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Role of Sternomastoid in Chronic Obstructive Pulmonary Disease-A

KEYWORDS: COPD, Sternomastoid muscle, Power Spectral Density, Electromyography.

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ABSTRACT *Chronic obstructive pulmonary disease (COPD) is fourth leading cause of death all over the world. Half a million people die every year due to COPD in India. COPD is confirmed by a simple diagnostic test called spirometry. It is has some limitations.Physiologically accurate and easy to perform method is needed to find severity of COPD.In COPD accessory muscles of respiration sternomastoid (SMM) and scalene are recruited. The aim of this paper is to survey papers which correlate COPD with SMM activity, finding out the best technique of signal processing to analyze frequency shifts and amplitude changes in EMG signals, finding effect of pulmonary rehabilitation training on SMM.*

I Introduction:

Chronic obstructive pulmonary disease (COPD), a common, preventable and treatable disease, is characterized by persistent airflow limitation that is usually progressive and associated with an enhanced chronic inflammatory response in the airways and the lung to noxious particles or gases[1]. A Common risk factor for COPD is tobacco smoking, biomass fuel consumption, and diesel exhaust, occupational exposure to organic or inorganic dust.

COPD remains a major public health problem. Although COPD has received increasing attention from medical community recent years, it is still relatively unknown or ignored by the public as well as public health and government officials [1][24].

Muscles of respiration:

Each respiratory cycle consists of inspiration followed by expiration. Normally during quite breathing inspiration is active while expiration is passive. The Diaphragm and intercostal muscles are inspiratory muscles, active during quiet breathing, while sternomastoid (SMM) and scalene are accessory muscles of respiration and recruited during rigorous activity [23]. Patients with COPD increasingly need to use their inspiratory accessory muscles like SMM even during quiet breathing.

Electromyography:

To study the activity of muscle electromyography is best well known technique. Electromyographical (EMG) signal is an electrical manifestation of the neuromuscular activity of muscle. It is complicated and affected by anatomy, physiology of muscle, peripheral nervous system and technique of detection [22]. The Shape of EMG depends on the orientation of recording electrode contacts with respect to active fibers. Amplitude of action potential depends on diameter of muscle fiber and distance between electrodes and recording site. Duration of action potential will be inversely proportional to conduction velocity [22]. Muscle fiber conduction velocity (v) is the propagation velocity of the depolarization along the membrane of the muscle fiber [19]. According to Lindstrom model, power spectral density (PSD) of EMG signal is [13].

$$S(f) = \frac{1}{v^2} G\left(\frac{fd}{v}\right) \quad \ldots\ldots\ldots\ldots\ldots\text{eq-1}$$

Where: f is frequency.

d is the distance between the bipolar electrodes.

$G\left(\frac{fd}{v}\right)$ Indicates, spectrum shape.

Power Spectral density of EMG signal undergoes shift in frequency because of a shift in conduction velocity. Conduction velocity is associated with muscle activity and localized muscle fatigue. As muscle fatigue, frequency of firing decrease (mean and median frequency decreases)[21]. Alterations in amplitude and Frequency are found depending on level of muscle contraction. EMG can be analyzed in time and frequency domain. There are two basic techniques to acquire EMG, non-invasive and invasive.

C. EMG Analysis:

EMG can be analyzed in time and frequency domain. Time domain techniques are: Envelope detection – gives onset and duration of muscle activity, Integration – provide relative myoelectrical activity over a set of time period. Root Mean square – provides instantaneous measure of power output. Every method gives different information related to muscle activity. Some Frequency domain Techniques are: Mean and Median frequency: With Fast Fourier Transform it is possible to find mean and median frequency, but detail analysis cannot be done as an EMG signal is non-stationary. Auto Regressive (AR): This method finds power spectral density of EMG signal applying local stationary principal over small window. Mananas [19] have done analysis at N=40. But Mohammadreza [21] suggested that same results can obtained with value of N=10. Average Instantaneous frequency: Georgakis [18] has concluded that Average Instantaneous frequency does not require any quasi-stationary assumption. It can be applied for non-stationary signals. Provide less variance compare to mean and median frequency, but can be used only in sustained contractions. Wavelet Transform: Wavelet transforms analyze non-periodic and non-stationary signals. Signal

Volume : 5 | Issue : 7 | July 2015 | ISSN - 2249-555X

values are weighted with wavelet function. Reaz [22] says that currently wavelet transform is a good technique to analyze EMG.

Researchers have collected EMG signal from SMM muscle, analyzed it in time and frequency domain and correlated the activity of SMM with COPD.

