



Review

Mechanomyography and muscle function assessment: A review of current state and prospects



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ABSTRACT

Previous studies have explored to saturation the efficacy of the conventional signal (such as electromyogram) for muscle function assessment and found its clinical impact limited. Increasing demand for reliable muscle function assessment modalities continues to prompt further investigation into other complementary alternatives. Application of mechanomyographic signal to quantify muscle performance has been proposed due to its inherent mechanical nature and ability to assess muscle function non-invasively while preserving muscular neurophysiologic information. Mechanomyogram is gaining accelerated applications in evaluating the properties of muscle under voluntary and evoked muscle contraction with prospects in clinical practices. As a complementary modality and the mechanical counterpart to electromyogram; mechanomyogram has gained significant acceptance in analysis of isometric and dynamic muscle actions. Substantial studies have also documented the effectiveness of mechanomyographic signal to assess muscle performance but none involved comprehensive appraisal of the state of the art applications with highlights on the future prospect and potential integration into the clinical practices. Motivated by the dearth of such critical review, we assessed the literature to investigate its principle of acquisition, current applications, challenges and future directions. Based on our findings, the importance of rigorous scientific and clinical validation of the signal is highlighted. It is also evident that as a robust complement to electromyogram, mechanomyographic signal may possess unprecedented potentials and further investigation will be enlightening.

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1. Introduction

1.1. Historical background

The origin of muscle sound in relation to the muscle physiologic condition could be traced to 1665 by Grimaldi (1665), who referred to the sound as “motion of animal spirits”, a formulation similar to other esoteric explanations of natural phenomena from that time (Rhatigan et al., 1986). In 1810, Wollaston was able to describe quantitatively with analogy the frequency of muscle sound within the range of 14–35 Hz (Wollaston, 1810). The characteristics of time and frequency domain analysis of the muscle sound during evoked and voluntary contraction was initiated by Oster and Jaffe (1980) and Oster (1984). They described the dominant frequency of muscle sound within 25 plus or minus 2.5 Hz. With the aid of stethoscope and microphone, the investigators verified that sound (a form of mechanomyogram (MMG)) is an intrinsic property of muscle contraction.

Rhatigan et al. (1986) and Orizio et al. (1990) in separate attempts to justify the mechanomyogram (MMG) relevance in muscle research, showed that the predominant power in MMG frequency spectrum of humans' biceps brachii under isometric contraction was within 10–22 Hz. Other investigators subsequently demonstrated that the lowest limit of frequency reported in human is approximately 2 Hz while the highest is 120 Hz (Beck et al., 2008). Consequently, MMG was validated as the complementary mechanical signal to the established electromyogram (EMG) to investigate neuromuscular activities (Stokes and Blythe, 2001) especially when noninvasive estimation of the muscle physiology underlying contraction and the fatigue phenomenon is sought (Esposito et al., 1998).

However, due to the emergence of sensitive, lightweight, inexpensive sensors, and advanced signal analysis techniques, acquisition of low frequency vibration of muscular activities in the form of MMG has been made feasible. The signal has been verified to be detectable at the skin surface during dimensional changes of active muscle fiber that generate pressure waves due to voluntary or evoked contraction and demonstrated to possess rich information of the underlying neuromuscular parameters leading to contraction and thus reliable in muscle function assessments (Orizio et al., 2003a). It has been suggested that

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