Validation of an IMU Suit for Military Based Tasks

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INTRODUCTION

- Inertial measurement units (IMUs) build on many limitations inherent in gold standard optical motion capture (OPT) setups:
  - e.g. marker occlusions, clothing artifacts, and transportability.
- Xsens MVN Link (Xsens, Netherlands) is a commercially available IMU system, which collects whole-body kinematics using a scaled biomechanical model.
  - Xsens has been validated for over ground walking [1], running [1], and stair ascent/descent [2].
    - Xsens is very accurate in the flexion/extension axis but has poorer performance in the ab/adduction and rotation axes [1,2].
    - Validations focus on lower limb joint angles [1,2].
- Canadian soldiers perform whole-body movements that were not accounted for in previous validation studies.
  - The goal of this study was to compare whole-body movement patterns outputted by an Xsens IMU suit versus a gold standard OPT system during military based movements.

METHODS

PARTICIPANTS:

- 10 male and 10 female civilian participants (174.8 cm (SD = 7.9), 71.9 kg (SD = 13.2), 23.7 years (SD = 3.4)) were recruited for this study. All participants were free of musculoskeletal disorders.

PROCEDURE:

- Participants performed 8 military based tasks (Figure 1):
  - Kneel-to-prone
  - Kneel-to-run
  - Prone-to-run
  - Walking
  - Prone-to-kneel
  - Run-to-kneel
  - Run-to-prone
  - Running
- Participants' kinematics were collected simultaneously by:
  - 17-sensor IMU suit (Xsens MVN BIOMECH, Netherlands; 240 Hz);
  - Passive full-body OPT marker set (Vantage V5, Vicon, UK; 240 Hz).
- Time series marker positional data from both systems were exported to C3D format and imported into Matlab (2018b, The MathWorks, USA).
  - Systems were synchronized using a hand clap.
  - Trials were cropped based on the visual starts and ends of the movements and/or gait events.
- Principal component analysis (PCA) was used to analyze the three-dimensional time series marker positional data from both systems.
  - For each task, movement trials were stacked into a single matrix [N trials x 9090 (30 markers*3axes*101 data points)], where the first ½ N rows were IMU data and the last ½ N rows were OPT data.
- The IMU and OPT systems were compared using Pearson correlations of the PC scores for each movement trial.
  - >90% trace criterion.

RESULTS

- The average r-value across all movements and PCs was 0.807 (high) .
- 35 out of 43 retained PCs (81%) had an r-value > 0.70 (high).
- 17 out of 43 retained PCs (40%) had an r-value > 0.90 (very high).

Table 1. *Correlation Coefficient Results*

Task	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9
Kneel-to-prone	0.960	0.962	0.918	0.855	0.503	0.860	0.914	-	-
Kneel-to-run	0.904	0.702	0.793	0.981	0.923	0.851	0.580	0.629	0.204
Prone-to-run	0.830	0.774	0.677	0.865	0.882	0.732	-	-	-
Walking	0.994	0.985	-	-	-	-	-	-	-
Prone-to-kneel	0.949	0.929	0.963	0.660	0.713	0.954	0.848	-	-
Run-to-kneel	0.913	0.768	0.715	0.936	-	-	-	-	-
Run-to-prone	0.953	0.761	0.847	0.988	-	-	-	-	-
Running	0.536	0.607	0.877	0.871	-	-	-	-	-

DISCUSSION & CONCLUSION

- PCA was able to capture similar amounts of variability in marker positional data between the IMU and OPT systems.
  - 81% of retained PCs had a high correlation; 40% were very high.
- Results are consistent with previous literature that found good agreement between Xsens and OPT systems [1,2].
- Due to the large percentage of high-very high correlation coefficients, we believe that the Xsens MVN BIOMECH system is an appropriate motion capture setup to capture whole-body movement variability during military based movements.

