

Is The All Or None Applicable To An Entire Muscle?

Researched and Composed by Jacob Wilson, BSc. (Hons), MSc. CSCS

Question

Mr. Wilson

I brought up EMG to my trainer, and he said it was useless because it has no way of giving any indication of how a muscle is being worked. He said he can't figure out for the life of him how they can relate that to a muscle. He said EMG had nothing to do with muscular activity. He also said that either an entire muscle group contracts or it doesn't contract at all. He said it's the all or none law, and you can't break a law as its set in stone and science has confirmed this. That's why he said you only need like one exercise to stimulate an entire muscle. What are your thoughts?

Answer

Very flawed, very flawed indeed.

Your trainer is showing a classic example of how a scientific concept, namely the all or none principal can be grossly misinterpreted and then used to come to an extremely illogical conclusion.

In fact, I would go so far as to say, that the concept of all or none is the most frequently misunderstood principle in all of bodybuilding. Whole books have based their techniques on what I call the all or none from another dimension. In other words, your trainer's interpretation has nothing to do with reality. And I would caution people to use the word science with a more skilled grip. The term science means " to know. " What we do not know at the cellular level far exceeds what we do know. Therefore, one must use knowledge to properly move forward, and not backwards. For example, many of the training methods used by Old School bodybuilders were interpreted by so called science to be flawed. As new discoveries have been made, we are finding that these so called outdated methods, are validated keys to building optimal mass. In fact, what must be understood, is that bodybuilders have been far ahead of the scientific world of published journals, in the realm of hypertrophy for a tremendously long amount of time. What also must be understood, is that scientists study the hypertrophy athlete, and his methods, and then use that data to enrich their own studies. William J. Gonyea, a scientist who many consider to be the leading authority in the world in both hypertrophy and hyperplasia has this to say about the subject:

" Despite progressively increasing resistance's long history, relatively little scientific information has been published regarding various training techniques and their effects on muscle mass.

A large part of the information concerning weight training has been gained through practical experiences and empirical observations of bodybuilders. The current body of scientific information regarding weight training's effects on muscle mass is small...(1)"

Translation – Even The badest scientists in the world base their studies on what bodybuilders have proven over and over again through hardcore, balls to the wall hypertrophy training! This is not to say, that there is not a tremendous amount of published data. Only, that everyday discoveries are being made, which have already been confirmed in the hardcore, die hard bodybuilding world. And, just as countless great scientists feed off of bodybuilding methods to fuel their studies, the athlete would do well to realize why they do so. Because it is apparent that the techniques work. This is why Dr. Benhamin F. Timson, in the journal of the American Physiological Society pointed out after doing a study on the subject that " bodybuilders have a 76 percent greater cross sectional area in the biceps brachii then the normal population (8)."

Indeed, one would be a fool not to tap into a resource as rich as that to build scientifically on what has already been shown to be true. Afterall, if hardcore training has continually been shown to work, then one must study why this is the case, and that is exactly what Scientists such as Dr. Timson, and Dr. Gonyea do.

What we will now do, is delve further into, what exactly the all or none principle is, and what it definitely is not.

All Or None Principle

This principle is based on an electrical event. Think of the electrical event as a signal stimulating a cell to perform a certain action. Notice my wording here, I said " cell. " That is – the all or none principle is based on single cellular units. It is not, and I repeat not applicable to multiple cells. To demonstrate this concept I want you to perform an experiment using your special sensory neurons from the auditory nerve. This is known as cranial nerve 8 and contains several sensory neurons in it. These neurons are stimulated by sound. As sound waves are generated, they cause small graded electrical impulses(receptor potentials) to occur in the neurons contained in this nerve. If, the wave is large enough for a particular neuron, then it completely depolarizes and an electrical impulse is carried across the entire neuron, and carries that signal to your brain where it is translated. I will explain depolarization further in a minute. Let me just say this: either a neuron(which is a single cell) is stimulated to conduct an electrical current across its entire self, or it is not(called an action potential).

