IMPACT BIOSYSTEMS

February 13th, 2023

Knot Detection with the Pact Sense

Case Report: Summarizing the capability of the Pact Sense to detect knot locations within a muscle region

Summary: Myofascial trigger points, commonly referred to as muscle knots, are estimated to affect as much as 85% of the population at some point in their lifetime [1]. A knot is usually no bigger than a pea size and is classified as areas in muscle tissue that are stiffer and hypercontracted, which can lead to pain, decreased range of motion, and tenderness. Typically, they can be identified by touch or ultrasound. However, those assessments do not allow us to objectively measure how tense that trigger point is, or track how it changes over time. The Pact Sense can be used to identify the location of the trigger points and measure whether or not the knot is becoming more or less stiff over time.

How the Pact Sense Measures Muscle Knots:

The Pact Sense classifies the mechanical properties of any soft tissue measured at five different depths of the body's tissues.. Measuring the mechanical properties at multiple depths increases the sensitivity of the device to accurately distinguish between different points in the same tissue regions (see Muscle Characterization Using System Identification). As a result, the Pact Sense can be used to determine the stark differences in mechanical properties between knotted tissue and healthy, pliable tissue.

The Pact Sense classifies soft tissue using five different parameters; stiffness, damping, stiffness slope, damping slope, & inertia (see Scanner Parameters Overview). In the case of a knot, it is hypothesized that the measured stiffness & damping will be significantly higher at the site of interest, while surrounding tissue will show lower stiffness & damping values. A control experiment was designed to determine the ability of the Pact Sense to distinguish a simulated "knot" and its surrounding material. Following the control experiment, an assessment was done using the Pact Sense on a patient with a muscle knot located on their right upper trapezius muscle.

A Plastic Knot in Silicone under Synthetic Muscle Tissue:

To validate and test the reliability of the Pact Sense to detect different material properties the following set-up was designed (figure 1). A plastic square was 3D printed with a hole in the center. An additional dish was printed and filled with dragon skin 20A silicone. At the center of the dish was a plastic knot with an 8mm diameter. Additionally, a sheet of synthetic tissue was placed on top of the plastic square and center mold to act as a medium between the Pact Sense and synthetic knot. A fixture was then attached to the plastic square to identify every 10 mm along the tissue sample. At the center point of this fixture was the position of the plastic knot.

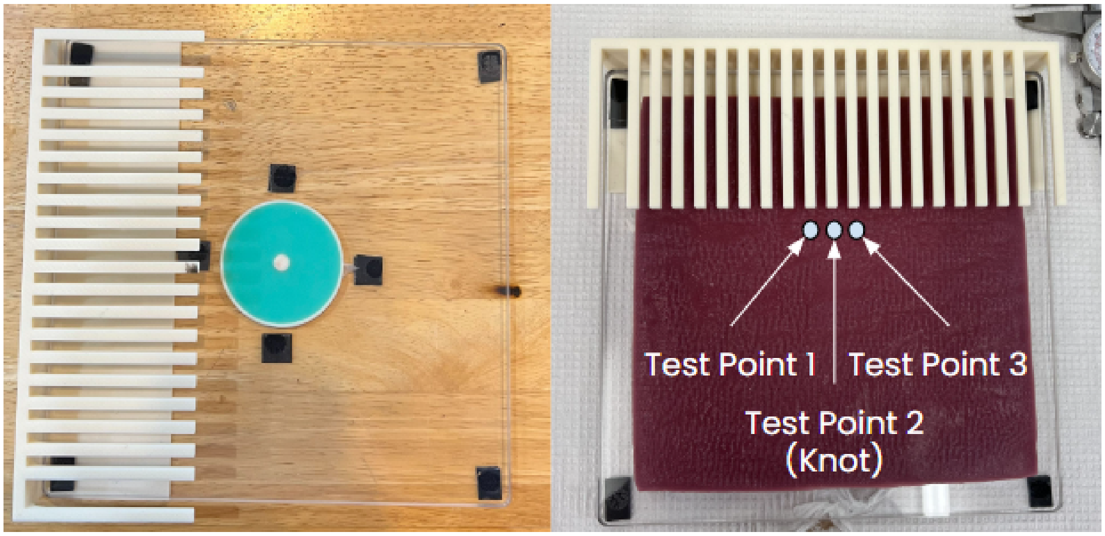

Figure 1. The test setup for detecting a plastic knot in a silicone dish under synthetic tissue.

