Chapter 5
Clinical Assessment of Muscle Fatigue using LabVIEW

5.1 Introduction

EMG has been applied as an effective and non-invasive technique to study human muscle fatigue. Fatigue is defined as a decrease in the capacity of muscle strength. Its assessment can be done by identifying changes occurring in the spectral characteristic of the EMG signal. Typically, the amplitude increases in the low-frequency range, and the mean or median frequency decreases with fatigue [Al-Mulla et al. 2011]. The EMG signal contains sufficient information regarding the muscular system and neuromuscular disorder whose analysis can be done by extracting time and frequency domain features [Hof, 1984].

The previous research works related to the assessment of muscle fatigue are described below.

A system was developed for the real-time muscle fatigue monitoring and assessment for the lower extremity muscles during cycling movement [Chen et al., 2014]. An EMG sensor and Force sensor based fatigue detection scheme was developed in the LabVIEW environment that allows real-time as well as offline monitoring of muscle fatigue using frequency-domain features [Jankovic et al., 2010]. M. Yochum et al. (2010) presented a technique based on LabVIEW and data acquisition device for online assessment of muscle fatigue using EMG signals. Yochum et al. (2012) presented an EMG based on novel device, and continuous wavelet transform was utilized for real-time quantification of muscle fatigue during myoelectrical stimulation.

Faller et al. (2009) developed a mechanomyography (MMG) signal acquisition system and an experimental protocol, i.e., neuromuscular electrical stimulation (NMES) for the assessment of muscle fatigue. Chattopadhyay et al. (2011) proposed a transfer learning framework based on the multi-source domain adaptation methodology for detecting different stages of fatigue using EMG signals.

Marri K et al. (2016) showed that the multifractal spectrum analysis with new singularity features could be used for medical assessment in different neuromuscular disorders, and the proposed features can also be useful in analyzing other physiological time series. Karthick et al. (2016) showed the analysis of muscle fatigue using a modified B distribution based time-frequency features. Helmi et al. (2017) presented the development of a wireless EMG device to measure muscle fatigue in swimming activity. Chunxiao Li et al. (2018) proposed a pulse width modulation (PWM) based technique for monitoring human muscle fatigue status through the measurement of EMG signal in real-time.

In this chapter, a wireless EMG system based muscle fatigue detection scheme was developed in the LabVIEW environment, which provides an offline assessment of neck pain using recorded EMG data of patients under different conditions (i.e., loading and no loading). The scheme mainly utilizes the time and frequency domain parameters of recorded EMG signals for analyzing muscle fatigue. The graphical program on LabVIEW uses EMG signal of patients as input, and it produces output as fatigue relaxation status through assessment of various time and frequency domain features of the EMG signal.

LabVIEW, an abbreviation for Laboratory Virtual Instrument Engineering Workbench is a graphical programming environment for creating the program using graphical notations. It provides more flexibility than standard laboratory instruments since it is software-based. The LabVIEW programs are termed as virtual instruments (VIs) because their operation and appearance resemble the physical instruments. LabVIEW with a set of VIs performs functions like acquiring, analyzing, displaying and storing data. It can communicate with various hardware devices such as data acquisition (DAQ), serial, vision, motion, and control devices [jovitha and Jerome].

5.2 Methodology

EMG data of fifteen neck pain patients were recorded those were undergoing traction treatment using a wireless EMG sensor. A software program using LabVIEW was established for acquiring the data analysis, and detection of fatigue. After approval from the ethical committee of IMS, BHU, the recording of EMG data was done with subjects for one week.

The wireless EMG sensor from Delsys Trigno is capable of detecting and acquiring 16 channel EMG data and 48 channel accelerometer data simultaneously. The use of wireless system makes the EMG signal detection easy and reliable. Figure 5.1 shows the clinical picture of the cervical traction application of the sensor.

The various features of the EMG signal contain significant information regarding the muscular contractions. Features in the time and frequency domain give the key details regarding fatigue and non-fatigue contraction of the muscle. Time-domain features such as MAV, RMS, and SD are related to the amplitude, whereas frequency domain features such as MNF and MDF are related to the frequency content of the EMG signal. These features were extracted from the recorded data of participated patients for quantitative analysis of muscle strain. Based on these features, an algorithm was implemented on the block diagram, which receives inputs as pre and post EMG data of a patient and generates boolean output as the status of fatigue relaxation on the front panel. Figure 5.2 (a, b) describes the developed block diagram for pre and post EMG data import, feature extraction, and fatigue analysis.

