RESEARCH PAPER

Cervical EMG profile differences between patients of neck pain and control

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Abstract

Purpose. The objective of this study was to investigate EMG signals of cervical muscles in five directional efforts from chronic neck pain patients and compare them with those of the healthy controls to discern differences between patients and controls with respect to strength and EMG characteristics.

Method. Seventeen male and 17 female idiopathic and non-specific chronic neck pain patients without any diagnosed pathologies or prior surgery in the age group 18–65 years were recruited into the study. The controls consisted of 30 male and 33 female subjects with no history of neck pain in the past 12 months. Both patients and controls performed the experimental activities of flexion, left anterolateral flexion, left lateral flexion, left posterolateral extension and extension. The patients exerted to their 20% maximum voluntary contraction (MVC), pain threshold and pain tolerance levels in three separate contractions. Similarly, the control subjects exerted to their 20% MVC, 60% MVC and MVC in random order. The descriptive statistics for strength, normalised peak EMG, median frequency (MF), 10% frequency bands and their power were calculated. Eight levels of wavelet decomposition and their coefficients were calculated and subjected to principal component analysis. These variables were subjected to analysis of variance and regression analysis to distinguish between patients and controls. The full wave rectified linear envelope detected EMG of patients and controls were plotted against time to reveal pattern differences.

Results. There was a lack of significant difference in the MF of the two samples indicating that the muscle conduction velocity was not disturbed by the pain. Significant differences were also found in 10 percentile frequency bands between patients and controls (p < 0.05). The wavelet decomposition with principal component analysis revealed that patients and controls could be identified as such 100% of the time at 20% MVC; and, patients and controls could be identified correctly 100% and 90% of the time respectively at pain threshold/60% MVC.

Conclusion. Thus, a combination of EMG spectral frequency banding and wavelet decomposition with regression can be used to distinguish chronic pain patients from controls.

Keywords: Chronic neck pain, classification, identification

Introduction

Neck pain is a common occurrence in our society and constitutes significant social and economic burden. In a cross-sectional study [1], it was reported that the life-time occurrence of problems of neck pain was 66.7% and the point prevalence was 22.22% in Saskatchewan adults. Overall 58.8% of women and 47.2% of men had experienced neck pain in the previous 6 months. In another prospective cohort study after involvement in traffic accidents, 58.8% of sample was reported to be work disabled [2]. In a cross-sectional study reported a life-time prevalence of neck pain 78% in military office workers, whereas the point prevalence was 59% [3]. On the other hand, among sedentary workers 6-month neck pain prevalence was reported to be 23.5% [4]. Among helicopter pilots, 3-month prevalence of neck pain was reported being 57% [5]. Thus, the prevalence of neck pain may vary with occupation and exposure to risk factors, but its occurrence in society is common. From epidemiological data of population survey and accounting the insurance claims, it would appear that it is the minor
accidents and events that are responsible for the large majority of these cases. The injuries are most likely to be located in musculoskeletal structure of the neck [6,7]. The latter group of authors demonstrated that in a simulated rear-end impact a speed change or 5 kph or less could cause 179% of maximal voluntary contraction in the sternocleidomastoid muscle. This rate of progression of muscle stress is likely to cause injury to these tissues resulting in pain. A similar finding for trapezius muscle has also been shown [8].

In a voluntary cervical motion the neuromotor control exercised by the central nervous system determines the time, intensity and a nature of excitation of agonists and antagonist muscles [9]. The neuro-motor control is responsible for carrying out two functions: (a) produce torque about a given a spinal joint to carry out the task at hand, and (b) develop appropriate forces required to stabilise it. In symptomatic subjects due to pain, the pattern of the neuro-motor control is disrupted altering the relationship between the muscle excitation, regional muscle balance and resultant mechanical output [10–12]. Therefore, the global objective of this study was to determine differences in EMG characteristics of muscles in patients with neck pain in comparison to those of normal controls. The hypothesis of the study was that the power spectrum profile time domain features identified by wavelet decomposition of the EMG of cervical muscles will deviate in pain patients from those off the normal subjects.