Test Point 1 was located 10 mm to the left of the plastic knot, while test point 3 was located 10 mm to the right of the plastic knot. Test Point 2 was located directly above the knot. Using the Pact Sense, 5 scans were taken at each test point with a fixed position (figure 2). For the actual measurements, the synthetic tissue was placed on the plastic square as depicted in figure 1. This process was repeated for a total of 3 times to test the repeatability of the Pact Sense's ability to differentiate the knot from the other test points.

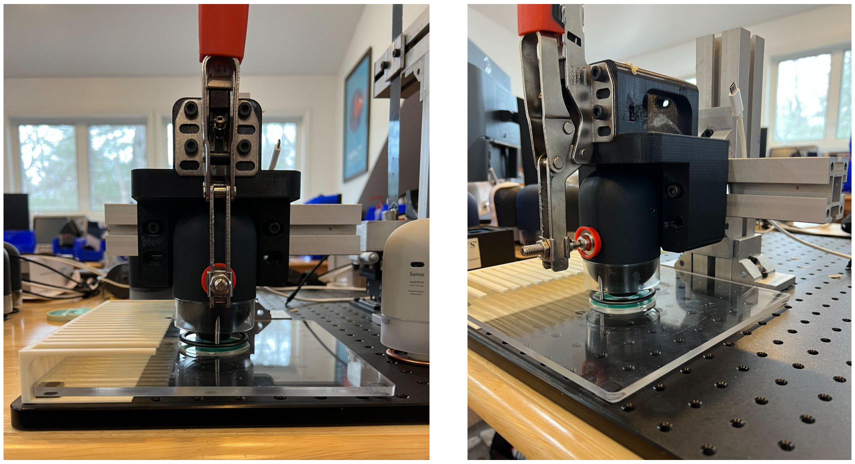

Figure 2. The fixture that holds the scanner in place during measurements.

Following the fixed Pact Sense measurements, the process was repeated using handheld scans at each test point. Here, a Pact Sense user manually held the scanner on each test point and took five scans, repeating the process 3 times. The purpose of these measurements were to show the user's ability to accurately locate and detect the knot present underneath tissue. Essentially if the knot is detectable, is it possible that a Pact Sense user can use the device to assess knots on the human body.

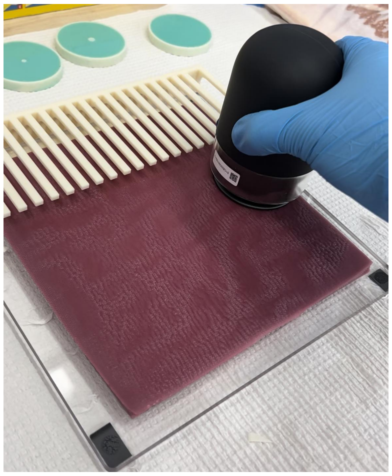

Figure 3. The handheld measurements on the test setup.

***A Plastic Knot in Silicone under Porcine Tissue*:**

Additional testing was performed to assess knot detection under more realistic conditions. To achieve this, the synthetic tissue was replaced with porcine tissue as the medium between the Pact Sense and the plastic knot. Porcine tissue is commonly used in research, as it is typically a reasonable representation of human muscle tissue. The porcine tissue sample includes layers of skin, subcutaneous, adipose, and muscle tissue, which is reflective of what is seen in human tissue.

For testing, Pact Sense measurements were taken under a single test point with 3 conditions. Five scans were taken by a Pact Sense user on the test point location with no knot underneath. Then a plastic knot that was 4 mm tall and 4 mm in diameter was placed under the test point location and five more scans were taken by the Pact Sense user. Following these scans a plastic knot that was 4 mm tall and 8 mm in diameter was placed under the test point location and five more scans were taken by the Pact Sense user. These 3 conditions were repeated 3 times each to determine the reliability and repeatability of a Pact Sense user correctly scanning the knot location.

Figure 4. The porcine tissue used for testing.

Case Study: Upper Right Trapezius Muscle Knot

Additionally, a patient diagnosed with a muscle knot in their upper right trapezius muscle was asked to come into the Pact HQ to assess the mechanical properties of the knot and surrounding tissue of the trap muscle. The site of the knot was identified using the Butterfly IQ+ Ultrasound device and marked on the skin surface with a body marker. Then two additional marks were placed 20 mm below the site of the knot and 20 mm above the site of the knot. Two sets of Pact Sense measurements were collected on each test point, while the patient laid in the prone position. The purpose of these measurements were to identify real, applicable differences in mechanical properties of a knot and its surrounding tissue.

