Journal of Biomedical Engineering Research 39: 10-15 (2018)
http://dx.doi.org/10.9718/JBER.2018.39.1.10

학 술 논 문

A Measurement System for Rounded Shoulder Posture using a Wearable Stretch Sensor

Manh Thang Nguyen, Quoc Khanh Dang, Younghoon Kim and Youngjoon Chee

Interdisciplinary Program of Medical & Biological Engineering, Graduate School, University of Ulsan

Abstract In this paper, we present a wearable measurement system for monitoring rounded shoulders. The system contains a shoulder correction band and a stretch sensor that can correct and measure shoulder posture, respectively. The capacitance of the stretch sensor changes linearly according to changes in the shoulders. To verify measurement, a motion analysis system was used as the reference to compare the change in the rounded angles of the shoulders and the change in the stretch sensor's capacitance. The results indicated that there is a high correlation between the two changes and the system can be used as a monitoring device for rounded shoulders.

Keywords: Rounded shoulders, Stretch sensor, Motion analysis system, Posture correcting band

I. Introduction

Rounded shoulders are one of the most common postural problems when a resting shoulder position has moved forward from the body's ideal alignment. Daily activities, such as using a smartphone, using a computer, sitting for long periods, and driving a vehicle, can contribute to slumped shoulders. Rounded shoulders lead to altered muscle activity and scapular kinematics, placing increased stress on the shoulders and causing shoulder pain and disturbances in the functioning of the shoulders [1]. Increased stress on the shoulder joints could cause pain around the neck and upper back [2].

Much effort has been made to diagnose rounded shoulders. Rounded shoulders could be found based on the change in scapular position because of the close relationship between them. One traditional approach used by physiotherapists is to observe a patient's posture while the patient is sitting in a hospital chair. An examination process of this approach was performed to find the change in scapular position based on therapist experiences. Because results of the traditional method depend on the subjective assessment of therapist, the reliability and accuracy of this approach are not enough to diagnose the rounded shoulders. Aiming for more accurate results, the application of high-precision equipment in diagnosis could be a good approach. By applying photography method, a camera was used to measure the forward shoulder angle (FSA), which is defined from the vertical posteriorly to a line connecting the C7 and the acromial markers, as shown in Figure 1 [3]. A larger FSA indicates more rounded shoulders. To monitor rounded shoulders based on the FSA, another study applied another system which is a three-dimensional optical motion analysis system with high-precision [4]. This system includes cameras placing around subjects when performing habitual sitting experiment. To collect motion data, the system was controlled by data acquisition software on a computer. Even though both systems have a blend of performance and usability producing high-precision, these systems almost were used in clinic, so it is complex to set up and difficult to apply in daily life as a monitoring system. For the purpose of checking our posture and still doing our regular works at the same time, the

Corresponding Author : Youngjoon Chee
Department of Biomedical Engineering, University of Ulsan, Daehakro 93, Nam-gu, Ulsan, Korea.
TEL: +82-52-259-1305 / Email: yjchee@ulsan.ac.kr
The research was supported by a National Research Foundation grant funded by the Korean Government (NRF-2017R1A2B2005321).

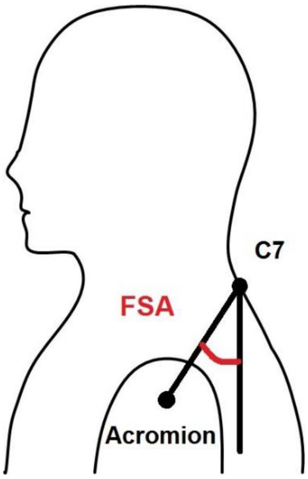


Fig. 1. FSA is measured from the vertical posteriorly to a line connecting the C7 and the acromial markers. When the subject's shoulders become more rounded, the acromion moves forward farther and so, the FSA is greater.

devices applying to monitor postures of office workers in daily life is necessary.

For posture monitoring, thanks to its low cost, light weight, and low power consumption, a wearable device, such as an accelerometer, is usually used as to measure the posture during daily activities. Some examples of such commercial devices that utilize a wearable sensor as a monitoring system are ALEX (Namu Inc., Ulsan, Korea), Lumo Lift (Lumo Body Tech Inc., San Antonio, United States), and Upright (Upright Technologies Ltd., Yehud, Israel). Based on the sensor's tilting angle, these products used to detect poor postures such as hunching. Besides, the poor postures happen together in daily life and make complexed one as hunching with rounded shoulders. Even though rounded shoulders is a well-known type of poor posture and happens with rounded shoulders, we cannot measure with accelerometer. Moreover, there has been limited trial for monitoring rounded shoulders.

