Accuracy and Precision of Inertial Sensors in Ergonomic Evaluations of Static vs Dynamic Work Postures

MICHIGAN ENGINEERING
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INTRODUCTION

- Wearable low cost inertial sensors (3D accelerometers, gyroscope, and magnetometer) have strong potential for field based ergonomics assessments by providing body kinematics data.
- Evaluation of the performance is needed to ensure the use of inertial sensors on quantifying cumulative work exposures.

Study Objectives:

- Quantify differences in torso kinematics relative to levels of physical demand in work-related simulated tasks
- Test the accuracy and precision of inertial sensors (IS) in obtaining body postural angles by comparing them with reliable optical motion capture (MC) system in lab-simulated experiment

METHODS

Participants:

15 healthy right-handed males (age:23.5 ±3.8)

Instrumentation

- 1 inertial sensor (YEI Technology, Inc.) at T6 thoracic vertebra
- MC marker triad attached to the IS and markers at T6, right and left acromion.

Task 1 – Static Push-Pull

- Isometric horizontal force exertion to match and maintain a required target force level (±5%) for a continuous 3s interval

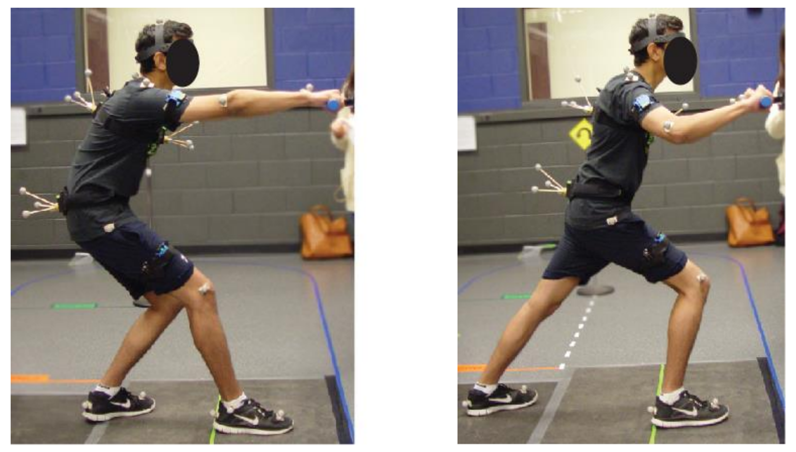

Figure 2. Example of a 2-H push (left) vs. pull (right).

- Target Force Intensity set as a % of maximum voluntary exertion (MVE) in a two-handed push with the handle at hip height

Handle Height	Force Intensity	Force and Magnitude %	
		Push	**Pull**
Shoulder	Low	19.2	15.9
	Medium	38.5	31.7
	High	57.7	47.6
Mid	Low	21.7	17.9
	Medium	43.5	35.9
	High	65.2	53.8
Hip	Low	25.0	20.6
	Medium	50.0	41.3
	High	75.0	61.9

Shoulder = 0.77x Hip

Pull = 0.83xPush

- Independent Variables: handle height (shoulder, mid, hip), force intensity (low, medium, high), force direction (push, pull)
- 18 counterbalanced task conditions.

Task 2 – Dynamic Lifting-Lowering

- Repetitive lifting and lowering of a weighted box using stoop and squat techniques (Figure 3).

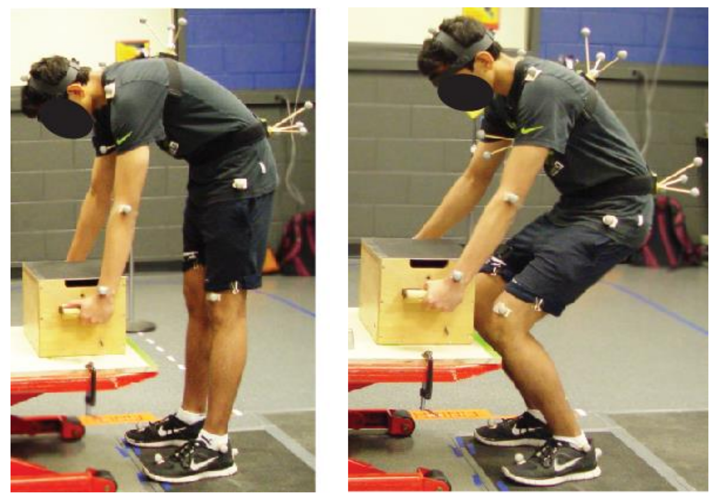

Figure 3. Example of a stoop (left) vs. squat (right) lifting posture

- Task Intensity was manipulated by changing box weights (table below) computed as a % of low-back MVE

