Epidermal Sensing of Muscle Compensation

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ABSTRACT

Towards effective and injury-free body building, we seek to explore the use of Electromyography (EMG) sensor for the detection of muscle compensation, a phenomenon often observed in physical exercises due to malcompliance or fatigue.

KEYWORDS

EMG, Muscle Compensation, Exercise Compliance

1 MOTIVATING APPLICATION

Weight training is one of the most popular modern exercises to build muscle strength and resistance. It benefits not only the physical but also mental health, where stronger muscles allow body movement at a higher caliber, and being in shape raises also self-confidence and social attention. Muscle building appears straightforward, involving lifting, pulling, or pressing of weights, and more repetitions or heavier weights result in more robust muscles. The dilemma is however that incorrect postures or lifting excessive weights might compromise the training effectiveness and, in the worst case, lead to injuries [6]. One common cause of injuries is *muscle compensation* – the phenomenon in which one overuses muscles that are not subject to training when the target muscles are exhausted and can no longer complete the training independently. **Figure 1** shows how the ill positioned elbow may activate the upper trapezius to compensate the load supposedly for the bicep. Given the difficulty spotting muscle compensation with bare eyes, these types of exercise malcompliance often go unnoticed.

To this end, we find opportunities in utilizing electromyography (EMG) signals collected from widespread body surface to assess muscle compensation. EMG signaling is a common and effective method to evaluate muscle performance. Past works have focused the use of EMG signals from a few targeted muscles and in the laboratory settings [1]. With the rise of multi-point epidermal EMG sensors that are soft and bendable [3], it is no longer far fetched to observe muscle interactions in everyday training. As a motivating application and a feasibility study, we share in this abstract a preliminary investigation of a wearable IoT that might grow capable of identifying specific patterns between EMG signals and issuing feedback in sign of muscle compensation.

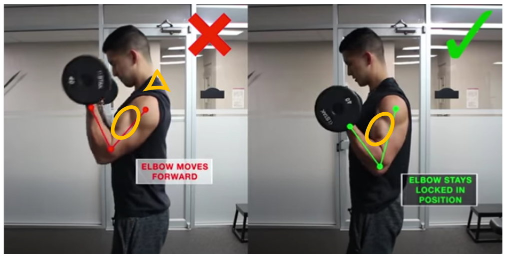

Figure 1: Malcompliance in dumbbell bicep curl.

2 RELATED WORK

The surface EMG (sEMG) refers to the sensing of biopotentials extracted from the electrodes on skin surface, and it has been used widely for sports analysis, physical rehabilitation and as means of human-computer interface. In particular, Ke Ma et al. [5] proposed an sEMG-based trunk compensation detection (sEMG-bTCD) mechanism, which was validated by the sEMG signals collected from nine superficial trunk muscles of the stroke participants during their rehabilitation therapy. Liu et al. [4] devised a miniature, mobile EMG patch to monitor muscle fatigue during isotonic contraction. The system was shown capable of computing the median frequency of sEMG signal in real time and displayed the level of muscle fatigue through a smartphone APP. Moreover, Biagetti et al. [2] presented a wireless system for sEMG and accelerometer signal acquisition to detect, monitor and recognize the human activity being performed.

3 SYSTEM PROTOTYPE

Our hardware consists of a microcontroller, two muscle sensors, and a Bluetooth module. We use an Arduino Uno [1] as the microcontroller for the prototype. The EMG signal is extracted from Myoware 3-lead muscle sensors [2]. We choose this particular muscle sensor because it provides not only raw EMG signals but also rectified and integrated EMG signals, which works well with Arduino's analog-to-digital converter. The gain of signal rectification is adjustable on-board. We also connect an additional HC-06 Bluetooth module [3] for data transmission.

4 PRELIMINARY RESULT

A small number of participants are invited to the prototype trial. As depicted in **Figure 3**, each participant is instructed to perform the bicep curl with dumbbells of specific weights. Within the participants' capabilities, 5 weights, 2 kilograms apart are lifted. The

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*Both authors contributed equally to this research.

[1] https://store.arduino.cc/usa/arduino-uno-rev3

[2] http://www.advancertechnologies.com/p/myoware.html

[3] https://components101.com/wireless/hc-06-bluetooth-module-pinout-datasheet

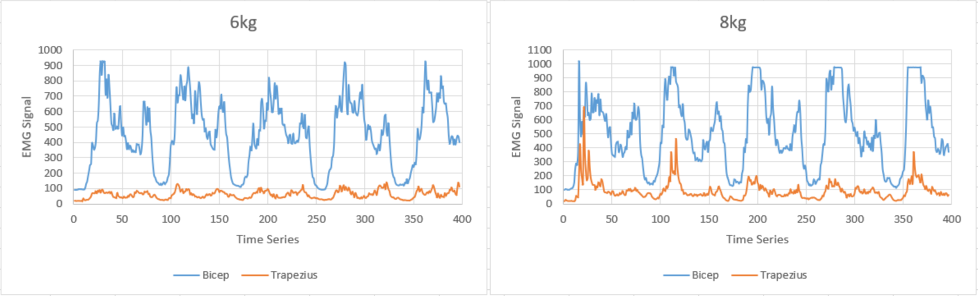

Figure 2: Bicep and trapezius muscle signals in 6kg vs. 8kg case.