**Methods**

**Sample**

The study was approved by the University of Ethics Review Committee prior to initiation of the project. 17 male and 17 female patients of idiopathic and non-specific chronic neck pain lasting 3 months or more in the age group of 18–60 years were recruited for the study. The exclusion criterion was any diagnosed pathology, trauma or surgery. The inclusion/exclusion criteria were established by taking history, imaging and EMG studies. The mean body mass index (BMI) of male patients was 29.8 and that of females was 25.8. There were 30 male controls with a mean BMI of 24.2 and 33 female control subjects with a mean BMI of 24.2.

**Subject preparation**

After suitable skin preparation Delsys bipolar active, knife edge, fixed inter-electrode distance (10 mm) surface electrodes were applied to upper trapezius (level with C4), splenius capitis and the sternocleidomastoids bilaterally to both patients and control subjects. These subjects were required to exert individual muscle specific activities to discern crosstalk; if any crosstalk was present the electrodes were replaced to an ideal location to minimise it. Such prepared subjects were seated in the experimental set up for cervical testing.

**Testing device**

The testing device consisted of an adjustable chair, sliding platform and floor mounted strength measuring device (Figure 1). The chair consisted of a molded plastic seat mounted on an iron platform with telescopic metal legs fixed to the base plate. The back-rest and seat and were fitted with a Velcro four-point restraint system to stabilise torso and both shoulders. The chair with its base plate was pivoted in the center and had casters on the periphery for circular motion with stability. The circular plate was graduated in intervals of 5° and holed through which bolts could be placed to match the holes in the sliding board of the platform. Two bolts were placed at opposite ends and tightened for a rigid fixation of the chair in the desired position of a subject. The resistance device consisted of a vertical telescopic 15 cm wide rectangular metal tube welded to a thick iron plate rigidly bolted in the floor. The 12-cm wide tube could be raised or lowered and securely locked into place. On top of the inner tube ball bearing was mounted to which another hollow tube was attached allowing it to rotate freely. Attached perpendicular to this tubing was an adjustable arm that was upholstered at the farther end for head contact and force application. At the lower end of the tubing, a counterweight was attached with an adjustable length rod to compensate for variable positioning of the horizontal resistance of arm. 14 cm below the pivot point a horizontal metal rod was built at right angles to the tubing which could be attached to a fixed object with an intervening load cell (L-250). Thus, any force exerted on the upholstered horizontal arm was registered on the load cell, which was fixed in its mechanical path. The directions of force exertions were chosen from a scheme shown in Figure 2.

**Tasks**

The subjects were informed about the objectives and procedure of the experiment. After signing the informed consent form, the prepared subjects were seated in the experimental set up for cervical testing. The subjects were asked to exert in isometric flexion, extension, left lateral flexion, left antero-lateral
flexion and left postero-lateral extension according to the scheme shown (Figure 2). The sequences of these exertions were fully randomised. The chair was rotated in the desired position for the testing condition. Using the adjustability, the pivot point of the resistance of arm was set at the same height as the horizontal upholstered bar. Prior to the start of a trial, the subjects were informed to exert their appropriate effort concentrating on using their neck only. The subjects where instructed to bring their contraction to the desired level in the first 2 s and hold it for another three. At this time the trial was terminated. The cervical muscle contraction force magnitude was measured in Newtons (N). The reliability and accuracy of this equipment and procedure was previously established [13]. The patients were asked to exert to their estimated 20% maximum voluntary contraction (MVC), pain threshold and pain tolerance levels. The control subjects were also asked to exert to their 20% maximum voluntary contraction (MVC), 60% MVC and MVC. All exertions were required to be 5 s long. While the subjects exerted force, the strength of exertion and EMG of all six channels were sampled at 2 kHz.

Data analysis

Force/strength. The force of contraction recorded in cervical isometric flexion, extension left lateral flexion, left antero-lateral flexion and left postero-lateral extension. These percentage data were quantitatively compared between the patients and normal control at contraction levels of 20%, 60% (pain threshold for patients) and MVC for both, controls and patients.

EMG. The raw EMG signals were band pass filtered with low cutoff frequency of 20 Hz and high cutoff frequency of 450 Hz. The signals in this frequency band were pre-amplified at the site by a factor of 10 and differentially amplified again with a gain of 100. The time constant used was 25 ms and the amplification system had a common mode

Figure 1. Cervical strength testing device.