Now to the experiment. Tap on your desk lightly, now progressively tap with increasing force. What did you notice? The sound got louder and louder correct? This is due to the fact, that more and more neurons were stimulated to threshold. The more neurons stimulated, the more intense the sound became. If the all or none principle were applicable to all the cells in that nerve, then every time someone whispered, it would sound as if Roseanne Bar came into your house and yelled at the

top of her lungs straight into your ear drums! That is frightening is it not!? The point is, that this principle is not, and I repeat not applicable outside of a single neuron, and the experiment you just conducted proved that.

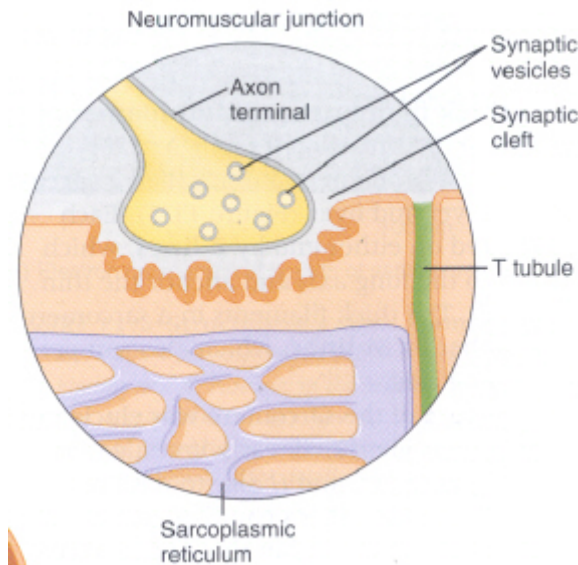
The question now, is what are these impulses to which I am referring? Simply put, an electrical current is defined as a positive charge flowing towards a negative charge. If you recall from my article on the nervous system, I discussed the fact that certain cells are specialized at conducting electrical currents. This is where electrolytes such as sodium, potassium and calcium(see [Seksi's article this month](#)) show their extreme importance to functions throughout the entire body! An electrolyte is an ion or a group of charged atoms which can carry such a current. Similar to magnets, opposites attract each other. Sodium (Na +) and Calcium are therefore attracted to any negatively charged area(this is called an electrical force). However, there are also chemical forces at work here. Everyone here knows the process of diffusion. Atoms or molecules always move randomly from areas of higher concentration, to areas of lower concentration.

To make a long story short, in the membrane of both muscle cells and neurons are several complex structures. There are voltage gated channels which allow sodium into the cell, and there voltage gated channels which let potassium out of the cell. Additionally there are sodium / potassium pumps, which literally pump three sodiums(against their electrical and chemical gradients) out of the cell, while only pumping two potassiums into the cell. Three positives out, and two positives in, translates to the inside of the cell, being more negative then the outside of the cell. In addition to this, there are also channels in the membrane which allow more potassium to escape then sodium to enter, which means that more positive charge leaves the cell, then enters. Finally, negatively charged proteins are manufactured inside of the cell. The point is simple, by complex machinery, both neurons and muscle cells set up what is called a negative membrane potential. Which means that the inside of the cell is more negative then the outside. Secondly, the cell has driven Sodium outside of the cell, against its chemical and electrical gradient – that is - if you could make the membrane more permeable to sodium it would rush into the cell like a bullet out of a gun!

This is precisely what occurs in an action potential. Without going into horrid detail, there is a certain threshold for each cell or action potential. This means that enough positive charge flowing toward negative charge has to occur in order for the entire cell to conduct an electrical impulse. Once this is reached however, the entire cell will go through an action potential(actually its more similar to tiny action potentials propagating themselves across the cell). Finally, once threshold has been reached there is no stopping the action potential from spreading across the entire cell! This is why it is the all or none principle.

Remember what Gonyea stated. We must use our eyes to understand why this process is applicable to a cell, and not an entire nerve, or an entire muscle. Think about it for a second, if every muscle cell in your shoulder was activated, how would you comb your hair? You'd reach to comb and your arm would jerk at unforeseen speeds! The reason why we are designed to recruit muscle fibers in an orderly fashion, is due to the different demands of our bodies(which can be mimicked through a variety of exercises for maximum stimulation across the gaster or belly). I will obviously use less force with my fingers to type, then during a deadlift with hundreds of pounds!

