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Flexible strain sensor module applied on the activation of spinal muscle

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Abstract: This research aims at developing a flexible strain sensor applied in the activation of spinal muscle. The assumption in this research is that the shrink of muscle accompany with the length variety of the epidermis. First, the relationship between the change of measured resistance of a flexible strain sensor and the length variety of the epidermis is developed. Then, one should measure the electric signal of flexible sensors attached at the detective position to obtain the strain of epidermis. After that, according to the measured signals, the level of activation of spinal muscle is determined. Therefore, the effective training mechanism of the activation of spinal muscle can be constructed. A standard for the normalized level of activation of spinal muscle is established by measuring the maximum voluntary contraction of muscle. Therefore, the flexible strain sensor developing in this research is expectable to achieve the appropriate effects for the activation of spinal muscle.

Keywords: flexible sensor, spinal muscle activation training

1. Introduction

Current medical science is highly developed; however, the causes of 85% of scoliosis cases are still unknown. Scoliosis refers to the bending and deformation of the spine to the left or right. Commonly seen situations are spinal deformation in developing young people and spinal deformation caused by muscle degeneration among elderly people. Scoliosis can cause imbalance in the stress received by related tissues, muscle ache and fatigue, and chronic tendonitis of the neck and back muscles. Severe scoliosis can cause degenerative spinal arthritis, increased incidence of bone spurs, produce a pain condition in the back and legs, causing mobility problems. Therefore, establishing an effective training system for spinal muscle activation is needed urgently. For muscle activation training, various scholars have used electromyography (EMG) to supplement the determination of muscle activation levels. In 1993, Dolan [1] used EMG to measure and determine the positive correlation between spine anteflexion angles and erector spine activation. In 2000, Larivière [2] proposed the muscle activation difference after chronic back pain sufferers received lateral bending training. In 2001, Konrad [3] stimulated muscle nerves to determine effective training methods for muscle activation. In 2013, Santos [4] investigated the differences in the muscle activation levels of women with and without chronic back pain during different sports training activity models. Dolan [1] determined that spine anteflexion angles and erector spine activation were related. As spine anteflexion angles increase, the epidermis also extends. Thus, we assumed that the extension of the epidermis has a positive correlation with muscle activation and used the changes in resistance values to determine muscle activation levels. We developed a flexible strain sensor module that can be used for spinal muscle activation training, and analysed the relationship between changes in resistance and epidermal length detected by the sensor during the training process. The data was used to establish an effective training system for spinal muscle activation, and the system was expected to generate appropriate stimulations of spinal nerves and activations of muscles around the vertebra.

2. Research Methods

The research methods comprised three steps: (1) fabrication of flexible strain sensor array; (2) epidermis strain testing during spinal muscle training; (3) Analysis of the relationship between the resistance variation of sensor and epidermis strain. For the flexible sensor fabricated in this study, artificial skin (commercial Hartmann Hydrocoll) that consists mainly of hydrophilic colloids and adhesive polymers was used as the substrate. The flexible sensor was fabricated by sputtering a thin film of silver on the substrate. The parameter settings of the radio frequency (RF) sputtering machine are shown in Tables 1 and 2. Aluminium was first coated as an interlayer on the substrate to increase the adhesiveness between the electrode layer and the substrate. Subsequently, silver was coated as the electrode layer. The size and dimensions of the sensor are shown in Table 3. Fig. 1 is the graphs of a flexible strain sensor, where 1.(a) represents the flexible sensor with original length and 1.(b) represents the flexible sensor stretched until reaching 12.5 % strain. Fig. 2 shows the training of stiff-leg deadlifts on a roman chair.