MILITARY MOVEMENTS

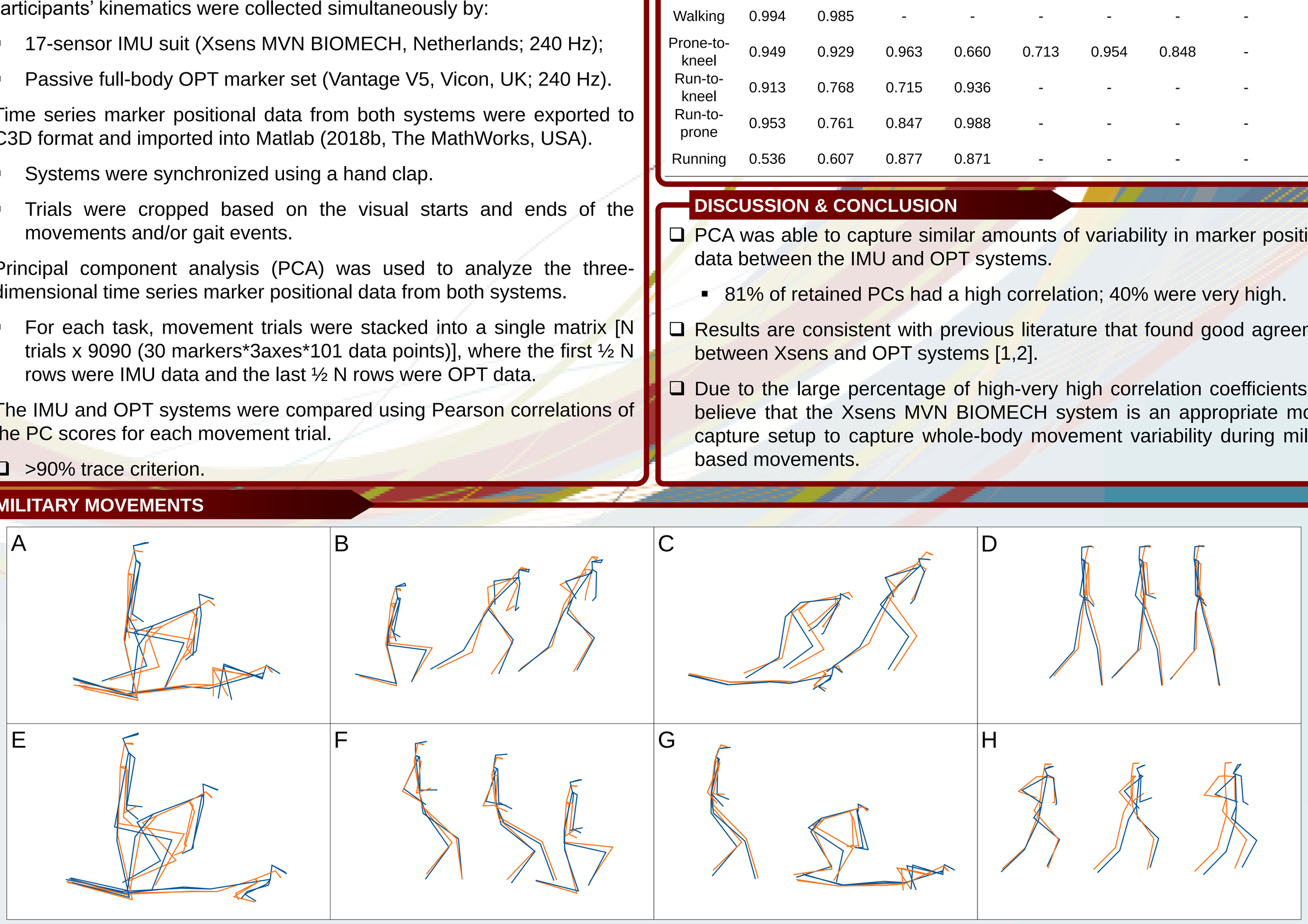

Figure 2. Military Movements. **Blue** represents an average OPT mover; **orange** represents average IMU mover A) Kneel-to-prone, B) Kneel-to-run. C) Prone-to-run. D) Walking. E) Prone-to-kneel. F) Run-to-kneel. G) Run-to-prone. H) Running.

REFERENCES

[1] Schepers, M., et al., (2018). Xsens MVN: Consistent Tracking of Human Motion Using Inertial Sensing. XSENS Technol. B.V 1–8. [2] Zhang, et al., (2013). Concurrent validation of Xsens MVN measurement of lower limb joint angular kinematics. Physiol. Meas. 34, N63–N69.

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