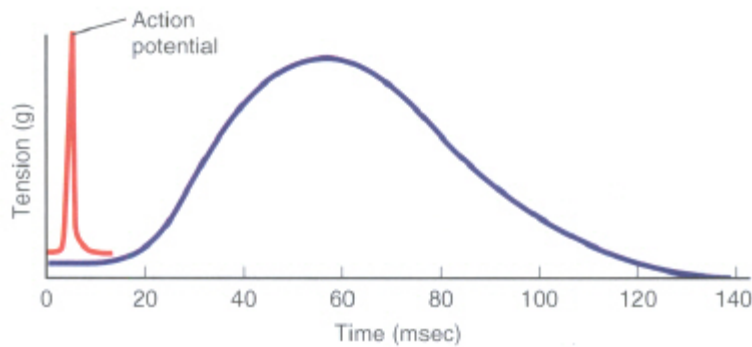
All Or None As it Applies to Muscular Contraction



The end plate of a muscle cell is one of the most incredibly designed features in the human body. In the future we will analyze just how incredible this design truly is. In it, you will find an intricate array of gated and non gated channels, and a countless array of complex machinery.

As stated, an all or none propagation always leads to a physiological action. In the case of a neuron, that action may be to release a neurotransmitter. This is a specialized messenger, and it is vital to muscular contraction. The muscle cell has what is called an end plate. On this end plate are gated channels for sodium which are closed at rest. As you recall, if opened, sodium will flow into the cell at an accelerated rate(+ to - = electrical current). After an action potential travels along a neuron, its axon terminal(essentially the end of the neuron), which communicates with the end plate of the muscle cell, will release its neurotransmitter. This transmitter which stimulates depolarization(to make a cell more positive, again by letting in sodium) is always Ach or acetylcholine. That is more detail, then we need. But the point is, that this neurotransmitter acts like a key to a locked gate. When released, the key opens the gate, and sodium rushes in, causing the cell membrane of the muscle cell(the cell membrane of a myofiber is called the sarcolemma, see [anatomy of a muscle](#)) to reach threshold. This means that an electrical current will travel throughout the entire cell!

Remember what I stated! An electrical current(the action potential which operates on the all or none principle) always precedes the physiological action which the cell carries out. What is the action of a muscle cell? To contract correct!? I can tell you right now, the contraction mechanism of the cell, initiated by the action potential is sheer genius! One could easily talk for all day on how stupendous the mechanism is! However, I will get to the point.



As You can see, the action potential is in reference to the electrical events which have taken place within this particular cell being studied. The long wave represents the actual contraction of the muscle cell. Consequently, the AC is noticeably shorter than its contraction.

In the cytoplasm(called sarcoplasm in a muscle), which is the intracellular environment, are literal storage bins of calcium(again I would refer you to [Seksi's article on Ca ++](#)). Calcium, is the key to muscular contraction. As you know, from my muscle fiber article, a muscle cell is made up of myofibrils, which are long cylindrical contractile units, made up of smaller units called sarcomeres([click here](#) for more info).

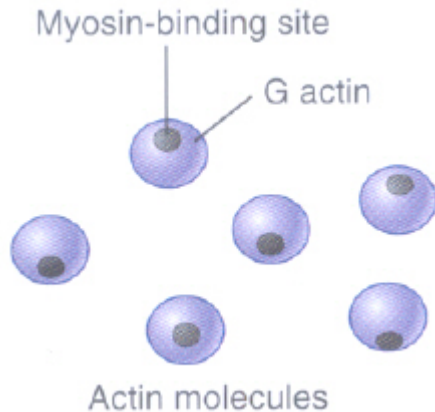
The sarcomeres are lined up one after the other to form a myofibril, and the myofibrils are lined up parallel to each other to form the muscle cell (its more in depth but that is the overall concept). Now, inside the sarcomere are contractile proteins called actin and myosin. Myosin has protrusions called heads, and actin has binding sites for these heads to bind to. The heads are continually breaking down atp to bind to the actin, but, the binding sites are masked by another protein called the troponin-tropomyosin complex(actually two seperate globular proteins). Calcium, like a key unmasks the binding sites, and allows the myosin to bind to the actin. The binding of myosin to actin is called a cross bridge, and this is defined as " tension. " The more myosin bound to actin, the more tension is built up in the muscle!

