Sleep scoring system and its classification by using EMG signals – A review

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ABSTRACT
Proper analysis of sleep scoring system and its stages can give clinical information on diagnostic patients with sleep disorders. Since, manual sleep stage classification is a tedious process that takes a lot of time to sleep experts performing data analysis on this field. Moreover errors and inconsistencies between classifications of same data are frequent. Due to this, there is a great need of automatic classification system to support reliable classification. Automatic schemes based on EMG (Electromyography signals) analysis are discussed in order to understand the problem associated with sleep scoring and its stages. EMG is an electro diagnostic medicine technique for evaluating and recording of the electrical activity produced by skeletal muscles. EMG is performed using an instrument called electromyograph to produce record called electromyogram. These signals can be utilized to detect medical abnormalities, activation level or to analyze the biomechanics of human movement. This review provides an overview in using biomedical signal that is EMG signal for the sleep analysis.

Keywords: *Sleep scoring system, Sleep Stage Classification, EMG Signals*

1. INTRODUCTION

a. Sleep and sleep scoring

Sleep is an essential element for an individual's well-being and is considered vital for the overall mental and physical heath of a person. Sleep is a state in which the physical and mental functions of a human being are in a state of a pause, as well as various external stimulations do not affect the individuals which is in the resting state **[1].** Thus sleep can be considered as a virtual detachment of an individual from his environment. In normal humans, about 30% of their life-time is spent for sleep. The concept of sleep is considered to be highly mysterious and a topic of discussion and research interest since ages and it has fascinated the researchers all over the world **[2].**

Prolonged sleep disorders or a continuing sleep insufficiency invites various diseases of heart, kidney, etc and increases the risk of contracting long term passive diseases like diabetes, high blood pressure as well as stroke in extreme cases. These are a source of discomfort and distress to the individual experiencing them such as insomnia, sleep walking, narcolepsy and nocturnal breathing disorders and hence, they need to be treated **[3].**

Sleep scoring is an important aspect in the field of sleeps research as well as sleep medicine. Classically, for years together, the sleep scoring has been under taken by the examination and visual inspection of polysomnograms (PSG) done by a sleep specialist **[4].** Here, PSG is specialty test, the conduction of which includes the recording of various physiological signals like Electrooculerogram (EOG): the records of eye movements both for left and right eyes, Electroencephalograph (EEG):a measure of well known brain waves generated by cortex and other integrative processing mechanism, Respiration, Electromyogram (EMG):the record of electrical activity that emanates from active muscles and pulse Oximetry. All of these signals when recorded for a short period of time called epoch and analyzed indicate different stages of sleep **[5].**

b. Sleep Stage Classification

The Rechtschaffen and Kales manual for normal sleep classifies the epochs and scores them as waking, Rapid Eye Movement (REM), Non-Rapid Eye Movement (NREM) as the basic three stages of sleep. Further, there is a classification provided NREM four stages of sleep. These stages are scored according to the various signals recorded in that particular epoch **[6].** There are various stages of sleep as described by Rechtshaffen and Kales manual for normal sleep. These stages are defined as follows [**7**]:

- Stage 0: This stage is called the wakeful stage and is the condition of an individual when he/she prepares to sleep. Here, the body is at rest and in a relaxed state with eyes closed and the EMG of the subject may be high or in a moderate range dependent upon the muscle tension.
- Stage 1: This stage comes after some time is elapsed in stage 0 and the EMG of the subject would be lower value as compared to the previous stage.
- Stage 2: This is the progression of the subject into the condition of sleep and the EMG value further decreases as compared to the previous stages on account of reduced muscle tension.
- Stage 3: The EMG in this stage reduces due to relaxed muscles rapid eye movements are negligible in this case.
- Stage 4: This stage records a moderate EMG value and the subject may be termed asleep.

