Quantifying Upper Body Postures with a Motion Sensing Garment

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ANALOG DEVICES

Introduction

- Upper extremity musculoskeletal disorders occur at high rates within the workplace [1].
- There is a need for a non-optical, wearable device for evaluating ergonomic posture.
- A motion sensing garment (MSG, Analog Devices, Inc, Wilmington, MA) is a lightweight garment that is instrumented with seven inertial measurement units (IMUs).
- The MSG enables the quantification of torso, shoulder, and elbow angles, which can be used to inform an ergonomic assessment model such as the Rapid Upper Limb Assessment (RULA).
- The goal of this study is to compare the measured postures of the MSG and VICON motion capture.

Methods

- 6 participants subsampled from 30
  - 5 male (1.84 m, 83.8 kg)
  - 1 female (1.70 m, 61.2 kg)
- Data were recorded simultaneously by VICON (VICON Nexus v2.41, Vicon Motion Systems Ltd, UK) and the IMUs in the MSG.
- Selected movements:
  - Elbow sagittal flexion
  - Elbow transverse flexion
  - Shoulder external rotation
- VICON data were post-processed in Visual3D (C-Motion, Inc, Germantown, MD).
- IMU data were processed using custom algorithms written in Python.
- Analyses were run in Python using 1D Statistical Parametric Mapping (SPM) with paired t-tests.

Figure 1. MSG with highlighted circles indicating IMU locations

Figure 2. Retroreflective markers were placed based on a modified Helen Hayes full body marker set.

Results

Non-optical, wearable technology such as the MSG has the potential to accurately measure kinematics and identify hazardous ergonomic postures in the workplace.

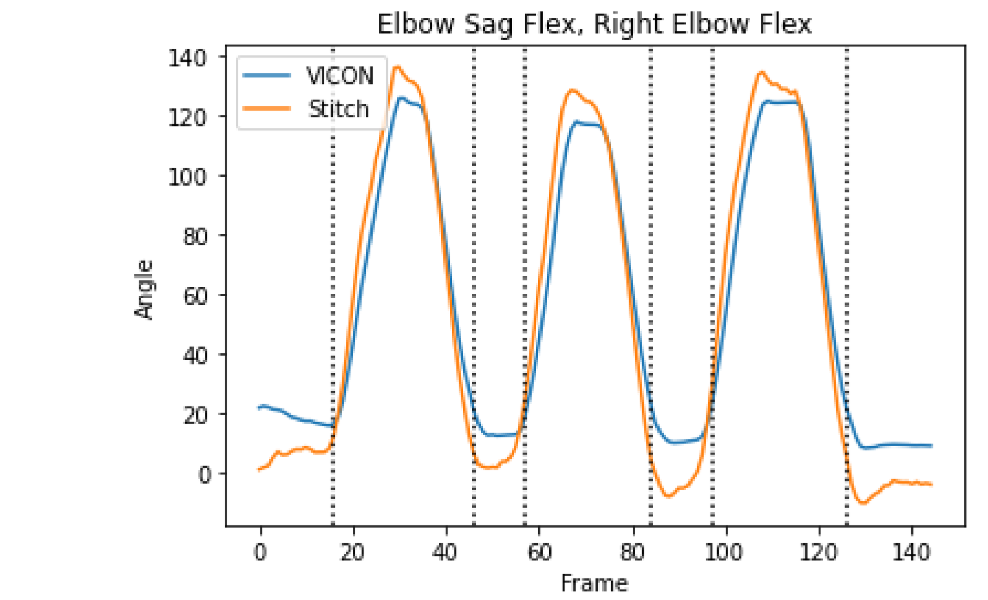

Figure 3. Processed angles showing VICON data relative to Stitch data for three cycles of elbow sagittal flexion of the right elbow in the flexion direction. Dotted lines denote cycles.

	Right Shoulder	Left Shoulder	Right Elbow	Left Elbow	Torso
Elbow Sagittal Flexion	>0.05 (24.3º)	>0.05 (19.7º)	**0.037 (80.9º)**	**0.001 (24.3º)**	>0.05 (6.56º)
Elbow Transverse Flexion	**<0.001 (134º)**	**<0.001 (149º)**	**<0.001 (91.9º)**	**<0.001 (96.7º)**	>0.05 (27.9º)
Shoulder External Rotation	**<0.001 (40.9º)**	>0.05 (44.9º)	>0.05 (45.0º)	**0.001 (27.4º)**	>0.05 (12.8º)

Table 1. Summary table of SPM results indicating p-values for data comparisons of a joint in the primary movement axis. Bolded values indicate significant differences. RMSE results are shown in parentheses.