Figure 2. Directional scheme for cervical exertion.
rejection ratio of 92 dB. Such recorded signals were full wave rectified and linear envelope detected over the 5-s recording duration. The peak amplitude of EMG was then measured and recorded. The peak EMG was normalised according to the following scheme. The sternocleidomastoid EMG in various activities was normalised against the peak EMG of the sternocleidomastoid in flexion. The EMG scores of splenius capitis were normalised against the peak EMG of left splenius capitis in left lateral flexion. Similarly, the EMG scores of the trapezii were normalised against the peak EMG of trapezi in extension. The pattern of EMG was observed by plotting the normalised EMG in time with one standard deviation confidence interval.

For the frequency domain analysis the raw EMG signals were subjected to DC removal. Subsequently, the sections of data that were in a stable force and EMG activities were marked and selected for Fast Fourier Transform analysis. Those activities were isometric and the data segments were stationary when chosen for such analysis. However, a test of the stationarity of the data was carried out before proceeding with the rest of the analysis. The spectral data analysis of each muscle in each of the 10 activities was done separately for patients of neck pain and control subjects. From the spectral analysis the lower and upper 3 dB frequencies and the bandwidths were extracted for patients and controls. All these three parameters were calculated for all three contractions (20% MVC, 60% MVC and MVC.) The median frequency of each of the cervical muscle in each of the 10 activities of both patients and controls were also extracted.

The descriptive statistics of the variables of strength, EMG magnitude, peak power normalised EMG, median frequency, mean power frequency, total power, peak power, frequency at peak power, time to onset and time to peak EMG was calculated. Each of these variables was also subjected to one-way analysis of variance to examine the differences between ‘control subjects’ and ‘neck-pain patients’ with respect to these features.

**Time domain analysis.** These EMG signals were first rectified and subjected to wavelet analysis to obtain eight levels of decomposition of signals for each subject under each condition and for each channel. Daubechies wavelet transformation was used for this purpose. The eight levels or scales, of the raw signals decomposition, were confined to following frequency bands: 0–7.08125, 7.8125–15.625, 15.625–31.25, 31.25–62.5, 62.5–125, 125–250, 250–500 and 500–1000 Hz.

At each of the abovementioned eight scales, the following were computed as frequency features.

- Eight RMS values (RMS1, RMS2 and RMS8)
- Mean (m), dispersion (d), skewness (s) and kurtosis (k).

For time domain features, rectified EMG signals were subjected to fourth-order autoregressive analysis

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### Table I. Cervical muscle strength in cervical pain patients \((n=34)\) and normal controls \((n=63)\) \((N)\).

<table>
<thead>
<tr>
<th>Gender</th>
<th>Subject type</th>
<th>Exertion levels</th>
<th>20% MVC</th>
<th>Threshold/60% MVC</th>
<th>Tolerance/MVC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mean</td>
<td>Std Deviation</td>
<td>Mean</td>
</tr>
<tr>
<td>Male</td>
<td>Patient</td>
<td>Flexion</td>
<td>14.63</td>
<td>3.68</td>
<td>38.70</td>
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<tr>
<td></td>
<td></td>
<td>Left antero</td>
<td>10.78</td>
<td>3.38</td>
<td>30.45</td>
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<tr>
<td></td>
<td></td>
<td>Left lateral</td>
<td>9.80</td>
<td>1.41</td>
<td>32.60</td>
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<tr>
<td></td>
<td></td>
<td>Left posterior</td>
<td>9.73</td>
<td>2.85</td>
<td>34.48</td>
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<tr>
<td></td>
<td></td>
<td>Extension</td>
<td>14.83</td>
<td>4.01</td>
<td>47.52</td>
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<td>Control</td>
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<td>13.72</td>
<td>17.56</td>
<td>26.31</td>
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<tr>
<td></td>
<td></td>
<td>Left antero</td>
<td>9.46</td>
<td>5.08</td>
<td>19.45</td>
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<td></td>
<td>Left lateral</td>
<td>10.44</td>
<td>5.61</td>
<td>22.34</td>
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<tr>
<td></td>
<td></td>
<td>Left posterior</td>
<td>12.96</td>
<td>7.13</td>
<td>27.56</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Extension</td>
<td>12.15</td>
<td>5.07</td>
<td>31.07</td>
</tr>
<tr>
<td>Female</td>
<td>Patient</td>
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<td>15.94</td>
<td>3.35</td>
<td>37.34</td>
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<tr>
<td></td>
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<td>Left antero</td>
<td>17.84</td>
<td>3.94</td>
<td>38.15</td>
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<tr>
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<td></td>
<td>Left lateral</td>
<td>18.76</td>
<td>4.81</td>
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<td>Left posterior</td>
<td>16.72</td>
<td>6.50</td>
<td>40.16</td>
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<tr>
<td></td>
<td></td>
<td>Extension</td>
<td>23.29</td>
<td>5.21</td>
<td>48.38</td>
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<tr>
<td>Control</td>
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<td>14.80</td>
<td>6.20</td>
<td>32.72</td>
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<td>Left antero</td>
<td>14.18</td>
<td>4.80</td>
<td>50.17</td>
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<td>13.43</td>
<td>6.59</td>
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<td></td>
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<td>Extension</td>
<td>19.06</td>
<td>6.59</td>
<td>44.43</td>
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using the ‘arfit.m’ in Matlab. From this fourth-order autoregressive model, autocorrelations ($r_{xx1}$, $r_{xx2}$, $r_{xx3}$, $r_{xx4}$) and auto-regression coefficients up ($\phi_1$, $\phi_2$, $\phi_3$, $\phi_4$) to order 4 were extracted to describe time-domain features, namely time dependency of the signals. All these signals were also subjected to wavelet analysis to obtain frequency domain features and time series analysis to obtain time domain features on all 97 subjects.

