EMG analysis of facial muscles exercise using oral cavity rehabilitative device

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***Abstract* - This study presents the analysis of surface electromyography (sEMG) of facial muscles in different age categories. The analysis was evaluated when the subjects performed the gripping oral exercise device in a static contraction. The sEMG measurements were taken at four positions; Orbicularis Oris Superiors Left (OOSL) and Right (OOSR), Orbicularis Oris Inferiors Left (OOIL) and Right (OOIR) using TeleMyo2400T. There are only 4 female subjects participated in the study which is divided into 2 Groups: Groups 1 and 2 with mean age of 47.5 and 23 years old, respectively. The findings indicate that the mean and median frequencies of sEMG activity recorded from both left and right of OOS and OOI muscles showed decreasing trend from the beginning until the end of the static contraction sessions. The power spectral density of sEMG signal on those muscles for both groups is in the range of 19 to 45 Hz.**

I. INTRODUCTION

Mean Frequency (MF) and Median Frequency (MdF) appear to be one of the useful parameter in evaluating fatigue exercise of facial muscle. The central tendencies of the electromyography (EMG) power spectrum can serve this purpose as a measurable parameter. It has been well known that the EMG power spectrum declines to a lower frequency domain during pro-longed static contraction [1]. This frequency decline can be interpreted as a sign of localized muscle fatigue and can be objectively measured by surface electromyography (sEMG) power spectrum statistics: the MF and MdF [2]. The mean power frequency is the average of all considerable frequencies. The median power frequency is the frequency where the spectrum is divided in two parts of equal power [3]. The development of localized muscle fatigue can be measured by the collected EMG sig-nal of the power spectrum [4-6].

The power spectrum analysis utilizes the frequency do-main processing for information content. The Fourier trans-form procedure is used to transform the time domain sEMG signals into the frequency domain data [7]. With a static muscle contraction, the low frequency components of the signal gradually increase while the high frequency components decrease. It was suggested the combination of synchronization and desynchronization of motor unit firing as a possible cause of frequency shift [8].

The spectral density of the sEMG signal will give the power carried by the signal, usually per unit frequency. This is then known as the Power Spectral Density (PSD) of the signal. The sEMG signal detected during a muscle contraction is a random, non-stationary signal. It should be noted that when estimating the PSD of a random signal, the muscle is assumed to be stationary over the analysis time window. Thus, the EMG signal is effectively considered quasi-stationary, which makes the selection of the epoch length an issue that requires careful investigation. The energy content is the mean value of energy spectral density on time do-main. The energy spectral density is referred to PSD.

This study proposes four different types of signal processing techniques to analyze the of sEMG of OOS and OOI in a fatiguing static contraction such MF, MdF, PSD and energy contents in different age categories.

II. SUBJECTS AND METHODS

A. Subjects

There are only 4 female subjects participated in the study which are divided into 2 groups according to their age category. Groups 1 and 2 consist of mean age of 47.5 and 23 years old, respectively. The subjects are healthy without functional disturbances or pain complaints in jaw, face, and head region, and with natural dentition. They were given an oral rehabilitative device (Patakara® LIP Trainer) and were asked to grip the oral device in a static contraction.

B. Measurement of EMG signal

Alcohol swap was used to removes makeup and dirt for a clean area of suction and the sEMG measurement were conducted in the sitting position. The main criterion for determining the recording sites was to maximize the distance to adjacent muscles (to reduce crosstalk), the locations of the innervations zones could not be considered in electrode positioning, because the facial motor units have neuromuscular junctions distributed over the whole muscle in several oval-shaped zones. The electrodes are positioned as close as possible to the vermillion border (due to the size of the double-adhesive tape used for attachment, there was a minimal distance of 1cm between the electrode center and the vermillion border). The medial electrodes are 18mm from the facial midline and then mark 8 positions on the face of subject [9].

After mark the positions, attach the electrodes which are cut to small size (10mm) and then connect to pre-amplifier wires, fixed as surgical tape. The subject is observed them-selves in a recorded monitor from video camera; the monitor

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size was same scale [10]. The subject gripped fully through the camera observing, start to record the sEMG from each muscle using EMG device the TeleMyo2400T. The recording time is sixty seconds; the measurement was taken three times.

