Evaluating Wearable Vibrotactile Feedback in Reducing WMSDs during Fine Motor Tasks

William R Bonin[1], Qingguo Li[1]
[1]Mechanical & Materials Engineering, Smith Engineering, Queen's University, Kingston, Canada
Email: bonin.will@queensu.ca

Summary

This study examined the efficacy of a wearable posture feedback system in mitigating work-related musculoskeletal disorders (WMSDs) during fine motor tasks. Thirty medical students completed a standing fine motor task in which they assembled a blank puzzle under two conditions: with and without feedback from a single vibrotactile motor. The primary objective determined whether feedback from a vibrotactile motor and sensor capturing posture could induce a behavioral shift in participants' posture during these tasks. A secondary aim assessed participants' cognitive load associated with the vibrotactile system, measured through a SURG-TLX survey. Notably, this study integrated the ergonomic Rapid Upper Limb Assessment Tool with Exposure Variation Analysis. This combination allowed for a more dynamic, continuous evaluation of ergonomic risk factors by considering posture variation over time. The findings inform the development and applicability of wearable devices that promote optimal posture during fine motor tasks, contributing to the reduction of WMSDs.

Introduction

Work-related musculoskeletal disorders (WMSDs) are a significant concern for individuals performing prolonged fine motor tasks, such as those in surgical environments. These disorders arise from repetitive motions, awkward postures, and long durations of physically demanding activities. Wearable feedback systems have been proposed to promote ergonomic postures through real-time feedback. This study investigates how a wearable vibrotactile feedback system influences posture and cognitive load during fine motor tasks. Beyond assessing its effectiveness, this research addresses a critical gap in establishing a framework for determining *when* feedback should be delivered to optimize postural control and cognitive focus.

Methods

A within-subject study design was employed with thirty medical students, each performing a standing fine motor task involving the assembly of a blank puzzle under two conditions: with and without feedback from a vibrotactile motor placed on the back. The device uses an ESP32-S3 microcontroller with a YSENS inertial measurement unit to measure posture (Figure 1). Originally designed for Parkinson's rehabilitation [1], the feedback system was adapted to deliver vibrations, signaling poor posture.

Posture was evaluated using the Rapid Upper Limb Assessment Tool (RULA) [2], which helps identify postural risks based on specific joint angles of the body. Exposure Variation Analysis (EVA) [3] was used to quantify changes in posture throughout the task, capturing both the frequency and duration of postural deviations. By assessing cumulative exposure rather than relying on a single static evaluation, this combined system can provide a more precise measure of ergonomic risk. Cognitive load was assessed using the SURG-TLX survey [4] to measure mental and physical demands, workload, and time pressure. This revealed whether the feedback system added cognitive strain, complementing posture data for a more complete assessment of its effects on fine motor tasks.

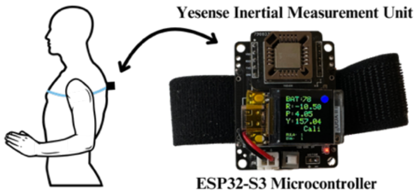

Figure 1: Wearable IMU sensor and vibrotactile feedback with real-time motion display, attached with a chest strap.

Results and Discussion

The data collection and results are expected to conclude in March 2025. The analysis will compare posture metrics under both conditions to determine whether the feedback system leads to significant improvements in EVA and RULA scores, indicating less risk of WMSDs. Participants receiving feedback are expected to adopt improved postures, potentially reducing their risk of WMSDs. Cognitive load data from the SURG-TLX survey and completion time will be analyzed to assess whether the feedback mechanism introduces additional mental strain or aids task efficiency by encouraging a more ergonomic posture. By integrating RULA with EVA, this study refines ergonomic assessments by capturing continuous posture variation, enabling a more precise evaluation of how wearable feedback influences posture and cognitive demands during fine motor tasks.

Conclusions

This study evaluates a wearable device designed to improve posture and reduce WMSD risk during fine motor tasks. By combining real-time vibrotactile feedback with RULA, EVA, and cognitive load assessments, it introduces a framework for determining the optimal feedback frequency to improve posture under high cognitive load. The findings will inform the design of wearable systems to promote musculoskeletal health in high-precision environments.

Acknowledgments

This research is supported by grants from Connected Minds Seed Grant (#CFREF-2022-00010), the Canada Research Excellence Fund (#410014846) and Queen's University.

References

[1] Bingfei Fan et al. 2025 Jan. *IEEE Sensors Journal* **25**
[2] L McAtamney et al. 1993 Apr. *Appl. Ergo* **24:**91-9
[3] S E Mathiassen et al. 1991 Dec. *Ergo*. **34:**1455-1468
[4] M R Wilson et al. 2011 Sep. *World J Surg*. **35:**1961-9