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Stress analysis of lower back using EMG signal.

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Abstract

The purpose of this study was to examine the force/EMG relationship during flexion and erection movement of human back during occupation at different positions using surface Electromyography (sEMG) signal. This tool is a non-invasive technique that allows the evaluation of muscle activity. Human's back is most sensitive part of human body and postures of human body have a significant role to analyze pain especially in the low back region. In this approach surface electrodes are used to record surface electromyography (sEMG) signals of lower back, in the limited forward and backward movement from vertical position, placed at different positions of vertebrae of the lumber region to have a prediction on the stress level of muscles involved in the movement. Preliminary Investigation on three subjects of age groups below 40 years and above 40 years was carried out for three different sitting postures to analyze the differences in EMG signals using Analysis of variance (ANOVA). After Preliminary investigation on three subjects, the experiment was extended to nine subjects in six different sitting postures. ANOVA test has clearly indicated that there exists a statistically significant difference amongst the mean values of EMG signals for different sitting postures and in further investigation, minimum stress level is found in the angle range from 90°-120°. According to the minimum stress level between the angle range 90°-120°, seat may be designed including back rest flexibility in the angle range of 90°-120°.

Keywords: Force, Low back pain, Position of lower back, sEMG.

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Introduction

The spine is a complicated structure providing support to the body [1]. One important mechanical function of the lumbar spine is to support the upper body by transmitting compressive and shearing forces to the lower body during the performance of everyday activities [2]. In recent times, low back pain is a common problem in all working professionals. In spite of growing knowledge pertaining to spinal diseases and momentous developments in modern medicine, chronic Low Back Pain (LBP) remains one of the most severe public health problems in all countries including India. Low back pain is the leading musculoskeletal disorder in terms of cost and work-absenteeism [3]. The effectiveness of different kinds of treatments has been studied in the literature, but a definite consensus has yet to be established [4]. LBP causes a socio-economic impact promoting many days lost in work [5]. Several studies suggest that instability can cause damages and lumbar dysfunctions and increase the risk of an initial episode and subsequent recurrence of LBP [6,7]. Severe back pain most often arises from intervertebral discs, apophyseal joints and sacroiliac joints, and physical disruption of these structures is strongly but variably linked to pain [8]. More of the people with persistent back pain who report limitations in functioning have used health care services compared with others in the sample who also reported functional limitations, presumably resulting from health conditions other than back pain [9]. Therefore, many authors have recommended inclusion in rehabilitation programs of exercises specifically designed to improve active stability of the spine [10,11].

The main motivation of this paper is to study the effect of sitting postures at different angles, which is primarily the main cause of occupational pain. Another purpose of the paper is to investigate the stress level of the muscles involved in these postures using Electromyographic (EMG) signals. Muscle activity is directly reflected by EMG signals. Low muscle activity indicates less energy is required to maintain the posture. So such a study will be useful ergonomic intervention to suggest a proper sitting angle. The proper posture is associated with elastic equilibrium, in which the least elastic stress and lowest joint load are produced [12], which is reflected by the low levels of muscle activity. The proper posture mean the less energy required to maintain the posture and ultimately may result in avoiding occupational health hazard leading to lower back pain. The study embodies the experimental investigation of the physical preparation and data acquisition of the lower back positions. The aspects of data pre-processing stage, which is an essential part to analyze the signal for feature extraction, are also incorporated. Surface electromyography (sEMG) signals are the most common form of non-invasive-measurement of muscle activities [13] and is widely accepted and used for investigation of muscle stress. Extensive researches were made to understand the surface EMG techniques and its application to the analysis of low back muscles for classifying healthy subjects and Low Back Pain (LBP) patients [5].

Material and Methods

Experimental setup

To improve understanding of the dynamic characteristics of the human lumbar spine, experimental method is required [14]. For this work, MP100 of Biopac System Incorporation has been used for recording EMG signals. MP100 is a complete and expandable data acquisition system that functions like an onscreen chart recorder, oscilloscope and X/Y plotter, which allows recording, viewing, saving and printing data [15].