C. Signal processing of EMG

The frequency analysis or spectral analysis includes some analysis methods such as mean frequency (MF), median frequency (MdF), power spectral density (PSD) distribution and energy contents. Because the sEMG signal is actually a summation of muap, some close and some distant from the recording electrodes, it is difficult to know which motor units contribute to it. Two different algorithms were implemented for the estimation of: the MF and the MdF. The calculations for the MF and MdF are based on the following formulas respectively [11].

$$MF=\frac{\sum_{i=1}^{M} f_i P_i}{\sum_{i=1}^{M} P_i} \quad (1)$$

$$\sum_{i=1}^{MdF} P_i = \sum_{i=MdF}^{M} P_i = \frac{1}{2}\sum_{i=1}^{M} P_i \quad (2)$$

Where Pi is the i-th line of the PSD and M is the highest harmonic considered. The spectral estimation was per-formed by the periodogram method. Each signal was divided into overlapping windows of fixed length fixed length and the PSD for every epoch was estimated. MF and MdF were then derived for each epoch from the corresponding PSDs. Energy content is the mean value of energy spectral density. Energy spectral density has the relationship with power spectral density. The relationship is known as Parseval's theorem for Fourier transform.

Two periods (beginning and end) of approximate 11.6 seconds and three periods (middle 1, 2, 3) 12.3 seconds sEMG recording were used for analysis after calculating mean value of 3 times measurement on time domain per each subject . The beginning and end (middle) periods are divided into 17(18) samples record of 0.6827s, which were bandpass filtered (6th ordered, 5 to 200 Hz) and notch filtered (50Hz; ambient noise), digitized sampling rate is 1024 Hz, tapered with a hamming window of each sampling period (1024 data) of the record and subjected to power spectral analysis by means of a fast Fourier transform. Power spectra were computed in the frequency range 0 -1024 Hz, with resolution bandwidth of 1 Hz, so that each spectrum contained 1024 estimates. The seventeen and eighteen spectra were averaged to compute MF and MdF. This procedure used Matlab for data collection, signal processing, calculating and graphical tool of EMG system

D. EMG Statistical Analysis

A nonparametric Wilcoxon test was conducted using SPSS version 13 for Window XP. The test was used to determine the MF and MdF decreasing trend differ significantly on the OOS and OOI muscles during the fatigue static contraction

III. RESULTS AND DISCUSSIONS

A. MF and power spectra in static contraction

The MF and MdF (□Sd) values of the fatigue static contraction for Groups 1 and 2 are summarized in Tables 1 and 2, respectively.

Table 1. MF (MdF) static contraction values for Group 1

Time,s	**OOS**		**OOI**	
	Left	**Right**	**Left**	**Right**
0-11	97.9 ±9.7 (45.8 ±0.4)	102.9 ±2.6 (47.9 ±11.1)	102.8 ±12.1 (49.2 ±4.2)	100.5 ±8.2 (48.8 ±3.9)
12-23	94.7 ±10.1 (42.5 ±0.1)	100.4 ±1.5 (47.4 ±10.6)	99.2 ±12.7 (45.7 ±1.6)	96.2 ±10.2 (45.7 ±0.4)
24-36	91.6 ±9.8 (39.5 ±1.8)	96.5 ±1.2 (43.6 ±7.6)	96.4 ±13.8 (42.2 ±0.4)	92.9 ±11.7 (42.2 ±2.3)
37-48	90.1 ±8.8 (37.1 ±2.8)	95.1 ±0.2 (43.2 ±8.1)	93.4 ±14.1 (39.3 ±2.3)	89.7 ±12.9 (39.3 ±3.9)
49-60	84.8 ±11.4 (35.2 ±5.4)	92.5 ±1.9 (40.3 ±4.6)	93.3 ±10.8 (38.1 ±1.6)	89.6 ±8.6 (39.0 ±3.7)

Wilcoxon test showed that there was significance decreasing trend ($p < 0.5$) for the MF (MdF) of the OOS and OOI muscles in both groups, beginning and at the end of the static contraction.

In a fatiguing static contraction, the muscle of PSD varied. The frequency characteristic of the beginning period is different from the end of the period. Fig. 1 shows an example of the change of power spectra distribution

