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Physiology #3

مجموعة التفريغ السريع

MSS

Subject: *Muscle Physiology #3*

Done by: *See last page*

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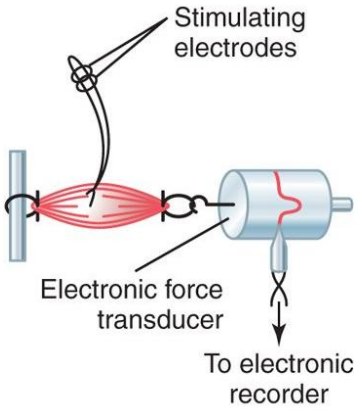
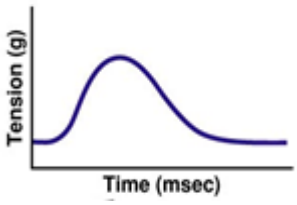
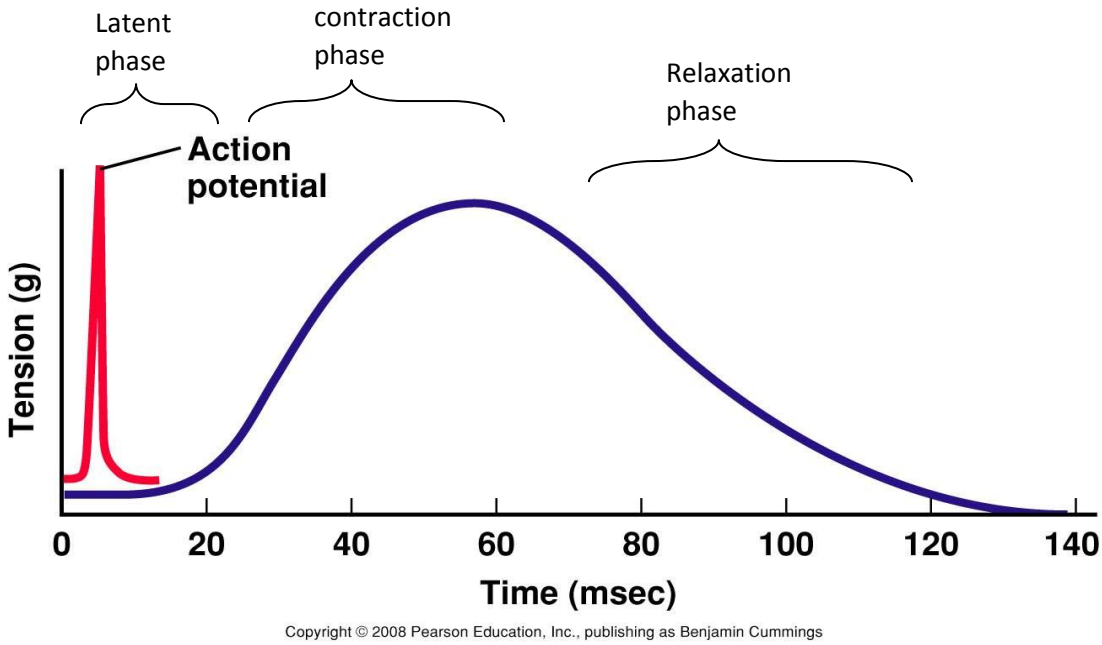
Characteristics of muscle contraction

In the previous lecture we started talking about the characteristic of muscle contraction and we said that we can record the single muscle tension using a devise like in the picture where we attach the muscle to this devise that has a force transducer connected to a monitor and we can get this shape (graph) which is called the "single muscle contraction" or the **twitch**.



The graph is composed of 3 phases (the latent phase , the contraction phase and the relaxation phase).