Figure 5.1 Clinical Picture of cervical traction application of the sensor

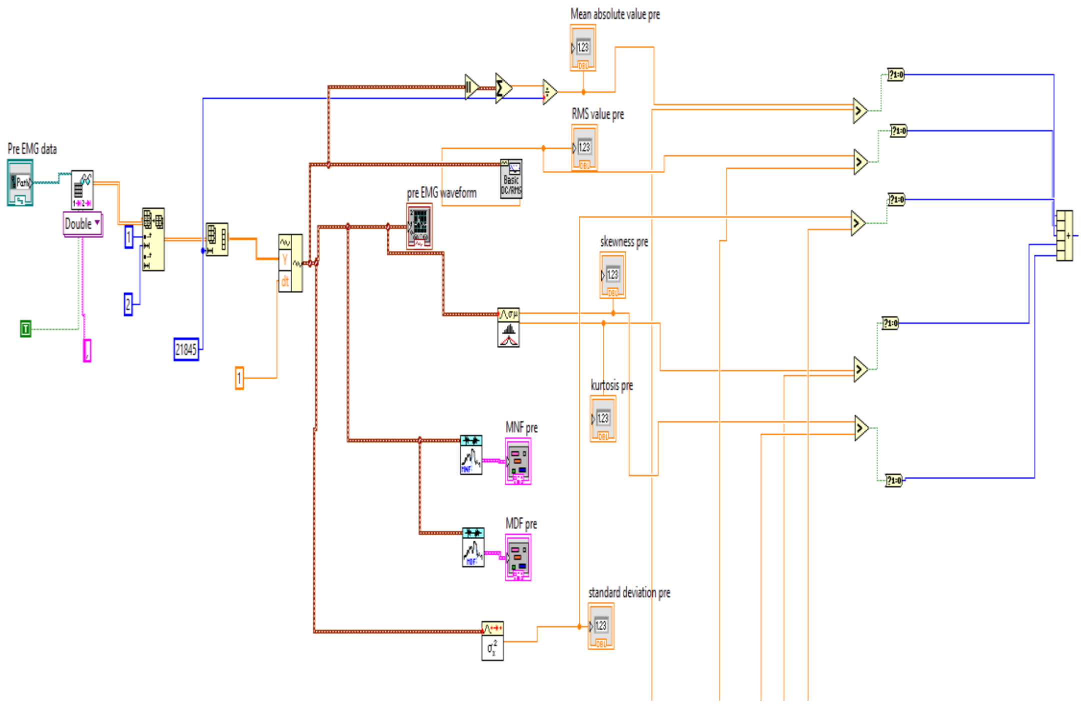

Figure 5.2 (a) LabVIEW block diagram for pre-EMG data import and feature extraction