Box Weight	Magnitude %	
	Stoop	**Squat**
Low	25	25
Medium	50	50
High	75	75

- Independent Variables: box weight (low, medium, high), posture (stoop vs. squat)
- 6 counterbalanced conditions; 3 repetitions each

Dependent Variables

- Root mean squared error (RMSE) in Torso Flexion-Extension angles measured using IS (θ_{IS}) and MC (θ_{MC}) ; RMSE = $\sqrt{\frac{\sum(\theta_{IS}-\theta_{MC})^2}{N}}$
- Accuracy computed as average RMSE by task condition**;** low RMSE values indicate high accuracy
- Precision computed as standard deviation (SD) in RMSE by task condition; low variance of RMSE indicates high precision

REFERENCES

[1] Chaffin, D. B., Andres, R. O., & Garg, A. (1983). Volitional postures during maximal push/pull exertions in the sagittal plane. Human Factors: The Journal of the Human Factors and Ergonomics Society, 25(5), 541-550.

RESULTS

Task 1 – Static Push-Pull

- Torso flexion angle is higher at the lower handle height and higher target force intensity in both push and pull exertions
- RMSE range (static task): 1.80 – 3.69 degrees
- RMSE and standard deviation of RMSE tended to increase with target force levels and decrease with handle heights

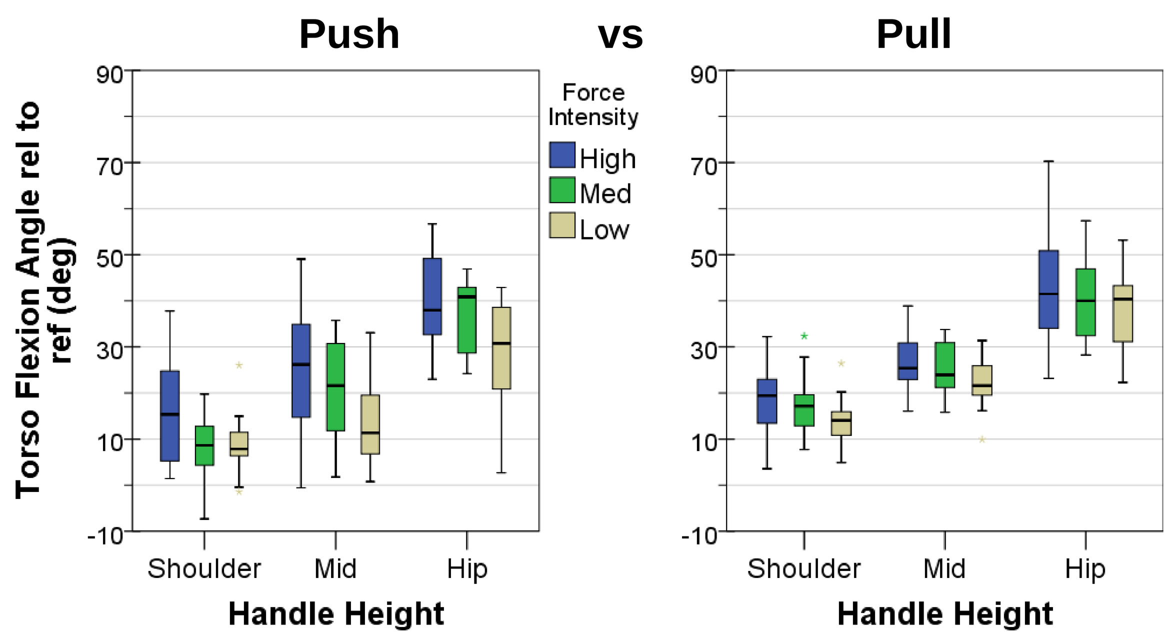

Figure 4. Box-plots showing the increase in Torso flexion angles relative to neutral standing posture for push (left) and pull (right) with decreasing handle height and increasing force intensity.