Data acquisition settings: Muscle activities from the lower back were recorded from the disposable surface electrodes (EL-503) connected to the MP100 Biopac Systems Inc. The data acquisition involves the recording of Electromyographic (EMG) activity [16]. Another important part in data acquisition is the amplification and signal conditioning, which includes artifact elimination of the signals. Since the SEMG signals are relatively small, their measurement is susceptible to the movement of cable that carries signals from the body to the measuring instrument. To eliminate these artifacts, the Electromyogram amplifier module (EMG 100C) high gain, differential input, biopotential amplifier has been used to acquire the EMG with 10-500 Hz bandwidth and gain setting of 2000. The sampling rate was selected to be 1000 Hz so that none of the useful information was lost during data acquisition. The placement procedure of electrodes will be explained in the next subsection.

Table 1. Feature values of EMG signals for three different angles for preliminary investigation.

Angle of Back	Subject 1		Subject 2		Subject 3	
	Average Value	Standard Deviation	Average Value	Standard Deviation	Average Value	Standard Deviation
75°	0.718743	0.563316015	0.447931	0.12138183	1.643806	0.9744
	0.703388	0.515772916	0.417474	0.12323651	1.708665	0.9951
	0.405779	0.281859859	0.310476	0.12518218	1.756806	1.0428
	0.479794	0.402271978	0.200008	0.12300078	1.777084	1.0467
	1.485074	1.333926257	0.264942	0.12272625	1.775545	1.0515
	0.447859	0.410923564	0.433159	0.12320205	1.816283	1.0762
90°	0.213493	0.155064423	0.391967	0.266012138	0.792189	0.4618
	0.212597	0.153007881	0.327655	0.225684525	0.845401	0.4866
	0.306643	0.397730595	0.375299	0.247464197	0.867605	0.4961
	0.428785	0.286482375	0.246629	0.158845505	0.825746	0.4885
	0.471512	0.310411638	0.333409	0.25919276	0.900564	0.5242
	0.508391	0.35971465	0.521975	0.337426988	0.906899	0.5251
105°	0.306535	0.148747823	0.494207	0.11921041	0.977155	0.5742
	0.243737	0.124624189	0.499736	0.11901171	0.985729	0.5729
	0.210168	0.113682065	0.512191	0.11969711	0.946091	0.5468
	0.177581	0.103052894	0.513105	0.12025388	0.894297	0.5216
	0.154409	0.095064539	0.509925	0.12078698	0.8356	0.4851
	0.142599	0.089057657	0.511921	0.12092837	0.841688	0.4842

Placement of electrodes and duration of recording: The surface electrodes were placed with a careful observation of anatomical studies of the muscles concerned with the lower back. EMG data was taken by using two channels of the equipment. The skin preparation was duly done prior to the placement of electrodes. The two active disposable Ag/AgCl surface electrodes were used for each channel in differential configuration at one and half centimeter distance from each other. The third surface electrode was placed as the reference electrode on the unconcerned muscle. Surface electrodes were placed at the skin surface of Erector Spinae at right side and were assigned as Channel 1 for L_1 and L_3 and Channel 2 for L_3 and L_5. The placement of channel 1 was to the right side of lumbar vertebrae, L_1 and L_3 on right erector spine muscle second channel was placed on L_3 and L_5. All recordings for a subject were taken for each position for a window of 10 sec without back rest.

Table 2. *ANOVA test summary for three subjects for three different sitting postures.*

ANOVA: Single Factor						
Subject 3						
SUMMARY						
Groups	Count	Sum	Average	Variance		
75°	6	5.138406	0.856401	0.001962		
90°	6	10.47819	1.746365	0.003746		
105°	6	5.480562	0.913427	0.004385		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F critical
Between Groups	2.978146	2	1.489073	442.5829	4.61E-14	3.68232
Within Groups	0.050468	15	0.003365			
Total	3.028614	17				

Subjects and subjects postures

For purpose of the experimental analysis, two stage experiments have been conducted:

Preliminary investigation: Three subjects of age groups below 40 years and above 40 years were considered for three different sitting postures to analyze the differences in EMG signals for a window of 10 sec each.

