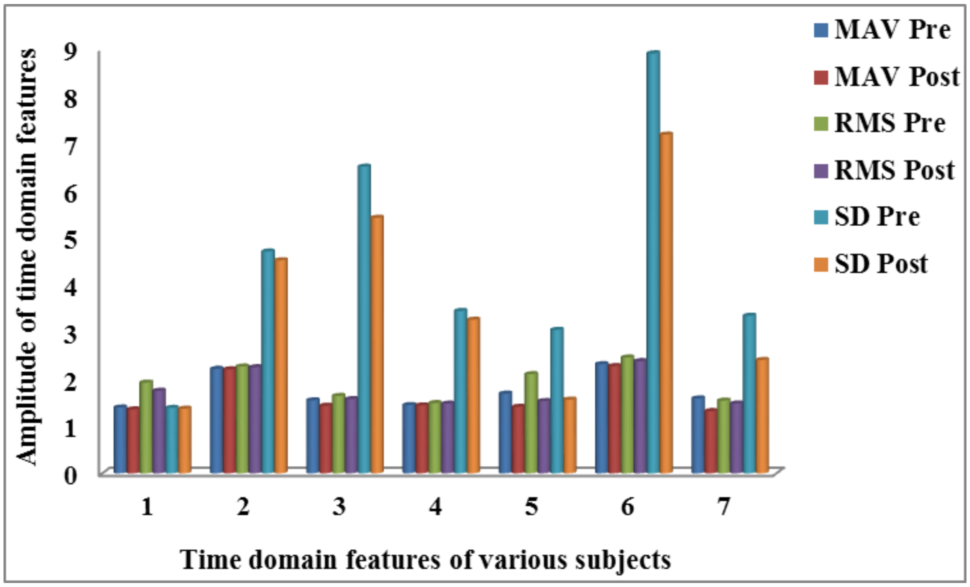

Figure 3.9 (c) Time domain features during traction in the sitting position for the last day

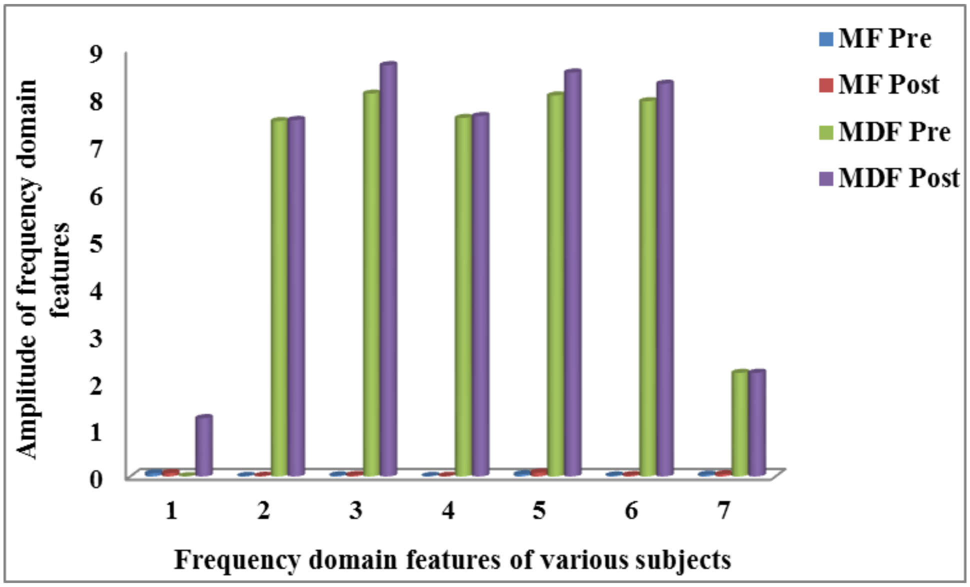

Figure 3.9 (d) Frequency domain features during traction in the sitting position for the last day

This group complained of neck pain in the therapy unit. The EMG data that were collected underwent traction treatment using a wireless EMG sensor in the sitting position. Based on the recorded EMG data and their extracted features, there is a decrease in the time domain parameters and an increase in the frequency domain parameters.

3.4 Discussion

In this study, various features were calculated using the recorded EMG data via the wireless EMG sensor for 15 minutes during the first and last day of the week. The EMG signal can be detected the parameters used are the amplitude and frequency of the signal. Figure 3.7 (a, c) shows the decrease in the time domain features from the first to the last day of the traction treatment, whereas Figure 3.7 (b, d) shows that the frequency domain features have increased from the first to the last day of the traction treatment. This study showed the decrease in the time domain value and the increase in the frequency domain value.

Few related studies with EMG during intermittent mechanical traction showed different outcomes. Our finding was consistent with the work of those who concluded that traction relieves muscle spasm and reduces the electrical activity in the muscles and produces relaxation (Voltonen et al., 1996). Krause et al. (2000) found that traction has been shown to separate the vertebrae, and it appears that large force is not required.

Murphy (1991) observed no significant difference at rest and within 10 minutes of supine traction. Atteya (2004) observed the different phases of cervical traction showed a significant decrease in EMG activity during the pull period of traction and after traction. Elnaggar et al. (2009) indicated that the intermittent and continuous cervical traction significantly affected neck and arm pain reduction and significantly improved nerve functions. Ali et al. (2015) reported that cervical mobilization is more effective than cervical traction in terms of reducing pain and disability in subjects with nonspecific neck pain.

The present study was conducted to evaluate the effect of cervical traction for neck pain and cervical radiculopathy pain. The activity of the neck muscle was recorded during the one-week course of traction in the patient’s neck pain with radiculopathy and neck pain without radiculopathy. The time and frequency domain parameters were extracted for neck muscle fatigue analysis. A decrease in EMG parameters in the time domain and an increase in the frequency domain parameters were identified during the pull phase of the first five minutes and the last five minutes of the traction. The effect of muscle activity for both groups was found the same for traction treatment in the sitting position. The data show that frequency values are gradually increased during traction in a sitting position. The previous studies showed that when muscle fatigue occurs, the value of the time domain features of muscle activity increases, and the frequency domain features decrease. The analysis of various parameters indicates the effectiveness of continuous traction treatment in the reduction of neck pain in cervical patients due to radiculopathy.

3.5 Conclusion

To examine the effectiveness of traction therapy in the treatment of neck pain and radiculopathy pain, various features in the time and frequency domains such as MAV, RMS, SD, MF, and MDF were extracted from the recorded EMG data of patients. These extracted features contain sufficient information about the fatigue associated with the muscle. A significant reduction in the time domain features and an increment in the frequency domain features were observed, which indicates a considerable decrease in the pain associated with the neck. The same effect traction therapy was obtained for the neck pain and radiculopathy pain. Up to some extent, traction therapy is capable of providing a solution to neck pain-related problems. However, to obtain a more positive aspect of the traction treatment, a detailed quantitative study of EMG data should be performed, and based on the intensity of the results of traction therapy should be decided.