Logistic regression analysis was applied to identify best frequency-domain and time-domain features in classifying subjects to ‘control’ and ‘neck-pain group’ by treating group as a binary response variable and all above-mentioned frequency domain and time-domain measures as predictors. Separate logistic models were fitted for three exertion levels. After identifying the ‘best model’ with minimum number of predictors, classification procedure was formed based on the best model by classifying a subject to neck-pain group if predicted probability from the model was greater than or equal to 0.5, otherwise the subject was classified to control group. On the basis of one-fold (delete one) and cross-validation approach, misclassification errors were computed to evaluate the performance of the proposed classification scheme.

We evaluated the accuracy of this classification method and miss-classification errors were calculated using re-substitution accuracy measures (the accuracy that is evaluated when the classifier is evaluated on the same sample that was used to construct the classification rule.) However, this accuracy measure is ‘optimistically biased’. To address this criticism, we also used one-fold (delete one) cross-validation approach to estimate misclassification errors.

In identifying best predictors under step-wise selection scheme the standard rule was used: a variable was entered into the model if the probability of its score statistic was less than the 0.05 and is removed if the probability is greater than the 0.10.

With the selected features from the logistic regression analysis we also performed linear discriminate classification to examine the discrimination power. Figures 3 and 4 display two-sigma bars on linear discriminate scores, separately for control and neck pain groups and hence demonstrates the appropriateness of the proposed feature selections to classify subjects to these two groups.

**Results**

**Strength**

The means and standard deviations of all strength of patient and control samples for 20% MVC, 60% MVC (control)/pain threshold (patients) and MVC (control) and pain tolerance (patients) for flexion, left antero-lateral flexion, left lateral flexion, left postero-lateral extension and extension are presented in Table I. Neck pain patient’s pain threshold strength values turned out to be between 67 and 82% of their MVC for males and between 48 and 67% for females. Pain tolerance values of the patients were significantly different from those of the maximum voluntary contraction efforts of the control subjects ($p < 0.05$). The ANOVA revealed that there was no significant difference between the body weight normalised strength due to gender. However, there were significant difference between patients and controls for pain tolerance/MVC contraction
efforts in flexion ($p < 0.05$), left antero-lateral flexion ($p < 0.05$), left lateral flexion ($p < 0.05$), left postero-lateral extension ($p < 0.05$) and extension ($p < 0.05$).

**EMG**

The sample plots of EMG of cervical muscles during 20% MVC, pain threshold/60% MVC and MVC contractions in flexion are shown in Figures 5–7. Clearly, there is significantly greater EMG activity in the cervical muscles of patients in flexion ($p < 0.05$). A similar pattern has been found in all five exertions ($p < 0.05$). In pain threshold contractions patient’s EMG was significantly greater than those of controls in 60% MVC contractions for all six muscles ($p < 0.05$). The ANOVA revealed that the left and right sternocleidomastoid in both males and females were found to be significantly different in patients as compared to the controls in all five contractions ($p < 0.05$). The splenius capitis muscle was significantly different between patients and controls in flexion, antero-lateral flexion and left lateral flexion both in males and females ($p < 0.05$). The trapezius muscle showed a significant difference between patients and controls except in extension ($p < 0.05$).