With a purpose of focusing on rounded shoulders, a stretchable sensor can be used to monitor rounded shoulder posture. Three thermoplastic strain sensors have been confirmed as capable of recognizing shoulder movements [5]. These sensors are stretched in the horizontal direction when the shoulders are moved forward. Even though these strain sensors can measure shoulder movements, there are no detailed reports about their performance or accuracy in measuring rounded shoulders. Moreover, using three sensors is complex, hard to set up and replace for using in daily life.

This paper proposes the use of a single, wearable stretch sensor attached on posture corrector band to monitor rounded shoulders. The implementation and principle of the sensor are described. The experiment to verify the relationship between the severity of the rounded shoulder and measurement and results are summarized.

II. Method

1. Rounded shoulders and stretch sensors

When a person shifts from a good posture to a rounded shoulder posture, the FSA increases according to the increase in shoulder length (Figures 2a, c). To measure this change in the shoulder length, a stretch sensor is placed on a Posture Correcting Band (PCB) attached to the subject's upper back. The sensor length increases when subjects round their shoulders (Figures 2b, d).

Our wearable measurement system is equipped with a commercial stretch sensor, known as a fabric

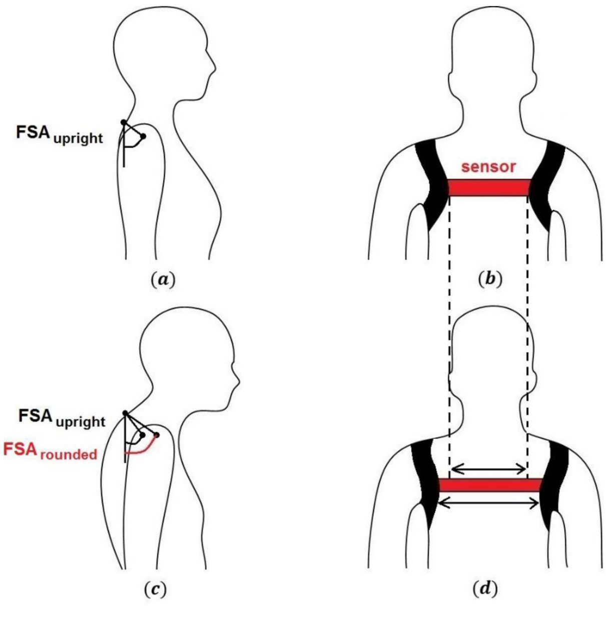
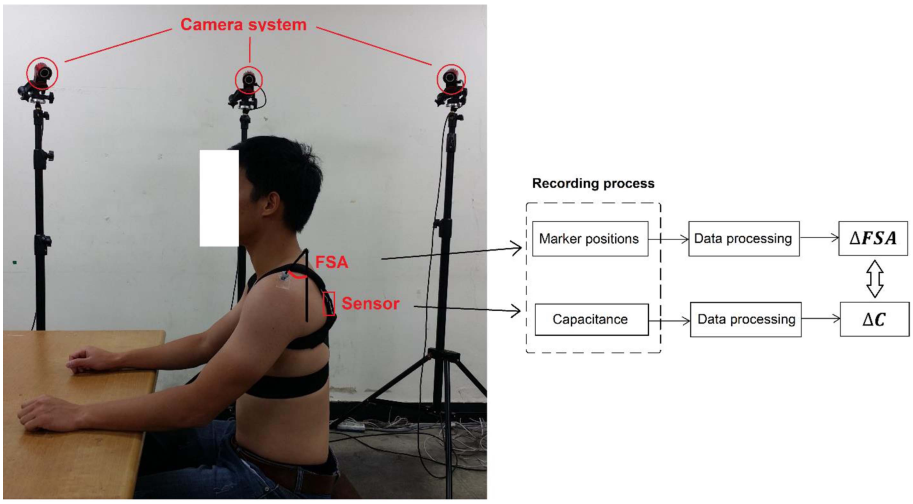
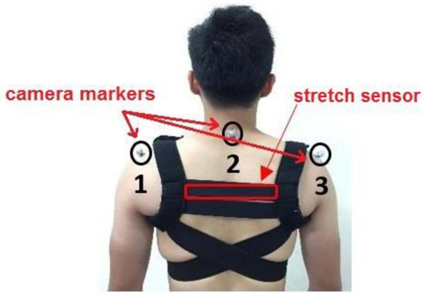


Fig. 2. The differences between rounded shoulder and upright postures. (*a*) $FSA_{upright}$, (*b*) Sensor length with upright posture, (*c*) $FSA_{rounded}$, (*d*) Sensor length with rounded shoulder posture.



