Non-Invasive Diagnostic Classification of Neurodegenerative Disorders

Kristin D. Morgan
Biomedical Engineering, University of Connecticut, Storrs, Connecticut
Email: kristin.2.morgan@uconn.edu

Summary

Gait is a powerful diagnostic tool. Here, we leveraged the diagnostic capabilities of nonlinear derived gait features to successfully classify individuals with ALS and PD.

Introduction

Amyotrophic lateral sclerosis (ALS) and Parkinson's Disease (PD) are progressive neurodegenerative disorders that can significantly impact individual's gait. Their altered gait often presents as increased stride time variability and is the result of a disruption in motor signal transmission due to weakened or destroyed motor neurons in individuals with ALS and PD, respectively. These impaired nerve cells originate from different structures in the brain and spinal cord; therefore, ***it is possible that the combined effect of the location and how the nerve cells are impacted can lead to distinct differences in stride time patterns in these populations.***

This study sought to classify individuals with ALS and PD from their stride time dynamics. Poincaré analysis was implemented to extract gait features to serve as inputs to the classification algorithm. This work is significant as it can aid in the non-invasive clinical diagnosis of individuals with neurodegenerative disorders.

Methods

Sixteen controls (40.6±18.4yrs; 1.8±0.1m; 67.9±10.5kg; gait speed 1.4±0.2m/s, gender: 13f:2m), 12 individuals with ALS (ALS) (54.9±13.1yrs; 1.8±0.1m; 76.7±22.1kg; speed 1.0±0.2m/s, gender: 3f:9m), and 15 individuals with PD (66.8±10.9yrs; 1.9±0.2m; 75.1±16.9kg; gait speed 1.0±0.2m/s, gender: 5f:10m) participated in a walking protocol conducted at Massachusetts General Hospital [1]. Participants were instructed to walk at a self-selected pace along a 77m hallway for 5 minutes. Force sensitive resistors embedded in the participants shoes measured the stride data.

Stride time waveforms were created for both limbs for each participant from stride time data obtained from online [2]. Poincaré analysis was performed on each stride time waveform to extract the SD1 and SD2 parameters that represented the short- and long-term variability in each waveform [3]. A one-way ANOVA was conducted to assess if there were significant differences in mean stride time dynamics amongst the groups (α=0.05).

The three gait features served as inputs into the classification model and a k-fold cross-validation approach was employed.

Results and Discussion

A fine gaussian support vector machine (SVM) model classified individuals into the ALS, PD, and Control groups with accuracy, sensitivity, and specificity of 92.3%, 90.6%, and 80.4%, respectively. Additionally, 95% confidence ellipsoids fit to each group illustrated how the gait features separated the groups into 3 different regions (Fig. 1). The one-way ANOVA identified significant differences in mean stride time, SD1, and SD2 amongst the groups (Table 1).

The ability to differentiate between the ALS and PD groups is impactful as it not only shows that there are gait patterns associated with specific neurodegenerative disorders but opens up the possibility that we could link gait patterns to specific locations in the central nervous system. The Poincaré derived gait features drove the strong classification amongst the ALS, PD, and Control groups and is proving to be a strong method for quantifying pathological movement [3].

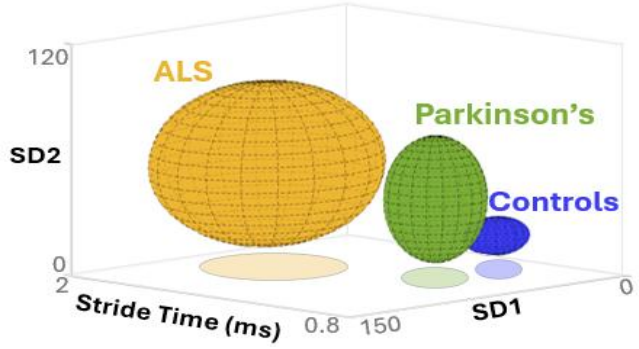

Figure 1. Comparison of 95% confidence ellipsoids were fit to the ALS, Parkinson's and Control Groups to illustrate gait differences amongst the three groups.

Conclusions

Strong classification of the ALS, PD, and Control groups was achieved using gait features derived from Poincaré analysis. Future studies will further investigate the classification of other neurodegenerative disorders using gait.

References

[1] Hausdorf et al. (2000). *J Appl Physio* **88**: 2045-53.
[2] Goldberger et al. (2000). PhysioBank *Physionet*,215-220.
[3] Davidson et al. (2024). *Gait & Posture* **110**: 17-22.

Table 1. Comparison of Mean Stride Time, SD1 and SD2 Gait Features Extracted from the Control, ALS and PD Groups

Variable of Interest	Control Group	ALS Group	Parkinson's Group	P-value
Stride Time (ms)	1.1 ± 0.1^a	1.4 ± 0.2^b	1.2 ± 0.1^a	<0.001
SD1	19.3 ± 4.6^a	57.2 ± 20.3^b	43.7 ± 21.0^c	<0.001
SD2	31.0 ± 10.3^a	100.8 ± 31.3^b	58.7 ± 24.3^c	<0.001

*a, b, c denotes groups with significantly different mean