Optimizing the Human Weapon System: Utilizing Wearable Sensor Data to Inform Readiness

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INTRODUCTION

Musculoskeletal injury (MSKI) is the leading threat to Service Member (SM) readiness, driving more limited-duty days than combat trauma and accounting for most Military Health System outpatient encounters (Clark et al., 2023). Ankle injuries account for roughly 63% of parachuting injuries (Schmidt et al., 2005); prophylactic bracing can cut these by up to 67% and save up to $865K annually, yet uptake remains low (Schmidt et al., 2005; Fogle et al., 2018).

Progress is limited by underreported symptoms and a lack of objective RTD tools. The DoD has called for wearable monitoring to enable individualized, evidence-based readiness determinations (Friedl, 2018; de Vries et al., 2025).

The TayCo Sensor External Ankle Brace (**sXAB, Figure 1**) meets this need, integrating an IMU into the existing CombatX Brace for continuous, objective motion monitoring without disrupting duty, addressing DHA MSKI Strategic Research Plan Capability M6.1. This work validates the brace-mounted sensor against gold-standard motion capture (MoCap) during balance and walking tasks, establishing accuracy benchmarks for the sXAB.

Figure 1. *TayCo sXAB*

RESEARCH OBJECTIVES

OBJECTIVE 1:

Compare the performance of the external brace-mounted sensor system to gold-standard MoCap during balance and walking tasks while test subjects wear their own footwear.

OBJECTIVE 2:

Establish foundational comparison data needed before expanding testing into additional military-relevant environments (e.g., military boots, running, stairs, drop jumps).

METHODS

SENSOR & PARTICIPANTS

The IDL PhySens v5B IMU sensor (**Figure 2**) was selected based on its high-performance capabilities and compatibility with the TayCo Sensor External Ankle Brace (sXAB). The IDL sensors were mounted using the standardized three-hole attachment pattern shown (**Figure 3**). A total of 20 participants (19 analyzed) were tested at the Indiana University Biomechanics Laboratory.

Figure 2. *IDL PhySens v5B IMU*

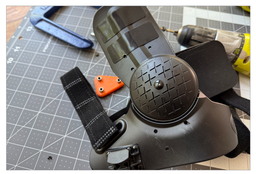


Figure 3. *TayCo sXAB Hole Pattern*

METHODS (CONT.)

TESTING PROTOCOL

Participants completed two walking tasks while force plate and motion capture data were collected (**Figure 4**). Motion capture cameras recorded reflective marker positions at 240 Hz; force plates (embedded in an instrumented treadmill) captured ground reaction force and center-of-pressure data at 1200 Hz. Trial order was randomized, and each participant completed the full protocol with and without the ankle brace using the same trial order for both conditions. **Two walking tasks performed:** 1) Preferred walking speed (average 1.25 m/s, range = 1.10–1.52 m/s), and 2) Set walking speed (1.3 m/s).

Figure 4. *Participant Sensors*

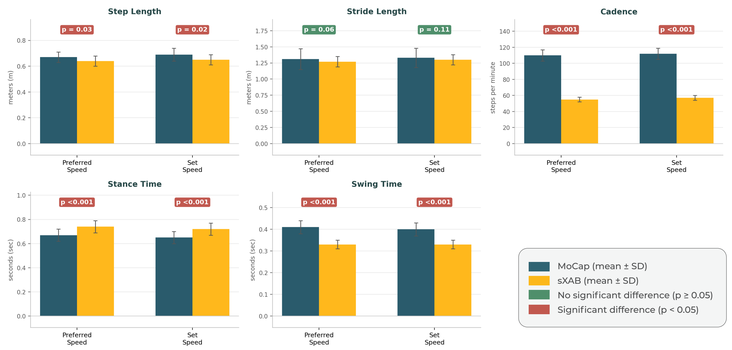
To synchronize MoCap and sXAB data, participants performed a hop–kick–hop sequence with the braced limb at the beginning and end of each walking task, and between balance conditions. Balance tasks were recorded for up to 30 seconds; walking tasks for a minimum of 45 seconds following the synchronization sequence.

RESULTS

SPATIOTEMPORAL GAIT METRICS: SXAB VS. MOCAP

Figure 5

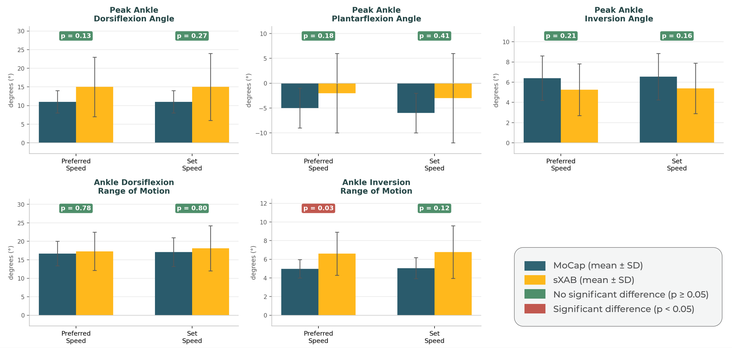
Mean ± SD Gait Metrics During Walking. Milestone 05 Validation Study (n=19)



ANKLE KINEMATICS: SXAB VS. MOCAP

Figure 6

Mean ± SD Peak Angles and Range of Motion During Walking. Milestone 05 Validation Study (n=19)



CONCLUSION

Ankle joint kinematics measured by the sXAB were largely statistically consistent with laboratory-grade motion capture across both walking speeds, supporting the sensor's potential as an objective tool for monitoring warfighter ankle motion in operational and clinical settings.

Spatiotemporal gait metrics (step length, cadence, stance/swing time) showed statistically significant differences from MoCap at both speeds, indicating further calibration or algorithm refinement may be needed before these variables can be used interchangeably with MoCap-derived values in return-to-duty assessment.

NEXT STEPS

Additional testing is currently underway at the Indiana University Biomechanics Lab in collaboration with Dr. Allison Gruber. This phase will compare sXAB data (incorporating IDL sensors) to MoCap during more advanced tasks while participants wear military boots, including: **balance testing, walking, running, stair ascent/descent, and drop jumps.**

MoCap data collection will continue to include force plate data to enable calculation of sway variables during static balance tasks and kinetic variables during movement tasks (e.g., ground reaction forces, center of pressure, joint moments). Current IMU technology does not enable direct collection of these variables; obtaining them from IMU data will require additional predictive modeling approaches to be explored as research progresses.

ACKNOWLEDGMENT

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