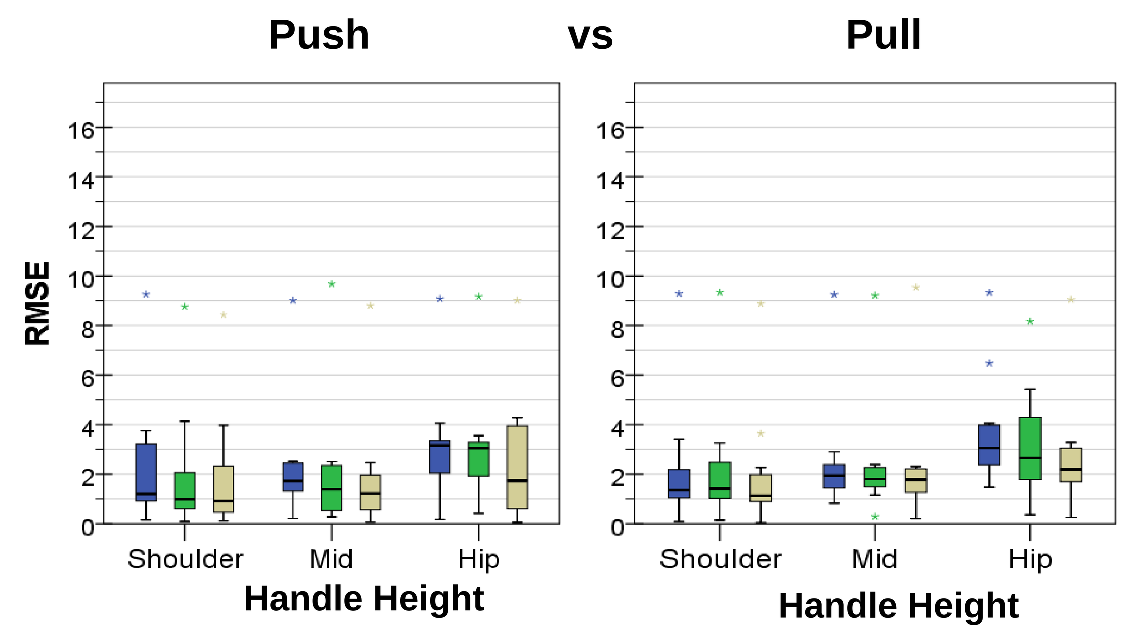

Figure 5. RMSE calculated from IS and MC measurement systems while subject is performing static push and pull task.

Task 2 – Dynamic Lifting-Lowering

- Torso flexion angles ranged from 82-15 degrees when participants were lifting and 10-82 degrees when participants were lowering relative to neutral standing posture
- RMSE range (dynamic task): 2.59 – 16.9 degrees
- RMSE and standard deviation of RMSE tended to increase with box weights.
- RMSE and standard deviation of RMSE tended to increase during the lowering phase of the dynamic task