The median frequency of the cervical muscles ranged between 80 and 130 Hz for both males and females in patients and controls. The median frequency of individual muscles also varied slightly between the five different activities. The ANOVA revealed no consistent and significant differences between patients and controls in the median frequency. When the total EMG bandwidth was divided into 10% intervals and compared between patients and controls activity specific differences emerged. In flexion and left antero-lateral pain tolerance/MVC contractions the right sternocleidomastoids were significantly different between pain patients and controls in each of the 10 percentile intervals ($p < 0.05$). In left postero-lateral extension

![Figure 5. Sample plot of the EMG for RSCM, LSCM, RSPL, LSPL, RTRP and LTRP for patients and controls for pain 20% MVC in flexion.](image-url)
of the left trapezius was found to be discriminating factor only in pain tolerance/MVC contraction ($p < 0.05$) in five bands only. In extension the left trapezius muscle discriminated between patients and controls in pain tolerance/MVC contractions in six of 10 frequency bands.

The classification results to distinguish between patients and controls at three levels of contractions are presented in Table II. The cross-validation method at 20% maximal voluntary contraction was most accurate identifying all patients as patients and all control subjects as controls. At this level of contraction the re-substitution method identified all controls as controls but miss-classified 13.8% of patients. At pain threshold/60% MVC both methods, re-substitution and cross-validation, classified patients with 100% accuracy but 10.3% controls were miss-classified. However, at pain tolerance/ maximal voluntary contraction, the accuracy of classification of patients decline to 66.6 % and 59.3% by re-substitution and cross-validation methods, respectively.

**Discussion**

Both rehabilitation and primary prevention of neck pain epidemic can be better managed with the knowledge of functional capacity and the physiological behavior of the cervical muscles. With pain, the force generating capacity of the cervical region may be compromised. It has been shown that the cervical strength in the chronic neck patients was significantly lower than that of age matched controls for both flexion and extension [14]. In this study, we found that the cervical strength at three levels of contractions (20% MVC, pain threshold/60% MVC and pain tolerance/MVC) were significantly different between patients and controls ($p < 0.05$). This could largely be due to pain mediated weakness among chronic neck pain patients. As such, the magnitude of contractions was not strictly comparable between chronic neck pain patients. However, the significant differences in strength for pain tolerance/MVC levels of contractions agree with the findings previously published [14]. Whether a higher level of contraction

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**Figure 6.** Sample plot of the EMG for RSCM, LSCM, RSPL, LSPL, RTRP and LTRP for patients and controls for pain threshold/60% MVC in flexion.
required to engender pain sensation at pain threshold level was due to chronicity of the pain cannot be established by this study. It is, however, noteworthy that in levels of effort exerted by patients and controls at 20% MVC and pain tolerance/MVC were comparable and hence the results obtained are also comparable.

The cervical spine is a mechanical structure which has both, strength and flexibility. It has been suggested that the biomechanics of the spinal movement is affected by abnormal patterns of muscle activity which could result in mechanically induced pain. Abnormal patterns of muscle activity during spinal movement may also predispose the spine to an unstable state and therefore result in abnormal loading causing neuromuscular dysfunction resulting in pain [15,16]. Asymmetry of muscle activity has also been assigned as a cause of pain development. Asymmetry of muscle activity can occur and thereby it may decrease or increase activity compared to normal symmetrical response. The decreased activity is attributed to the reflex inhibition and the increased activity has been attributed to muscle spasm which would prevent painful movement [17].

The sample plots of EMG of the six cervical muscles for flexion shown in Figures 5–7 clearly demonstrate a significantly different pattern and magnitude of activity between patients and controls. In this patient sample high EMG amplitude indicates to the fact that there may be hypersensitivity [17]. This has been assigned as muscle spasm which would prevent painful movements [17,18]. A presence of such a pattern in 20% MVC, pain threshold/60% MVC and in MVC/pain tolerance contractions remained unchanged indicating a possible presence of spasm.