REM Stage: In this stage, the EMG demonstrates muscle tones which may be called as "Twitches" or the occasional short tones of distal muscle along with transient activities which might have arisen from blood pressure or from the heart beating frequency **[8].**

c. Electromyogaphy Signals (EMG)

Any biomedical signal is a collective of electrical signals given out by any organ and is considered as a representative of some specific physical variable which is of research interest. These biomedical signals like any electrical signal can be represented as a function of time having essential attributes like amplitude, phase, and frequency **[9].** EMG signals are unique biomedical electrical signals which manifest out of the activity of the neuro-skeletal muscles. They have been widely employed for the purpose of electro diagnostic medicine. This particular technique can be employed with the help of an instrument called an electromyography there by yielding a record known as an electromyogram. Proper analysis of the EMG signals help in the diagnostic procedures undertaken to assess the health of a motor nerves and the activities controlled by them **[10].**

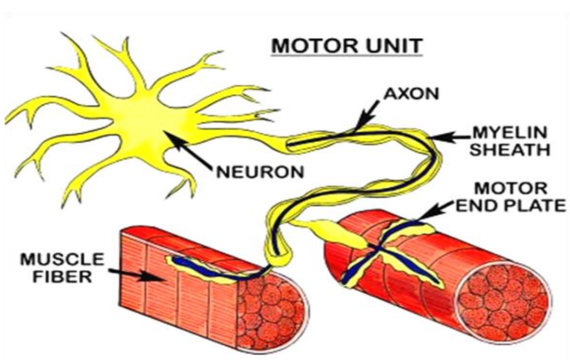

Fig.1.1 (a)

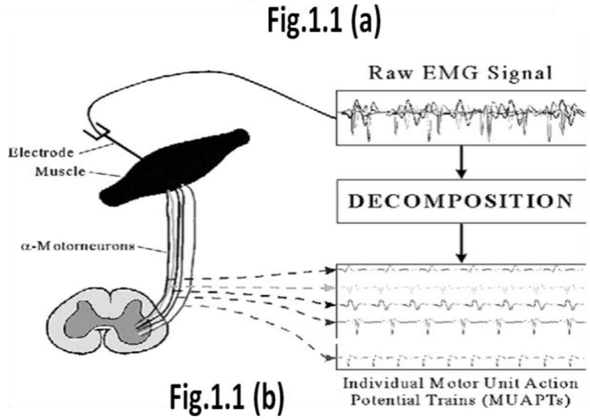

Fig1.1 (a) Presentation of Motor Unit (b) Motor Unit Action Potential

In their course of travel through organs and tissues, the EMG signals acquire noise. Usually, the

EMG signals are unique biomedical electrical signals which manifest out of the activity of the neuro-skeletal muscles like contraction, relaxation, etc **[11].** Bearing the fact in mind that all the contraction and relaxation activities of various muscles and organs are controlled by the central nervous system, it can be concluded that the EMG signals which is complex manifestation is a function of the nervous system which fully controls it and these signals are further dependent on various other properties of muscles like their anatomy and physiology **[12].**

The smallest functional unit to describe the neural control of the muscular contraction process is called a Motor Unit **[13].** It is defined as "the cell body and dendrites of a motor neuron, the multiple branches of its axon, and the muscle fibers that innervates it". The term units outlines the behavior, that all muscles fibers of a given motor unit act as one within the innervations process. This is shown in Fig.1.1 (a).

An EMG signal is the train of Motor Unit Action Potential (MUAP) showing the muscle response to neural stimulation. The process of acquiring EMG signal and the decomposition to achieve the MUAP has been shown in Fig.1.1 (b) **[14, 15].**

EMG signals are detected by an EMG detector which is isolated particularly at the surface of the skin **[16].** This EMG detector hence collects signals which originate from different motor units and could be a result of interaction of different signals which are generated at that particular time. Thus, the detection of EMG signals must be undertaken with powerful, sophisticated and advance methodologies when they are required for medical diagnostic purposes. The EMG signals which are collected from muscles involve sophisticated methods for the purpose of detection, noise, reduction and decomposition, analyses and processing, as well as classification **[17].**

HISTORIC OVERVIEW

Krausman et al. **[18]** used method and an apparatus which were disclosed for scoring the quality of sleep experienced for a specific period. This sleep monitoring apparatus includes a motion server that quantifies the temporal variation in the subject's motion, an analog to digital converter to sample the sensor data, a microprocessor with embedded programmable memory to store control and processing firmware **[19].** The firmware for this apparatus directs the microprocessor to a sample space sensor output directs the microprocessor to analyze temporarily stored data to compute a sleep score, controls the operation of display means. A high score indicates restful sleep (very low movements) while a low score indicates excessive restlessness during monitored sleep period.

