

## **Monitoring Human Muscular Contractions with Accelerometer**

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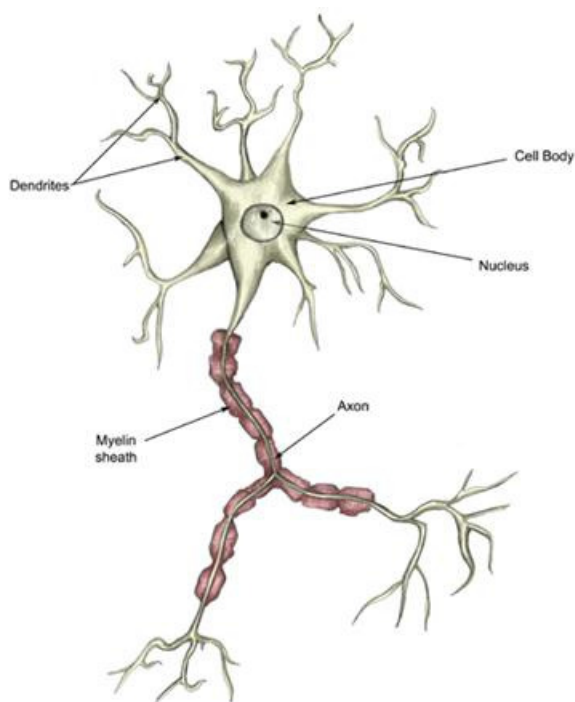
**This research work was carried out to monitor how nerves transmit impulses from muscular contractions using Electromyography (EMG) and its application in intramuscular injections. When it comes to intramuscular injection of products such as BOTOX®, there is no way to tell objectively whether the needle tip is actually inside the targeted muscle. However, we can provide an electrical stimulation using an EMG (Electromyography) needle (1.5 - 2.0 mA), then monitor the muscular contractions with an accelerometer (motion sensor). We have found that the muscles always responded on the first stimulation but never with subsequent stimulations. This means muscles run away from electrical stimuli, which would leave a needle tip just outside of the fascia, or right in the subdermal bloodless space. This subdermal bloodless space is the optimal spot for BOTOX® injections because BOTOX® acts on nerve endings that exist only on the fascia, not inside the muscle, which is where BOTOX® is typically injected.**

**Keywords:** Accelerometer (motion sensor), electrical stimulation, injectable EMG (Electromyography) needle, muscular contractions, subdermal bloodless space, subdermal injection.

### **INTRODUCTION**

A brief and basic understanding of anatomy and physiology of human muscles is necessary to understand where the subdermal bloodless space is

located and why it is an effective space for injectables (Teach, 2014). Each neuron contains a cell body and an axon (Figure 1). With a motor



**Figure 1.** Nerve Structure.



**Figure 2.** Skin and Dermis.

neuron, the axon carries electrical impulses towards the muscle and away from the cell body itself. The axon branches into axon terminals, and ends at neuromuscular junctions, which exist only on the fascia: the covering of the muscle (Figure 2;

Sanders, 1993; Witzemann, 2006).

The way in which the nerve transmits an impulse is referred to as nerve propagation. When  $\text{Na}^+$  (sodium) ions surge into the cell, depolarization takes place, which is where the inside of the cell becomes positive compared to its surroundings. When depolarization reaches a threshold, an action potential is established and the impulse can travel along the neuron. The “all or none” law states that without reaching this threshold, no impulse will be transmitted. Before another action potential can occur, the resting membrane potential must be restored, which ensures each stimulus is kept separate. This restoration, or re-polarization, is achieved by the surge of  $\text{K}^+$  (Potassium) ions out of the cell, making the inside of the cell negative again.

A motor unit is described as a single motor neuron, along with the muscle fibers the neuron supplies. Between ten and thousands of muscle fibers exist within a single motor unit. Muscles that produce larger, powerful movements contain motor units with great numbers of fibers, and muscles producing smaller, intricate movements contain only a few fibers within a motor unit. The “all or none” law as mentioned above also applies to the contraction of fibers within a motor unit (Skin Anatomy). When it activates, the fibers within the motor unit contract at full force; there are no strong or weak contractions.