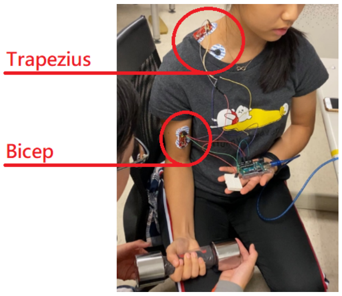

Figure 3: Prototype and experiment setting.

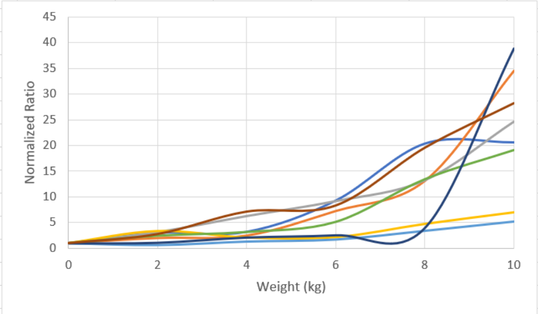

Figure 4: Normalized peak values of the trapezius muscles.

participants perform each set of exercise with constant speed within a 20 second duration. **Figure 2** shows the rectified sEMG signals of one participant lifting 6kg and 8kg weights. The blue lines display the signals of the bicep muscles, on which five clusters that correspond to five sets of bicep curl are clearly visible. The red lines display the signals of upper trapezius muscles. As the participant lifts a 6kg weight, this signal remains at a relatively low and stable level. On the contrary, when lifting an 8kg weight, one can observe apparent peaks in the signal, which implies the substantial use of the trapezius muscles. This showcases the plausibility of an EMG-based wearable for muscle compensation assessment.

Furthermore, **Figure 4** shows the normalized peak values of trapezius muscles of eight different participants. The peak EMG amplitude signals of the trapezius muscles in each exercise cluster are divided by the mean EMG amplitude signal during rest. As the weight increases, this normalized ratio increases as well. Generally, a surge of ratio occurs at 6kg and above, whereas individual differences can be observed. (1) The yellow and sky blue lines, which increase slightly and stably, are collected from athletic participants. (2) The brown and grey lines, which show a surge at 4kg but remain flat through 6kg, are the only data collected from male participants. (3) The dark blue line shows a unique pattern–not increasing much through 8kg but shooting up at 10kg, which suggests that the participant might have no strength left at all for lifting the 10kg weight. These distinctions imply the distinctive physical abilities of individual participants, thus various extents of muscle compensation.

As for further utilization of the results, we find that there is no binary classification but rather multiple levels of muscle compensation. It is also more sensible to take into account the change of (i.e, the slope) of signal ratios as well as the sheer amplitudes in characterizing types of muscle compensation.

5 WORK IN PROGRESS

We are currently pursuing work in two dimensions. First is computerization of the process to quantify the level of muscle compensation and to characterize the risk of posture deformation, excessive weight, or fatigue. In the meantime, we seek to stream line the computation tasks on board the epidermal wearable to enable real-time user feedback. This may require an upgrade to Raspberry Pi or processors of higher computation capability.

REFERENCES

[1] V. Andersen, M. Fimland, Dag-André Mo, V. M. Iversen, T. M. Larsen, Fredrik Solheim, and A. Saeterbakken. 2019. Electromyographic comparison of the barbell deadlift using constant versus variable resistance in healthy, trained men. *PLoS ONE* 14 (2019).

[2] Giorgio Biagetti, Paolo Crippa, Laura Falaschetti, and Simone Orcioni. 2018. Human activity monitoring system based on wearable sEMG and accelerometer wireless sensor nodes. *BioMedical Engineering OnLine* 17 (11 2018).

[3] Jun-An Chen, Cynthia Yun-Shin Liu, Hong Jhih Chen, Hsin-Yuan Chen, Hsea-Ching Hsueh, Yu-Chia Huang, Koji Yatani, Hao-Hua Chu, and Polly Huang. 2019. Position: Smart KT Tape – A Bendable Wearable System for Muscle Fatigue Sensing. ACM WearSys '19, Seoul, Korea.

[4] Shing-Hong Liu, Chuan-Bi Lin, Ying Chen, Wenxi Chen, Tai-Shen Huang, and Chi-Yueh Hsu. 2019. An EMG Patch for the Real-Time Monitoring of Muscle-Fatigue Conditions During Exercise. *Sensors* 19 (07 2019), 3108.

[5] Ke Ma, Yan Chen, Xiaoya Zhang, Haiqing Zheng, Song Yu, Cai Siqi, and Longhan Xie. 2019. sEMG-Based Trunk Compensation Detection in Rehabilitation Training. *Frontiers in Neuroscience* 13 (11 2019), 1250.

[6] Tom Erik Solstad, Vidar Andersen, Matthew Shaw, Mogstad Hoel, Andreas Vonheim, and Atle Saeterbakken. 2020. A Comparison of Muscle Activation between Barbell Bench Press and Dumbbell Flyes in Resistance-Trained Males. *Journal of sports science & medicine* 19 (08 2020), 645–651.