Kinematic Skin Strains and Muscle Activity Measurement of the Musculoskeletal Lumbar Region Using a Single Integrated Skin-Adhered Wearable System

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INTRODUCTION: In previous work, we developed a custom array of wearable nanocomposite sensors (the SPINE Sense System) arranged on the skin of the lower back to capture and analyze the skin strains in the lower spine, from which lumbar kinematic information can then be derived. Each sensor is secured using metal snaps that touch the skin of the user and provide an electrical connection from the sensor to a custom printed circuit board (PCB). The purpose of the present work was to investigate the potential use of the SPINE Sense System to simultaneously collect both the originally intended skin strain data, as well as surface electromyography (surface EMG) from the paraspinal musculature.

METHODS: To capture EMG data, the pre-existing SPINE Sense system was modified to include a separate ground node for the EMG. This ground node was placed on the L5 vertebrae which is also the orientation point for placement of the original SPINE Sense device. The sampling rate of the system was optimized to enable data acquisition at 150 Hz per sensor. Data was collected from each of the 16 strain sensors, followed by surface EMG data collection from each of the 16 metal snaps (acting as surface EMG electrodes). A subject wearing the device on their lower back performed a series of 14 functional movements. A Bluetooth connection to a local smartphone was used to transfer the recorded data from the custom PCB to the smartphone, and subsequently to a cloud storage system for subsequent analysis.

RESULTS: Preliminary results demonstrate the capture of both skin strains and surface EMG data, consistent with previously published results. The initial results were first captured by connecting a basic EMG circuit to the device, and then using the metal snaps as electrodes to read a signal. A follow up test was performed to capture the EMG signal using the PCB and SPINE Sense sensor array together, collecting EMG signals from the electrodes that exist on the SPINE Sense through several repetitions of Spinal Flexion, verifying the SPINE Sense’s capability to upgrade to surface EMG signal collection. The captured EMG data shows a correlation to muscle activation of the lower spine, and the movement from 0 degree spinal flexion, to a 90 degree spinal flexion.

DISCUSSION: Some limitations arose in the simultaneous collection of two separate data sets from the same PCB. The Strain data requires a much lower sampling rate than the EMG signals to capture the kinematics of the skin strain, and changing from one sampling rate to another can complicate the PCB’s performance. The limitation is removed through an emphasis in surface EMG data collection and it’s higher sampling rate, combined with a less frequent skin strain reading which still samples at a readable frequency.

SIGNIFICANCE: The combination of skin strain kinematic and muscle activation data sets allows for further insight into phenotyping and characterizing the movement of the lower back. Advantages of the system include a low cost (approximately $8 in materials), ease of use, and the low-overhead smartphone-based system for data collection and analysis.

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IMAGES AND TABLES: Figure 1: Preliminary Surface EMG Signals compared to Spinal Flexion angle of the participating subject
Figure 2: Spinal Flexion Angles as performed in the preliminary trial
Figure 3: Electrode Locations from pre existing strain nodes on the SPINE Sense System, and the added Ground Node over the L5 vertebrae (Yellow Node)