Table 1. Parameter settings for RF sputtering of the intermediate layer

Target material	Al
Power	50 W
Sputter time	30 min

Process stress	1.8×10^{-2} Torr
Environment temperature	27 °C

Table 2. Parameter settings for the RF sputtering of the electrode layer

Target material	Ag
Power	50 W
Sputter time	30 min
Process stress	1.8 × 10-2 Torr
Environment temperature	27 °C

Table 3. Size of flexible sensors

Length	40 mm
Width	25 mm
Substrate thickness	0.35 mm
Sensor thickness	0.3516 mm

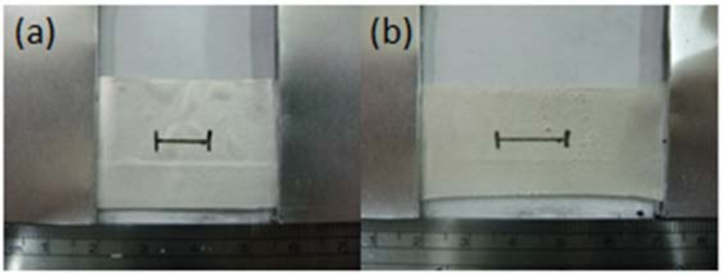

Figure 1. (a) Flexible sensor with original length; (b) flexible sensors extended to 12.5% strain.

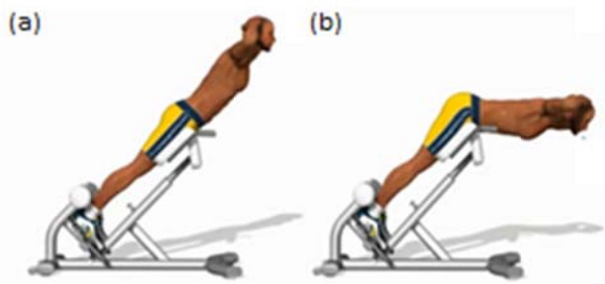

Figure 2. Stiff-leg deadlift training on a roman chair: (a) preparation posture; (b) flexion. [5]

3. Result and Discussion

The flexible sensor fabricated in this study was preliminarily used for training spinal muscles. Fig. 3 shows the resistance variation of five time roman chair tests measured by the sensor. The

Kinesio tape is used to find out the strain variation during the stiff-leg deadlift training. Fig. 4(a) shows the sixty detecting positions on the trapezius, erector spinae, and latissimus dorsi epidermis, and each Kinesio tape is with width 2.5cm, length 4cm. Then, flexible rule is used to measure the epidermis strain during stiff-leg deadlift training, and the results are shown in Fig. 4(b). Fig. 5(a) shows the fifteen detecting positions of epidermis on the trapezius, erector spinae, and latissimus dorsi epidermis. Fig. 5(b) shows resistance variance of the flexible sensor array. Fig. 4 and Fig. 5 shows the relationship between the resistance variance of the sensor and the changes of the epidermis in length during the stiff-leg deadlift training. It shows that the large length variety of the epidermis will induce the large resistance variety of sensor. Therefore, the flexible strain sensor developing in this research is expectable to achieve the appropriate effects for the activation of spinal muscle.

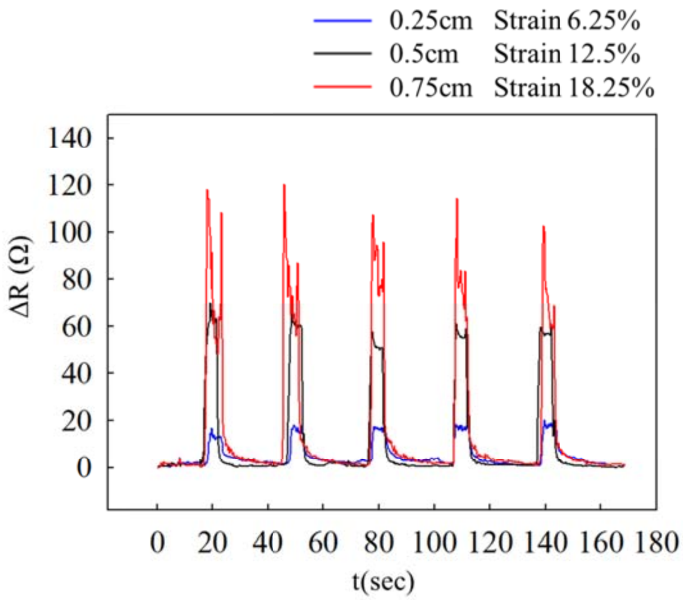

Figure 3. Five time roman chair tests measured by the sensor.

