Six precise gait measures, captured with body-worn inertial sensors during a 6-minute walk test, discriminate Multiple Sclerosis from healthy controls while gait speed does not

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Aim

Background: : Gait deficits are common in Multiple Sclerosis (MS) but poorly captured by stopwatch-timed tests or rating scales. Body-worn inertial sensors can detect precise gait abnormalities in people with MS who have normal walking speed but the most discriminative measures of gait for MS are unknown.

Aim: This study aimed to determine the best combination of gait measures to discriminate MS from healthy control (HC) subjects.

Methods

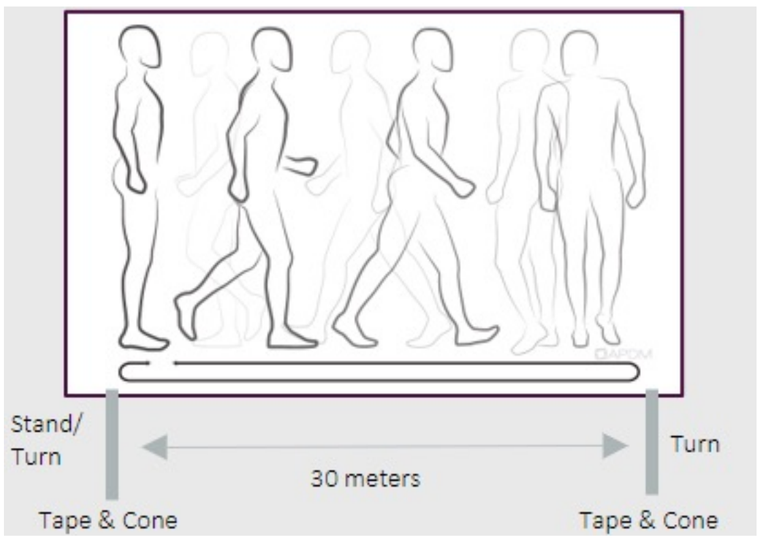
Protocol

- Participants wore 6 inertial sensors (2 feet, 2 wrists, 1 sternum and 1 lumbar; Opal by APDM Wearable Technologies, a Clario company)
- 6 min-walk test: Participants were instructed to walk at a comfortable and natural pace back and forth continuously over two lines of tape placed 30 meters apart (Study I) and 15 meters apart (Study II).

6-minute walk test

Development dataset [Study I: Walkway length=30 meters] (MS=14 and HC=17)

Test dataset [Study II: : Walkway length=15 meters] (MS=9 and HC=7)



