Parameter selection affects the local divergence exponent classification of multiple sclerosis

L. Eduardo Cofré Lizama[1,2], Maya G. Panisset[2], Tomas Kalincik[3], Liuhua Peng[4], Mary P. Galea[2]
[1]School of Health Sciences, Department of Allied Health, Swinburne University of Technology, Melbourne, Australia
[2]Department of Medicine (Royal Melbourne Hospital), University of Melbourne, Melbourne, Australia
[3]Clinical Outcomes Research Unit, The University of Melbourne, Melbourne, Australia
[4]School of Mathematics and Statistics, The University of Melbourne, Melbourne, Australia
Email: eduardocofre@swin.edu.au

Summary

The local divergence exponent (LDE) is a sensitive gait metric in early-stage multiple sclerosis (MS). We compared the MS classification ability of the LDE calculated using different parameter selections (embedded dimensions and time delay) for state-space reconstruction: individual per trial, sample median, and fixed. The best classification of people with (pwMS) was achieved when using the sternum mediolateral direction and a fixed m=5 and τ=10.

Introduction

There is still a need for more sensitive mobility biomarkers of MS progression [1]. The short-term local divergence exponent (LDE; or Lyapunov), which assesses walking stability, has been proposed as a more sensitive measure of MS progression at early stages compared to standard metrics (e.g. speed) [2]. However, calculating the LDE relies on the selection of two main parameters for state-space reconstruction: dimensions (m) and time delay (t) [3]. Here we investigated how parameter selection affects the classification of pwMS at early stages of the disease.

Methods

33 pwMS with no evident gait dysfunction at clinical examination (EDSS<3.5) and 23 healthy controls (HC) performed a 6-minute walking test while wearing a set of 4 IMUs on the sternum, lumbar area, and feet. Tests were conducted in a 20-meter corridor of an outpatient clinic. Turns were removed from data and walking episodes were used to extract 150 consecutive strides. To reconstruct the state-space, 3 commonly used sets of embedded dimensions (m) and time delay (t) were utilized to calculate the LDE: 1) m and τ individually calculated for each trial (individual), 2) m and τ median across all pwMS and HC trials (median), and 3) fixed m=5 and τ=10 (fixed). The LDE was calculated separately for each direction's acceleration (VT, ML, and AP) and the norm (N) acceleration, as well as in 3D, using 2 fixed m=3 and m=5 with a τ =10, for both sternum and lumbar sensors using the Rosenstein's algorithm [2]. For each parameter selection method, we applied QDA to classify pwMS versus HC. The dataset was randomly split into training and testing sets with a 2:1 ratio. We then calculated the classification accuracy on the test set and averaged the results over 1,000 random splits.

Results and Discussion

Overall, the results show a better classification accuracy when using LDEs calculated using sternum sensor timeseries compared to lumbar. This is similar to our previous findings [1,2]. The best classification of pwMS was achieved when using the sternum ML LDE obtained with a fixed m=5 and τ=10 (78% accuracy). The second best was the sternum 3D LDE a fixed m=5 and τ=10 (67% accuracy). Table 1 and figure 1 present accuracy and descriptive statistics, respectively.

	AP	*ML*	*VT*	*N*	*3D**
			Lumbar		
I	0.532	0.530	0.513	0.555	0.630
M	0.573	0.549	0.544	0.583	0.600
F	0.544	0.538	0.551	0.589	
			Sternum		
I	0.511	0.498	0.505	0.505	0.627
M	0.570	0.543	0.552	0.587	0.668
F	0.528	**0.777**	0.684	0.628	

Table 1: Accuracy results using individual (I), median (M) and fixed (F) m and τ. * I and M are fixed with m=3 and m=5, respectively.

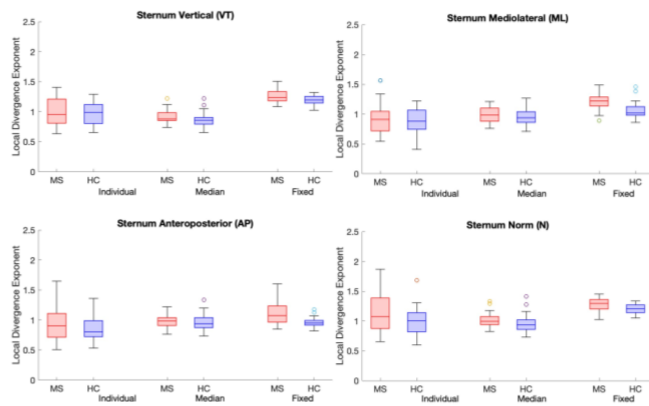

Figure 1: Sternum LDE for each direction using the 3 m and τ sets.

Conclusions

The best classification of pwMS was achieved when using the sternum mediolateral direction and with a fixed m=5 and τ=10. Using fixed m and t values can facilitate the clinical implementation of the LDE by reducing calculation steps and standardizing procedures for comparison across studies.

Acknowledgments

MS Research Australia (2019–22), University of Melbourne ECR Grant (2023-147). RMH MS neurologists and nurses.

References

[1] Cofré Lizama et al. (2022). *Mult Scler*, **28(11)**, 1773-82
[2] Cofré Lizama et al. (2023). *Gait Posture*, **102**:39–42
[3] Rosenstein et al. (1993). *Phys. D.* **65**: 117-134.