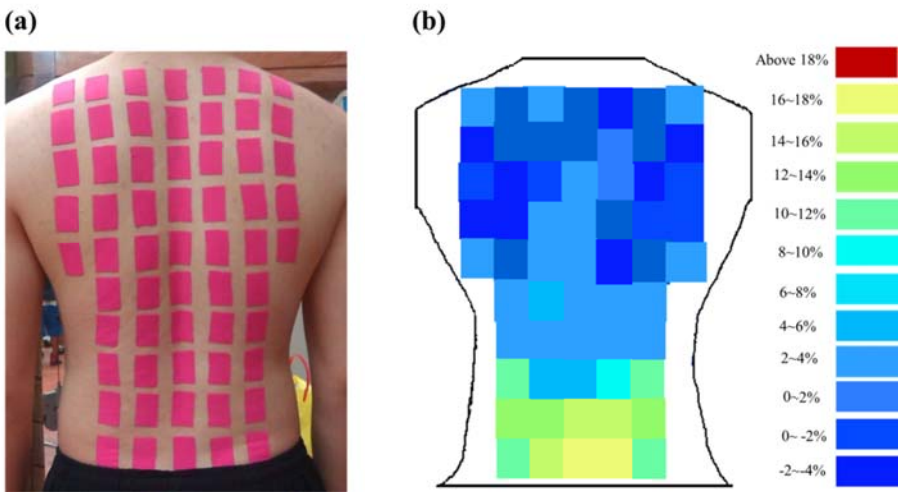

Figure 4. (a) Kinesio Tape on trapezius, erector spinae, and latissimus dorsi epidermis; (b) graph of the epidermis strain.

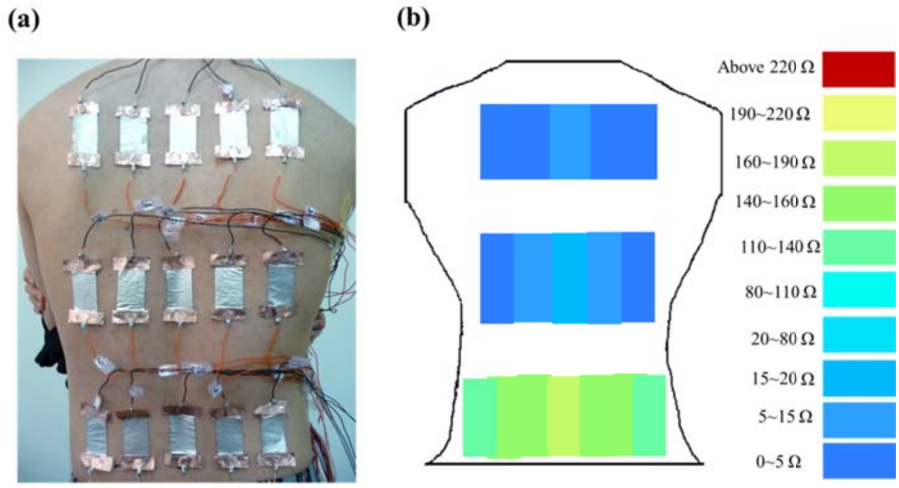

Figure 5. (a) Fifteen flexible sensor array.; (b) Resistance variance of the flexible sensor array.

4. Conclusions

We integrated flexible sensor arrays produced for this study into the spinal muscle training process to analyse the relationships between changes in resistance and the changes in the length of the muscular epidermis. A positive correlation exists between the strain of the epidermis during Roman chair spinal hyperextension and muscle activation levels. Furthermore, we explored the reproducibility of this sensor array module in five times. The changes in resistance measured by sensors can be used to effectively judge whether Roman chair spinal hyperextension training movements are accurate. Thus, this study established a spinal muscle activation training system that is beneficial for the establishment of an effective training system for spinal muscle activation. This system enables users to effectively stimulate spinal nerves and activate the muscles surrounding the spine.

Acknowledgments

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