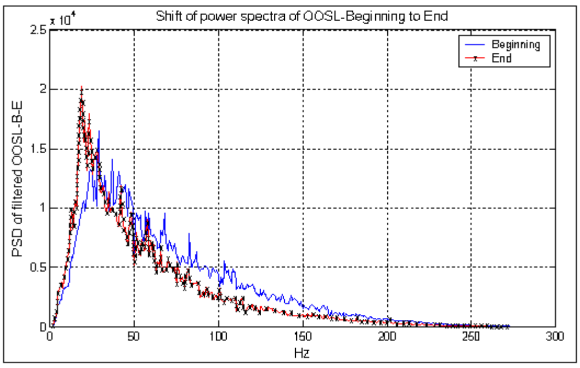

Fig. 1. Change of power spectra distribution of OOSL muscle

Table 2. MF (MdF) static contraction values for Group 2

Time,s	OOS		OOI	
	Left	Right	Left	Right
0-11	97.9 ±9.7 (45.8 ±0.4)	102.9 ±2.6 (47.9 ±11.1)	102.8 ±12.1 (49.2 ±4.2)	100.5 ±8.2 (48.8 ±3.9)
12-23	94.7 ±10.1 (42.5 ±0.1)	100.4 ±1.5 (47.4 ±10.6)	99.2 ±12.7 (45.7 ±1.6)	96.2 ±10.2 (45.7 ±0.4)
24-36	91.6 ±9.8 (39.5 ±1.8)	96.5 ±1.2 (43.6 ±7.6)	96.4 ±13.8 (42.2 ±0.4)	92.9 ±11.7 (42.2 ±2.3)
37-48	90.1 ±8.8 (37.1 ±2.8)	95.1 ±0.2 (43.2 ±8.1)	93.4 ±14.1 (39.3 ±2.3)	89.7 ±12.9 (39.3 ±3.9)
49-60	84.8 ±11.4 (35.2 ±5.4)	92.5 ±1.9 (40.3 ±4.6)	93.3 ±10.8 (38.1 ±1.6)	89.6 ±8.6 (39.0 ±3.7)

The change in spectral shape found during fatigue seems for the major part to be determined by change in propagation velocity. MF and MdF were shown to be a good index of these changes, confirming earlier study [12].The MF and MdF of the OOS and OOI were decreased to a lower domain in a fatiguing static contraction. The results present the MF (or MdF) of Group 1 was decreased with a mean of 9.90 Hz (11.10 Hz) for the OOS, and 11.48 Hz (11.05 Hz) for the OOI muscles. The MF (or MdF) of Group 2 was decreased with a mean of 11.48 Hz (9.08 Hz) for the OOS, and 10.26 Hz (10.43 Hz) for the OOI

B. PSD and Energy contents

The window of PSD distribution represents the dominant region of the electromyography. Fig. 2 shows the dominant region of first group during 60 seconds is 26 to 45 Hz, while Group 2 region (19 to 35 Hz) is shown in Fig. 3. The energy content shows that each muscle has how many strength during the same period. The values (mean ± Sd) are shown in Table 3. OOIR and OOIL values are higher than OOSL and OOSR values in the first group. OOIR and OOSL values are higher than OOSR and OOSI values in Group 2.

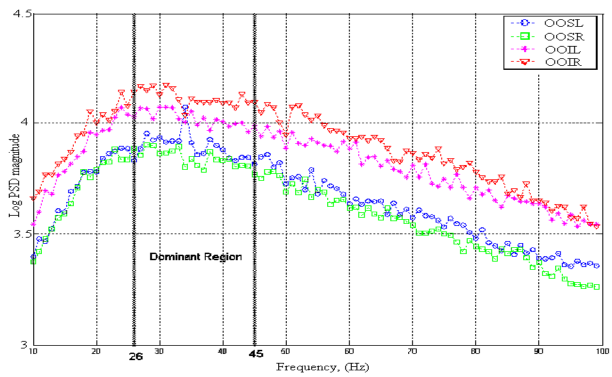

Fig. 2. EMG PSD distribution in Group 1

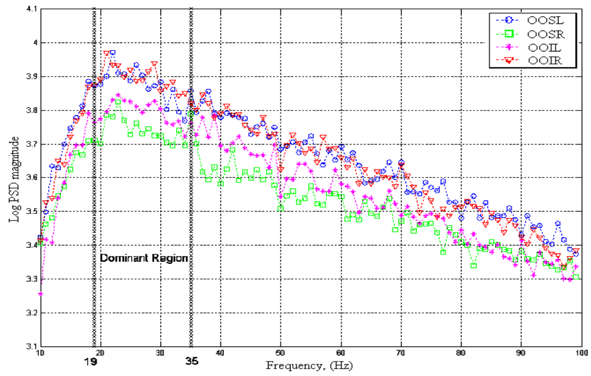

Fig 3. EMG PSD distribution in Group 2

IV. Conclusion and Future work

PSD of OOS and OOI muscles showed frequency shape changes from the beginning until the end period of the static contraction. The MF and MdF of OOS and OOI muscles investigated showed a decreasing trend in the OOS and OOI muscles in the fatigue static contraction. This study justified the use of MF and MdF as reliable and valid fatigue indicators which may be added to the examination test and measures for physical therapy practice. The PSD and energy contents represented the strength of each muscle on frequency and time domain.

Further work is to evaluate the decline differences in MF and MdF value during static contraction before and after using oral cavity rehabilitative device for the duration of 3 months period.

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