Poster Abstract: Muscle-Mind: towards the Strength Training Monitoring via the Neuro-Muscular Connection Sensing

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ABSTRACT

Strength training is essential for both physical and mental well-being. Muscular mass and strength gain can help with weight loss, balance improvement, and fall prevention. The neuromuscular connection, or mind-muscle connection, is critical for improving strength training performance. However, many fitness trackers and applications are missing a feature that allows users to track their neuromuscular workout performance. The goal is to immerse the user experience while keeping the cost and size of the healthcare device to a minimum. A wearable EEG hairband and EMG shirt are outfitted with dry and non-invasive bio-signal detecting that securely attaches to the body's surface during exercise. Participants in our study are exposed to five upper-limb free-weight exercises. The result shows that low-intensity exercise can increase upper-limp muscle contraction by over 30%, and individuals with mental effort have an average precision of 81%.

CCS CONCEPTS

•Human-centered computing~Ubiquitous and mobile computing~Ubiquitous and mobile devices~Mobile devices

KEYWORDS

Biometric Sensing, Exercise monitoring, Wearable device

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1 Introduction

Strength training has been the most attractive exercise in the past decade. It is standardly used for training to develop muscle strength, muscle mass, and joint strength. In the actual situation, the exercise goal varies among people. Each exercise program has a different result in the long term, but everyone wants to train each time effectively. On the other hand, the term 'exercise effectiveness' has various definitions depending on the programs. National Strength and Conditioning Association or NSCA has defined four specific goals: endurance, hypertrophy, maximum strength, and power [1]. So, the number of repetitions and weight needs to be adjusted for each plan. However, many people fail to track their exercise effectiveness in various mediums that sometimes do not match their goals. This paper aims to track the exercise effectiveness for strength training in hypertrophy through mind-muscle connection. We moreover raise the issue between heavy-load exercise and exercise effectiveness that we should or should not lift heavyweight to get the most effective hypertrophy training [4]. Therefore, we present wearable devices to detect the mental effort on strength training based on the mind-muscle connection, as shown in Figure 1(a). We propose our custom design of a low-cost dry non-invasive EMG sensing electrode that is highly conductive. The system is a wearable that (1) detects the mental effort of strength training, (2) captures EEG and EMG signals simultaneously along with performing the exercise, and (3) analyzes users' high mental effort regarding the muscle contraction.

2 System Architecture

An integrated wireless transmission terminal circuit was placed on the back of the headset and t-shirt. The EEG signals (collected by NeuroSky TGAM1) and the EMG signal pass through an analog front-end, band-pass hardware filter, signal amplifier, and a 512 Hz A/D converter to enable reliable recording of small-amplitude signals in a frequency range of 0.5–50 Hz. The EEG and EMG signals were transmitted to a microprocessor (STM32F103RCT6, 32-bit ARM Cortex-M4) and transferred by Bluetooth (serial module HC-05). Each exercise repetition length was trimmed by adaptive sliding window segmentation into n windows where n=12 to ensure signal equal length. In Figure 1(b), we find the mean frequency of EMG signals in each window. Also, we window the EEG signal by FFT at [1: 30] Hz in Figure 1(c). To extract the mental effort of the motion state, we apply the attention-based models [3] through the normalized softmax of the mean frequency (MNF) from the last four data sequences and obtain the EEG input data sequence through the vector product as shown in Figure 1(d).

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Finally, the extracted EEG frequency data was processed by the LSTM model. Then, the output of the LSTM vectors is selected as the fully connected neural network's input parameters. The hidden layer is followed by a 20% dropout layer, a fully connected layer with 300 hidden units, and a final linear layer with two outputs corresponding to the two classes, "high mental effort" and "low mental effort."