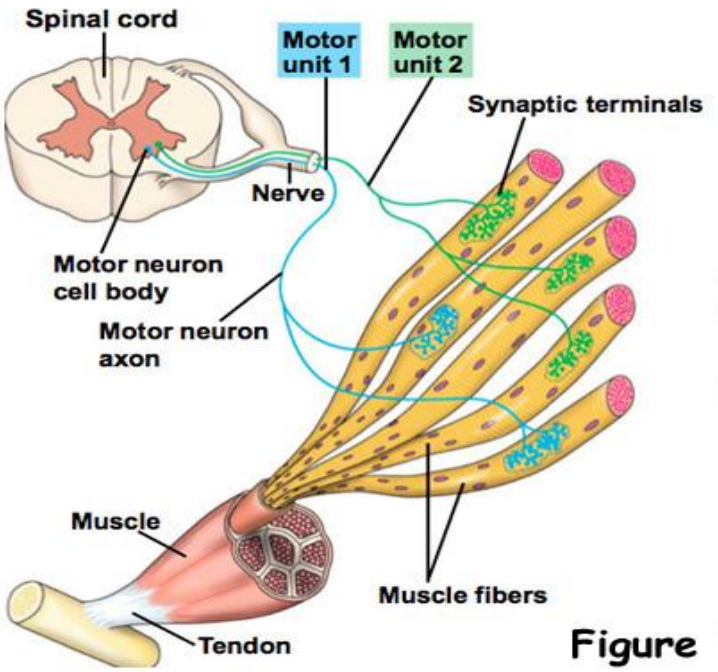




From the previous picture which represents a muscle action potential notice that the duration of action potential is very short compared to the duration of muscle contraction.

And we talked about the motor neurons and its origin from ventral horn of the spinal cord.

Each motor neuron innervate couple of muscle fibers , the motor neuron and all the muscle fiber that it innervates called the "**motor unit**"



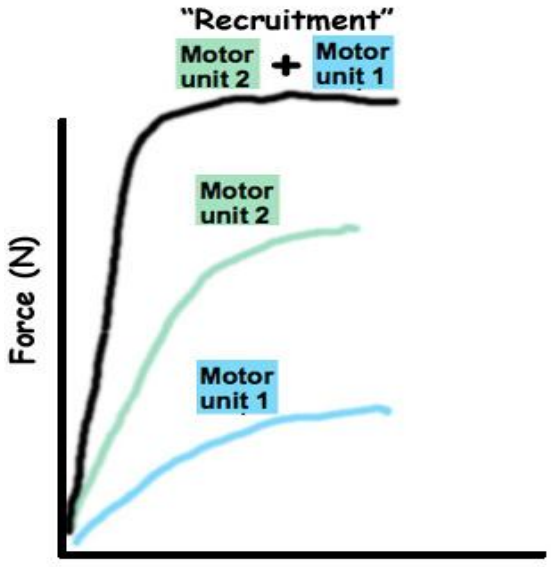
Figure

For example we have motor unit 1 (blue) and motor unit 2 (green); in motor unit one it innervates two muscle fibers while the motor unit two innervate three muscle fibers.

▶ Muscle force of contraction can be increased by 2 manners:

1) Increasing the number of motor units that are activated

so if we just stimulate motor unit 1 , we get small magnitude of force (the blue curve) because it's smaller motor unit , if we stimulate motor unit 2 we get larger magnitude of force (the blue one) and it's greater than motor unit 1 because it has more muscle fibers and it's a larger motor unit .



Motor units are stimulated according to their size ; the smaller the more excitable , so they will be stimulated first and this phenomenon is important in human body , because we can adjust the magnitude of force according to the task , for example fine skills need small motor unit , so we can mentally stimulate only small motor unit and generate smaller force.