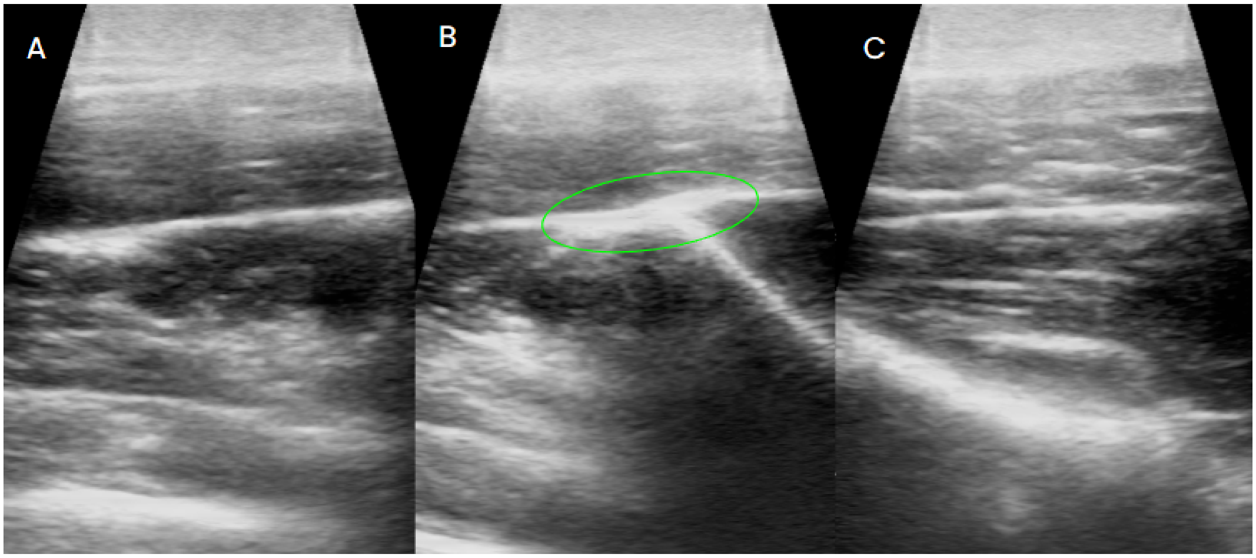

Figure 5. A) Ultrasound cross section of the site 20 mm below the muscle knot. B) The site of the muscle knot identified under ultrasound, indicated by thickened fascial tissue. C) Ultrasound cross section of the site 20 mm above the muscle knot.

Pact Sense Results:

Plastic Knot Under Synthetic Tissue - Fixed Position

Following measurements on the synthetic tissue with the scanner in the fixed position, there is a clear increase in stiffness when the scan is taken over the plastic knot. The mean stiffness over the knot is 2022 N/m with a standard deviation of 3.6 N/m. The mean stiffness 10 mm to the left of the knot is 1919 N/m with a standard deviation of 29.2 N/m. The mean stiffness 10 mm to the right of the knot was 1952 N/m with a standard deviation of 15.1 N/m. Therefore, the scanner is measuring elevated stiffness when placed over the knot.