II Survey of work done:

In 1984, Wilson[6] has studied SMM function and fatigue in normal subjects and patients with COPD. They have selected 4 normal and 5 COPD (FEV1, 1.03L) subjects, acquired EMG of before and after 5 minutes. After 12 minutes of walk on treadmill. They used two protocols i) progressive exercise test, 10 minutes of sustained maximal volumetry ventilation. They have observed that high sustained levels of ventilation cause SMM low frequency fatigue. Peche R [7] in 1996 studied SMM size and strength in patients with COPD . They have measured the cross-sectional area of SMM by computed tomography of ten COPD subjects of same age , sex and height. Cross sectional area of SMM in COPD was 4.29±1.48 cm^2 and control subjects was 3.96±0.82 cm^2. They concluded that this small difference can be accounted by hyperinflation and not statically significant, therefore SMM should be essentially normal with severe COPD. But they state that frequent prominence on clinical examination is apparent.

In the Study of Myographic Signals from SMM in Patients with Chronic Obstructive Pulmonary Disease, done by Miguel Angel Mañanas, et al, in May 2000, has done an analysis of EMG, Vibromyographic (VMG) of SMM muscle to detect the severity of COPD. They have selected six COPD patients. They have applied two protocols to detect signals i) Maintained ii) Incremental. They have used non-invasive technique to capture EMG and VMG. The Activity of SMM was found by means of several indexes: root-mean-square (rms) values, mean frequency, median frequencies and ratio between high and low-frequency components. In order to do analysis in frequency domain they have used some parametric and non-parametric methods to estimate power spectral density. Influence of a spectral estimator of frequency parameters is studied refer figure 1 and identified that an Auto Regressive (AR) model with high order 40 is more suitable to study variations in EMG at certain moments of the test in EMG signal(refer figure 1).

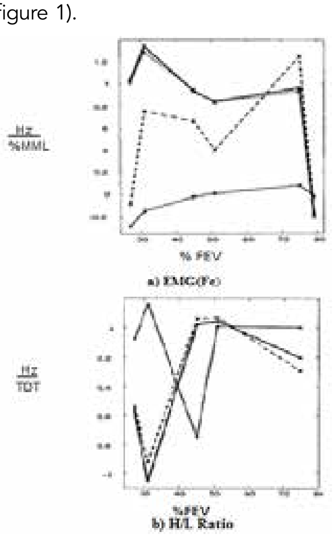

Figure 1: fc slopes and H/L ratio plotted against FEV1. (AR (40) (continuous, bold), MA (4) (continuous), ARMA (4, 2) (dashed), and correlogram with the Hanning window (dotted)[4].

In their study they have concluded that there is relation between SMM muscle function and severity of COPD. As well as the results are dependent on the spectral estimator technique [4] and suggested that, more study should be done on large number of subjects to confirm results. One of major limitation of his study is that EMG signal is non periodic and non-stationary so stationary analysis should be done and result varies with Power spectral density estimation method.

Anna L. Hudsonet al hasfoundlung volume effect on the recruitmentof scalene and SMM muscles. Intramuscular EMG of scalene and SMM muscles recorded for 7 subjects, with EMG oesophageal pressure is recorded while performing inspiratory ramps upto maximal inspiratory pressure (MIP) and dynamic inspirations from functional residual capacity (FRC) to total lung capacity (TLC). Inspiratory ramps procedure was repeated at three lung volumes: FRC, FRC + tidal volume, and TLC. To find activation of muscle during inspiratory cycle, root mean square (rms) values are calculated. Results shows recruitment of scalene was earlier compare to SMM. Scalene has reached only up to 80% of its MIP weather SMM increase from 20 to 100% MIP as shown in figure 2.

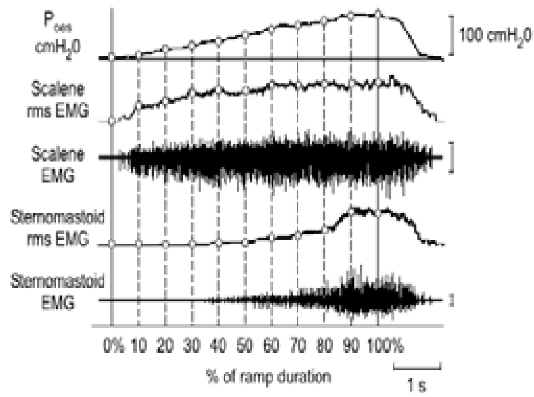

Figure 2: Esophageal Pressure, Intramuscular EMG and their rms values[4]

Irrespective of initial lune volume, the ratio of rms value of EMG of SMM to scalene was same. Similar stereotypical profiles has observed scalene and SMM during dynamic inspiration [10]. They have suggested that for certain volumes, Depending on the mechanical advantage SMM and Scalene are recruited. If there is feedback for changes in lung volume both muscles do not change their activation.

