Muscle Spasm Relief Device

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Abstract

An estimated 80 percent of the U.S. population will experience pain caused by lower back spasms at some time in their lives. These spasms are involuntary contractions of muscles. During the spasm there is a sudden spike in electrical activity within the muscle. Muscle spasms can occur frequently and cause pain and difficulty in moving the muscle. Current treatments include topical creams and manually-applied massaging to a broad area. The main issue with these treatments is that they are all used after the spasms occur. The goal of this device is to detect muscle spasms in the lower back at the moment of onset and apply vibrations to the localized area to alleviate the pain without the need for human input. The final version of the device is able to detect electrical activity of the muscles in the lower back and provide targeted vibrational therapy to several regions of the lower back. Vibration motors can be independently activated but struggle to vibrate when the belt is very tight. Tests for adjustability, weight, comfort, and safety of the device were successful. More precise calibration may be necessary to allow the device to better differentiate muscle spasms from normal muscle activity.

Introduction

Muscle spasms are involuntary contractions of muscle that can last for a few seconds or up to 15 minutes. Spasms in the lower back are especially problematic as they can be very painful, and can impair movement. Vibrational therapy has been studied, and research shows that it can help to reduce pain and increase blood flow.[1] In the Muscle Spasm Relief Device (MSRD), vibrations will be localized to specific areas of the lower back. The device will detect spasms throughout the day and alleviate pain caused by these spasms through targeted vibration. The target population for this device is people who experience chronic lower back spasms.

The device includes four EMG sensors that monitor the electrical activity of muscles in the lower back. When the electrical activity exceeds a certain threshold, the vibrations are activated in the area of the spasm. The main advantage of this device over others on the market is the automatic and targeted treatment. Alternative methods of pain relief such as heating and compression are used in other devices, but none of the treatment methods target the specific area of the spasm.

Design Inputs

The device must differentiate between voluntary muscle activity and lumbar spasticity. A muscle spasm is identified by a 50ms period of above-threshold integrals, where the threshold is +3SD above the mean baseline signal.[2] The device must produce vibrational stimulation automatically to the user's lower back in response to signs of a muscle spasm. With a frequency of 30 ± 5 Hz and an amplitude of 5 ± 1 mm, the vibrations will proceed for 10 ± 1 seconds once a spasm is initially detected. Detection and vibrational treatment must occur at 4 lumbar regions independently, 2 on each side of the spine, primarily targeting the erector spinae and lower ends of the latissimus dorsi. The device must be adjustable to fit the human waist range 23.5 to 55.2 in. The device must allow for clinically acceptable movements when one is standing and walking.[3] Users must be able to achieve at least the following motions in respect to the back from a standing vertical axis position: Minimum angles: Flexion: 40°, Extension: 20°, Side-flex: 15°, Rotation: 3°. The device must have a manual override switch to turn off the motors. The vibrations will cease within 1 second of the button being pressed with at least 90% success. Users must be able to support the weight of the device on the back throughout the day. The device will weigh no more than 13.6 lbs. Batteries must power the device long enough to allow for constant detection of muscle spasms and periodic application of vibrations throughout the day. Battery will be capable of lasting for 16 hours while powering constant EMG activity and an hour of vibrations. Battery capacity will be at least 5.5 Watt-hours and provide at least 7 Volts.

Design Solution

In order to monitor for muscle spasms, four EMG electrodes (each with a positive and negative lead) are fastened to the inner surface of the belt so that they make contact with the skin. One shared ground electrode is positioned at the hip bone. An Arduino Nano microcontroller board receives the EMG signals, compares them to a threshold, and activates vibrational motors accordingly. The threshold for each electrode is defined as the mean rectified baseline signal plus 3 standard deviations.

Before entering the arduino, the signals are filtered with a bandpass filter and amplified to a gain of 1000x in a separate circuit. Four DC vibration motors, covered in a fine cloth, are lined up horizontally on the inside of the belt, each paired with an EMG detection unit. A separate motor control circuit allows the Arduino to activate each motor independently. Two 9V batteries are used to power the components and an easily accessible power switch allows the user to turn the device on and off.

The circuits and batteries are housed in plastic containers, attached to the outside of the belt. The belt was made by using neoprene fabric to extend the waist-size range of a pre-existing exercise belt. The material choice and overall design of the belt allows the user to maintain a full range of motion and be comfortable overall.

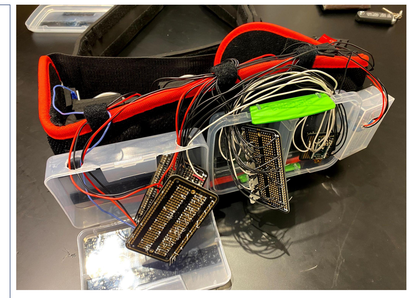

Figure 1: Exposed Circuitry. With the housing compartments open, the soldered PCB boards and internal wiring can be seen.

Figure 2: MSRD internal surface. Four pairs of EMG electrodes surrounding the vibrational motors.

Testing

The device is successful in monitoring electrical activity of the back muscles in real time. Each motor is able to be activated by its corresponding EMG sensor. This was validated using voluntary muscle activity in the forearm. The belt is adjustable for waist sizes in the range of 22.0 inches to 56.7 inches. The power switch was determined to be 100% successful in shutting off the vibrations in five trials. The batteries were able to power the device for 12 hours, failing to reach the specification of 16 hours. The motors vibrated at an average frequency of 22.6 Hz, with an amplitude of 4.8 mm, which was determined to be statistically acceptable. Once the EMGs detected muscle activity, the vibrational motors lasted for 10 seconds.

Five test subjects reported that vibrations from only two of the motors could be adequately felt. This was due to the pressure of the belt against the back suppressing vibrations of some of the motors. The final weight of the device was 3.6 lbs,which is lightweight, thus passing the verification testing. All five test subjects reported that the power switch was in an easily accessible location. Finally, the device allowed for clinically acceptable ranges of motion, with five subjects all being able to reach acceptable levels of flexion, extension, side-flexion, and rotation.

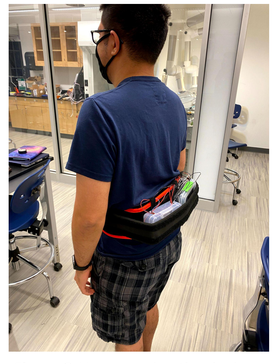

Figure 3: User wearing the device

Conclusions

The final version of the device is able to monitor electrical activity in the lower back and provide targeted vibrational therapy to specific regions. The device met the majority of our specifications, mostly functioning as intended in addition to being adequately adjustable and comfortable. For future directions, the group would like to explore different calibrations of the threshold and look into more powerful microcontrollers to allow for higher sampling rates.

Acknowledgements

We would like to thank our advisor Dr. Xuefeng Wei, the BME faculty and staff, Brian Wittreich, Joseph Zanetti, and the School of Engineering for assisting and supporting our senior project.

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