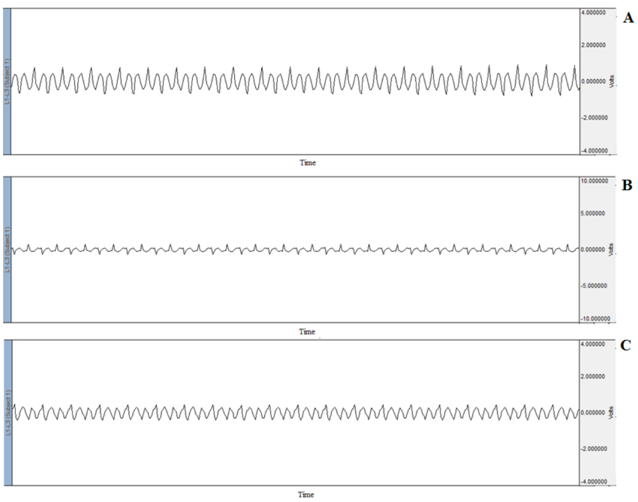


Figure 1. *sEMG signals of Subject 1 at different sitting postures at (a) 75 (b) 90 (c) 105*

After Preliminary investigation on three subjects, the experiment was extended to 09 subjects in six different sitting postures without backrest. Healthy subjects (male and female) aged 20-30 years were chosen and they have participated in the experiment with their written consent.

Table 3. *Angle for minimum gross stress level of EMG.*

Subject	**L_1-L_3 location**	**L_3-L_5 location**
Subject 1	105°	90°
Subject 2	90°	90°
Subject 3	90°	90°
Subject 4	90°	90°
Subject 5	90°	120°
Subject 6	90°	120°
Subject 7	120°	90°
Subject 8	105°	105°
Subject 9	105°	90°
Total	90°-11 times (61.1%)	
	105°-4 times (22.2%)	
	120°-3 times (16.6%)	

The required essential training for the desired positions of the back was imparted to each subject individually. Back positions were separated by 15 degrees. The six positions of back for which the data was acquired are selected as 45°, 60°, 75°, 90°, 105° and 120° from horizontal plane.

Feature extraction

Generally, most of signals in practice are time-domain signals in their raw format. In other words, one obtains a time-amplitude representation of the signal. The main purpose of the feature extraction is to emphasize the important information in the measured signal. After the successful processing of the sEMG signal, it was required to extract the features of different positions of back. One may easily evaluate the features in time domain because time domain does not need a transformation. Absolute mean and variance time domain features were extracted from acquired EMG signals and has been used for analysis purpose.

Results

For Preliminary investigation, one-way Analysis of Variance (ANOVA), a statistical method was used to test the differences between the mean values of EMG signals of three different sitting postures. The Preliminary test was conducted on three subjects and absolute mean values of muscle activity (EMG) for a window of 10 sec each have been recorded and presented in the Table 1.

Null hypotheses: means of all the EMG signals at different angles of sitting posture are equal.

Alternative hypotheses: means of all the EMG signals at different angles of sitting posture are not equal.

