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Poster Abstract: Sedentary Posture Muscle Monitoring via Active Vibratory Sensing

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1 INTRODUCTION

With the rise of desktop computers and televisions, people around the world have been leading increasingly sedentary lifestyles. It is estimated that people spend between 8-10 hours sitting each day, occupationally or otherwise [10], which has translated to increased reports of neck and back pain as well. In 2018, neck and back pain was the third most reason for taking days off work, accounting for more than 264 million workdays lost in a single year [1]. In America alone, approximately 40% of adults experience some form of back pain by the age of 30 [5]. Not only can this condition be debilitating – left unchecked, it can also progress into nerve damage, disc compression, spinal disorders, or loss of lung capacity [1, 12].

Consequently, neck and back pain is strongly associated with sitting posture, which makes practicing healthy sitting habits all the more essential. Healthy posture is generally defined by the alignment of the head, torso, and pelvis. It is a part of the musculoskeletal system and is characterized by the interaction between the skeletal structure and the muscles. The position that is assumed is based on the skeleton, however how long the body can support that position is based on muscle integrity and activation [2]. Prior work on sitting posture emphasizes the positioning of the spine, neck, and hips by identifying the angles they should be made relative to one another using pressure sensors, IMUs, or electrogoniometers [3, 8, 11]. However, it overlooks the role of muscle group interaction and activation, which is much more critical to achieving ideal sitting posture defined by a position that minimizes unnecessary static muscle activation [12]. Muscle group compensation can cause muscle over activation and stiffness, which can progress into back or neck pain [7] and detrimentally affect the quality of life.

Research on muscle status sensing has been largely focused on the use of the mechanomyogram (MMG) with an electromyogram (EMG) [4], and increasingly accelerometers [9]. These state-of-the-art approaches target use cases with high impact movements with significant muscle activation, such as sports or physical therapy. Additionally, sensing often requires close contact with the muscle, i.e, directly onto skin. On the other hand, several physical correction apparatuses, such as the back brace [1] or vibration/electric neck massager [2][3], have also been developed to combat slouching and rounded shoulders. However, these often prove to be temporary fixes and are insufficient to instill healthy sitting habits.

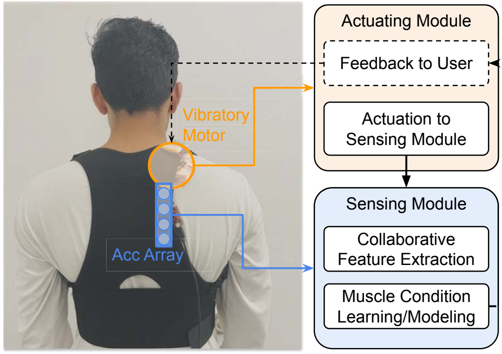

Figure 1: System overview. The system mainly consists of two modules, the actuating module, and the sensing module. We use the actuating module to 1) provide excitation sources for active vibration sensing, and 2) provide feedback to users for their active posture adaptation. We leverage the accelerometer array to capture this vibration to estimate muscle condition collaboratively. The solid lines depict current implementation and the dash lines indicate future work.

We propose leveraging current physical correction apparatuses in tandem with accelerometer-based sensing to achieve ubiquitous muscle activation during sedentary activities, such as studying or using the computer, for **precision** feedback and **prevention** of muscle compensation.

In order to do so, we foresee two reasons leading to an **extremely low Signal-to-Noise Ratio (SNR)**: (1) During such sedentary activities, it is uncommon to wear physical correction apparatuses that make direct contact with the skin. Therefore, having clothing separate the sensor and muscle will result in high noise levels. (2) Flexor muscles in the neck responsible for maintaining posture are deep muscles and are primarily made up of slow-twitch muscle fibers that are shorter fibers that generate less force [13] than fast-twitch muscle fibers found in the biceps. Hence, producing smaller vibrations, leading to low signal levels for passive vibration sensing.