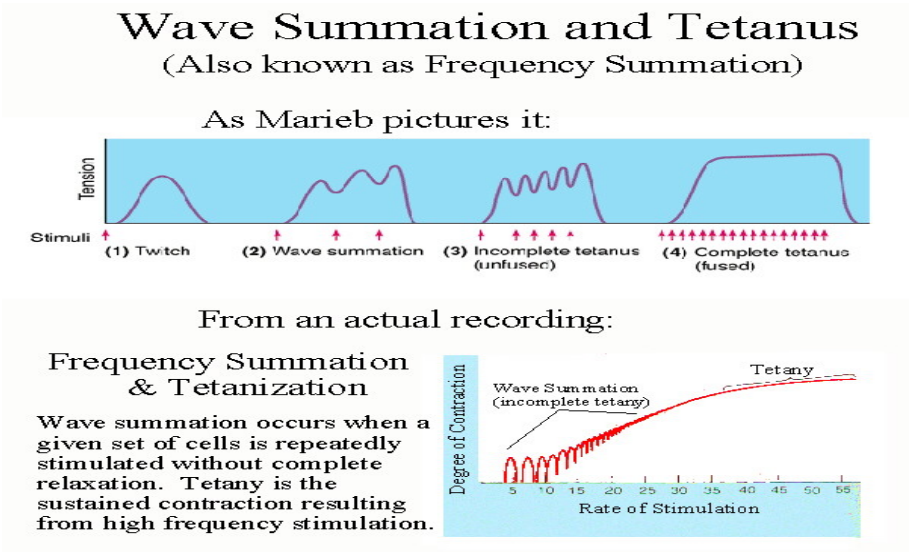
"**recruitment**" means stimulation of more motor units , for example if we give multiple stimulations with increasing magnitude we can recruit more and more motor units , and hence increase the force developed by muscle contraction , so we can increase the force developed by muscle by recruit more motor units.

2) increasing the frequency of motor neuron firing

we said that the action potential is much shorter than the duration of the muscle contraction , so we can stimulate the muscle again before it has relaxed , or even before it reaches its peak tension so we increase the magnitude of contraction by increasing the frequency of stimulation

The frequency of stimulation must exceed 1/twitch time (period of contraction) in order for summation to take place.

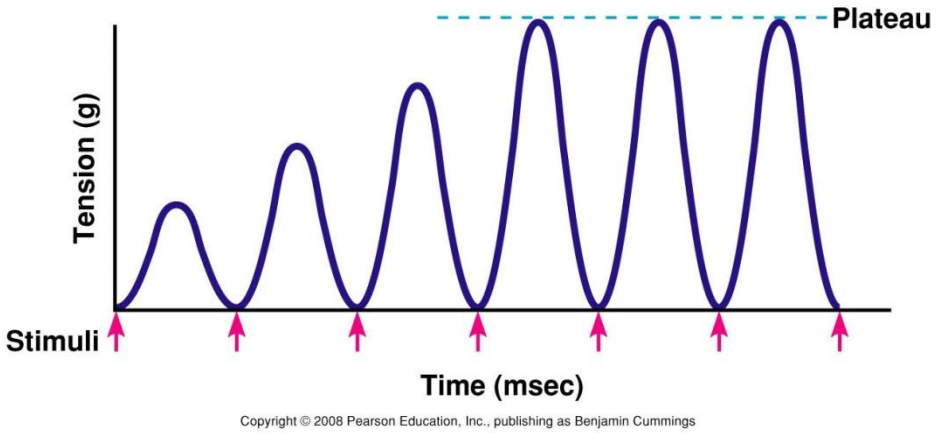
Look at the graphs here is the low frequency stimulation (second graph), note that there is some waviness. We can increase the stimulation to an extent where there is no waviness and we call it **Tetanus**. (last graph)



Molecular rational behind frequency summation and tantalization

Single AP causes single calcium transient (The release of calcium ions from the sarcoplasmic reticulum then it will go to troponin C …. etc), so calcium release channel is opened briefly and no enough time for calcium ions to be retained long enough to maintain the force developed by the muscle. Now if we increased the frequency of stimulation the number of calcium transients will increase ➔ so more calcium and longer contraction ☺

The force of contraction of a relaxed muscle will be less than the contraction of previously stimulated muscle. This phenomenon is called **Treppe**.



There is a gradual increase in contraction intensity during sequential stimulation that in the first contraction the contractility reached a certain limit but in the later contractions of the same muscle it's stronger.

The mechanism is not well known yet but it might be due to calcium ions accumulation in the cytoplasm with each stimulation.