Digital Measures from 6-minute Walk Test

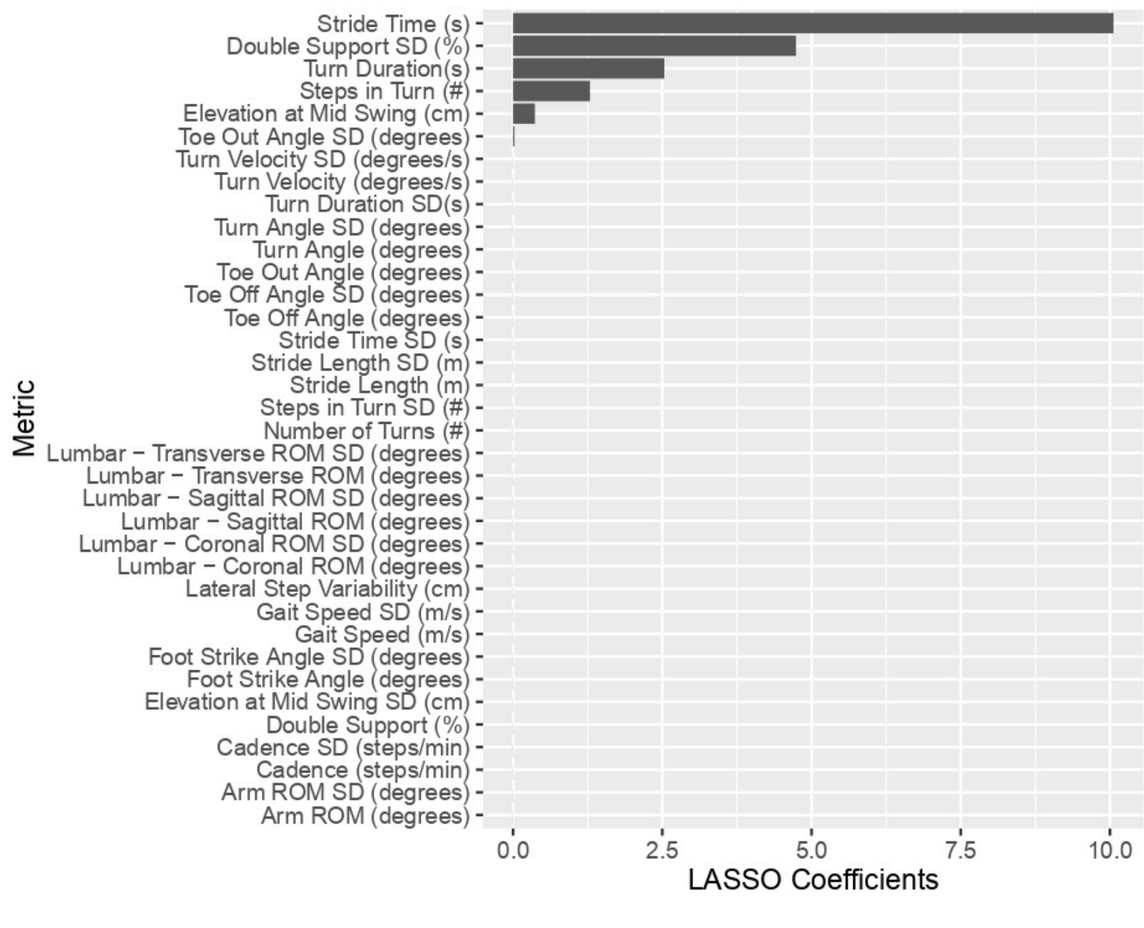
Lower Body	Gait Speed
	Stride Length
	Cadence
	Stride Duration
	Step Duration
	Double Support
	% Swing of Gait Cycle
	Elevation at Mid Swing
	Pitch at Toe Off
	Pitch at Initial Contact
Upper Body	Transverse Range of Motion
	Sagittal Range of Motion
	Coronal Range of Motion
Turning	Turn Angle
	Turn Duration
	Turn Rate Average
	Number of Steps in Turn
	Turn Jerk
	Medio-lateral Turn Range
Variability	Coefficient of Variability of all gait measures

Feature Selection Method

- Least Absolute Shrinkage and Selection Operator (LASSO)
- 5-fold, cross-validated LASSO
- Selected features are used to train 70% of the dataset of Study I using logistic regression
- Trained model validated on 30% of Study I
- To test the generalizability of the proposed model, we applied the same mode on independent data (Study II)
- The area under the curve (AUC) of receiver operator characteristic (ROC) curves was used to evaluate the discriminate ability of the proposed model

Results

The proposed model applied to a totally independent dataset (Study II) resulted in AUC=0.92 (sensitivity=0.89, specificity=1)



- From 36 gait measures, LASSO selected 6 measures from the training dataset:
  1. Stride time
  2. Variability of double support time
  3. Turn duration
  4. Total number of steps in a turn
  5. Elevation at mid-swing
  6. Toe-out angle standard deviation

  Gait speed was not selected
- Logistic regression trained with the 6 gait measures on 70% of Study I resulted in AUC=1 (sensitivity=1 and specificity=1) when applied on the validation dataset (30% of Study I)

Conclusion

- The best combination of gait measures for accurate classification of MS from HC gait during the 6-minute walk test did not include gait speed. Digital gait measures show promise for endpoints in clinical trials.

Acknowledgements

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Conflict of Interest

Drs. Shah, and Horak are employees of APDM Wearable Technologies, a Clario company that may have a commercial interest in the results of this research and technology. This potential conflict of interest has been reviewed and managed by OHSU.