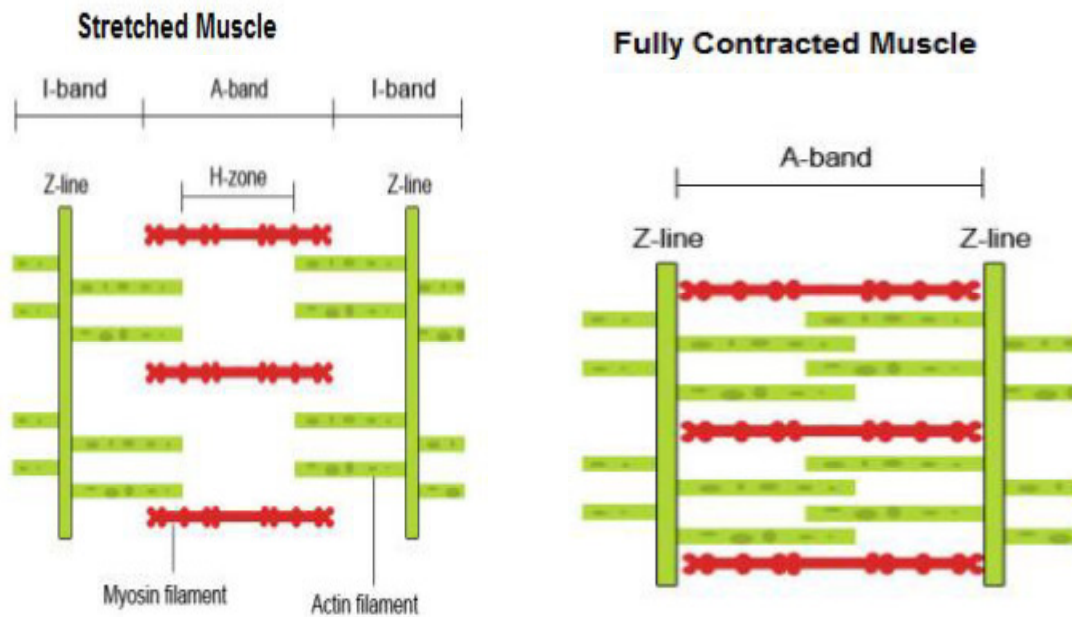
The neuromuscular junction is where the synaptic knobs of the neuron meet the muscle fibers. When an impulse is transmitted to this neuro-muscular junction, a neuro-transmitter called acetylcholine is released, which filters across the synaptic cleft, a microscopic space between the synaptic knob and motor endplate (Sine, 2012). This causes depolarization of the motor end plate and puts the sliding filamentsof muscular contraction into action (Figure 3).

## MATERIALS AND METHODS

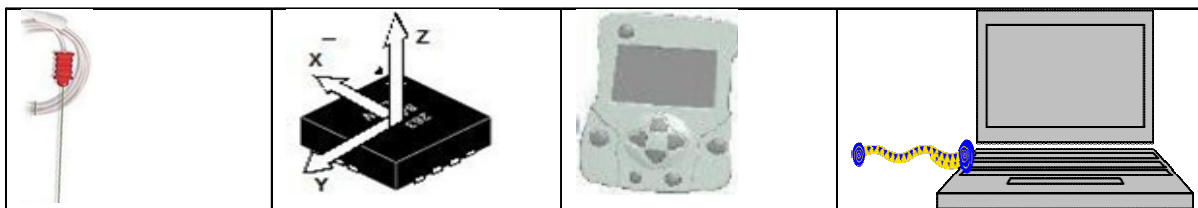
Our preliminary studies were conducted in compliance with the Good Laboratory Practice (GLP), and all procedures were approved by the Institutional Review Board. Our set up included a 3-Axis Multifunction Digital Accelerometer (Digi-Key), injectable monopolar subdermal EMG needle (EMGneedles.com), data processor, and computer (Figure 4).

The procedures took place at ASIS Corporation in Westminster, California using three healthy, normal

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**Figure 3.** Neuromuscular Junction Depolarization (teachpe.com).