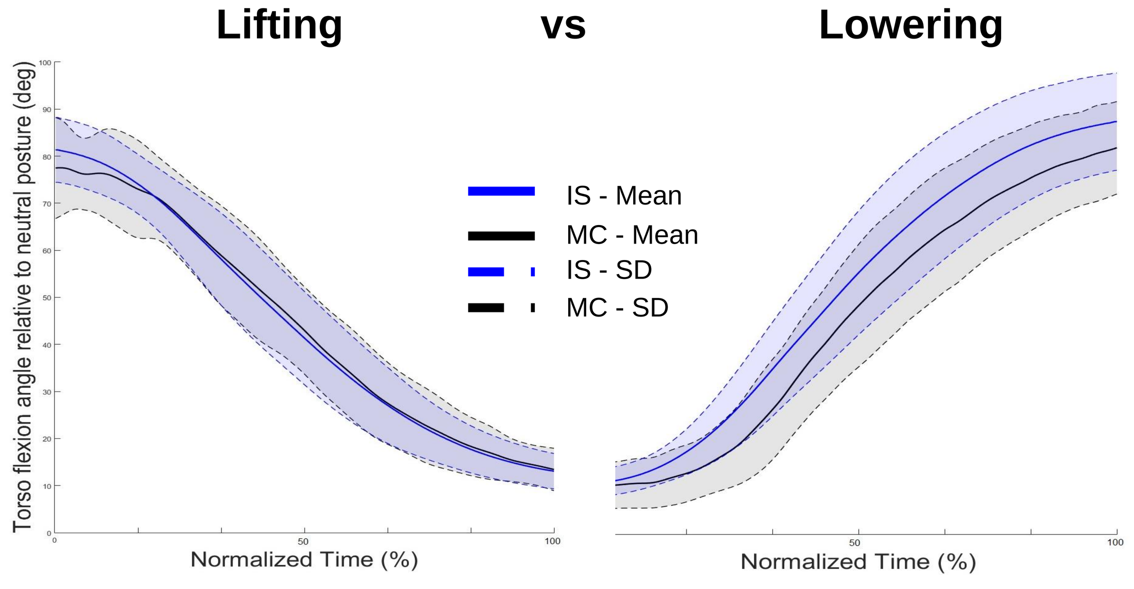

Figure 6. Mean (SD) Torso flexion-extension angle normalized to the start and end for lifting (left) and lowering (right) measured using IS (blue) and MC (black). Shaded area depicts the standard deviation

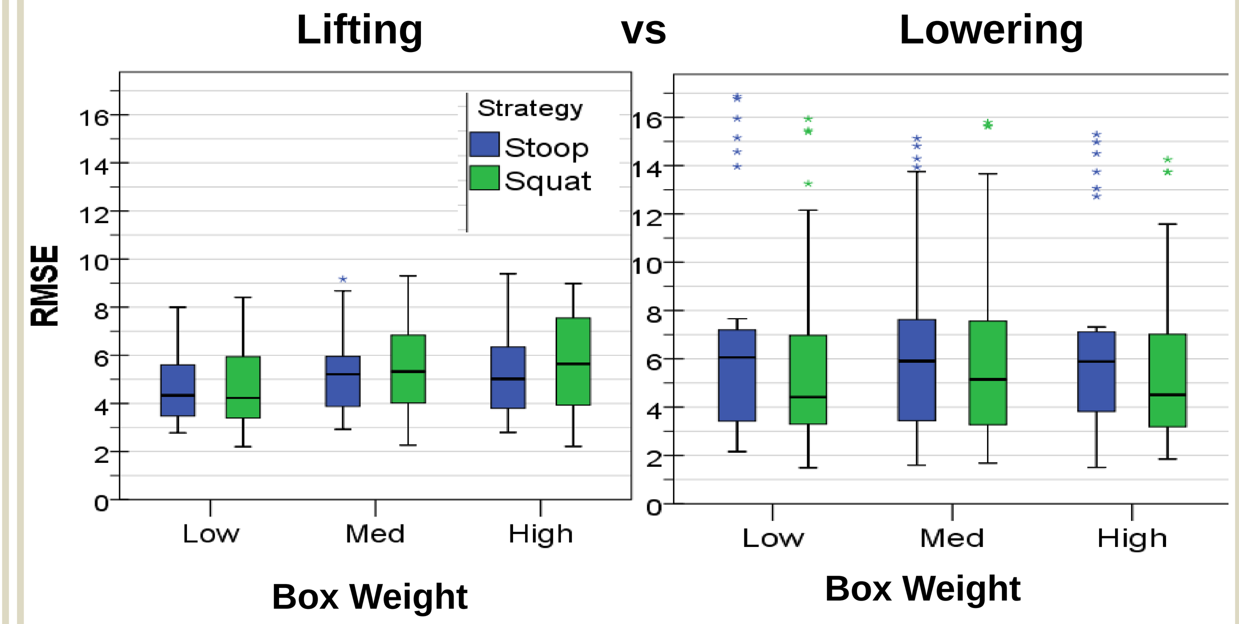

Figure 7. RMSE calculated from IS and MC measurement systems while subject is performing dynamic lifting and lowering task

CONCLUSIONS

- Static Push-Pull: systematic changes in torso flexion angle by physical task demands
  - Lower handle heights and higher target force intensity increased torso flexion angle in both push and pull exertions
- RMSE and SD values for dynamic task were greater (2.59-16.9 degrees) than the static task (1.80-3.69 degrees)
  - Accuracy of the measurement is affected by the type of task. Dynamic task showed higher RMSE
- Precision of the measurement was higher at the static task compared to the dynamic task

Next Steps

- Work is ongoing to investigate the cause of RMSE and SD differences between static and dynamic

ACKNOWLEDGMENTS

This work is funded presently by a PPRT award to S. Lim through the training grant T42-OH008455 from the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention

National Institute for Occupational Safety and Health NIOSH