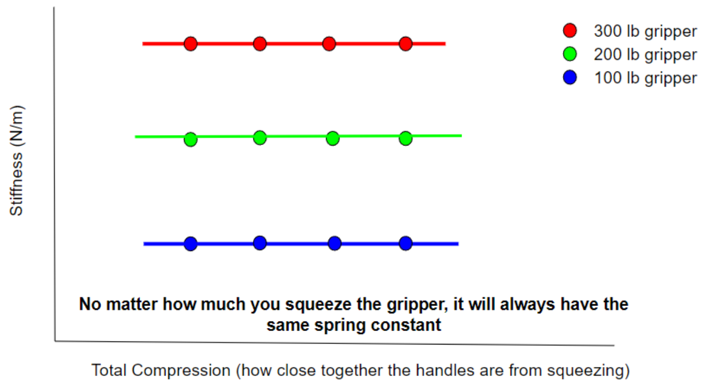
Pact Scanner Parameters General Overview

There are four parameters that the Pact system uses to characterize the mechanical state of muscle - stiffness, damping, stiffness slope, and damping slope. With these four parameters, Pact can quantify the state of any superficial muscle and the soft tissues around it.

Stiffness

When you read stiffness you should immediately think of a spring. The stiffness of a spring, also called spring rate, is how hard you have to push or pull on a spring to get it to compress or extend. The unit of stiffness [N/m] are Newtons (units of force) per meter (units of distance). A good way to visualize a spring mechanism are grip strengtheners. Grip strengtheners come in a variety of weights. In this case, the weight represents the amount of force required to bring the ends of the unit closer together. A grip strengthener with a higher weight indicates that the spring in the middle is stiffer and will require greater force to squeeze. Doing the exercise with the higher stiffness grip strengthener (300lbs), will be much more difficult than the lower stiffness grip strengthener (100lbs) because the lower stiffness grip strengthener requires far less force to squeeze.

Grip strengtheners are examples of springs. Each strengthener will have a different stiffness. The higher the stiffness, the harder it is to perform a given exercise with that grip strengthener.



In regards to muscles, stiffness is a measurement of how much the muscle compresses when you apply a force perpendicular to the muscle fibers. A relaxed muscle has considerably lower stiffness than a flexed muscle does. You can test this on yourself by gently pressing your finger into your relaxed bicep and noting how much your finger sinks into the muscle. Then repeat the test, this time with your bicep flexed. You'll notice that your finger depresses your bicep considerably less when it is flexed, because a flexed muscle has higher stiffness than its relaxed counterpart.

Damping

Damping is similar to moving friction — the faster something is moving, the more it is slowed down by damping. For example, think of riding a stationary bike. There is typically a knob used to control the friction of the flywheel when biking. If the bike is set to have high friction, it is harder to pedal than if the knob is set to low friction.

Friction on a stationary bike is similar to the damping of a muscle.
The higher the friction, the harder it is to pedal and the bike's flywheel will stop quicker after you stop pedaling.

A key difference from stiffness is that, to measure damping, the system being assessed must be in motion. To use the example of the bike, if the flywheel is not moving, there is no way to tell how high the friction is. Likewise, damping in your muscles can only be measured as your finger is moving in and out of muscle.

To see the damping force effects, imagine you are pedaling at speed "A" and remove your feet from the pedals, the pedals will continue to spin until the damping force stops their motion. If you increase the knob to make pedaling harder and repeat this, the pedals will stop spinning with less rotations. Similarly, muscles with high damping will bounce slower after being poked by your finger.

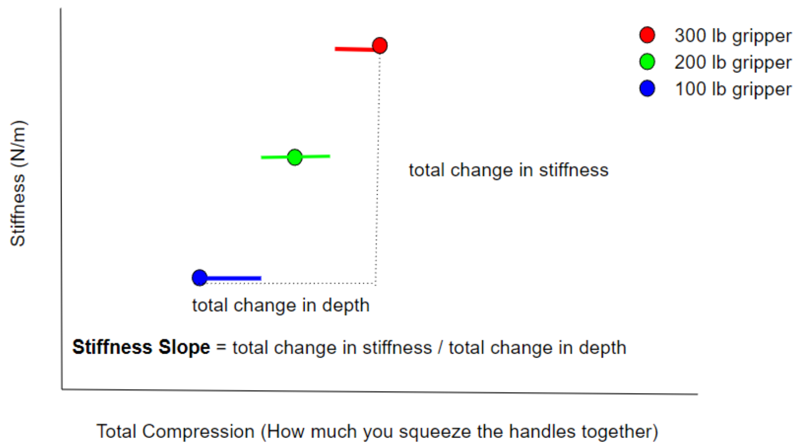
The units of damping are Newton-seconds per meter [Ns/m] . If you multiply the damping value by the speed at which you're moving (meters per second), you get the damping force that is slowing you down. When applying this concept to your muscles, tissue with a higher damping force will slow down the speed it compresses when prodded.