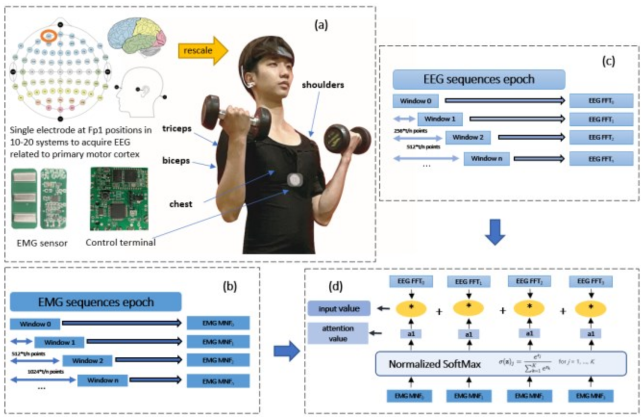

Figure 1: (a) The proposed wearable biometric sensing. (b) EMG and (c) EEG sequences were trimmed, (d) derive EEG during more muscular activities through the attentional model.

3 Experiment and Evaluation

Ten healthy male subjects were recruited, and informed consent was obtained before collecting data about our exact purpose in the experiment. We do physical checking on all subjects who underwent a strength assessment under NSCA [1]. Experiment ground truth findings align with the constrained action as clinical research in resistant training and weightlifting [3,4]. Participants performed five isolated exercises with dumbbells weighted with a mass equivalent to the estimated 67% and 85% bilateral maximal force according to NSCA recommended of a person's 1RM [1]. Reminders regarding the mental effort condition (with or without) were given before each session with the 5 minutes rest periods. Each subject performed ten repetitions of each exercise in each session, resulting in 200 repetitions under both conditions.

We divided the evaluation into two categories, i.e., system robustness and user impact. System robustness examines the accuracy of mental effort detection across subjects in practical scenarios, while the user impact studies the relationship between users' mental effort and muscles during exercise. To evaluate the system's robustness, we use precision and specificity as criteria of corrected recognized performance of mental effort. In this context, precision indicates how many total positives of the actual mental effort were detected. Specificity measures the performance of recognized non-mental effort exercises. Figure 2(a) summarizes the recognition results for the high mental effort across the subjects—the averaging precision of 81%. The average per maximal force classification accuracy exceeds 70% for all conditions. As shown, 4 out of 10 subjects achieve 90% precision while the other three subjects achieve a precision of 70% at 67%RM. The muscle contraction (%) across subjects indicates result in Figure 2(b) that all subjects surpass the minimum at 30% MVC from normalizing EMG signal, which means training with mental effort can guarantee the strength gaining in 6 weeks around 20 ± 8% (P = 0.01) [3]. We examine muscle activation to provide a detailed look at the exercise effectiveness of each session. We use no weight movement as a baseline of muscle contraction against mental effort exercise at 67%RM and 85%RM. Here, at 67%, RM averages 43.47%, yet at 85%, RM is contracting only 32.08%. The result in Figure 2(b) illustrates the muscle contraction (%) across subjects. The overall impact of muscle contraction surpasses 30 % as required for mental effort exercise. Then we further investigate with the two-way ANOVA test. We test the high mental effort group's result in 67% and 85% Rm, both EEG and EMG signals. The test priori power is strong 0.899 in factor – EEG, factor – EMG, and interaction. These results validate that the biometric device enables simultaneous EEG and EMG signals to detect mental effort.

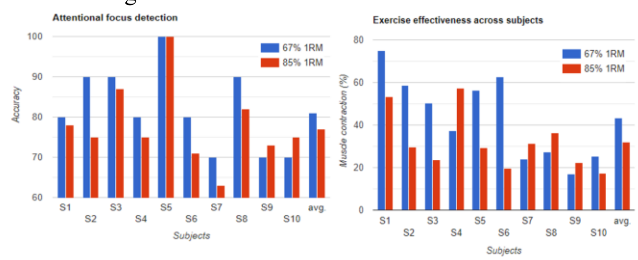

Figure 2: (a) Accuracy of high mental effort detection across subjects. (b) Muscle contraction across subjects

4 Conclusion

We introduce a wearable biometric sensing device to monitor the mind-muscle connection via physiological signals. Our study suggests that the system can detect the subjects' mental effort obtained with the proposed device, with an average precision of 81% across subjects at various maximum forces. Moreover, the proposed system can perform 67% RM and 85%RM to investigate muscle activation effectiveness in each session across subjects. The result is also valid to the hypertrophy training goal that adopting mental effort with lightweight lifting can activate more muscle contraction.

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