Escape Motions for Real-World Scenarios: Kinematic & Kinetic Investigation of Rapid, Dynamic Movements

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Motivation

- Augmentative exoskeletons traditionally address *steady-state locomotion* and *repetitive tasks*.
- In dynamic environments where *surrounding threats* exist, The kinematic and kinetic behavior ***of rapid, evasive movements*** have not been studied in order to rush towards safety.

What is the *biomechanical response* when given a *visual instruction* in dynamic environments?

Methods

- **Protocol**: Subjects must escape a pre-defined circle in randomly-chosen directions (8 directions at 45° increments) from a visual instruction (Fig. 1).
- **Sensors**: Motion capture markers, IMUs, EMG, GRF. Sensor locations are illustrated in Fig. 2.

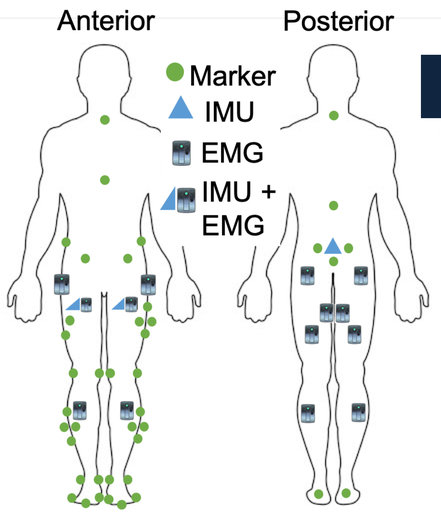


Fig. 2: Sensor locations annotated.

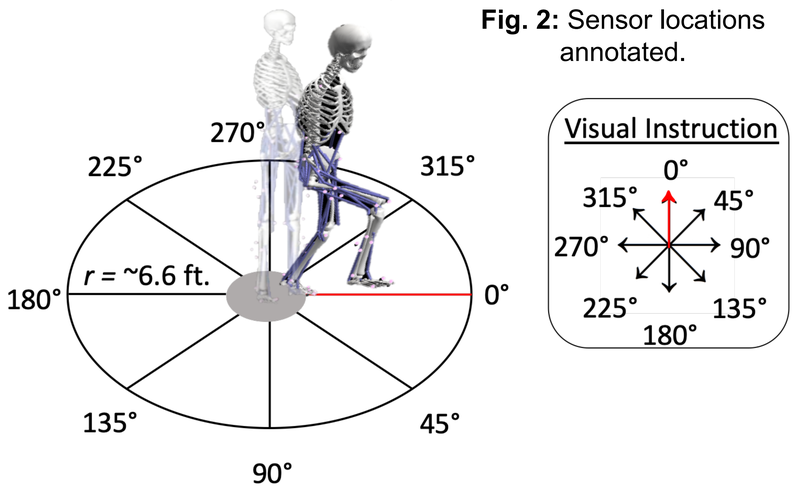


Fig. 1: Subjects escape in the direction of visual instruction displayed. 0° is annotated here.

Experiment Collection

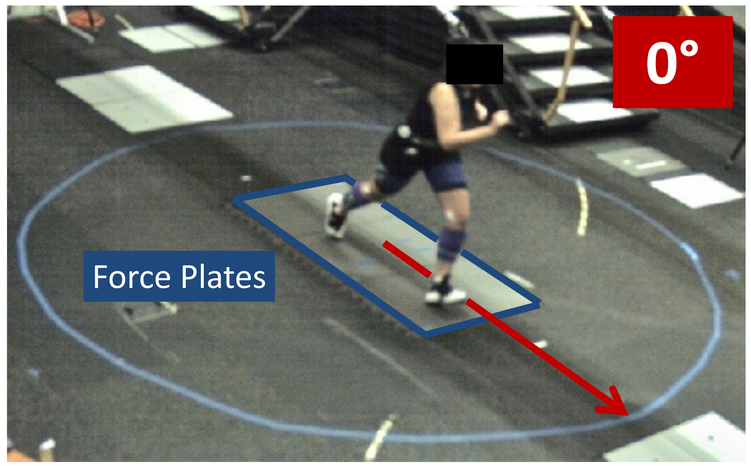


Fig. 3: Experiment being conducted with the given visual instruction of 0°. Video captured using Vicon.