Dornelas de Andrade in 2005evaluated that the activity of diaphragm and the SMM muscle with a 30% Threshold load in 7 healthy and 7 COPD patients [11]. EMG is acquired using surface electromyography (SEMG) during preloading, loading and post loading. Analysis is done using root mean square value. Refer figure 3. Good correlation has found with obstruction level with correlation factor of r=-0.5370.

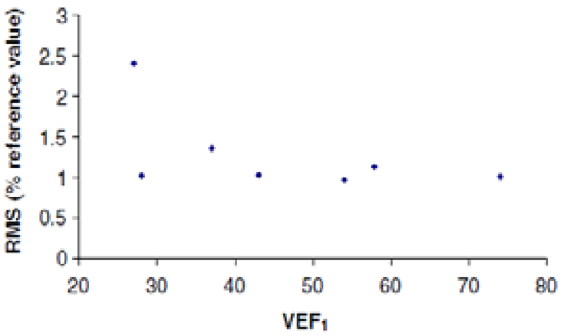

Figure 3: Correlation between RMS value of SMM activity during loading and VEF1 in patients with COPD [11].

They observed that, to overcome the threshold load there is increase in activity of inspiratory muscle. In COPD patients, there is need of excess work respiration; accessory muscles like SMM get activated. As obstruction level increases activation level of accessory muscles increases. Result shows no significant correlation between activation levels and maximum inspiratory pressure has found. This paper suggests that, while planning for inspiratory muscles training for COPD patients, obstruction level and accessory muscular activity should be taken into account.

In 2010 D. Kobayash [12] investigated tissue oxygen saturation ( ) measured using tissue oxymeter at SMM during deep inspiration, breath holding and then relax.In patients with COPD during the repeated deep breathing ( ) of sternomastoid muscle significantly decreased from the baseline (63.2 ± 3.8%) to the minimum (55.2±5.4%). Similar decrease has also observed in healthy subjects. After final deep breathing, time to recover 50% recovery for SMM towards baseline was longer in patients with COPD than healthy patient.

Effect of breathing pattern is studied by Ki-song Kim [13] for different sitting posters. They have studied tidal volume (TV), respiratory rate (RR), activity of accessory muscles. They conduct study on 12 male COPD patients. Inductive respiratory plethysmography and surface electromyography are used to measure TV, RR and muscle activity of SMM, scalene and pectoralis muscle. These signals are acquired for two types of breathing pattern, quiet natural breathing (QB) and pursed-lips breathing (PLB) for three sitting posters (neutral position (NP), with arm support (WAS), and with arm and head support (WAHS)). After comparing breathing pattern he observed that for PLB muscle activity for SMM and scalene has increased compare to QB, so favorable breathing pattern is observed for PLB. He concludes that, during pulmonary rehabilitation program accessory muscles such as SMM and scalene can studied for COPD patients.

Diogo F. Bordin et al (2014) [14] proposes inspiratory muscle training of diaphragm and SMM muscle for improving breathing pattern and handgrip strength. 45 individuals were divided into three groups (COPD Participating in Pulmonary rehabilitation program (PR), COPD does not participate in PR program, control group (healthy individuals)). SEMG of SMM and diaphragm, lung volume and breathing pattern is studied before and after 8 week of training. This study is currently going on with hypothesis that TMI in COPD patients participating in a program RP produces greater increase in MIP< handgrip strength, improves breathing pattern and reduction in activity of SMM and diaphragm in group who have participated in PR program than those who have not participated.

M. Schmidt et al in 2014 [15] in studied activity of scalene, SMM, and genioglossus using Surface EMG of inspiratory muscles in the intensive care unit for 26 patients.

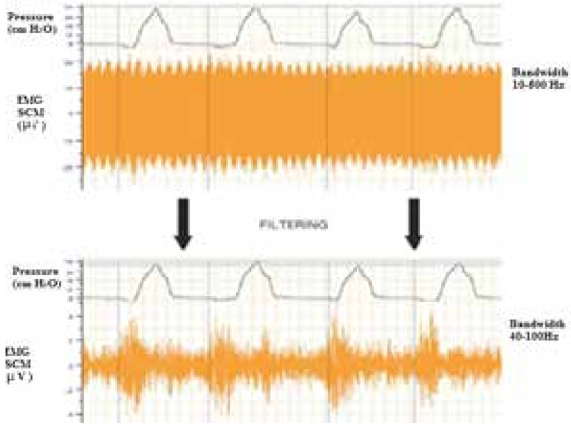

Figure 4: Sternocleidomastoid EMG signals filtering for different bandwidth [15].

