Chapter 42
Detection and Conditioning of EMG

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ABSTRACT

In this chapter, the monitoring of the electrical activity of skeletal muscles is depicted. The main components of the detection and conditioning of the EMG signals is explained in the sense of the biomedical instrumentation. But, first, a brief description of EMG generation is introduced. The hardware components of the general instrumentation system used in the acquisition of EMG signal such as amplifier, filters, analog-to-digital converter are discussed in detail. Subsequently, different types of electrodes used in different EMG techniques are mentioned. Then, various EMG signals that can be detected and monitored via EMG systems are described and their clinical importance is discussed with detail. Finally, different EMG techniques used in clinical studies and their purposes are explained with detail.

INTRODUCTION

Electromyography (EMG) is an electrophysiological technique for displaying and for assessing the electrical activity generated by the skeletal muscles. These signals are analyzed to find medical abnormalities in peripheral nervous system and muscles, or to study the biomechanics of human or animal movement. As a result, EMG is commonly used in either the diagnosis or differential diagnosis of neuromuscular disorders. As the knowledge in neurophysiology has increased, specific EMG methods have been developed in terms of the requirements of the clinical studies. With the advances in the hardware and software technology, various EMG systems, including some for electrophysiological methods such as Nerve Conductions Studies, have been manufactured. In this chapter, general principles of the instrumentation in EMG systems will be described. Then, various EMG electrode types will be introduced. Afterwards, different EMG signals and their clinical implications will be explained. Finally, different EMG techniques including not only conventional EMG used in routine examinations but also specific EMG techniques such as Single Fiber EMG, Macro EMG, Scanning EMG, Quantitative EMG and Surface EMG will be

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depicted in details. The principles of these methods, the parameters measured by these methods, their applications, their purposes in clinical use will be discussed.

BACKGROUND

Movement in the living milieu is essential for many organisms in maintaining life. The musculoskeletal system is responsible not only in achieving the movements including locomotion but also in the maintenance of the posture and in the establishment of the gestures and speech by means of the actuators referred as skeletal muscles (Pozzo, Farina, & Merletti 2004; Moritani, Stegeman & Merletti 2004). In human beings, skeletal muscle has four functions which can be explained as follows.

1. Production of body movement: In order to enable the organism to adapt rapidly to environmental changes, skeletal muscles have responsibilities for all locomotion including not only the movements playing role in displacement but also gestures and speech.
2. Maintenance of Posture: In the presence of gravity, equilibrium of the body is ensured by means of some skeletal muscles.
3. Stabilization of Joints: The joints such as shoulder and knee without complementary surface and hence with poor reinforcement can be stabilized with the help of the skeletal muscles
4. Generation of Heat: The skeletal muscles constituting 40% of body mass produce heat during their contractions which has a vital importance in maintaining normal body temperature (Marieb, 1995; Tortora, 2009; Tortora, 2010).

These functions are controlled by electrical signals transmitted from the nervous system to muscle fibers that bring about skeletal muscle contraction. (Henneberg, 2000, 2006). During the contractions the conversion of the chemical energy and electrical energy into mechanical energy takes place by the cleavage of ATP molecules in order to establish the motor activity (Guyton, 2002). Hence mechanical force is generated as the output of the motor system (Cotterill, 2002). The process of contribution of additional motor units to produce force at a certain level is referred as motor unit recruitment and it occurs in an orderly sequence based on the size of the motor units (Preston & Shapiro, 2005). According to the Henneman's Size Principles, as the contraction increases the small motor units are recruited first and then larger ones participate to this process (Loeb & Ghez, 2000).

Since it is not feasible in humans to insert force sensors in series on tendons, electrical activity of the muscles is used to assess muscle contraction (Pozzo, Farina, & Merletti 2004). These electrical activities are generated by the basic anatomical and functional unit of the skeletal muscle called as Motor Unit (MU). The concept of motor unit was first introduced by Sherington in 1925 (Burke, 2001; Liddell & Sherington, 1925). A motor unit consists of a motoneuron in anterior horn of the spinal cord, and all the muscle fibers innervated by this motor neuron (Preston & Shapiro, 2005).

Motor unit is a functional and anatomical unit and its different components such as nerve and muscle tissue achieve the movement in coordination by using the bioelectrical activity. The number of motor units in a muscle varies from muscle to muscle. The number muscle fiber contained in a motor unit can also vary in various muscles in human body (e.g. gastrocnemius muscle of the leg serving in coarse