(*a*)



(*b*)

Fig. 3. The experimental setup. (*a*) The camera system and the experimental process to verify the measurements of the stretch sensor based on the relation between ΔFSA and ΔC, (*b*) The positions of the stretch sensor and the three markers.

sensor, manufactured by StretchSense Ltd. (Auckland, New Zealand) [6]. The fabric sensor has an active sensing zone of 90 mm × 10 mm surrounded by a 2-mm sewable area and can be sewn into garments. The stretch sensor has an 80-mm maximum extension with a sensitivity of 3.82 pF/mm. When the subject has rounded shoulders, the sensor is stretched horizontally and the capacitance of the sensor increases linearly according to the movement of the shoulders.

2. Experiment setup and protocol

A camera system was used to verify the measurements of the stretch sensor. As shown in Figure 1, the FSA from the camera system was used as a reference to measure rounded shoulders. The FSA was calculated by taking the average of the FSAs of the left and right sides. A larger FSA indicates that the shoulders are more rounded. To analyze the rounded shoulders, the changes in the FSA and capacitance, as calculated by Equations 1 and 2, respectively, were compared to each other (Figure 3*a*). The changes in capacitance and FSA increased when the subjects were sitting with more rounded shoulders.

$$\Delta FSA = FSA_{rounded} - FSA_{upright} \qquad \text{Eq. (1)}$$

$$\Delta C = C_{rounded} - C_{upright} \qquad \text{Eq. (2)}$$

where ΔFSA (°) is the change in FSA, and ΔC (pF) is the change in capacitance from an upright to a rounded shoulder posture.

Before performing the experiments, photo-reflective markers were attached to three bony points on the back of each subject: C7 (the vertebrae of the spine), and the left and right acromion process, as shown in Figure 3. Data were collected from two systems