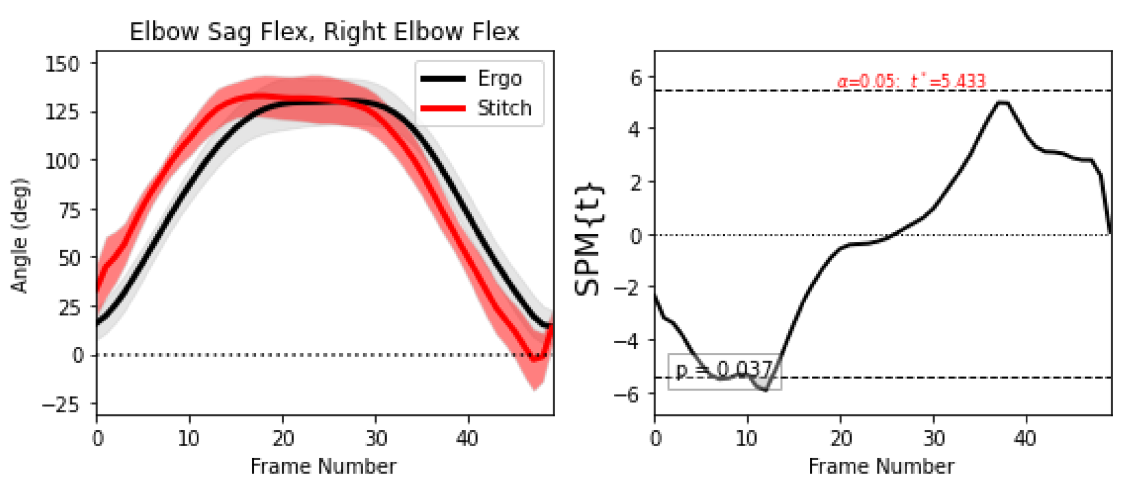

Figure 4. An example of good tracking between the two systems via SPM results illustrating average values for each system and indicating areas where system outputs significantly differed.

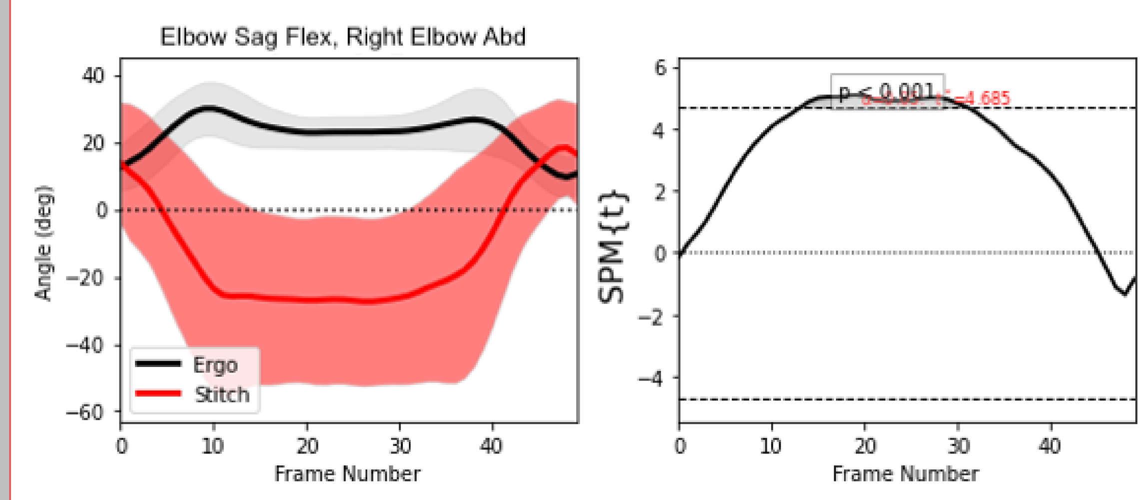

Figure 5. An example of poor tracking between the two systems via SPM results illustrating average values for each system and indicating areas where system outputs significantly differed.

Figure 3 shows the full movement cycle, with the dotted lines indicating where the cycles were split and standardized to the cycle average seen in Figure 4.

The MSG shows significant differences in most primary planes of movement. However, the general shapes of the waveforms match (Figures 3 & 4). Figure 4 is an example of when the MSG tracks well with the motion capture data. In non-primary joints and planes of movement, the MSG shows significant differences of angle values ($p < 0.001$) (Figure 5). Figure 5 is an example of how angles calculated from the MSG can track poorly with the motion capture system.

Table 1 summarizes SPM results by indicating if the two trajectories reported by both systems were significantly different from each other. Shown in parentheses is the root mean squared error (RMSE), giving context to the error magnitude for a significant p-value.

Discussion

Further investigation of the IMU data is needed to fully determine the capabilities of the MSG. Sources of error could be originating from the sensors themselves, post-processing, time alignment of the data, calibration poses, or improper size of shirt for the participant.

Figure 4 shows potential time misalignment as seen by the significant difference at the beginning and end of the trajectory. The waveform matches the shape well, but the differences in magnitude arise from the misalignment that occurs during synchronization of the two systems.

In processing IMU data, calibration poses were uniquely defined for each movement trial, whereas in the processing of the VICON data, one calibration was used for all trials. Any variance in the calibration poses could be contributing to the error. In addition, deviation from the expected calibration pose could be impacting the IMU data and contributing to error.

Significance

A wearable system like the MSG can help provide knowledge about how the posture, frequency, and duration of movements contribute to workplace musculoskeletal disorders. This technology would offer a non-optical and noninvasive solution for ergonomic monitoring in the workplace. Outside of occupational biomechanics, this wearable garment could also have impact in rehabilitation, at-home physical therapy and athletic training.

References

[1] US Bureau of Labor Statistics. (2019). *Occupational injuries and illnesses resulting in musculoskeletal disorders (MSDs)*.

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