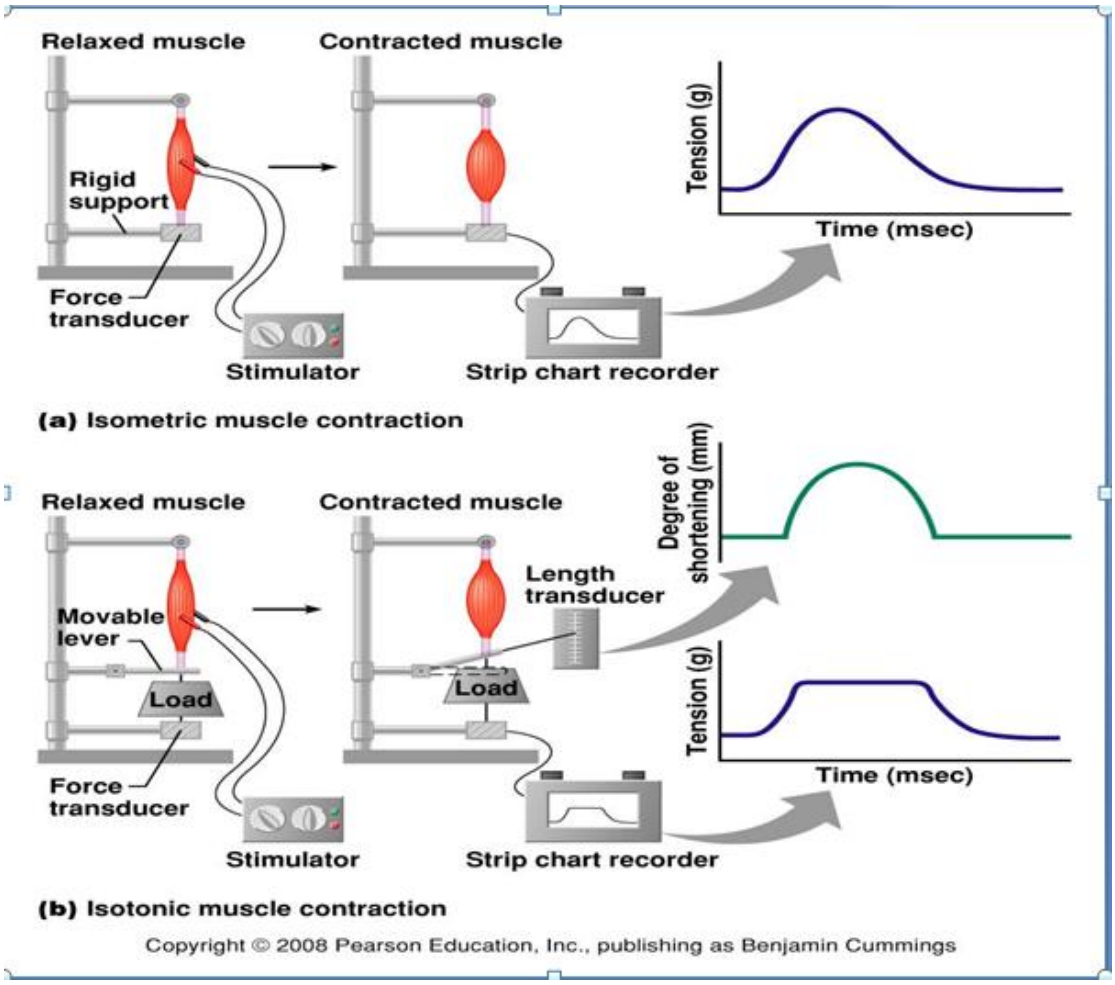
▶ Types of muscle contraction:

1-Isometric contraction: Muscle contraction without shortening. As when you lift an object against the gravity.

2-Isotonic contraction: Muscle contraction (and shortening) but without changing in force.

Isometric contraction means that the developed force is less than afterload , so there is contraction (force) without shortening . but in isotonic contraction force exceeds afterload so there will be shortening and movement when contraction happens .