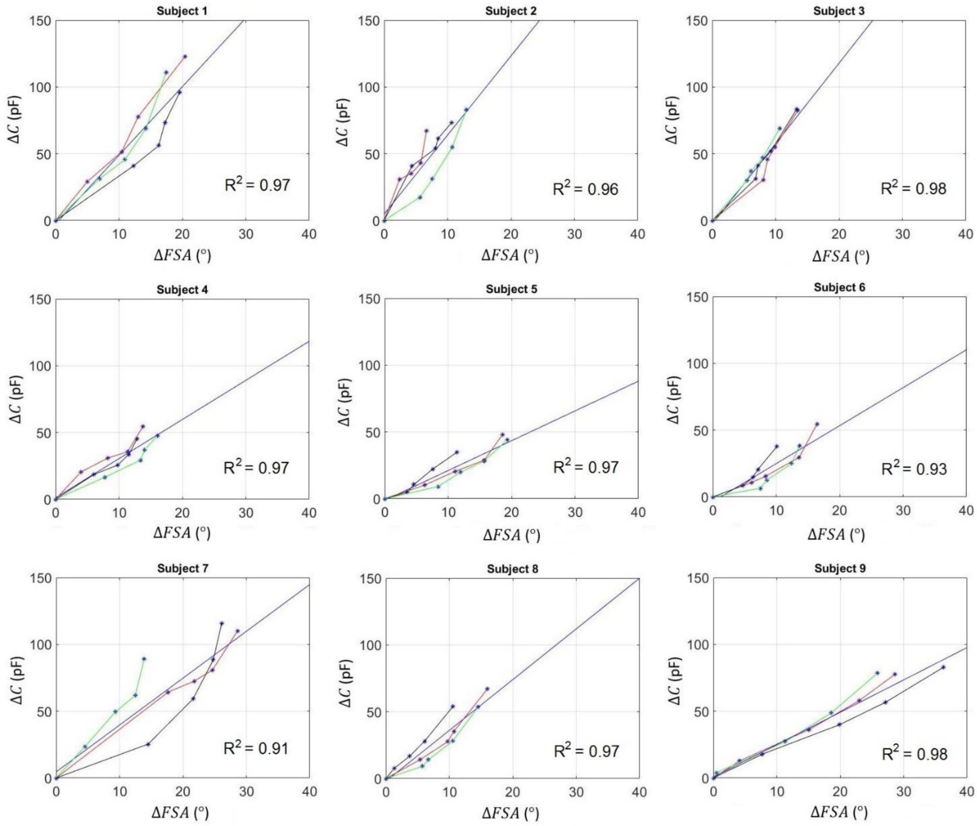


Fig. 4. The relationship between the changes in FSA and capacitance of the nine subjects.

simultaneously: the camera system (motion analysis system, OptiTrack, Oregon, USA) and the sensor module. The camera system consisted of six cameras placed around the subject, who is sitting, and connected to a computer. The sensor module was attached to the PCB and the module's data were recorded by a mobile application.

The experiment was conducted with nine healthy young male participants (age = 27 ± 3 years, height = 171.5 ± 4.5 cm, and weight = 65 ± 6.7 kg) who had no history of back pain, spinal surgery, any kind of injuries, or any disorder affecting the cervical, thoracic and lumbar regions.

Each subject was measured three times during the experiment. Each time, the subject sat with a 90° angle between the femur and tibia, then placed their shoulder for three seconds in each of five different degrees of shoulder roundedness, ranging from a neutral upright posture to maximally rounded shoulder posture.

III. Results

Figure 4 demonstrates a high positive correlation coefficient (R^2) between ΔFSA and ΔC.

The results show that the more rounded shoulders, the greater is the increase in the capacitance. The correlation coefficients of each subject were calculated by taking the average of the correlation coefficients of the subject's three times of measurements. The average correlation coefficients of all nine subjects were larger than 0.9, implying that, without a doubt, a larger change in the capacitance indicates "more rounded shoulders", as the corresponding FSA is wider.

Even though there is a high positive correlation between ΔFSA and ΔC, the range and trend in the ΔFSA and ΔC of each person are different, which is due to the different shoulder widths of the subjects. The changes in FSA and capacitance in the maximally rounded shoulders range from 14° to 37°

and from 49 pF to 123 pF, respectively. The stretch sensor was sensitive enough (3.82 pF/mm) to monitor the rounding of the shoulders.

IV. Discussion

This research has demonstrated that the stretch sensor was able to estimate the rounded shoulders, the evaluation of which was conducted by using a camera system. The sensor showed a high relation between the changes in FSA and the capacitance, of which the correlation coefficients were larger than 0.9 (Figure 4).

With its compact features, the product could be applied as a wearable sensor in daily life. To overcome the disadvantages, such as difficulties in implementation, experience requirements or time-consuming, of traditional rounded shoulder monitoring, PCB can support the monitoring of rounded shoulders for a long time, evaluation of sitting habits, rehabilitation of the shoulders, and positive feedback to encourage maintenance of a healthy posture.

Although Figure 4 shows the high positive correlation between the change in FSA and in capacitance, the slope of the correlation line for each subject has not been the same. As we know, body shape of each subject has difference and it tends to the difference in shoulder curve of each people also. This difference in shoulder curve leads to sensor's stretching range (change in capacitance) in each subject when having same the change in FSA. That is a reason why there is the difference in the slope of correlation line for all subjects. Even though there is the difference in the slope of correlation lines, we still can apply our device to monitor rounded shoulders for many persons. Based on individual shoulder curve of each person, a customization in stretch sensor length will be performed to suitable for each people. To monitor rounded shoulders, a stretch sensor could be used to measure the difference from a threshold of neutral posture.

Even though the stretch sensor was able to estimate the rounding of the shoulders and the correlation coefficient was over 0.9, there were disadvantages of the PCB that led to some discrepancies in the data. In this case, the changes in the capacitance and FSA do not follow the trend as shown in Figure 4. Figure 5 illustrates the relation between the changes in FSA and capacitance when a product with an inappropriate size is worn. In the first stage, when the subject changed from an upright posture to one with maximally rounded shoulders, the FSA and capacitance changed linearly. However, within a certain range, the change in capacitance increased more rapidly than did the change in FSA, because the size of the posture correcting band did not fit the subject, who could not tighten the band around the back sufficiently. Moreover, each person's shoulder width is different. It tends to that the sensor of the product cannot respond normally when particular subjects exhibit rounded shoulders. To overcome these disadvantages, a size of the PCB that is particularly suited to each person should be considered. In some cases, the band is not tight enough and the sensor slips from its original position. The initial length of the sensing area is important and depends on each person’s shoulder width.