**Figure 4.** Study setup included an EMG needle, accelerometer, data processor, and computer.

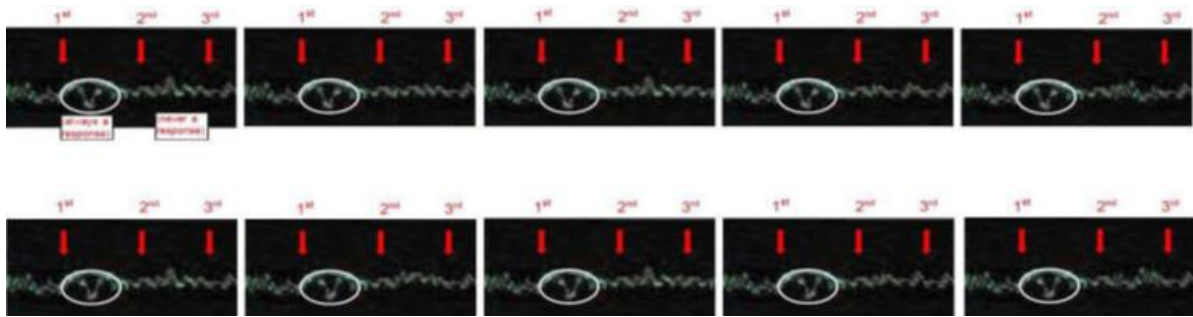
human subjects. Using an injectable EMG needle to provide an electrical stimulation (1.5 - 2.0 mA) to various human muscles, we could sense the muscular contraction/motion below when the accelerometer was placed on the skin or needle itself.

## RESULTS

After thousands of stimulations on hundreds of muscles, the exact same recording below was found (Figure 5). Each muscle always responded on the first stimulation, but never with subsequent stimulations, which implies that the muscles ran away from electrical stimuli, just like balloons away from a firecracker.

## DISCUSSION

If we were to make an adjunctive device using electrical stimulation to confirm the needle tip was actually inside the targeted muscle, the subsequent injection result would not be optimal for intramuscularly injected products since the needle tip will not stay inside the targeted muscle following an electrical stimulation. If the needle cannot stay within the targeted muscle, then it must be just outside of the fascia or right in the subdermal bloodless space. The needle tip seems to naturally want to be just outside of the fascia after electrical stimulation, which makes the subdermal bloodless space the optimal injection spot, especially for BOTOX®, because BOTOX® acts on nerve endings and nerve endings exist only on the fascia, not



**Figure 5.** Recording of muscle contractions. The first stimulation resulted in muscular response, while subsequent stimulations resulted in no muscular responses.



**Figure 6.** The portion of the muscle that contacts the path of the stimulating current first must also contract and shorten first, forcing the muscles to run away.

inside the muscle, where it is typically injected (Allergan, 2014; BOTOX).

The physiological explanation for why the needle tip must end up in that subdermal bloodless space after stimulation every time, it has to do with the fact that the portion of the muscle that contacts the path of the stimulating current first, must also contract and shorten first, thus forcing the muscles to run away every time (Figure 6). Of course, if the muscle does not contact the path of the stimulating current, then contraction cannot happen.

## CONCLUSION

The ASIS (Automatic Subdermal Injection System) technique and device itself offers benefits for non-

cosmetic injectables or fillers. Since the bloodless space has the natural ability to expand rapidly and contain abscesses or hematoma, this will allow rapid, effortless, and painless infusion of injectable products that come in high volume such as GAMMAGARD (20-30 mL) and antibiotics (50 mL; Gidley and Stiernberg, 1997; Miller et. al., 1999; Panoessa and Goldstein, 1976; Scott et. al., 1998).

The focus of our next study will be to determine whether the EMGneedle tip indeed ends up in the subdermal bloodless space by injecting gadolinium through it and monitoring with MRI (Magnetic Resonance Imaging) over a period of time. If gadolinium remains in the bloodless space longer than it remains within the muscle itself, this would imply that injections into the subdermal bloodless space may provide longer-lasting medicinal effects.

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