Development of a Plantar Pressure Postural Analysis & Biofeedback System For WMSD Corrective Therapy
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Impact of WMSDs

Work-related musculoskeletal disorders (WMSDs) account 130 million total health care encounters annually (CDC) – with an annual economic cost of WMSDs to between $45 and $54 billion. In addition to the remarkable financial burden these injuries inflict upon industry and the healthcare system, WMSDs affect workers’ physical and mental health for the duration of their lives.

WMSD Detection Tools

- Ergonomics Methods
- Rapid Entire Body Assessment (REBA)
- Rapid Upper Limb Assessment (RULA)
- NIOSH Lifting Equation
- Hazard Analysis Tool (Snook Tables)
- Medical Methods
- Medical History & Physical Examination
- Electromyography (EMG)
- Imagery (e.g., X-Ray, CT, MRI, Ultrasound)
- Pedobarography
- Motion Capture

Few options for accurate, portable, and affordable WMSD detection and therapy exist. The closest commercial application – Lumo Lift – provides only upper-body posture data. For full-body WMSD detection, analysis, and therapy – a new device must be designed.

Method

Consequently, our team is developing a bioinstrumentation system that consists of pressure (piezoelectric) sensors attached to the bottom sole (plantar region) of the feet, and inertial measurement unit (IMU) sensors at the shoulders, hips, and knees; all connected to an Arduino microcontroller that algorithmically calculates the individual’s deviation from healthy standing posture and provide biofeedback via haptic vibrations in offending areas of the body – to assist as a corrective behavioral treatment in prevention or therapy for work-related musculoskeletal disorders (WMSDs) relating to posture.

Results

Our results demonstrate the viability of this device as well as the method of in vivo data collection. The algorithm was likewise successful, in that accuracy for detection of states / classes as identified in the certainty matrix range between .70 and 1.00 accuracy in pilot tests dependent on the complexity of the mannequin movement and position.

Discussion

Our initial development of the reference model, posture deviance detection algorithm, machine learning process, and mobile application prove the feasibility of this device. However, significant improvements to our system are needed in preparation for the first device prototype.

Foremost, our analyses signify a lack of sensitivity and a high margin for error in the current commercial inertial measurement units (IMUs) and plantar pressure sensors used for this device. Upgrades are required. Second, neural network analyses will replace the MGA used for the rapid prototype current machine learning process. Next, user data will be integrated into the models as a wider range of motions and body positions are understood by the system and addressed by the posture deviance detection algorithm. Incorporation of the non-intrusive haptic biofeedback will follow. Lastly, app data will be customized to the needs of users following a series of usability tests using human factors and ergonomics methods to be conducted throughout the iterative product design process.

References