An action potential causes the calcium, stored in bins(these bins are called the sarcoplasmic reticulum) to be released, thus allowing contraction to begin. A contraction, followed by a relaxation is known as a " twitch. "

Consequently, this is where we derive the term, slow twitch and fast twitch muscle cells. You see, myosin must hydrolyze(break down) ATP before it can bind to actin. Its quite simple, a slow twitch fiber contains the so called " slow myosin ATPase. " The fast twitch fiber contains fast myosin ATPase(whenever you see an ase it is an enzyme, ATP is what it breaks down). The latter breaks down ATP quicker and can subsequently bind to actin at a faster rate then can the former.

Note: For More Information On ATP - [Click Here](#) and [Click Here](#) For Old School's article on how to optimize ATP levels

Does EMG have to do with Muscular Contraction?



Now to directly address your first question. The answer is yes! EMG stands for Electromyography. Myo stands for muscle. It measures electrical activity within an entire muscle. Before a muscle cell contracts, it must conduct an electrical current. Putting two and two together, it doesn't take an Einstein to figure out, why this is a vital tool of research! The fact, that someone would state that it has nothing to do with the action of an entire muscle, simply means that the person does not understand what an action potential is, or how any type of muscle, be it skeletal, cardiac or smooth work.

Does it have limitations? Sure it does. We will discuss these in a moment. This is why true science, collectively uses knowledge. In other words, one cannot rely on one method to study something as complex as an entire muscle!

Let me delve deeper into this. Electromyography has shown that specific exercises elicit more electrical activity in the long head of the biceps brachii, then the short head, and of course vice versa.

I have heard people state, " Yes, but electromyography is best at measuring the superficial muscle cells of an entire muscle, so it doesn't count to show that an entire muscle functions in a non uniform manner. "

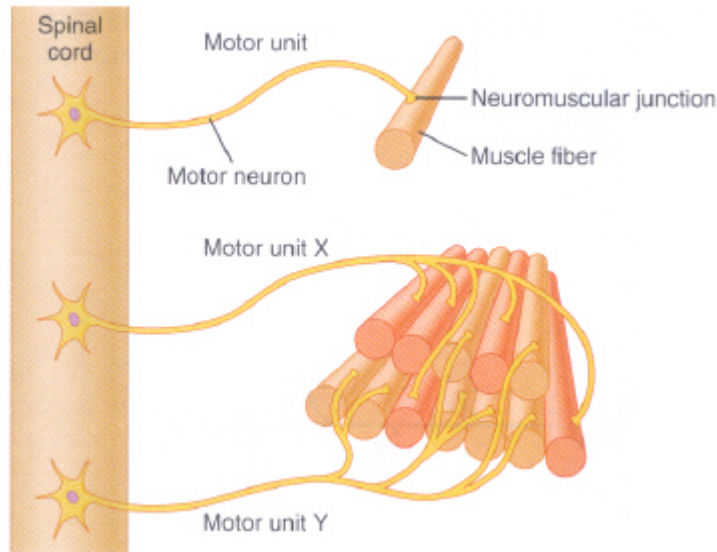
On the contrary! It shows that it actually reacts in an even more complex manner! You see, if the superficial cells are activated in a non uniform manner, then we can realize that this is also occurring in the deep aspects of the muscle! A quote from an earlier article of mine discusses this:

" There are also many signs of compartmentalization, where we cannot physically see septum. Septum is what the connective tissue is called when it spans out and forms the barrier(i.e. your nasal cavity is separated into two cavities by a septum). For example, if we look at motor nuclei and examine them closely in the biceps brachii, we actually find that " functionally " speaking there is compartmentalization. Meaning, that different aspects of this muscle, function differently. English, A.W., S.L. Wolf, and R.L. Segal. In their study, Compartmentalization of muscles and their motor nuclei found this to be so, not only for this muscle, but several others(10). "

To compound the situation, muscle biopsies reveal that this complexity is reflected by different fiber ratios superficially, as opposed to deep. I can reference example after example of this! The adductor magnus is 53 percent type I muscle cells

superficially and yet when you go deeper it has a slow twitch make up of 64 percent (12)! That's a large increase! And one only has to study fiber makeup to realize that there is always a purpose behind it(i.e. functional compartmentalization). The same discrepancy can be found in the biceps muscle as well and every single other muscle examined. Therefore, what EMG is demonstrating is that muscle groups are far more complex than we ever believed them to be, in both functionality and force recruitment patterns!