Park et al. **[20]** proposed an automated method for sleep stage scoring using hybrid rule and case based reasoning. The method comprised of signal processing unit, rule based scoring unit and case based scoring unit. Authors applied this methodology to three recordings of normal sleep and three recordings of obstructive sleep apnea (OSA). Average agreement rate in normal recording was 87.5% and case based scoring showed agreement rate by 5.6% **[21].** This showed several advantages in sleep scoring: high performance on sleep disorder recordings and learning ability.

Silber et al. **[22]** have discussed the work of AASM visual scoring task force behind the new rules. Reliability studies of R and K scoring were reviewed; reliability was low for stage 1 and moderate for slow wave sleep.

Moser et al. **[23]** investigated differences between visual sleep scoring according to classification developed by Rechtschaffen and Kales (R and K) and scoring based on AASM (American Academy of Sleep Scoring). All night polysomnographic recording were scored visually according to R and K rules and AASM rules by experienced sleep scorers. Healthy subjects (38 females and 34 males) aged between 21 and 86 years were taken. While sleep latency, total sleep time, sleep efficiency were not affected by classification standard, time spent in sleep stage 1(S1/N1), stage 2(S2/N2) and slow wave sleep (S3+S4/N3) differed significantly between R and K and AASM classification **[24].**

Tagluk et al. **[25]** classified an alternate system which estimates sleep stages of human being through a multi-layer neural network that simultaneously employs EEG, EMG, EOG. The data was recorded through polysomnography device for 7 hours for each subject. A good scoring was attained through trained ANN.

Linssen et al. **[26]** have used the inter and intra individual variability of the frequency power density spectral and the surface EMG signals. Surface EMG amplitude parameters and the muscle fiber conduction velocity (MFCV) was studied in 26 healthy volunteers during fatiguing isometric ischemic intermittent exercise of the biceps brachii at 80% of the maximal voluntary contraction level, with a contraction rate of 30/min. No significant age effects were found. Males were significantly stronger.

Mambrito et al. **[27]** discussed a system for acquiring, processing and decomposing EMG signals for the purpose of extracting as many motor unit action potential (MUAP) with greatest level of accuracy. The system consisted of four sections. The first section employs signal acquisition and quality verification. The second section includes signal sampling and conditioning. The third section consists of signal decomposition technique. Thus, from these three sections motor unit action potential trains were extracted from EMG signal using highly computer assisted algorithm. It was showed that performance of system has consistency and accuracy **[28].**

Raez et al. **[29]** have used EMG signal for biomedical applications. EMG signals acquired from muscles require advanced method for detection, decomposition, processing and classification. Authors illustrated various algorithms for EMG signal analysis to provide efficient and effective ways of understanding the signal and its nature. The researchers provided a good understanding of EMG signal and its analysis procedure.

Measurement of EMG signals

EMG Signals fluctuates with time and can be utilized to control machines and frameworks. EMG signals is the electrical movement created amid the compression of a skeletal muscle.EMG measures muscle reaction or electrical action in light of a nerve's incitement of the muscle **[30].** Amid the estimation, one or all the more little needles (additionally called obtrusive anodes) are embedded through the skin into the muscle. The electrical action got by the anodes is then shown on an oscilloscope (a screen that shows electrical action as waves). EMG signals can likewise be taken by noninvasive anodes. EMG measured by non-obtrusive terminals is called surface EMG signals **[31].**A pictorial perspective of the EMG signal has been demonstrated in the Fig.1.2. After a terminal has been embedded, patient may be requested that agreement the muscle, for instance, by lifting or twisting his hand. The activity potential (size and state of the signal) that this makes on the oscilloscope gives data about the capacity of the muscle to react when the nerves are invigorated. As the muscle is contracted all the more compellingly, more muscle filaments are actuated creating activity possibilities.

