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Tajmed Khan
Full-time Ph. D Research Scholar, Department of Physical Education Jadavpur, University, West Bengal, India

Dr. Papan Mondal
Associate Professor, Department of Physical Education Jadavpur, University, West Bengal, India

Dr. Sridip Chatterjee
Associate Professor, Department of Physical Education Jadavpur University, West Bengal, India

Dr. Najmun Nahar
Department of Food Science, Maulana Abul Kalam Azad University of Technology, West Bengal, India

Corresponding Author:
Dr. Papan Mondal
Associate Professor, Department of Physical Education Jadavpur, University, West Bengal, India

Effect of exercise on electromyographical factors: A literature review

Tajmed Khan, Papan Mondal, Sridip Chatterjee and Najmun Nahar

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Abstract
Surface electromyography is a reliable technique used to detect the electrical activities of skeletal muscles. In the field of sports science and exercise physiology, surface electromyography is commonly used to assess the effectiveness of exercise and training on muscular development. The researchers investigated the effect of regular and structured exercise and training on electromyographical factors. The subject of influence was the changes of EMG signals in skeletal muscles produced by these activities. Through a review of the relevant literature, we have demonstrated that there is a definitive association between exercise electromyography and muscular strength building. This relationship is modifiable by a number of factors that can be promoted with exercise or training, in particular when the physical activity is regular and structured, as in approximately 12% to 29% of cases. A crucial component of the electrical signal that causes a muscle to contract is due to the electromyographical factors, which include signal origin, muscle membrane excitability, electromechanical coupling, and signal. In addition, increasing muscle strength is being influenced by electromyographical parameters. And strength is one of the primary things that allows you to do it. Strength is essentially gained through consistent structural exercises and training.

Keywords: Electromyography, parameters, amplitude, exercise training signal composition

1. Introduction

Electromyography (EMG) is a diagnostic tool that measures the functional status of skeletal muscles and their controlling motor neurons [1]. It quantifies the muscular response to nerve stimulation, thus providing information on muscle fiber electrical activity and neuromuscular transmission efficiency [2]. This test involves placing electrodes on the skin or inserting needle electrodes directly into muscles. Surface electrodes are non-invasive and generally used to assess muscle activity, while needle electrodes offer a more comprehensive view of the electrical activity in the muscles [2]. When muscles work, electrical signals are generated by the contraction and recovery of muscle fibers. These electrical signals are detected by electrodes and recorded by an EMG machine. The recorded signal, known as an electromyogram, represents the electrical activity of muscles at rest, during contractions [3]. Muscle fibers generate electrical signals during the contraction and relaxation of a muscle at work. Electrodes capture these electrical signals, and an EMG machine records them. The recorded signal is called an electromyogram, and it reflects the level of electrical activity of muscles at rest, in other words, during contractions. EMG signals were recorded and analyzed for amplitude, frequency, and pattern of muscle electrical activity [2]. At the physiologic level, this test is valuable in diagnosing a multitude of neuromuscular diseases, assessing muscle function acutely as well as over time with disease progression and in response to rehabilitation and exercise programs [4]. The association between exercise and Electromyography (EMG) is described because it is relevant for health science as well as sports science. EMG is employed for (a) analysis of exercise techniques, (b) detection and monitoring fatigue, (c) evaluation of the effectiveness exercises on muscle activation, and to get a deeper understanding of the neuromuscular features during performing various activities [5]. The EMG may be used to study how muscles are recruited during dynamic exercise, such as weightlifting, running, or cycling [5]. One exercise taxes the muscles differently from another. Electromyography (EMG) is a valuable tool for identifying the specific muscles being recruited and their level of activation [6]. EMG is also useful for

studying muscle activation during isometric exercise, where the length of the muscle does not change [7]. The intensity of muscle activation can be compared between isometric and dynamic exercises [6].
Therefore, the main objective of the study was to understand and explore the effects of exercise on electromyographical factors.

