

SURFACE ELECTROMYOGRAPHY BASED ASSESSMENT OF MUSCLE FATIGUE USING TIME SERIES IMAGES AND GRAY LEVEL CO-OCCURRENCE MATRIX FEATURES

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ABSTRACT

Muscle fatigue is a major area of study in biomechanics. Non-linear dynamical analysis of surface electromyography (sEMG) signals is useful in studying the changing transitions taking place in neuromuscular system. sEMG signals are complex non-linear in nature. Transformation of these signals into images is useful in studying the underlying mechanisms of muscle activities. This study aims to analyze the texture patterns of sEMG signals using fuzzy recurrence plots (FRP) and gray level co-occurrence matrix (GLCM) features during muscle fatigue condition. Dynamic sEMG signals are acquired from Biceps brachii muscle of 45 subjects. These signals are divided into ten equal parts with the first segment as non-fatigue and the final as fatigue. Gray scale FRP images are generated from all the segments. Further, GLCM parameters such as energy and entropy are extracted at angles 0°, 45°, 90° and 135° from each segment with distance parameter set as 1. The texture patterns in FRP are observed to be different for the segments during fatigue progression. Increased motor unit firing rate and synchronization resulted in high energy and reduced entropy during fatigue. Both the features exhibited large variance at 135°. Also, the extracted features are able to discriminate non-fatigue and fatigue conditions with high statistical significance ($p<0.001$). This study can be adopted for analyzing various neuromuscular diseases by incorporating complex networks and machine learning algorithms.

Keywords: Biceps brachii, surface electromyography signals, gray level co-occurrence matrix, fuzzy recurrence plots, energy, entropy.

INTRODUCTION

The influence of fatigue in neuromuscular disorders, sports mechanics and rehabilitation has led to the deep exploration of the mechanisms underlying this phenomenon. Muscle fatigue is a gradual degradation of maximum force generating capacity of muscles. Persistent fatigue may result in permanent muscular damage[1]. It is generally analyzed in isometric movements. However, the dynamic contractions of muscle are reflected in most of the activities in everyday life. Moreover, in dynamic contractions, the signals show a high level of chaotic complexity, non-linearity, and non-stationarity[2]. There are many techniques available for the analysis of muscle fatigue like biopsy, imaging techniques like ultrasonic imaging, near infrared spectroscopy, clinical tests, and electromyography (EMG)[3].

Surface electromyography (sEMG) detects electrical signals from a larger volume of myofibers by placing electrodes on the skin surface. This characteristic makes it a potential tool in numerous fields such as muscle fatigue analysis, sports medicine, and rehabilitation[4], [5]. Neuromuscular system is highly complex and non-linear in nature. sEMG signals reproduces this nonlinearity by its complex patterns. Assessment of these signals under varied myoneural conditions can reveal non-linear dynamical behavior of the system[6].