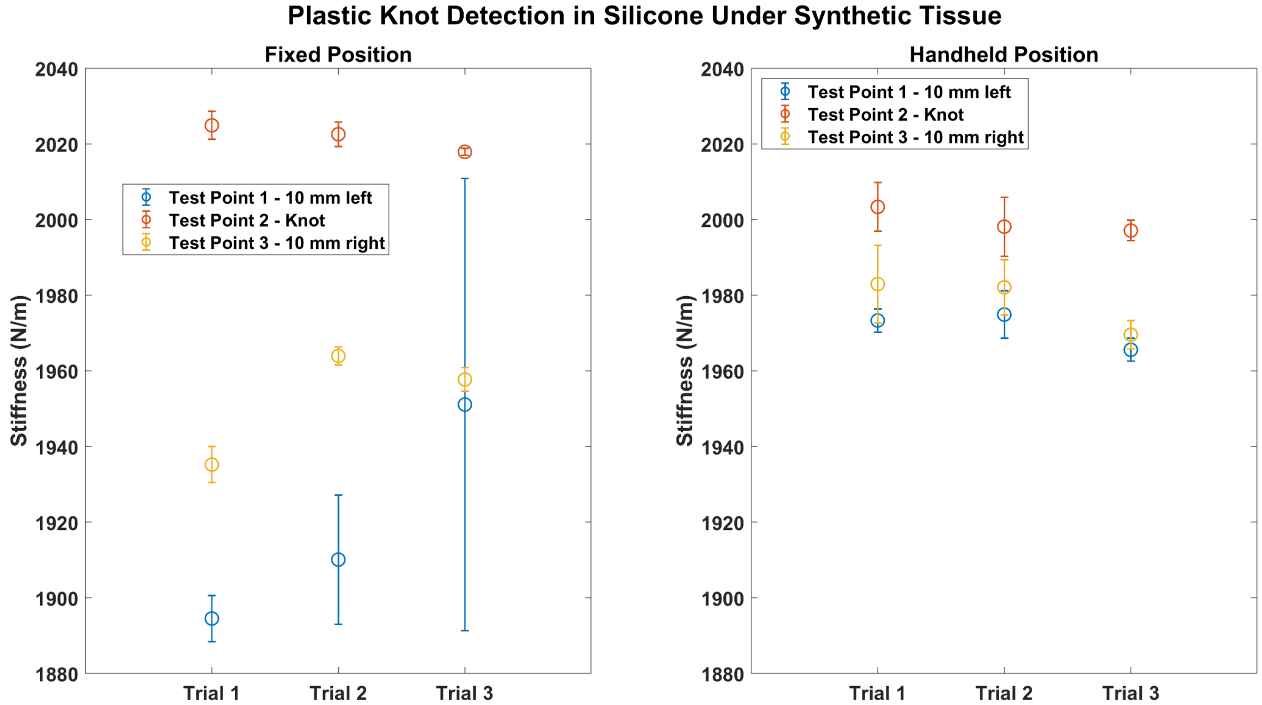

Figure 6. The stiffness (N/m) measured by the Pact Sense on the test points outlined in figure 1 using the fixed position method (Left) and the handheld method (Right).

Plastic Knot Under Synthetic Tissue - Handheld Position

When the user directly measures the plastic knot under synthetic tissue, there is again an increased stiffness when placed over the knot. The mean stiffness measured over the knot was 2000 N/m with a standard deviation of 7.6 N/m. The mean stiffness measured 10 mm to the left of the plastic knot by the user was 1970 N/m with a standard deviation of 4.8 N/m. The mean stiffness measured 10 mm to the right of the plastic knot by the user was 1984 N/m with a standard deviation of 11 N/m. Therefore, the Pact Sense detects higher stiffness over the knot, but due to human error, the signal difference becomes smaller. Presumably, the user placement of the scanner is closer than 10 mm to the knot at the time of measurement. To detect a knot successfully with the Pact Sense, this placement error must be accounted for.

Plastic Knot Under Porcine Tissue

Following measurements under synthetic tissue, it was found that measuring over a plastic knot results in increased stiffness with a signal difference of roughly 70 - 100 N/m. Because of this,, it was desired to see the signal difference when the medium between the Pact Sense and plastic knot was closer to human tissue. To achieve this, porcine tissue was used as the medium between the Pact Sense and plastic knot. Results show the stiffness of the porcine tissue to have a mean of 1187 N/m with a standard deviation of 12.8 N/m. When the knot with a 4 mm diameter was placed under the test site, the mean stiffness increased to 1284 N/m with a standard deviation of 14 N/m. Then after increasing the plastic knot size to 8 mm, the mean stiffness increased to 1565 N/m with a standard deviation of 143.4 N/m, showing that as the knot size increased, the signal difference also increased.