2. Effect of Electromyographical factors on structural intervention

2.1 The motor unit

The functional fragment of a skeletal muscle is known as a motor unit. The motor unit is composed of a single motor neuron and all the muscle fibers. The motor unit is a single motor neuron that controls muscles. At the time of receiving impulses from the brain by the neuron, it stimulates all the muscle fibers in a particular motor unit. Motor neurons are specialized cells found in the brain and spinal cord [8]. They play a crucial role in allowing us to perform essential functions such as movement, speech, swallowing, and breathing. These neurons transmit commands from the brain to the muscles responsible for carrying out these actions. Motor neurons use a rate coding to convey the desired force a muscle should apply [9].
Motor unit recruitment may be defined as "the successive activation of the same and additional motor units with increasing strength of voluntary muscle contraction" [10]. Exercise has a complete effect on the motor unit, which is the basic functional unit of muscle contraction composed of a single motor neuron and muscle fiber. Motor unit adaptation to exercise depends on the type, intensity, and duration of exercise [11]. During exercise, especially resistance training, motor unit recruitment increases. Initially, small motor units with slow-twitch fibers are activated, but as exercise intensity increases, large motor units with fast-twitch fibers are also recruited. This sequential recruitment, known as the size principle, enables the enhancement of muscle force production [12]. Better synchronization of motor unit firing can result from training. This increases the number of motor units firing at the same time, increasing the muscle's overall force production. This adjustment is especially crucial for tasks requiring the highest level of strength and power [13].
Exercise, especially strength training, can increase the firing rate of motor neurons. Higher firing rates lead to greater force production by the muscles. This change helps improve the rate of force development, which is important in many athletic activities [14].
Resistance training causes muscle hypertrophy, meaning there is an increase in muscle fibers regarding their cross-sectional area. This mainly happens in fast-twitch fibers. As these muscle fibers in the motor unit grow larger, the overall force produced by the motor unit also increases. At the connection point between motor neurons and muscle fibers, known as the neuromuscular junction (NMJ), exercise can bring about structural and functional changes [13]. These changes can improve nerve impulse transmission, which increases muscle strength and activation.
Motor units play a key role in the development of electromyographical (EMG) amplitude, a measure of electrical activity produced by a specific skeletal muscle. The EMG signal's amplitude relies on the level of muscle activation, mainly influenced by recruitment of motor units and firing rates [5].
Motor unit synchronization boosts the mean rectified EMG amplitude and reduces the consistency of force exerted by the muscle during strong contractions [4].
Motor units are recruited in a specific order based on their size. Smaller motor units, which control fewer muscle fibers and allow for delicate, precise movements, are recruited first. Larger motor units, which manage more muscle fibers and generate greater force, are recruited as the need for force increases. This idea is known as Henneman's Size Principle [12]. As more motor units are brought in, more muscle fibers are activated, leading to a rise in the overall electrical activity detected by the EMG. Thus, EMG amplitude increases with the number of active motor units [15].
The frequency at which motor neurons fire action potentials also influences the EMG amplitude. Higher firing rates mean more frequent activation of muscle fibers, which boosts muscle force and the EMG signal. Greater synchronization of motor unit firing can significantly enhance the amplitude of the EMG signal due to the cumulative effect of simultaneous electrical activity from multiple muscle fibers.
Recruiting additional motor units raises the number of activated muscle fibers, creating a larger total electrical signal and subsequently increasing EMG amplitude. The amplitude of the EMG signal in a time series of EMG data rises during muscle contraction, and this increase usually relates to greater recruitment of the motor units [1].

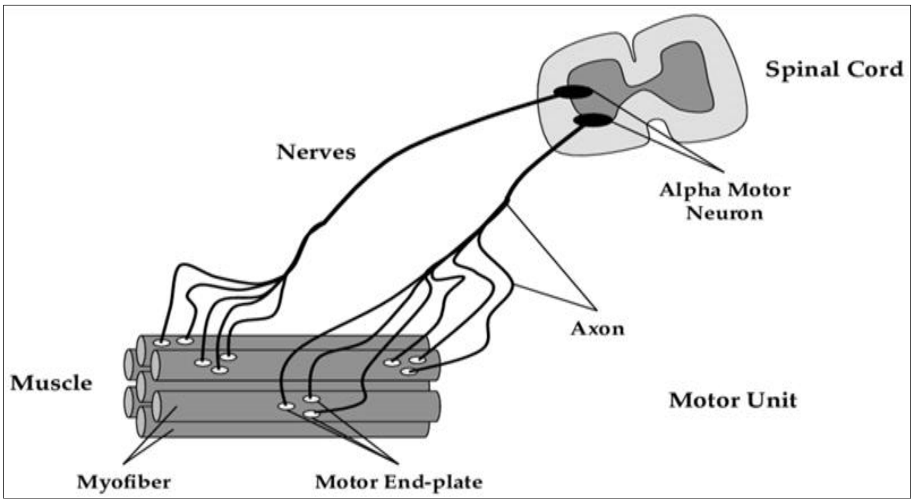

Fig 1: The diagram illustrating the Components of a motor unit for muscle contraction [16]

