Myofascial Pain Syndrome Trigger Point Detection based on Ultrasound Image

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Abstract: - Myofascial Pain Syndrome is pain revolved around a trigger point, a nodule located in a taut band of muscle. Treatment needs to be administered to area of trigger point to alleviate the pain. Currently, the location of trigger point is mostly determined through physical examination by clinicians, which is considered unreliable due to the dependency on the clinician's discretion. This project had developed a system that quantifies the location of trigger point using ultrasound images to detect the presence of trigger point. Normal muscle and muscle with trigger point shown morphological difference in ultrasound images, in which, is accentuated through image processing and pattern recognition. Statistical properties of the final signal output were analyzed to determine the most optimum value used for classification. The images were subsequently classified into the categories 'Normal Muscle' and 'Muscle with Trigger Point'. System performance testing shows that this system has high accuracy when detection was performed with the current collection of sample images.

Key-Words: - Myofascial Pain Syndrome, Trigger Point, Ultrasound Imaging, Image Processing, Signal Processing

1   Introduction

Approximately 85% of the general population is in some way affected by musculoskeletal pain from time to time [1]. One of the frequent syndromes that affect millions of people is Myofascial Pain Syndrome [2]. In short, Myofascial Pain Syndrome (MPS) is a form of chronic muscle pain centered on sensitive points in muscles called trigger points. The trigger points are painful when pressure is applied on them and can spread throughout the affected muscle. MPS is caused by muscle trauma and is treated by many forms of muscle stretching to release the muscle and reduce the muscle deformity.

There are a few methods used to identify and determine the location of trigger points, including physical examination, pain pressure threshold, electromyography, magnetic resonance elastography and ultrasonography.

Table 1 Comparison of method to identify trigger point

Method	Equipments	Parameters
Physical Examination	None	Feeling
Pain Pressure Threshold	Pain algometry	Pressure applied
Electromyography	EMG machine	Electrical activity
Magnetic Resonance Elastography	Magnetic Resonance Imaging	Stiffness
Ultrasonography	Ultrasound scanner	Morphology

Physical examination and pain pressure threshold depends on the discretion of the clinician and the patient's feeling of pain. [3] Hence there is a degree of subjectivity in this method. Electromyography is able to indicate increased muscle electrical activity as a result of pain but unable determine the exact location of trigger point. [4] Magnetic Resonance Elastography would be able to show the location of trigger point based on stiffness, though it is an expensive procedure.

[5, 6] Ultrasonography would be able to show the location of trigger point based on the morphology of the muscle, and the cost to undergo this procedure is considerably lower than MRE. [7, 8] Therefore, this method can be further developed to effectively detect trigger points.

The main objective of this project is to design a software system that can detect myofascial pain trigger point using ultrasound images of muscles. In order to achieve that, the morphological differences between normal muscle and muscle with trigger point needs to be discovered. It is achieved by processing and analyzing the ultrasound images using the software MATLAB®. Based on the differences, an algorithm that will successfully classify the images will be developed.

2 Materials and Method

This system was developed based on the concept that normal muscle and muscle with trigger point have morphological differences, and this difference can be portrayed using ultrasound imaging. Based on observation, the muscle layer of normal muscles appears to be flat and parallel to the surface while the muscle layer of muscle with trigger point appears to form a peak at the area of trigger point.

Fig.1   System Block Diagram

2.1 Data Collection

Ultrasound imaging was done on 160 subjects, 50 with trigger point and 110 without trigger point. The subjects are in the age range of 20 to 50 years old, and include both the male and female gender. The trigger points are latent trigger points.

Images of the shoulder muscles were taken, with the subjects sitting upright in a comfortable position. The transducer head were placed in a way that it is parallel to the direction of the muscle fibers. The pressure exerted on the muscle throughout the scanning was held constant to avoid distortion of muscle layer.

Ultrasound machines used were from two different models, which were Mindray DUS 100 and Toshiba Aplio MX. The scanning mode used to capture the images was B- mode. The transducer of the ultrasound

machine was of flat head and linear array with frequency 7.5 to 7.6 MHz.