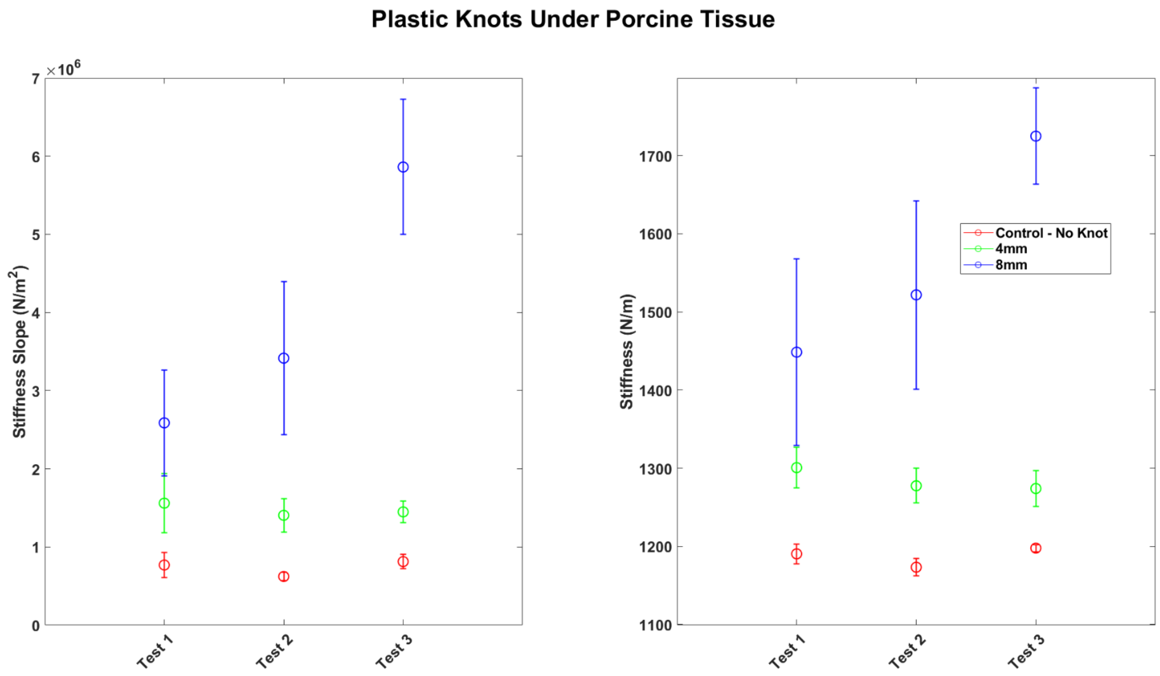

Figure 7. The stiffness slope (N/m^2) and stiffness (N/m) measured by the Pact Sense on the porcine tissue with various knots placed beneath.

Case Study: Upper Right Trapezius Muscle Knot Assessment

Following measurements on a patient, there were clear differences in damping slope, damping, & inertia detected by the Pact Sense on the site of the knot. The mean damping slope below the knot was 1930 Ns/m^2 and 2614 Ns/m^2 above the knot, while the mean damping slope directly over the knot was 6712 Ns/m^2. Furthermore, the mean damping below the knot was 8.2 Ns/m and 9.4 Ns/m above the knot, while the mean damping over the knot was 11.4 Ns/m. Finally, the average inertia below the knot was 0.023 kg and 0.021 kg above the knot, while the mean inertia directly over the knot was 0.016 kg. Therefore, damping and damping slope were found to be elevated over the site of the muscle knot and inertia decreased on the site of the knot.