2.2 Excitability of Muscle Membranes

One of the key factors in electromyography is the excitability of the muscle membrane. This excitability is controlled by neural signals. When the muscle fiber is at rest, its potential is typically around -70 mV [17]. The excitability of the muscle membrane (EMM) relies on various physiological substances, like enzymes and potassium ions, which are found mostly inside the cells [8]. Exercise plays a critical role in boosting muscle membrane excitability, which is essential for improving muscle performance. It affects the excitability of the muscle membrane through several mechanisms. Exercise can increase the density and function of sodium channels in muscle membranes. This improvement helps muscles generate and send action potentials more effectively [5]. Changes in potassium channels support the repolarization phase of action potentials, keeping muscle excitability intact [3]. Exercise also enhances how the sarcoplasmic reticulum handles calcium. This ensures quick and efficient release and uptake of calcium, vital for muscle contraction and relaxation cycles [6]. Additionally, during exercise, the number of calcium channels increases, making muscle fibers more responsive to nerve signals [2].

Regular physical activity can change the lipid makeup of muscle cell membranes. This change improves their fluidity and function, helping maintain the strength of muscle membranes. As a result, there is less risk of damage and better overall function Exercise boosts the activity of the Na+/K+ ATPase pump, which is crucial for keeping the resting membrane potential and preparing for future action potentials. The proteins involved in excitation-contraction coupling increase with exercise, raising the overall excitability and responsiveness of muscle fibers [18]. Enhanced insulin sensitivity from regular exercise improves glucose uptake, supplying the energy needed for consistent muscle excitability. Hormonal changes due to exercise, such as higher levels of adrenaline and noradrenaline, further enhance muscle excitability and performance [19].

Exercise improves muscle membrane excitability through several mechanisms. These include increased ion channel density and function, better sarcoplasmic reticulum performance, improved membrane fluidity and composition, adaptations in proteins related to excitability, and positive hormonal and metabolic changes. Together, these adaptations increase the muscle's ability to generate and transmit action potentials, resulting in better muscle performance and resilience.

A significant aspect of developing electromyography (EMG) amplitude is the excitability of muscle membranes. The increase in EMG amplitude is influenced by processes relating to muscle membrane excitability. Muscle membrane tension is important in determining the EMG signal's amplitude. Higher excitability results in stronger and more frequent action potentials, better neuromuscular transmission, and greater EMG amplitude due to more muscle fiber recruitment. In contrast, low arousal levels, such as during fatigue, lead to lower EMG amplitude [1].

3. Action potential development

The development of action potentials involves several steps. These steps include resting potential, threshold stimulation, depolarization, hyperpolarization, and returning to resting potential.

In the resting potential stage, the neuron stays stable with its membrane potential at about -70 mV. In the threshold stimulation stage, the membrane potential reaches -55 mV, which triggers the action potential. During depolarization, the Na+ ion (sodium) channel opens due to the cell membrane's rising potential of +30 mV [20]. In repolarization, the potassium (K+) ion channel opens, allowing potassium to flow back in and lowering the membrane potential to a negative value. In hyperpolarization, the membrane potential becomes more negative for a brief period compared to the resting potential, before returning to the resting potential stage. This restores the membrane potential to its resting state, preparing the neuron for the next action potential [21].

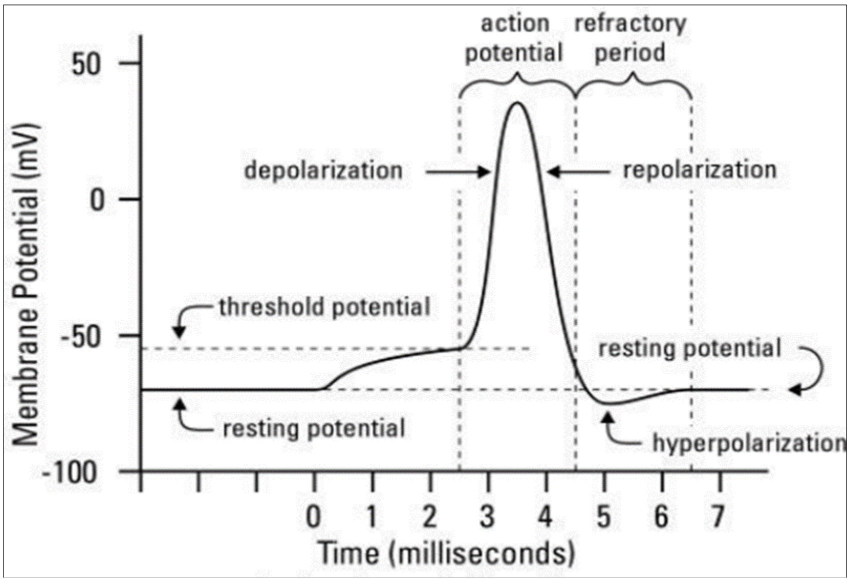

Fig 2: A diagram of an action potential in a neuron [22]

Exercise plays a vital role in developing the capabilities of muscle cells. Regular physical activity leads to various changes in the body that increase muscle membrane tension and function, which ultimately affects performance. Additionally, consistent exercise enhances the muscles' capacity [23]. To eliminate lactate and other metabolic waste.