Normal upper trapezius muscles taken with the method explained above appeared as a layer that is parallel to the surface. As shown below is one of the normal muscle images obtained during the course of the project.
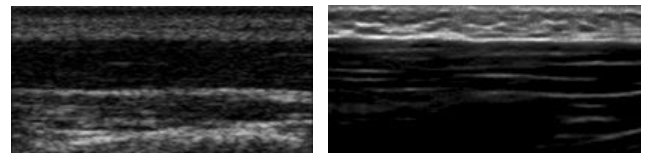

Fig. 2   Images of normal muscle: DUS 100 (left), Aplio MX (right)

Muscles with trigger point appeared to be curved with a peak forming at the trigger point. The slope of the peak differs for trigger point with different severity. As shown below is one of the images of muscles with trigger point.
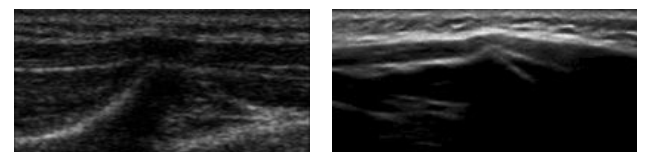

Fig. 3   Image of muscle with trigger point: DUS 100 (left), Aplio MX (right)

2.2 Image Processing

Image processing was done on the ultrasound images obtained in order to extract the relevant parameter for detection. Ultimately, the purpose of image processing in this project was to obtain the upper boundary of the muscle layer, which is the line representing the shape of muscle layer. Image processing is done using MATLAB® Image Processing Toolbox

Fig. 4   Algorithm of image processing

2.2.1 Convert to Binary Image

Binary conversion with thresholding replaces all pixels f(x,y) in the input image with luminance greater than T with the value 1 (white) and replaces all other pixels with the value 0 (black).

Fig. 5 Binary conversion: normal muscle (left), muscle with trigger point (right)

2.2.2 Eliminate Isolated Pixels

All connected components that have fewer than P pixels are removed. This step is to produce two distinct and solid layers, with the white layer being on top and black layer being in the bottom.
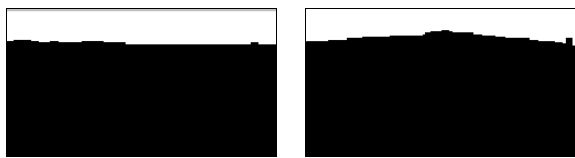

Fig. 6 Elimination of small objects: normal muscle (left), muscle with trigger point (right)

2.2.3 Boundary Detection

Only pixels that are located at the boundary between the two layers are retained. This boundary is assumed as the line of the muscle layer, and will be used in the next step which is the curve detection.
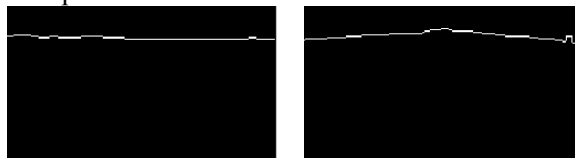

Fig. 7 Boundary for muscle layer: normal (left), muscle with trigger point (right)

2.3 Curve Detection

After the line of the muscle layer is obtained in the image, it will be converted into a one-dimensional signal representation. Next, this signal will undergo signal processing such as filtering with moving average filter and squaring in order to be successfully classified.

Fig. 8 Algorithm for curve detection

2.3.1 Conversion of signal

Signal representation for this muscle line can be obtained by obtaining the coordinate of the line. A 'for'

loop is used for that purpose. The result from this loop will be the one-dimensional signal for the muscle line.

```
for i = 2: p-1;
     for j=1:50;
          if f(j,i) == 1;
               x(i) = j;
          end
     end
end                                    (1)
```

2.3.2 Moving Average Filter

A moving average filter is applied on the signal in order to make the signal more smooth and reduce the effect of outliers.

$$Moving\ Average = \frac{1}{N}\sum_{n=1}^{i}(X_n + \cdots + X_{(n+N)})\quad(2)$$

2.3.3 Accentuation of Slope

The signal is subtracted with its minimum value to bring the signal down to the x-axis (y=0), and obtain the relative height of the signal. Subsequently, each value of the signal will be square to accentuate the curve of the signal.

$$X_2 = X - \min(X)$$
$$output = X_2^2 \quad(3)$$

2.4 Classifier

The signal after the curve detection will be categorized with a classifier. A threshold value is set based on data collected.