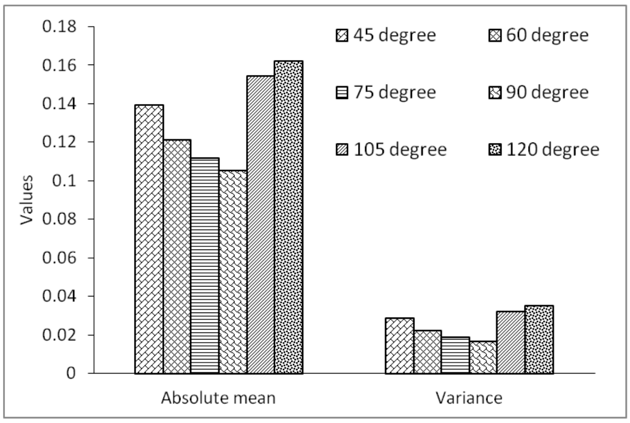
Results of ANOVA test for one subject is presented in Table 2. P-value of ANOVA test for other two were found 0.009447 0.005992 respectively.

Table 4. *Minimum stress level of EMG signal at different angles (2 sec window).*

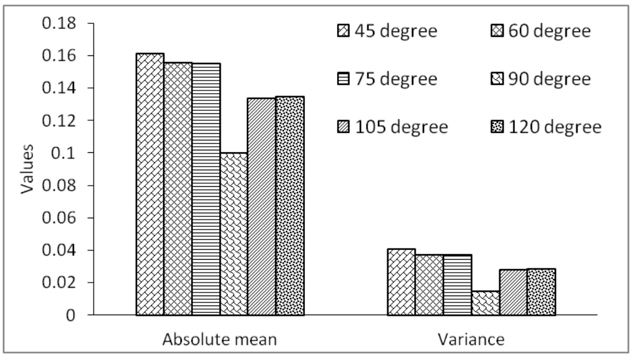
Subject	L_1-L_3 location						L_3-L_5 location					
	45°	60°	75°	90°	105°	120°	45°	60°	75°	90°	105°	120°
1	0	0	0	0	5	0	0	0	0	5	0	0
2	0	0	0	5	0	0	0	0	0	5	0	0
3	0	0	0	5	0	0	0	0	0	5	0	0
4	0	0	0	2	3	0	0	0	0	2	0	3
5	0	0	0	5	0	0	0	0	0	0	0	5
6	0	0	0	5	0	0	0	0	0	0	0	5
7	0	0	0	0	0	5	0	0	0	5	0	0
8	0	0	0	1	4	0	0	0	0	0	5	0
9	0	0	0	0	5	0	4	0	0	1	0	0
Total	0	0	0	23	17	5	4	0	0	23	5	13
% of occurrence of min. stress	0	0	0	51	38	11	9	0	0	51	11	29

It is clear from the ANOVA method that the p values are considerably lower than 0.05. So the null Hypothesis is rejected and alternate Hypothesis is accepted. It is concluded that the EMG activity is significantly (statistically) different at different angles of sitting posture (Figure 1). Each EMG value represents muscle activity during different sitting with trunk inclinations in flexion and extension positions from the sagittal plane [17]. After the preliminary investigation, the experiment was extended to nine subjects with six different sitting postures without backrest. Two channels for two different locations (L_1-L_3 & L_3-L_5) were utilized for each recording. In this analysis, a window of 10 sec. for gross activity and a window of 2 sec. for short duration study have been used for the feature extraction. Figure 2 shows the feature values at six different positions for 10 sec window for three subjects sitting (without backrest) ideally with hands down. It clearly indicates that the EMG output varies for different angle positions of back and comes out to be minimum at 90° in most if the cases.