This can impact membrane excitability and the generation of action potentials during intense exercise [4]. Exercise boosts the activity of the sodium-potassium pump (Na+/K+-ATPase), which helps keep the resting membrane potential stable and allows for quick recovery of ion gradients after action potentials. This results in greater stability and adaptability, leading to improved performance and potential for growth [3]. Physical training increases both the quantity and effectiveness of voltage-gated sodium and potassium channels. These channels are essential for starting and transmitting action potentials. A rise in the number of ion channels makes the muscle membrane more responsive to stimuli. Exercise can also elevate the release of neurotransmitters like acetylcholine at the neuromuscular junction. This makes the muscle membrane more depolarized and raises the likelihood of reaching the threshold needed to generate action potentials [24]. Regular physical activity boosts the sensitivity and density of acetylcholine receptors on the muscle membrane. This enhances synaptic transmission and ultimately improves muscle activation. Exercise increases mitochondrial density and efficiency, leading to better ATP production. Sufficient ATP is crucial for the proper functioning of ion pumps and channels that maintain membrane potential and generate action potentials [25]. Endurance training can shift muscle fiber types from fast-twitch (type II) to slower-twitch (type I) fibers, which have greater oxidative capacity. Slower-twitch fibers resist fatigue better and can sustain longer periods of activity, aiding in the generation of sustained action potentials during extended exercise [26]. Resistance training promotes muscle hypertrophy, which is the growth in size of muscle fibers. It also enhances blood supply and capillarization, which improves the delivery of nutrients and oxygen to muscle cells. This supports the effective generation and transmission of action potentials [27].

4. Electromechanical coupling

The process that links the electrical activity inside a muscle cell to the muscle contraction is called electromechanical coupling [8, 20].

This process is crucial for converting an action potential, which is an electrical signal, into a mechanical response, or the actual contraction of a muscle. The main steps of electromechanical coupling include initiating the action potential, releasing neurotransmitters, propagating the action potential, releasing calcium ions, binding calcium ions, cycling cross-bridges, muscle contraction, and relaxing the muscle. In short, electromechanical coupling in skeletal muscles occurs through electrical signals that involve initiating and propagating the action potential, releasing calcium ions from the sarcoplasmic reticulum, and mechanical responses like releasing troponin, cycling cross-bridges, and contracting the muscles [28].

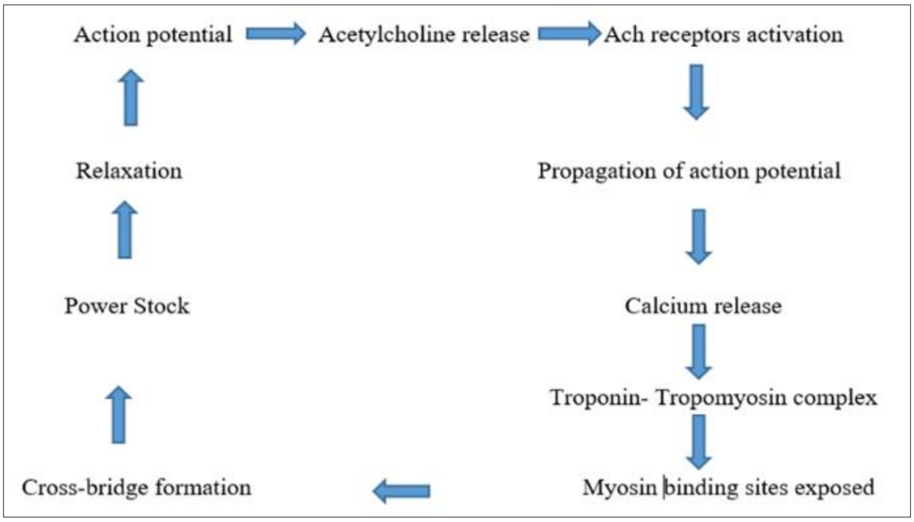

Fig 3: A diagram of an electromechanical coupling of skeletal muscles.