3 Results and Analysis

3.1 Image Representation

Based on the methods and processes described in the previous chapter, the system is tested with ultrasound images collected throughout the implementation of project.

Figure 9 shows the ultrasound image of normal muscle captured using Toshiba Aplio MX and the resulting output signal.
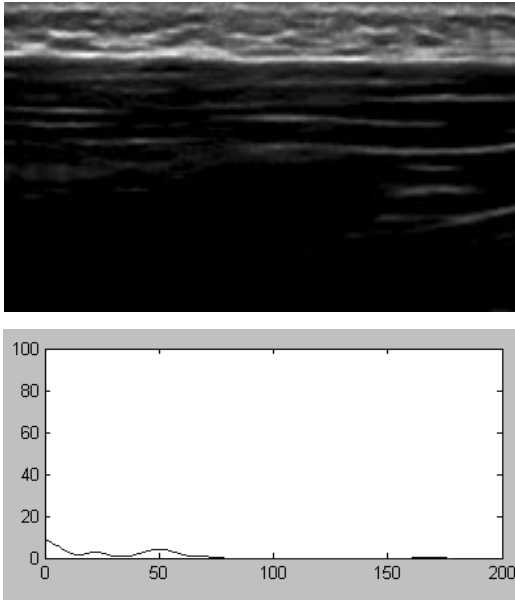
Fig. 9   Image and signal of normal muscle (Toshiba Aplio MX)

Figure 10 shows the ultrasound image of muscle with trigger point captured using Toshiba Aplio MX and the resulting output signal.
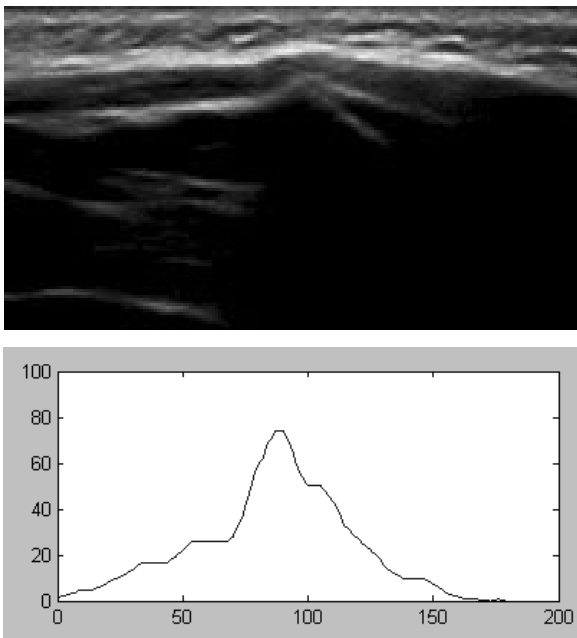

Fig. 10   Image and signal of muscle with trigger point (Toshiba Aplio MX)

3.2   Pattern recognition through statistical analysis

Table 2: Mean and Standard Deviation for Signal Representation of Muscles (Mindray DUS 100)

Image	Condition of Muscle	Mean	Standard Deviation
01	Normal	19.6075	7.9739
02	Normal	18.8255	7.1256
03	Normal	5.7211	3.1374
04	Normal	2.6797	3.2713
05	Trigger Point	12.2683	16.9532
06	Trigger Point	9.2745	13.6313
07	Normal	3.9248	2.2358
08	Normal	2.6308	2.7501

Table 3: Mean and Standard Deviation for Signal Representation of Muscles (Toshiba Aplio MX)

Image	Condition of Muscle	Mean	Standard Deviation
01	Normal	1.5478	1.1914
02	Normal	1.0328	1.6481
03	Trigger Point	37.3856	25.1892
04	Normal	11.5344	10.4919
05	Normal	12.5099	11.1172
06	Trigger Point	26.8823	20.1710
07	Normal	8.8225	6.5713
08	Trigger Point	22.8192	20.6081

Upon observation, the value of standard deviation can be used in setting the threshold value for the classifier to differentiate between normal muscle and muscle with trigger point.