Significant differences in normalised peak EMG were reported in 20% MVC, pain threshold/60% MVC and pain tolerance/MVC contractions. However, there were more muscles which were showing significant differences in the 20% MVC and pain threshold/60% MVC contraction. In these, the left and right sternocleidomastoids in both males and females were significantly different in patients as
compared to controls for all five contractions (flexion, left antero-lateral flexion, left lateral flexion, left postero-lateral extension and extension). The splenius capitis muscle was found to be significantly different for flexion, left antero-lateral flexion and left lateral flexion. It would clearly appear that the role of the sternocleidomastoids is a dominant one. In all flexion activities, symmetrical or asymmetrical, sternocleidomastoids were the major flexor muscles and they had to balance the mechanics of the neck as agonists, synergists or antagonists. In extensor activities, as one would expect, that the trapezius muscle were significantly different in patients as compared to the controls. It would, therefore, appear that when pain threshold contractions are compared with the sub-maximal 60% MVC contraction of normal controls, there is a significant difference and can be used as a useful classifier. This observation is also supported by the findings of Sohn et al. [19] who reported a significant increase in the twitch amplitude as a result of experimental pain induced by injection of 0.2 ml Capsaicin (\(p < 0.05\)) without changes to half relaxation time and contraction time. They also reported no significant changes to single motor unit twitch properties. They suggested twitch force may be a passive compensation mechanism to maintain constant force output in painful muscles. Others [20] have demonstrated that in repeated contractions of shoulder muscles there was a shift in the mean frequency of the surface EMG that was greater in patients than in controls. However, no repetitive contractions were studied in this study.

No significant difference between the median frequency of the cervical muscles between patients and controls indicates that they had insignificant changes in the conduction velocity of the muscles. However, when Levene’s test for equality of variances was conducted for spectral power at 10% of bandwidth of the muscles the sternocleidomastoids had significantly different power in left and right sternocleidomastoids for flexion and left antero-lateral flexion. The left trapezius muscle had significantly different power between patients and controls for left postero-lateral extension and extension. This clearly indicates that the prime mover muscles demonstrated clear power differences between patients and controls in activities specific to their functions.

An accurate classification of patients and controls with cross-validation method at 20% MVC, and with both methods (re-substitution and cross-validation) at pain threshold/60% MVC contractions suggests that at lower levels of contraction there is a greater discriminatability between these groups using the technique employed. It is conceivable that at the initiation of contraction and at lower magnitudes of contraction the decomposed components of wavelets show a higher level of differentiation, perhaps due to the spasmodic nature of the muscles in patients. As the level of contraction increases the subtle differences between the signals of muscles of patients and controls become smaller in proportion to the overall magnitude of the signals or get submerged and hence less discriminatory. However, a high level of discrimination between patients and controls at two levels of contraction is valuable and potentially clinically useful. Such techniques could assist in localizing pain by identifying muscles with altered characteristics. Also, a future study can explore if relief in pain begins to reverse these EMG changes. Such approach can be used to determine efficacy of treatments. Additionally, it is also possible that this methodology may be able to differentiate between psychogenic and physical pain, and thereby assist in strategy for treatment selection.

**Limitations**

The limitations of the study are that the findings apply only to patients with non-specific idiopathic...
neck-pain. Thus, the effect of specific pathologies can not be inferred from the data presented. The data relates only to the muscles identified and activities studied. Also, these findings relate only to patients with chronic neck pain lasting for 3 months or more.

Conclusions

The patients of neck pain demonstrate lower muscle strength than normal controls. The EMG responses in patients are pronounced in some muscles than those of controls. The median frequency of EMG does not vary between patients and controls indicating no difference in conduction velocity of muscles. A frequency banding of EMG at 10% bandwidth to determine differential power of the prime muscles in appropriate motion frequently differentiated between patients and controls by demonstrating significant differences between these groups. The time series data obtained from wavelet analysis decomposition demonstrated a perfect differentiation between patients and controls at 20% MVC when analysed by cross-validation method. The patients were also identified as such at pain threshold contraction using either method though controls were miss-classified as patients 10% of the time. The classification of patients and controls at pain tolerance/maximum voluntary contraction deteriorated significantly leading to a correct identification of patients between 59.3% and 67.7% of times. Thus using described methodology for analysis of EMG signals at 20% MVC using cross validation method can be used to differentiate between patients and controls.

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