Exercise is essential for developing and improving muscle fibbers' electromechanical coupling. This process involves converting an electrical signal, called an action potential, into a mechanical response, which is muscle contraction [29]. Key steps in this process include activating muscle fibers, releasing calcium, and interacting with contractile proteins. Important factors include improved neurotransmitter release, greater receptor density and sensitivity, better sarcoplasmic reticulum efficiency, increased calcium channel and pump activity, enhanced myofilament sensitivity, a higher cross-bridge cycling rate, fiber type transformation, and muscle hypertrophy [30]. Exercise is essential for developing and improving muscle fibers' electromechanical coupling. The activation of muscle fibers, the release of calcium, and the interaction of contractile proteins are some of the most crucial steps in this process [31].

5. Composition of EMG Signals

Electromyography signals are complex electrical processes that provide important information about muscle activity. The EMG signal has several key components, including various aspects of function and neural control [5]. The composition of the EMG signal is examined in different areas of muscle physiology, such as motor unit action potential, summation of motor unit action potential, frequency component, and amplitude of the EMG signal [32]. The simultaneous activation of the motor neuron primarily generates the motor unit action potential [2].

Partial summation and temporal summation are the main parts of the summation of the motor unit action potential. The motor unit activates at the same time as the development potential of all activated motor units. Electromyography captures the sum of the action potentials, a process called partial summation. Motor units' fire at varying rates, leading to their action potentials building up over time. This creates a continuous EMG signal that changes in frequency and amplitude, known as the temporal summation of the EMG signal [33]. There are different types of frequency components in EMG signals. Low-frequency components relate to type II muscle fiber and low-intensity contraction [2]. High-frequency components connect with type I muscle fiber and high-intensity activity. contraction. And frequency range, which generally is 0 to 500 Hz, with most energy concentrations between 5 and 150 Hz [33].

Amplitudes of EMG mostly refer to indicate the magnitudes of neural drive to the muscles [34]. The EMG signal's amplitude is measured using a microvolt or millivolt unit. The amplitude of muscle activation level indicates that a higher amplitude indicates greater activation and force production [20].

There are several influencing factors of EMG signal, among those tissue characteristics and physiological cross-talk between muscle groups are most important. does not exceed 10% to 15% of the overall signal content [32]. Muscle fatigue [35], firing rates of the motor unit, changes in the intercellular action potential, and mean turn of amplitudes played very effective roles in changes in EMG amplitude [15]. Both motor unit behavior and muscle fiber properties are responsible for EMG amplitudes [36].

Exercise plays a significant role in the development and modulation of action potentials in muscle cells. Regular physical activity induces a variety of physiological changes that enhance the excitability and function of muscle membranes, thereby impacting action potential development.

6. Conclusion

Regular physical exercise affects electromyographical factors such as the motor unit, excitability of muscle membrane, action potential development, electromechanical coupling, and composition of EMG signal that happens due to neurophysiological changes in skeletal muscles. By increasing the firing rate of motor neurons, muscular strength enhances motor unit recruitment and force production in skeletal muscles. The firing of motor neurons can significantly increase the amplitude of the EMG signal due to the cumulative effect of concurrent electrical activity from multiple muscle fibers.

Motor neuron firing can significantly increase the amplitudes of the EMG signal due to the additive effect of simultaneous electrical activity from various muscle fibers. Electromyographical coupling follows neurophysiological reactions such as troponin release, cross-bridge cycling, and muscle contractions (Fiber), which can develop through exercise. Motor unit action potentials, summation of motor unit action potentials, frequency, and amplitudes of EMG signal are considered as components of the EMG signal that can be changed and developed by regular physical exercise and training. Individuals can enhance their muscle membrane excitability, improve neuromuscular transmission, and optimize the metabolic environment within muscle cells by physical exercise, all of which contribute to more efficient development and overall muscle function. Overall muscle function leads to the maximum EMG amplitude. This indicates to ability to develop maximum force by the particular muscles and muscle groups, as well as the efficiency of sports for the performance.

Novelty of the work

To achieve high performance in games and sports where the required maximum amount of force, coaches and players may be involved in regular exercise and training. An individual may be engaged in regular physical activity to enhance the electrical activity of the muscles. EMG results indicate the electrical activity of the muscles so, may be recommended for the rehabilitation requirement of players.

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Conflict of interest

No conflict of interest was stated by the author.

Author's Contribution

Tajmed Khan: Investigation, manuscript writing.
Dr. Papan Mondal: Supervision
Dr. Sridip Chatterjee: Supervision
Dr. Najmun Nahar: Manuscript Editing

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