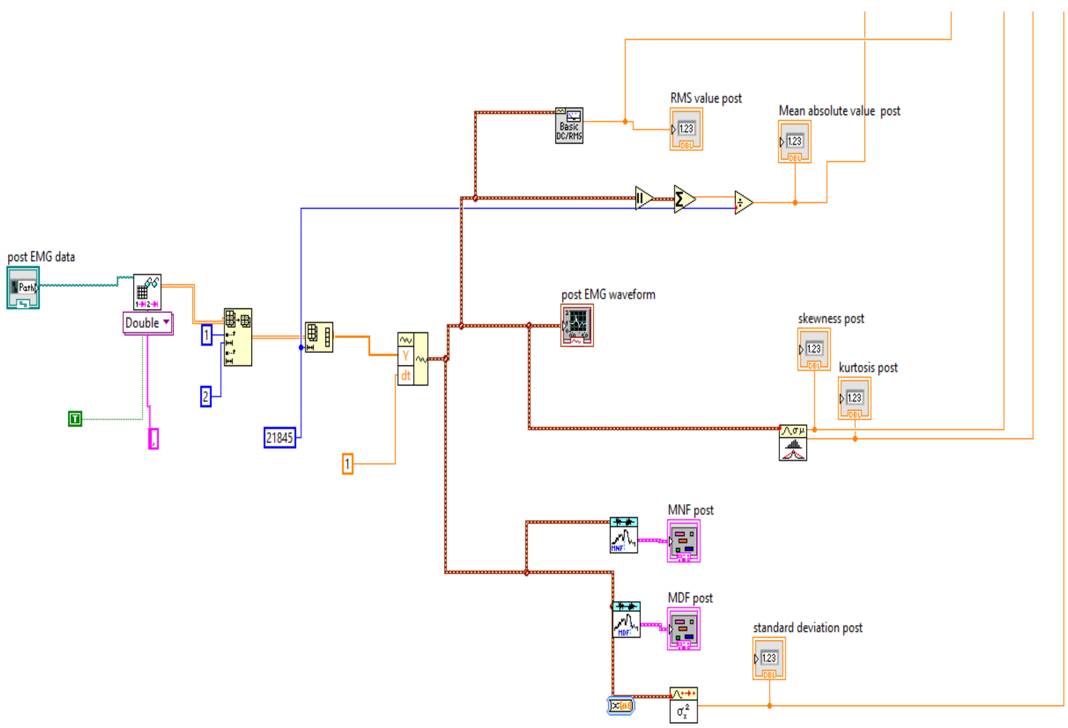

Figure 5.2 (b) LabVIEW block diagram for post-EMG data import and feature extraction

5.3 Results and Discussion

Fifteen male and female patients suffering from neck pain participated in this study. The EMG data for each subject were collected for pre and post 5 minutes of the first day (Fd) to last day (Ld) of the week during the traction session. All these recorded data were acquired on LabVIEW to extract various time domain and frequency domain features from them. Analyzing these features for pre and post-session, a graphical program was developed in LabVIEW to indicate the muscle fatigue status of the patients. MAV, RMS, SD, KURT, SKEW, MF, and MDF are features, which were used for fatigue analysis. Muscle fatigue status was generated based on the increment or decrement in the time and frequency domain features.

The Front panel window of the LabVIEW takes pre and post EMG data of a patient as inputs and indicates the recreation status of muscle fatigue as boolean output. Figure 5.3 (a, b) illustrates the outputs for two different patients showing no relaxation in neck pain for the first case and relaxation for the second. Table 5.1 shows various extracted features of EMG data in which significant varying in time and frequency domain features during pre and post traction treatment were observed. Also, the same was noticed on the first day and last day features.

Table 5.1 Time and frequency features of various subjects

Subjects	Time Domain features						Frequency Domain features			
	MAV		RMS		SD		MNF		MDF	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1.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
2.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
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	6.709	6.414	8.445	8.114	8.314	7.933	0.136	0.143	0.087	0.093
Ld	2.196	1.598	7.847	2.074	7.692	1.492	0.120	0.670	0.014	0.069
5.Fd	2.213	2.187	1.488	1.465	4.563	4.284	0.019	0.043	8.033	8.094
Ld	2.203	2.080	2.4	2.31	9.39	7.48	0.024	0.031	7.937	8.239
6.Fd	1.689	1.448	2.987	1.612	7.393	2.602	0.064	0.069	0.046	3.124
Ld	1.693	1.688	1.917	1.885	9.670	8.588	0.034	0.042	9.071	9.642
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
8. Fd	2.401	2.197	2.296	2.263	6.584	5.875	0.016	0.019	7.734	7.805
Ld	1.512	1.425	1.985	1.476	3.839	1.409	0.017	0.055	0.013	0.712
9. Fd	1.712	1.658	2.395	2.111	1.925	1.568	0.055	0.062	0.030	0.042
Ld	2.207	2.204	2.266	2.251	4.706	4.420	0.011	0.013	7.492	7.512