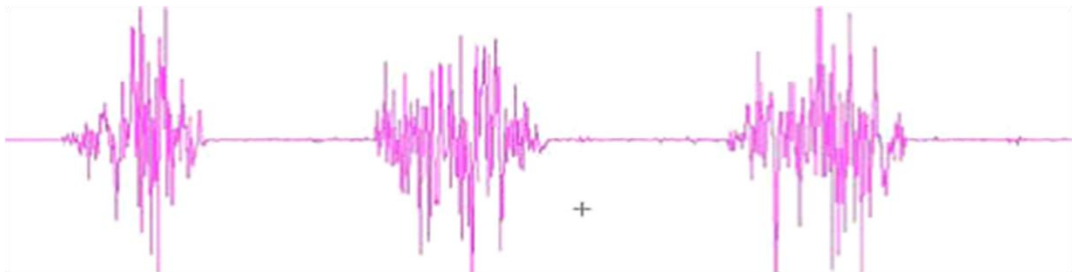

Fig.1.2 Representation of EMG Signal

The EMG signal shown in the Fig.1.2 obviously demonstrates that EMG signal is a non-stationary signal. Genuine EMG signal is extremely powerless and is exceptionally delicate to commotion. It is likewise of low adequacy. The estimation of EMG signals must be done precisely to keep it away from twisting and lapses **[32].**

Applications of EMG signals

EMG signals are extensively utilized in applications such as controlling dynamic prosthesis, wheelchairs, exoskeleton robots, restoration, quiet discourse acknowledgment, and controlling computer games as it can be measured on a human skin surface with non-intrusive electrodes **[33].** In monetarily accessible prosthetic gadgets EMG signals have been misused for a corresponding control method in which the abundance of the engine voltage or its rate and power fluctuate in direct extent to their amplitude. To enhance usage, a control technique in light of the characterization of EMG signals has been broadly concentrated. In such a system, a classifier is developed for the surface EMG signals to perceive the proposed human developments utilizing ordered developments. The EMG signal is likewise used to help in distinguishing neuromuscular variations from the norm **[34].**

Uses of EMG signals in sleep stages

The EMG signals are muscle twitch potentials that may offer additional assistance in defining a sleep stage. Their use is based on the finding that muscle activity decreases during sleep, with muscle activity at its nadir during REM sleep **[35].** In many cases, however, appreciating a decreasing muscle tone can be difficult and the relative silence during REM sleep may not be of help in distinguishing it from the preceding or subsequent sleep stages. Compounding the problem of interpreting EMG channels is intrusion of artifact into the signal. Some examples include cyclic jaw movements, teeth grinding (bruxism), or steady high-amplitude noise generated by increased pressure on an electrode (eg, as caused by lying on the chin) **[36].** Additionally, muscle artifact spilling over into cortical leads is not an unusual finding. ECG signal is a specific type of cardiac artifact that can appear in all or several channels and can be recognized by tracking the repeating QRS complex throughout the other leads. Recommended EMG technical requirements include 3 chin EMG electrodes, 2 of which are used throughout the study with an additional lead as a backup **[37].**

CONCLUSION

The study would result in an effective system for sleep scoring and its classification using Electromyography signals (EMG). These signals are very versatile and can be used for various other purposes like feature extraction, hand gesture recognition, etc. which can be researched in future. EMG signals are unique electrical signals which manifest out of the activity of the neuro-skeletal muscles. They have been widely employed for the purpose of electro diagnostic medicine.

The data for the analysis of sleep scoring and its classification would be a set of EMG signals. These signals would be collected from a sleep laboratory. Once collected the records of EMG signal, optimization technique is employed for the purpose of pattern recognition and computation which are the major purpose in the area of sleep scoring.

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