To solve the first challenge – high noise level – we use active vibration sensing and leverage a physical correction apparatus, the

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[1] https://amzn.to/3rhKX8V
[2] https://amzn.to/3L0gO5w
[3] https://amzn.to/3s58nxj

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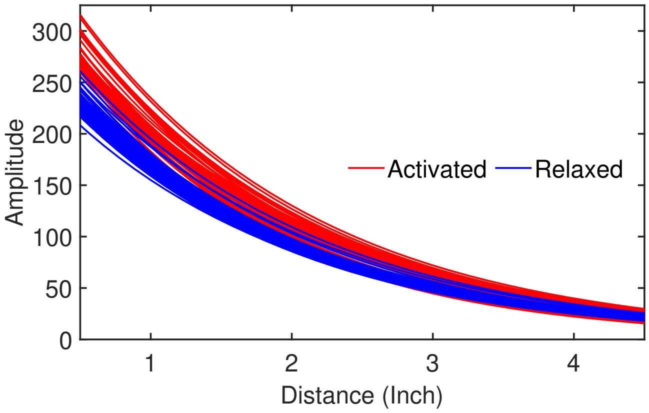

Figure 2: The exponential curve fitting results of signal energy over sensor-actuator distances for activated and relaxed muscle conditions.

back brace, as a form factor. The vibration motor and the accelerometer array are integrated into the back brace posture corrector linearly as shown in Figure 1.

To solve the second challenge – low signal level – we focus on the monitoring and analysis of the trapezius muscle, which is directly measurable from the skin, to indirectly infer other sedentary posture muscles' conditions. The trapezius muscles are often exceedingly and unnecessarily activated in those with back or neck pain compared to those without [6].

2 SYSTEM AND PRELIMINARY RESULTS

The system consists of two modules, shown in Figure 1, the actuating and the sensing modules, which augment vibration sensing on the trapezius muscle. The actuation module uses a coin vibration motor that generates a 200 Hz vibration every other second. This vibration propagates through the muscle and is captured by the accelerometer array placed on the monitored muscle. The array, consisting of four triple-axis accelerometers, captures this vibration signal and extracts features from signals captured by the sensors. The accelerometers are sampled at 517 Hz, which is sufficient for capturing the vibration motor-induced vibrations.

We first extract the vibration signal segments of the motor-induced vibration, and apply Fourier Transform to extract the frequency components. Next, we and obtain a 50 Hz frequency band centered around the frequency with the highest energy based on the Fourier Transform. Then we calculate the signal energy of this frequency band for each sensor in the accelerometer array. Finally, we conduct an exponential fitting between the calculated band signal energy E and the sensor-actuator distances d to the function $E = Ae^{Bd}$. The fitting parameters A and B can be used for features to interpret muscle conditions such as stiffness.

We conducted preliminary experiments in a real-world setting, as shown on the left-hand side in Figure 1. To collect the relaxed muscle data, we asked the subject to relax their trapezius muscle as much as possible. To get activated muscle data, we asked the subject to hold a brick to activate their trapezius muscle and repeated the same process. We depict the fitting curves of the activated muscle and relaxed muscle in Figure 2. The red lines depict fitting curves of the activated muscle, and the blue lines show those of the relaxed muscle. We observe a clear distinction of the fitting curves over activated v.s. relaxed muscle conditions. This distinction indicates the possibility to further achieve classification/quantification of muscle activation condition.

3 CONCLUSION AND FUTURE WORK

We present a sedentary posture muscle monitoring system via active vibration sensing. The system uses accelerometers to sense motor vibration propagating through muscle and collaboratively estimate the muscle activation condition. The system focuses on two challenges, including 1) sensor indirectly contacting targeted muscle (high noise level), and 2) muscles related to sedentary posture are often weak (low signal level), which leads to low SNR for existing passive sensing. We propose to convert a physical correction back brace into a muscle activation monitor via active vibratory sensing using a motor and an accelerometer array. We conducted real-world experiments to demonstrate the feasibility of the system. In the future, we plan to explore the robustness of the system over different clothing conditions, i.e., multiple layers of clothes and fabrics can impact the data distribution. Besides, we will explore the sensor and actuator placement for flexible modeling over different users to enhance the generalizability of the system. Last but not least, we plan to identify multiple stages of muscle activation to enable more informed and personalized feedback for users.

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