Depth Dependency of Muscles

Muscles are an impressive feat of engineering by nature. Accordingly, this means that they are not as simple to model as we'd perhaps like them to be. **Stiffness** and **Damping** values are a great starting point for our model, but fall short in a key way — depth dependency. Depth Dependency is how the values for stiffness and damping change as you press deeper into the muscle. This means that the mechanical feeling of your muscle changes depending on how deep you are palpating it.

Stiffness Slope

Because of muscles' unique properties, the deeper you press into your muscles, the higher the stiffness gets. This is like if you were to compress a spring and it were to get stiffer and stiffer as you keep compressing it. Going back to the grip strengtheners, imagine you have a special grip strengthener that changes its stiffness as you squeeze. When you do the initial squeeze, it feels like the 100lb grip strengthener. Then as you keep compressing the handles, the stiffness changes to the 200lb grip strengthener, requiring more force to continue squeezing the grip strengthening arms together which feels much harder. Then as you displace it again, the stiffness turns to that of the 300lb grip strengthener, again requiring even more force to be squeezed together.



As you squeeze the handles together, it gets harder to compress

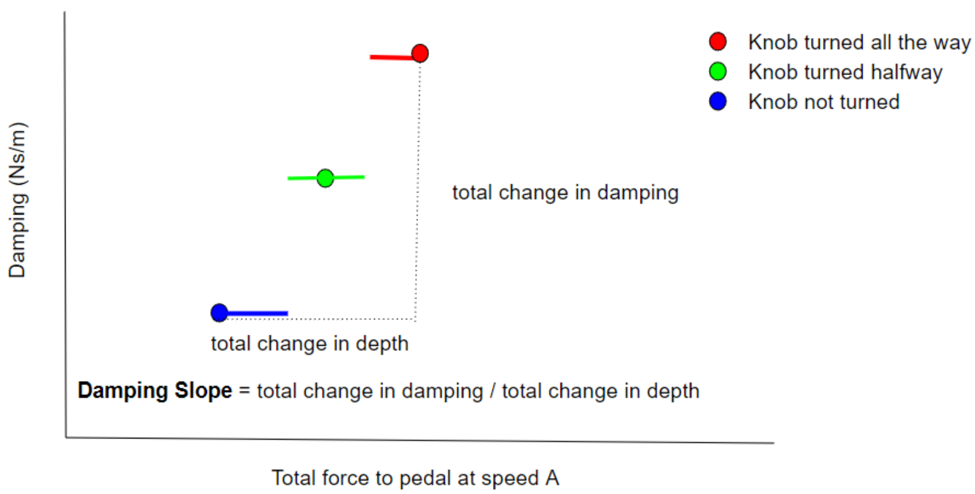
The **Stiffness Slope** is a measurement of how much the stiffness of a muscle changes, as a function of depth. A stiffness slope of zero would mean that the stiffness does not change with depth; the 100lb grip strengthener remains the same spring no matter how compressed the handles are. A high stiffness slope means that the stiffness is strongly dependent on depth; The grip strengthener goes from the 100lb squeezer to the 200lb to the 300lbs as you continue pressing the handles together

Stiffness Slope is measured in units of stiffness per meter $[N/m^2]$, which can be interpreted as the degree to which the stiffness changes when the muscle is depressed by a certain amount. To test this, depress your finger a little bit into the bicep muscle. Then press deeper into the muscle. You'll notice it gets harder to compress as you go deeper and deeper, even though this feeling may be subtle. Because of the depth dependency of muscles, the force required to push deeper and deeper is not constant, but instead increases.

Through our research, we have seen that weight training can cause short term increases to stiffness slope, while activities like marathon training have been shown to decrease it.

Damping Slope

Similar to Stiffness Slope, Damping Slope is a measurement of how quickly the damping changes with increased depth. For our stationary bike example, a non-zero damping slope would be like someone changing the control knob as you are pedaling at speed A. If you continue to pedal with the same force, then the pedals will start spinning slower and slower until the knob is turned high enough to stop all movement. In order to compensate for the knob turning, you must pedal harder to maintain speed A. You have to overcome the damping force at each turn of the knob. Similarly in a muscle, the damping force is increasing as you push deeper into the tissue. Therefore, if you push shallow into the muscle, it will bounce back faster than if you poke deeply. This is because the damping force is smaller at a shallow depth and increases as you push deeper.



The knob is turned, it gets harder to pedal at the same speed

Damping Slope is measured in units of damping per meter [Ns/m^2] , which should be interpreted as the degree to which damping changes when muscle is depressed by a certain amount. Through our research we have seen the damping slope to decrease in response to long term weight lifting.