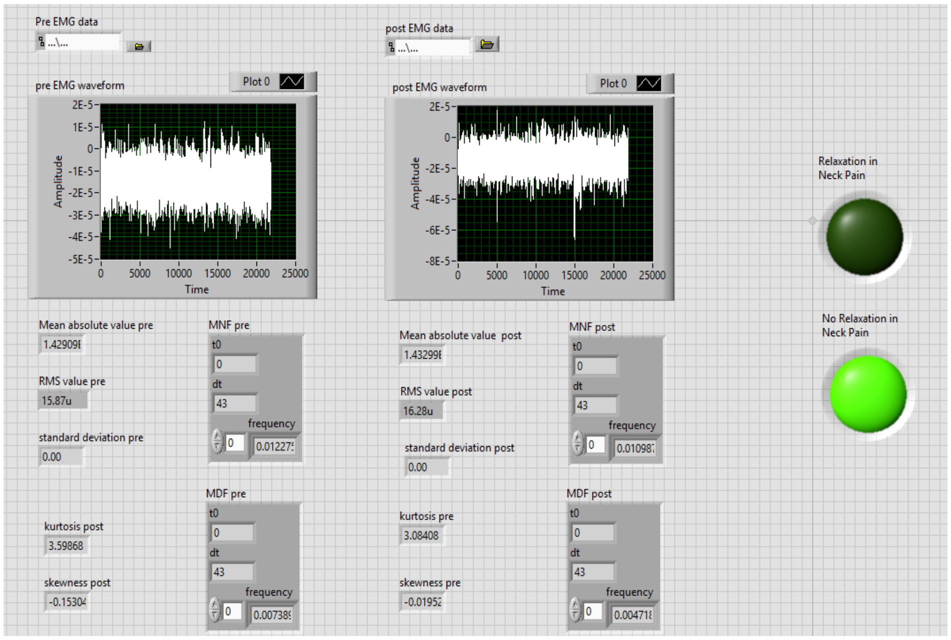

Figure 5.3 (a) LabVIEW front panel VI showing no relaxation in neck pain

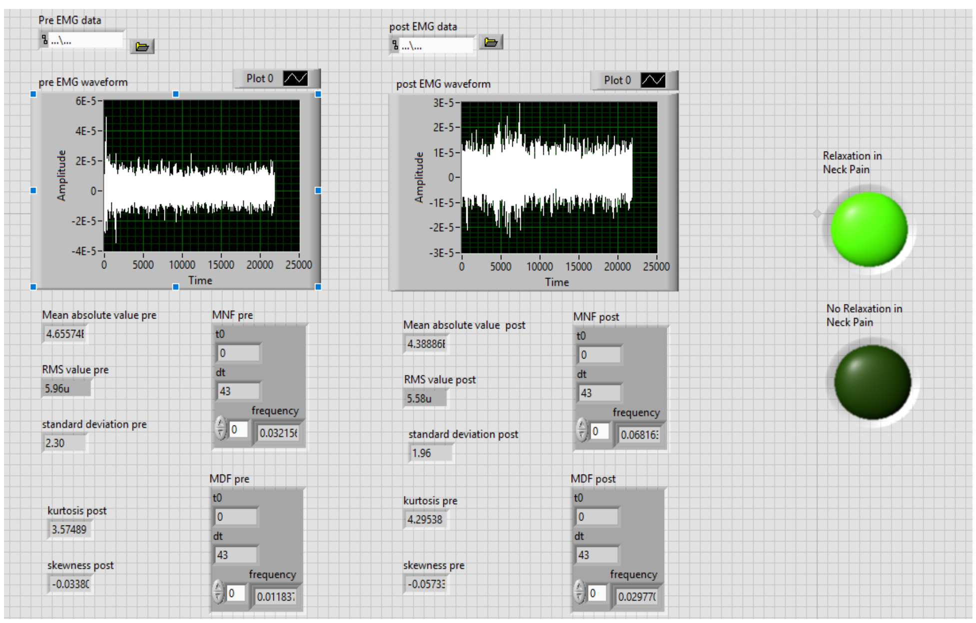

Figure 5.3 (b) LabVIEW front panel VI showing relaxation in neck pain

From the previous studies regarding the dependency of the muscle strain on different features of EMG signal, the graphical programming was developed, which was able to quantify the fatigue status of the neck muscles from the pre and post traction treatment session. In this study, the time domain features were found to decrease whereas there was an increment in frequency domain parameters. From the previous study, it is clear that when muscle strain occurs, the time domain features to increase, and frequency domain features decreases. The proposed system here provides an efficient approach for the assessment of muscle fatigue as it does not require EMG data analysis of every patient individually. Using the developed program, a significant reduction in fatigue level was observed for 9 patients from the EMG data of 15 patients.

5.4 Conclusions

In this study, a LabVIEW based system was developed for monitoring fatigue status of patients suffering from neck pain based on their EMG data recorded during traction treatment. Different features in time, as well as the frequency domain, were extracted from these data for the analysis of strain in neck muscles as these features are related to the fatigue and non-fatigue contraction of neck muscles. The algorithm was implemented in the LabVIEW block diagram showing the fatigue relaxation status on the front panel window from the uploaded pre and post EMG data of the subject. This approach requires very less computation time for fatigue detection as we don’t have to analyze EMG data for every patient separately. The proposed work was able to reveal the diagnosis or evaluation of neck muscle fatigue. The main conclusion made from this study is the effectiveness of traction in the reduction of the neck pain of various patients.