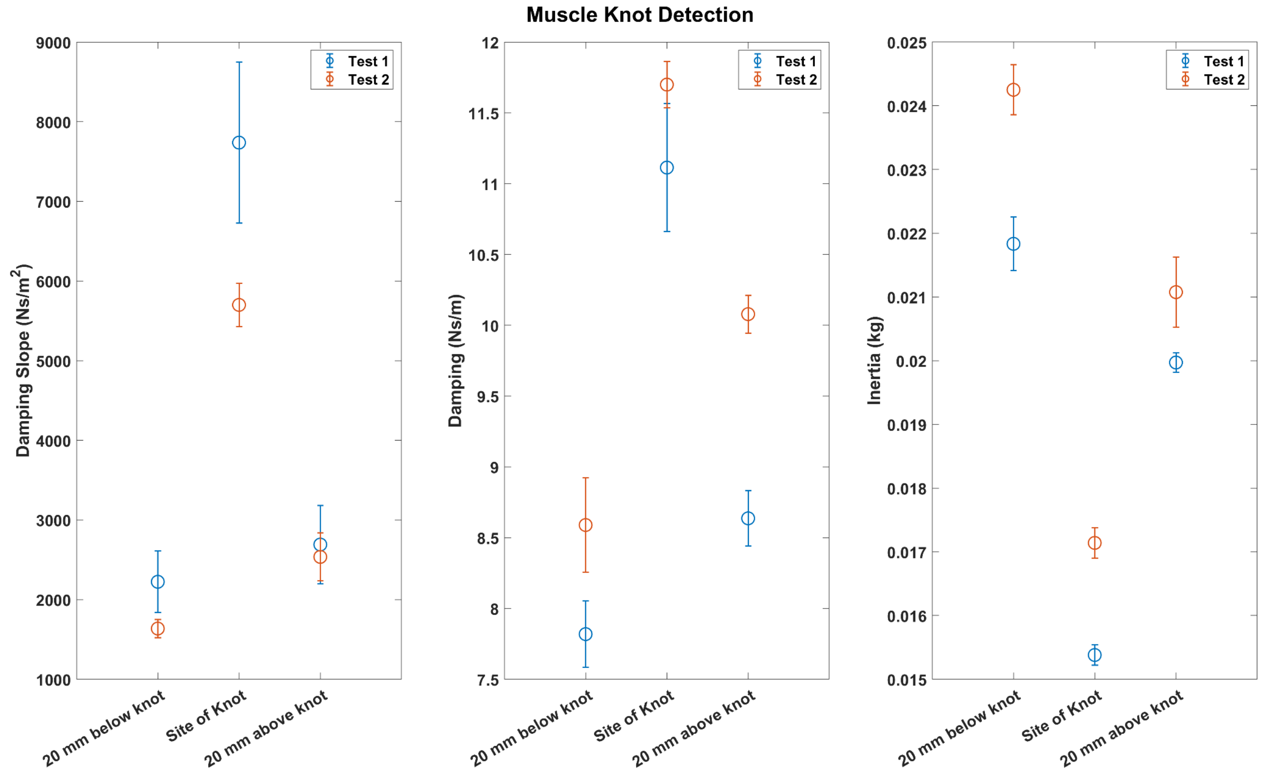

Figure 8. Damping Slope, Damping, & Mass below the knot, above the knot, and directly over the knot

What does this mean:

In practical applications of the Pact Sense, the device shows clear sensitivity to the difference in mechanical properties below a specified medium resembling human tissue. This gives us high confidence that correct use of the Pact Sense will detect increased stiffness at the site of the knot and will be able to track its changes over time. Additionally, once the knot is located, it can be clearly distinguished with the Pact Sense.

This opens a possibility for a continuous scanning feature to detect an unknown knot. Because there are significant differences in stiffness 10 mm to the left and right of the plastic knot, a continuous scanning feature can be utilized to "sweep" a muscle region to scan for major signal differences in the stiffness. In the case of the real knot, the "sweep" can scan for signal differences in the damping, damping slope, and inertia. What remains unknown before implementing this feature is determining if all knots produce the same signal differences to damping, damping slope, and inertia. It may be the case that each knot is unique and could show differences in stiffness and stiffness slope as well, indicating the importance of understanding each Pact Sense parameter in a continuous scan. For this, additional clinical data should be collected.

Pact Sense shows high sensitivity to the location of the scanning site with increases in stiffness up to 100 N/m over the site of the plastic knot, which makes detecting a small knot very feasible and practical. High sensitivity was confirmed on the patient with an upper trapezius muscle knot, where differences in damping slope over 4000 Ns/m^2, as well as over 2 Ns/m differences in damping, and 0.05 kg differences in inertia were detected. These differences are quite significant, as shown through the repeatability of Pact Sense measurements, gathering similar results in two separate trials.

Furthermore, more data is desired in clinical settings to determine the signal differences between a healthy tissue and knotted tissue. Despite one case showing differences in damping slope, damping, and inertia, other knotted tissue could show a different response (e.g. increases in stiffness & stiffness slope). Pact Sense shows high sensitivity on human-like porcine tissue, with signal differences up to almost 400 N/m on the 8 mm-diameter plastic knots, suggesting that muscle knots would also be very detectable if their mechanical stiffness is the property with most change. Plastic is not representative of the stiffness for a muscle knot, but it is representative of a stiffer material embedded beneath tissue. Being able to detect a small, stiff material underneath human-like tissue reassures Pact Sense's ability to detect a stiff muscle knot.

How can I use this knowledge for monitoring my own tissue health:
Muscle knots are a common occurrence and understood to be small pea-like knotted tissue that can be felt as much stiffer than healthy tissue. Once the knot is identified, the Pact Sense can objectively tell you how stiff that knot is and how damped the site is. With the goal to reduce stiffness and damping of that knot to increase tissue pliability, Pact Sense measurements can be taken after recovery, stretching, and various treatment techniques to monitor their effectiveness in treating the knot. As you examine the changes in stiffness and damping over time, you can see if the treatment is effective or if another technique should be used. Additionally, as continuous scanning is developed, the Pact Sense will be able to diagnose the muscle knot directly while continuing to monitor its changes over time. Offering a much cheaper and efficient alternative to ultrasound imaging, while still providing an objective diagnosis and monitoring system.

Resource:

1. Jafri MS. Mechanisms of Myofascial Pain. Int Sch Res Notices. 2014;2014:523924. doi: 10.1155/2014/523924. PMID: 25574501; PMCID: PMC4285362.