Inspiratory time locked analysis is done for the signals collected from accessory muscles of respiration. Signals amplified and converted into digital form at 10 kHz, divided into inspiratory time locked epochs and averaged. (Refer figure 4). Results shows appearance and dis-appearance of inspiration activity and electromechanical inspiratory delay (time from EMG onset to inspiratory flow onset)[11]. Phasic EMG activity of SMM is detected in 19 patients while no identification of EMG activity at scalene electrodes and SMM electrodes by 31% and 27% of the patients respectively.

Mariana Alves Coutinho Myrrha et al in 2013 studied [13], chest wall volume and breathing pattern of COPD patients. They have selected 13 male patients of COPD and observed SMM and abdominal muscle activity during rest and during inspiratory loaded breathing (ILB). Activity of SMM has increased by 63.84% and that of abdominal muscle has increased by 1.94% during Inspiratory load breathing pattern. No such increase has found for quiet breathing. COPD patients are increasing their tidal volume by increasing chest wall volume to defeat the load created by ILB. He suggested that SMM muscle activation is there for COPD patients to overcome the load. For increase of 30% MIP during ILB RMS value of SMM muscle increases (p = 0.04), while diaphragm activity remain constant.

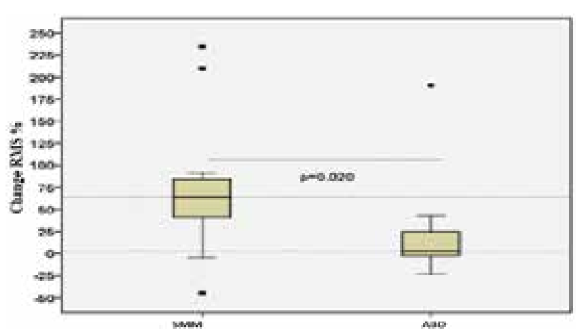

Figure 5: Change (%) in rms value during load for SMM and abdominal muscles.[13].

Volume : 5 | Issue : 7 | July 2015 | ISSN - 2249-555X

Dannuey Cardoso et al (2012) [15], has observed the effect of positive expiratory pressure (EPAP) on EMG activity of SMM and Parasternal muscles in COPD patients. He included 21 stable COPD and observed effect of 10 and 15 cm O on actvity on SMM and parasternal muscle in stable COPD Patients.EMG activity evaluated for spontaneous breathing, during application of EPAP. They concluded that application of Oreduced EMG activity in SMM and increases parasternal muscle activity. This can be used to reverse the use of chest wall muscles and reduce mechanical disadvantage in patients with COPD.

III Discussion and Conclusion:

It is needed to find easy to perform and physiologically accurate method to access pulmonary mechanism in COPD patients. By study accessory muscle such as SMM activity can contribute to get more information related to pulmonary mechanics in COPD patients. Acquiring EMG of SMM with less interference by other muscles is difficult and should be carefully done by technician. Electromagnetic interference induced while collection of signals should be handled carefully. Table summarize of method of analysis of SMMin COPD patients by many people.

Table 1: Comparison of Methods, used for correlating COPD and SMM.

Ref. No.	Methodology	No. of Subjects	Limitations
2	SEMG-rms	7	Time domain analysis, stable COPD,Similar Age
3	By tissue Oxymeter, STO2	5	Similar Age, Stable COPD,
4	Tidal volume at rest and during ILB,SEMG-rms	13(male)	Time domain analysis stable COPD,Similar Age
6	10 and 15cm H2O, EPAP mask, SEMG-rms	21	No Breathing protocol, Stable COPD
12	SEMG-phasic, Ventilatory flow	8	Time domain analysis, stable COPD,Similar Age
13	SEMG-Power Spectral Density(PSD)	6	Result varies with PSD estimation method
16	For IMT: SEMG-rms, Inspiratory pressure	Going on, (uptill 45)	Time domain analysis, stable COPD,Similar Age
17	Pursed-lips breathing, variance in tidal volume and respiratory rate	12 (male)	Time domain analysis, stable COPD, Similar Age and sex.

By observing table we can conclude that, most of papers has done EMG analysis in time domain, only Mañanas[19] has used frequency domain technique for EMG analysis, but concluded with PSD changes with PSD estimation method. Lot of scope is there to find Correlation of COPD with SMM, if some advance frequency domain techniques are used for analysis.

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