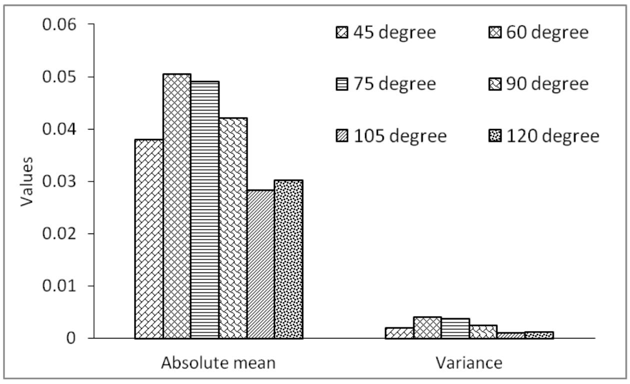
For further understanding the behaviour of back signals the Table 3 shows the angle for minimum gross stress level of EMG for lower back for the considered nine subjects. It is evident from Table 3, minimum stress level is found maximum times at an angle of 90° i.e. 61%. In rest of the cases the minimum stress level is found at an angle 105° and 120°. Further analysis EMG is analyzed in a smaller window of 2 second each i.e. each 10 sec. recording is divided into 5 parts of 2 sec. each. Table 4 presents the angle of minimum stress level for each 2 second window. It is evident from Table 4, minimum stress level is found maximum times at an angle of 90° i.e. 51% for L_1-L_3 and L_3-L_5. Next minimum stress level was found at 105° i.e. 38% for L_1-L_3 and 11% for L_3-L_5. Few cases of minimum stress level were found at 120° i.e. 11% and 29% for L_1-L_3 and L_3-L_5 respectively. In rest of the cases (9%) the minimum stress level is found at an angle 450 for L_3-L_5 position.



(a) Feature values of Subject 1 at L1-L3 position



(b) Feature values of Subject 4 at L1-L3 position



(c) Feature values of Subject 9 at L1-L3 position

***Figure 2.** Feature values of subjects.*

Discussion

SEMG has been used in numerous settings to measure voltage output of relative muscle recruitment, in ergonomic analyses when comparing musculoskeletal stress in a specific muscle(s) associated with postures and to evaluate the efficacy of ergonomic interventions [18,19]. The study utilizes the average amplitude measurement from the sEMG to provide quantitative observation of recruitment intensity for specific muscle groups affected by a task. The analysis used average amplitude directly rather than the often-used percent of maximum voluntary contraction, because some subjects had active injuries and were unable to obtain a reliable maximum reading [20].

Mastalerz and Palczewska observed statistical influence of the trunk inclination on erector spinae, gastrocnemius lat. and tibialis anterior ($p<0.05$) [17]. Similarly, in our preliminary investigation it has been concluded that the EMG activity is significantly (statistically) different at different angles of sitting posture. A study on effect of postural angle on back muscle activity by Kamil and Md Dawal [12] concluded that neutral upper trunk posture, in which the angle deviates between 0° and -5°, minimizes CES and longissimus muscle activation. This posture allows the subject to maximize balance and optimize the proportions of their body mass and framework based on their physical limitations while performing computer tasks. Low muscle activity indicates less energy is required to maintain this posture, because the muscles are at their ideal length in a neutral position. The neutral posture is associated with elastic equilibrium, in which the least elastic stress and lowest joint load are produced [19], which is reflected by the low levels of muscle activity. The neutral upper trunk position can be considered the ideal posture because it encourages proper alignment of the body's segments such that the least amount of energy is required to maintain a desired position [12]. In our study occurrence of minimum stress is at an angle 900 for 61% of the readings taken (gross EMG) from nine subjects and is obvious that minimum stress level is mostly found in the angle 900 which is equivalent to neutral position.

Conclusion

The positions of back were investigated by the EMG signals. There is difference in feature values of EMG signal for different sitting posture. Further, ANOVA test has clearly indicated that there exists a statistically significant difference amongst the mean values for EMG signals for different sitting postures, which shows the possibility of investigating the good posture of back using EMG signals. The window selected for the analysis helps us to analyze the changes in EMG signals with time, so it is always better to select a proper window before extracting the features. It is also clear from Table 3 and Table 4 that occurrence of minimum stress is at an angle 900 for 61% of the readings taken (gross EMG) from nine subjects and is obvious that minimum stress level is found in the angle range from 90°-120°. This fact was also verified when shorter duration window (2 sec) of EMG was taken for analysis. So the comfort sitting posture maintaining minimum stress of each individual may vary between the angles range of 900-1200 from the horizontal plane. Accordingly, the seat design may include back rest flexibility in the angles range of 90°-120°.

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