Kinetic and Kinematic Results

Table 1: Design values for each limb with absolute peaks annotated.

	Trailing Limb		Leading Limb	
	Peak Torque (Nm/kg)	Peak Speed (°/sec)	Peak Torque (Nm/kg)	Peak Speed (°/sec)
Hip	1.11	175	2.19	402
Knee	1.93	373	1.17	390
Ankle	2.96	619	2.33	620

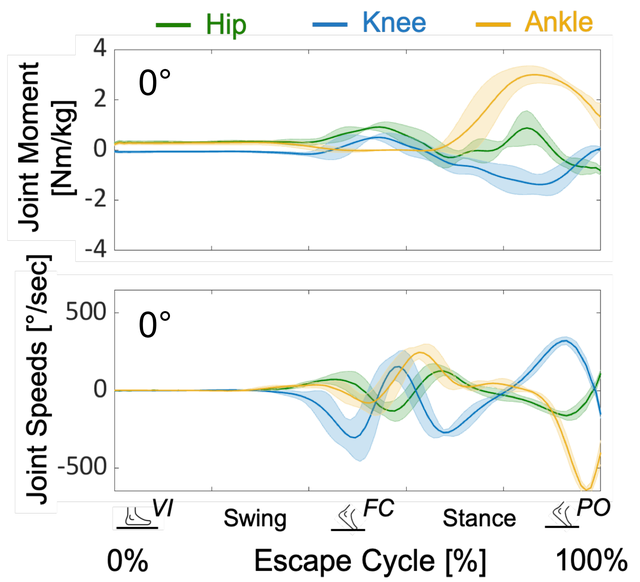


Fig. 3: Joint moments (top) and speeds (bottom) for the escape cycle defined as when visual instruction is given (VI) to foot contact (FC) and then final push-off (PO) for 0°.

Intent Recognition

- The biomechanical response was also characterized through ***estimation of direction of travel and the motion start*** of such movements.
- Intent recognition architecture: *feature extraction* (Table 2), *dimension reduction* (Fig. 4), and *sensor contribution* (Fig. 5).

Mechanical Features	EMG Features
Mean	Root Means Squared
Standard Deviation	Mean Abs. Value
Maximum	Zero Crossings
Minimum	Slope Sign Changes
End Value	Waveform Length

Table 2: Feature extraction.

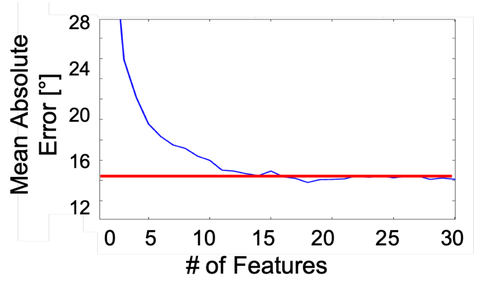


Fig. 4: Dimension reduction.

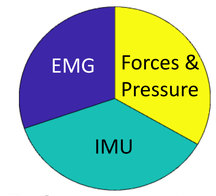


Fig. 5: Sensor contribution.

Analysis and Conclusions

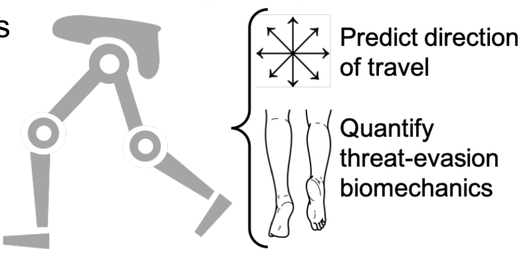
Preliminary Findings:

- Trailing limb is dominant with great contribution from knee and ankle, while leading limb completes cycle fastest.
- Direction of travel is estimated with just a few sensors.

Future Work:

- Analyze biomechanics of other directions.
- Implement prediction methods to anticipate direction prior to movement start.

Design Objectives:



References

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[2] Dos'Santos, T., Thomas, C., Comfort, P., & Jones, P. A. (2018). The Effect of Angle and Velocity on Change of Direction Biomechanics: An Angle-Velocity Trade-Off. *Sports medicine (Auckland, N.Z.)*, *48*(10), 2235–2253.

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