Development and Validation of Machine Learning Algorithms to Evaluate Overall Walking Patterns of Lower Limb Prosthetic Users using Inertial Sensors.

Kuepper E.[1,2], Ng G.[1,3], Andrysek J.[1,3]

1. Bloorview Research Institute, Holland Bloorview Kids Rehabilitation Hospital
2. Integrated Biomedical Engineering and Health Sciences, McMaster University
3. Institute of Biomedical Engineering, University of Toronto

Background & Objective

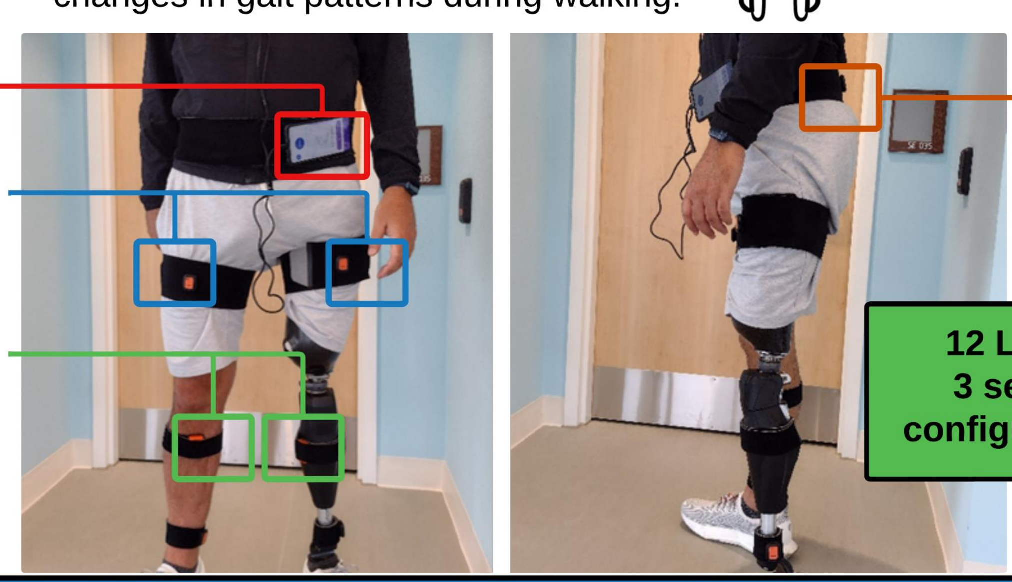
Assess walking patterns with wearable technology → Obtain metrics for clinical use → Monitoring + multimodal feedback → Guide rehabilitative care in and out of clinical settings

Algorithms required

Objective: Validate a machine learning (ML) algorithm to **assess changes in walking patterns** corresponding to **clinically relevant gait parameters** for lower limb prosthetic users (LLPUs).

Methods

Auditory feedback system: Elicited changes in gait patterns during walking.



12 LLPUs
3 sensor configurations

Hidden Markov model (HMM), self-organizing map (SOM), and dynamic time warping (DTW) were implemented to **detect changes** in stance time symmetry **from baseline**.

Input: Accelerometer + gyroscope data from walking trials → Baseline / Symmetry Level 1 / Symmetry Level 2 / ... → **Output:** Machine learning (ML) based gait deviation score

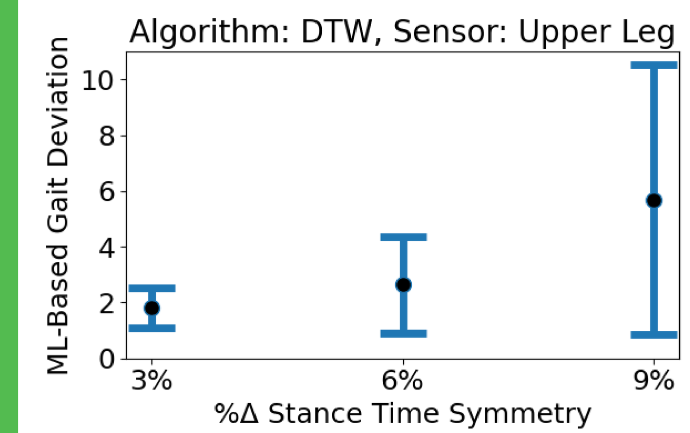
Combining Simple Wearable Technology With Machine Learning to Assess Walking Patterns in Lower Limb Prosthetic Users.