Clarifying The All Or None To An Entire Muscle



Note The display here and discrepancy presented. Each motor unit is separate from its counter parts, and are separate structures. Also note, that each contains a different number of muscle cells. This is of extreme significance as you will see below.

To recap past articles, a motor unit is the neuron and all the muscle fibers it innervates. This can range from as low as 2 cells to thousands of cells. Now, each motor unit fires as a unit. Which means when the neuron is fired, that the muscle fibers innervated will undergo action potentials. Even a small muscle such as the brachialis has over 150, 000 muscle fibers. This means, a tremendously large amount of motor units, and therefore a tremendous amount of complexity. This is why studies show non-uniform hypertrophy in experiment, after experiment(7, 13, 14,)!

Therefore to answer this question. No, all the muscle fibers in an entire muscle group are not all activated at the same time, and the all or none is not applicable to an entire muscle group.

Is it Always Applicable Even Across a Single Cell?

Indeed, the extreme complexities of skeletal muscles are tremendous. What I am now going to do, is go deeper, and I mean extremely deep. I say this, because an all or none action potential leads to the contraction of a cell, but, when that cell is fatigued, though it depolarizes, it does not, under conditions of fatigue(which is

where a bodybuilder lives) always do so uniformly. Buckle up and I will expound on this concept!

We need to take a look at what has been found when muscle fibers have been analyzed. Through a deepened look, via electrophoresis it has been found that many of these cells express varying forms of myosin throughout the fiber. As you now know from earlier in the article, myosin atpase hydrolyzes atp at differing rates. Thus, it would stand to reason, that differing contractions would effect a cell nonuniformly. For more information on this, "[click here](#)."

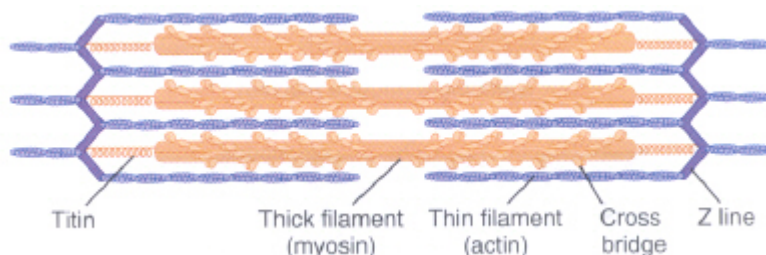
To compound this situation, it has been demonstrated on countless occasions, when studying individual fibers that indeed non-uniform hypertrophy had clearly taken place(1, 2, 3, 4, 5, 7, 18). For example, in a quote from my article on this subject states the following:

" Sakuma, K., A. Yamaguchi, and S. Katsuta. entered experimentation with the same question we have. In fact the title of their journal was Are region-specific changes in fibre types attributable to nonuniform muscle hypertrophy by overloading? They discovered that type IIB fiber areas increased more in the middle and distal regions of the muscle cells they tested rather than the proximal regions(18)! "

What is the explanation for this clear nonuniform growth? While there are several reasons, I intend to expound on this from a cytoskeleton standpoint in the present article, as this is what is responsible for the organization found within a single muscle fiber. The cytoskeleton protects, and organizes a cell, much like your bones do for your entire body. Several areas on this structure can be examined and shown to have a non uniform effect under fatigue. I am going to address two aspects of this today to highlight just how non-uniform a muscle acts when trained(though I can and will go deeper into this subject in the near future).

Overview

Desmin proteins connect in series sarcomere units, allowing them to work together over long distances(9). Desmin is also responsible for unifying parallel force across a muscle fiber. That is, combining the force of two sarcomere units which are side by side. Consequently this means that one damaged sarcomere can effect tension levels on its parallel counterpart. A second and fascinating protein is Titin. It is an extremely elastic molecule, and has the ability to store energy much like a rubber band (18, 19), additionally it aids in the alignment of the thick myosin filaments relative to actin binding sites(18, 19,). When a muscle is stretched, the elasticity of Titin assists greatly in bringing it back to its optimal length.