Another limitation worth mentioning is the low number (9) of participants in the experiment. Moreover, these participants were young males between the ages of 25 and 32 years. Future experiments should be conducted over a prolonged

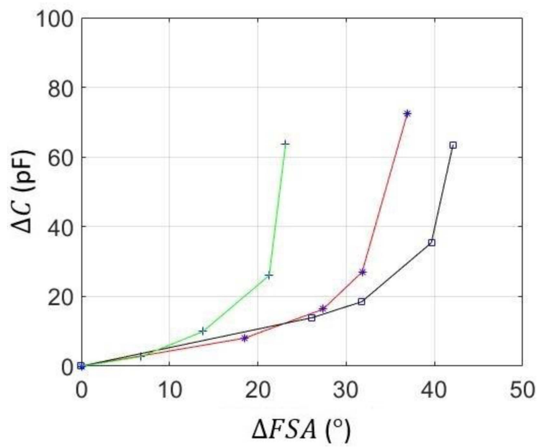


Fig. 5. The relation between the changes in FSA and capacitance when a product with an inappropriate size is worn. Each symbol in the graph shows a subject performing the experiment once going from an upright posture to maximally rounded shoulders.

period of time spent monitoring daily activities with a larger number of individuals of different ages.

In case of criteria for rounded shoulders, there were some research presenting their criteria to classify rounded shoulders. In a research of Sawyer, FSA of subjects with and without rounded shoulders were larger 52° and smaller 22°, respectively [7]. But it is their own criteria without references. Actually, until now there is no official criteria for deciding whether a person would have rounded shoulders. There is no standard of criteria because there is no reliable monitoring device in rounded shoulder posture. In case of our device, we still can apply our device to monitor rounded shoulder posture of patients by affiliation with the hospital. After we collect enough data and clinical validation, we may suggest the standard FSA for rounded shoulders. Based on that, users can set the threshold of neutral and rounded shoulder posture before using.

Because of the close relation between hunching and rounded shoulders postures, in the future we will integrate the stretch sensor and accelerometer into one device when we apply this technology to the commercialization. The device with real time monitoring and a feedback capability, such as vibration motor, could be designed to immediately warn the user of sitting with rounded shoulders. These features would help improve a user's posture during daily activities.

Conclusions

A posture correcting band with a stretch sensor could be used to measure the changes in rounded shoulders.

References

[1] T.S. Roddey, S.L. Olson and S.E. Grant, "The Effect of Pectoralis Muscle Stretching on the Resting Position of the Scapula in Persons with Varying Degrees of Forward Head/ Rounded Shoulder Posture," *Journal of Manual & Manipulative Therapy*, vol. 10, no. 3, pp. 124-128, 2002.

[2] B. Valachi and K. Valachi, "Mechanisms leading to musculoskeletal disorders in dentistry," *The Journal of the American Dental Association*, vol. 134, no. 10, pp. 1344-1350, 2003.

[3] C.A. Thigpen, D.A. Padua, L.A. Michener, K. Guskiewicz, C. Giuliani, J.D. Keener and Stergiou, "Head and shoulder posture affect scapular mechanics and muscle activity in overhead tasks," *Journal of Electromyography and Kinesiology*, vol. 20, no. 4, pp. 701-709, 2010.

[4] S.J. Edmondston, H.Y. Chan, G. Chi Wing Ngai, M.L.R. Warren, J.M. Williams, S. Glennon and K. Netto, "Postural neck pain: An investigation of habitual sitting posture, perception of 'good' posture and cervicothoracic kinaesthesia," *Manual Therapy*, vol. 12, no. 4, pp. 363-371, 2007.

[5] C. Mattmann, "Body posture detection using strain sensitive clothing", *Doctoral Thesis*, 2008.

[6] https://www.stretchsense.com/fabric-stretch-sensor/, accessed on Jan. 01, 2018.

[7] Q.L. Sawyer, "Effects of forward head rounded shoulder posture on shoulder girdle flexibility, range of motion, and strength," *Master Thesis*, 2006.