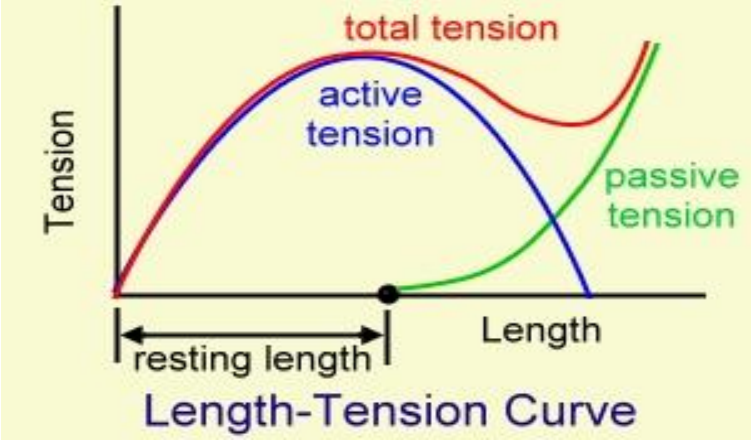
These figures explain the two processes and the difference between them .



3- Eccentric contraction: means lengthening of muscle fiber when the afterload is greater than force , this type of contraction is more likely to cause muscle injury .

▶ length and tension curve:

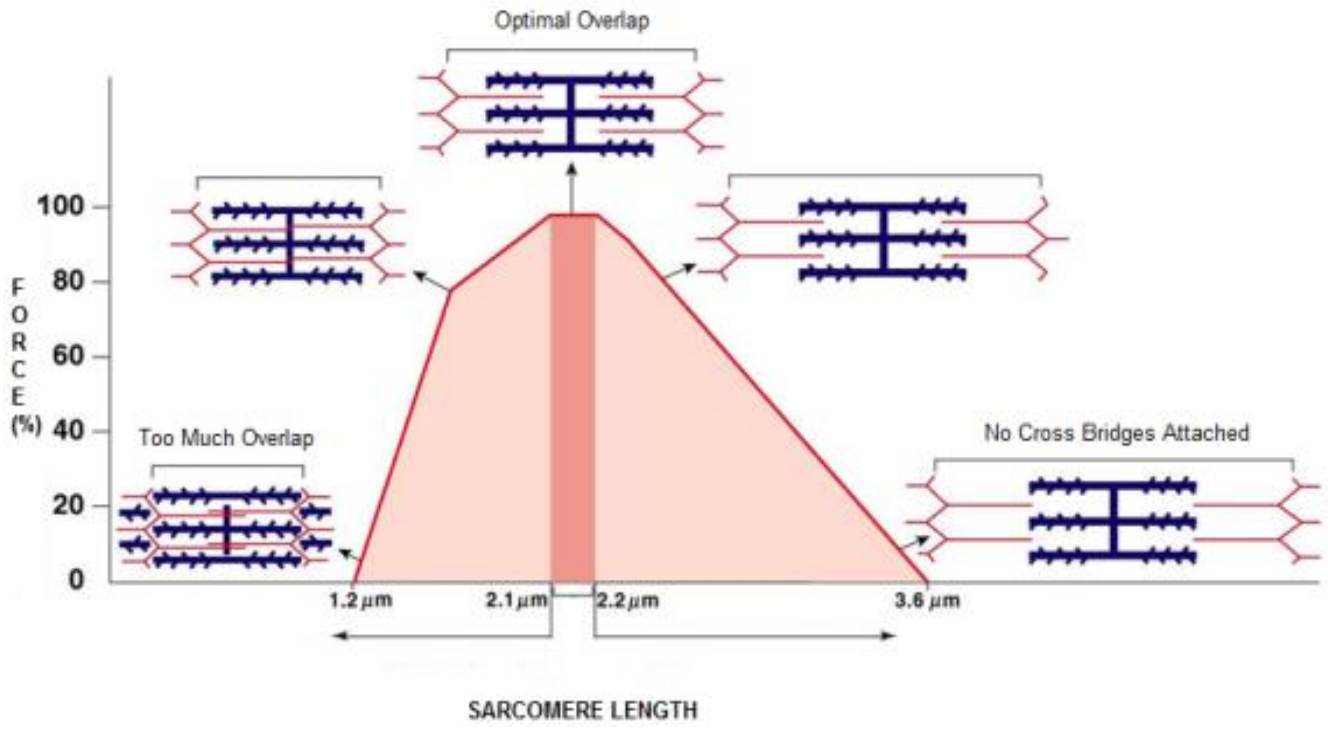
in intact muscle it operates near its rest length:



- stretching a muscle produces a passive force because there is plasma membrane and the elastic fibers in the muscle there has some elasticity (which is property of muscle tissue) , so they can be stretched and this produces a passive force without shortening and formation of cross bridges that's why we call it passive force.
- The active tension rises and then falls with the stretch of the muscle

Remember that we have the active tension and the total tension. The active tension means the tension related to cross bridges formation so if you increase the length beyond the resting length the active tension will be decreased.

for example if we ask any person to lift 5 kg weight he will initially produce isometric contraction then he can lift this weight so it is isotonic contraction , but if we ask him to lift 50 kg weight the afterload will be more than maximum force he can produce so there will be lengthening of the muscle.



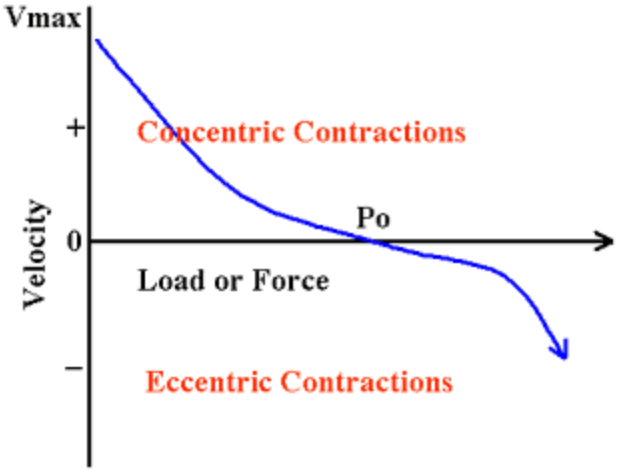
as an explanation to that in the level of sarcomere, we can see the resting sarcomere length is 2.2 or 2.3 micrometer , if we stretch the sarcomere that there is no overlap between thin and thick filaments , so that there will be no active force , because the active force is the result of cross bridge formations and the magnitude of force increases with the number of cross bridges .

if you notice from the figure , at length (3.6) there will be no developed force because no cross bridges are formed at all , if we decrease the length the force will start increasing because of more cross bridges formation until we reach the resting sarcomere length at which there is maximum active force .

the length at which maximum active force is developed is in the range (2.1-2.2) why ? because all myosin head are overlapped with the actin.

But if we decrease the length below that , the thin filaments will start to past against each other , this will cause decreasing in the cross bridges and then decreasing the magnitude of the active force. At this length, thick filaments start to put against the **Z** line, which demarcates the two sides of the sarcomere, and here the developed force will decrease tremendously.

▶ The velocity of muscle contraction depends on the afterload



Imagine if we start with no load and stimulating the muscle and increasing the afterload and measuring the rate of shortening (velocity of shortening) in each case.

⇨ As you can see at the ZERO load , there is the maximum velocity.

⇨ If you increase the load , the velocity is decreased until we reach the (Po) (the maximum isometric force can be developed by this point)

⇨ after that, if we applied a heavier load, the muscle will get lengthened , producing an eccentric contraction and the velocity will be in the minus (reverse direction)

▶ **Muscle Power**: Force x velocity

We multiply the forces we measured with the velocities we used and creating the ‘force-power’ relationship

As it is inverted meaning that the power of muscle equal 1/3 of the peck of the maximal force (see the related slide) sorry! we haven't them yet!

Skeletal muscle tone:

In order to produce contraction you have to stimulate the muscle, but at rest there is a basal level of contractility, and this is called “muscle tone”

The doctor office is at M2 L5 physiology department

The slide covers 90% of the material and 5% of doctor’s lecture and 5% from the two chapters from the book Ch6 & 7

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