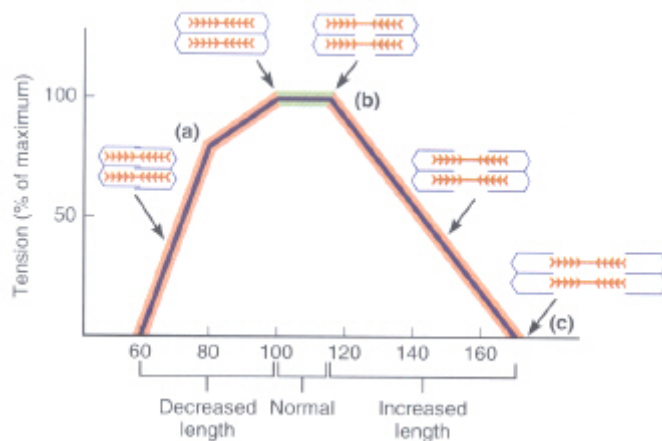
I intend to delve further into this subject in the near future. I believe that Titin is a key to several physiological aspects, including enhanced athletic field performance.

This is important to understand, because at this stage I will address what occurs during an eccentric contraction. In the Biophysical Journal, Dr. DI Morgan explained the following:

" Lengthening of active muscle on or beyond the plateau of the length tension curve will take place very nonuniformly(9). "

What he is saying needs to be further analyzed. An eccentric contraction of a muscle fiber, involves the lengthening of that fiber as it is being activated. That is-it is contracting-and lengthening at the same time.

What needs to be understood is that a muscle fiber has an optimal length. This length produces optimal tension in the cell, as tension is defined as, or rather measured by the number of cross bridges formed between myosin heads and actin binding sites. Think of it this way: when pushing a large and heavy object, what will generate more force-one person or 10 people parallel to each other? The same principle applies. When a myofiber is at optimal length, myosin and actin filaments overlap so that each head on the myosin filament has access to a binding site. However, when stretched, the actin filaments are pulled out of range of the myosin filaments, and they have less to bind to.



Lets carry this one step further. What happens, when actin is pulled completely out of reach of the myosin filaments? All the weight that the load being placed on the muscle has now been transferred to the cytoskeleton. This is similar to the deadlift. When my spine is flexed, by extensors or erectors spinae are relaxed. If I lift the weight when flexed, my spine bares the load, and consequently this leads to tendon and ligament strain. Dr. Morgan explains that during eccentric contractions, this lengthening, or rather the extent of lengthening per sarcomere unit does not take place uniformly. In fact, depending on the exercise it can be quite selective.

When a sarcomere is lengthened to a point in which myosin can no longer bind to actin, a vulnerable position will have been reached. Desmin can lose its integrity in connecting adjacent Z-lines, and Titan can be stretched to a point beyond its

capacity to bring a sarcomere unit back to resting length. This occurs when its association with thick filaments is broken(19). As a consequence, the effected area on the myofibril can lose its ability to build maximum tension, or completely lose its ability all together to build tension! This in turn places further stress on sarcomere units that are parallel and increases their risk for high tension damage(9).

What does this mean? Simply put, if an area loses its ability to form cross bridges, that muscle fiber is no longer contracting as a complete unit, even though the membrane in the sarcomere region is still depolarizing! Secondly, the specific regions associated with this area that is now weakened would become more susceptible to damage, and subsequent hypertrophy(15, 16, 17, 21,), then another area of the muscle fiber. It does not get more nonuniform then that!

Considering the fact, that bodybuilders are continually training to fatigue, it would be contradictory to ever make a generalized statement in regards to such a complex subject, especially when that generalized statement can be shown to be overtly false.

Conclusion

One cannot even phantom the complexities found at the cytological level in a muscle cell. The integral proteins embedded in the sarcolemma alone are worth countless articles. This is why a high is reached when discussing such insanely advanced levels of technology. I intend on capitalizing on such physiological aspects in the future.

Yours In Sport

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