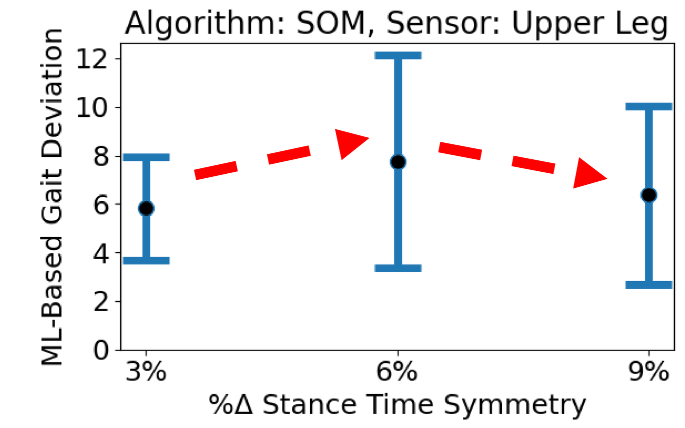
University of Toronto

Holland Bloorview Kids Rehabilitation Hospital

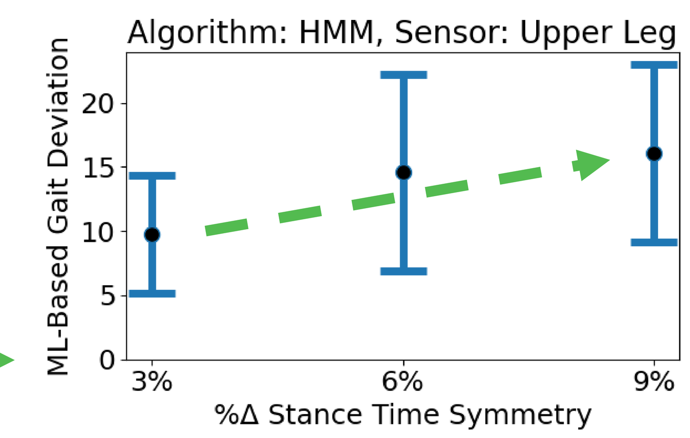
Results

Example – Mean + 95CI of ML-based gait deviation scores across symmetry levels





Expected result: Changing symmetry = higher ML-based deviation score



Poor result: Changing symmetry does not correlate with ML-based deviation score

Effect Size – Standardized Response Mean (SRM)

Low Moderate High responsiveness

Sensor Location	Pelvis			Upper leg			Lower leg		
Symmetry Change	3%	6%	9%	3%	6%	9%	3%	6%	9%
DTW	0.05	0.15	0.41	0.33	0.66	0.61	0.45	1.76	1.46
SOM	0.24	0.04	0.02	0.18	0.05	0.07	0.3	0.82	1.04
HMM	0.62	0.78	0.85	0.69	0.87	1.82	0.77	0.58	0.63

- **HMM** → moderate-high responsiveness for all sensor locations and gait symmetry levels.
- **Lower leg sensor location** → highest responsiveness across all algorithms.

Conclusions

✓ ML algorithms trained on inertial sensor data can be responsive to changes in stance time symmetry.

Next steps:

❑ Assess responsiveness of algorithms to changes in other gait parameters (ex. step length).

Impact

Wearable systems can **offer cost-effective, portable, and user-friendly gait monitoring**. When integrated with reliable gait evaluation models, these systems could:

1. Provide **real-time feedback** without a clinician present.
2. Monitor changes in and out of the clinic to **inform clinical decision making and rehabilitation goals.**