Images of muscle with standard deviation higher than 12 (DUS 100) and 18 (Aplio MX) will be categorized as muscle with trigger point while images with standard deviation lower will be categorized as normal muscle.

3.3   System Performance Testing

Table 4: Accuracy of System using Automatic Mode

Model	Number of Images		Correct	Incorrect	Accuracy (%)
	Normal	Trigger Point			
DUS 100	6	2	8	0	100
Aplio MX	5	3	8	0	100

Table 5: Accuracy of System using Manual Mode

Machine	Number of Images		Correct	Incorrect	Accuracy (%)
	Normal	Trigger Point			
DUS 100	60	20	80	0	100
Aplio MX	50	30	80	0	100

Table 4.3 and Table 4.4 above show the accuracy of the automatic mode and manual mode of the detection system. It is tested with ultrasound images captured from from both ultrasound machines (DUS 100 and Aplio MX). The images used for the testing of both modes are the same.

As can be seen, the accuracy of the automatic system is high, which recorded 100% for both machines. This is due to the fact that this system is developed based on the current collection of ultrasound images. The contrast and quality of the images from the same model of machine are similar to each other, causing the present values to be suitable for every image.

For the manual mode, the accuracy of the system is also high, recording 100% for both machines. This is due to the ability of the user to control the procedure of image processing. The contrast of the image can be enhanced by selecting the desired method, producing optimum image for the detection algorithm.

3.4 Discussion

Based on the calculation done on DUS 100 images, the mean value is inconsistent with the condition of muscle. It is not favorable to set a threshold according to the mean value to classify the images. This situation might be due to the presence of noise in the image, since the ultrasound machine is low cost. Images of Aplio MX do not show inconsistent values of mean, where images with trigger point have higher mean values.

The value of standard deviation however is consistent with the condition of muscle, for both DUS 100 and Aplio MX. Images of normal muscle have lower values of standard deviation as compared to images of muscle with trigger point. Therefore, the threshold for the classifier is set based on the value of standard deviation in order for the system to accommodate for both models of ultrasound machine.

After testing with the ultrasound images collected, the detection system performed high accuracy (100%).

This is largely due to the fixed contrast setting when scanning and capturing the muscle images. Furthermore, the sample size (160 images) enables the setting of values that are highly specialized to detect images for current collection.

Different contrast setting of ultrasound machine will cause error in detection, since the values used in image processing and also the classifier will be different. Hence, the manual mode is developed to enable higher degree of freedom in image processing for optimum detection. More settings for image processing in the manual mode can also be introduced.

4 Conclusion

A system that is able to detect the trigger point of Myofascial Pain Syndrome has been developed. This system could be useful in assisting physical therapists to accurately locate the trigger point, in complement to the current situation in which physical therapists use physical examination to locate trigger points.

Detection was done by using ultrasound images of the muscle, and classification of images was based on the morphological differences between normal muscle and muscle with trigger point. The morphological difference observed was the contour of the muscle layer, where normal muscle appeared flat and muscles with trigger point appeared to peak at the area of trigger point.

The morphological difference in ultrasound images, in which, was accentuated through image and signal processing. Methods used in image processing include morphological operations such as thresholding, dilation and boundary detection. As for signal detection, moving average filter and mathematical functions were applied to the signal.

Statistical properties of the final signal output indicate that the standard deviation (SD) for the signal was suitable to be used to recognize the trigger point pattern. Threshold value for the classifier was thus set according to the value of standard deviation. For DUS100 images the SD threshold value was set to 12 while for Aplio MX the SD threshold value was set to 18. This system performed with high accuracy (100%) with the current collection of sample ultrasound images.

Compared to the conventional way of identifying trigger point with physical examination, this method of detection using ultrasound images is more reliable since quantitative data can be obtained. The condition of the muscle itself will be portrayed with the ultrasound imaging. However, the system developed

was highly dependent on the quality of ultrasound images and the method of image processing used.

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