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# Lyapunov estimation from smartphone acceleration signals: Comparison between elderly and young adults

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## Summary

Short-term maximum Lyapunov exponent (LyE) has been proven useful in identifying gait instability in fall-prone aged adults. This study aims at demonstrating the feasibility of estimating LyE using very simple set-up (smartphone + simple walking protocol) which could be used to monitor the LyE evolution for elderly adults.

## Introduction

It is essential to identify falling risks and instability measures to reduce falls within the elderly population. The LyE has gained increasing interest in the present literature. In the context of gait stability, the LyE quantifies the motor system's ability to recover from small perturbation and maintain dynamic stability in the presence of kinematic variability which increases with age. LyE has been successfully measured by [1] using a non-aligned inertial measurement unit (IMU). To date, LyE has not been measured using smartphone IMU. Smartphone IMUs have been proved to be practical in terms of gait analysis. There is no restriction in terms of smartphone IMU signal's quality for LyE calculation. Measuring gait instability during a simple walking protocol, 6-minute walk test (6MWT), using smartphone accelerometer data can greatly benefit clinicians and individuals in terms of affordability and accessibility. Therefore, in this study, we aim at demonstrating the feasibility of estimating LyE using very simple set-up (smartphone + 6MWT) which could be used to monitor the LyE evolution for elderly adults.

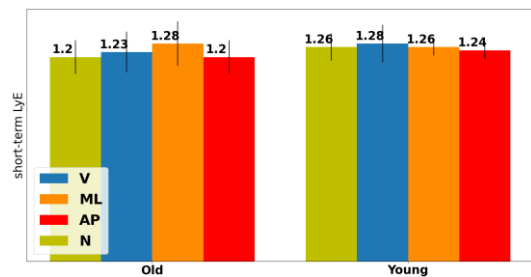
## Methods

Six elderly ( $72 \pm 6$  y, 6 men,  $89 \pm 23$  kg,  $170 \pm 6$  cm) and six young adults ( $26 \pm 6$  y, 4 women and 2 men,  $66 \pm 7$  kg,  $168 \pm 9$  cm) volunteered for this study. The participants had no history of falls. Each participant signed an informed consent. Participants walked in a corridor back and forth for 6 minutes with a smartphone, One plus 7, placed in a sport's belt at the waist. The acceleration signal was recorded at 100 Hz using a customized application. Because of the phone power-dependent sampling frequency, the recorded acceleration signal is resampled to 100 Hz. The LyE is calculated on the mediolateral (ML), anterior-posterior (AP), and vertical (V) acceleration components and on the acceleration norm (N). Pre-processing methods before LyE calculation of the four signals are similar to those found in [2]. No filtration was done because of the unwanted effects of filtering nonlinear signals. 150 consecutive strides are analyzed for each case. Signals are time-normalized to contain 15,000 samples. The chosen time delay is 10 samples and, the embedding dimension selected is

5. The LyE is estimated on 0 to 50 samples using the Python package nolds [3] and the Rosenstein et al. algorithm.

## Results and Discussion

Average LyE calculated on the V, ML, AP, and N signals for old and young adults are shown in figure 1. The LyE showed no difference between elderly and young adults and no difference between signal types.



**Figure 1:** Short-term Lyapunov (Lye) exponent calculated on vertical (V), mediolateral (ML), anterior-posterior (AP) components of acceleration, and acceleration norm (N) for old and young adults.

Due to the lack of standardized methodology, disparate LyE values for young and elderly adults are present in the literature [4]. Still values of LyE obtained in this study are within the range found in the literature [4]. Moreover, the findings that young and elderly with no history of falls present similar LyE is in line with the previous study [5] where negligible differences between healthy old and young adults were found.

The feasibility study is the first to show that it is possible to assess the LyE using a smartphone and a simple over-ground walking protocol. This evaluation, that can be either be performed by a clinician or by the person himself at home, represents an interesting possibility to monitor the risk of fall. Further investigations are on-going on a larger database including elderly with a history of falls. A follow-up of elderly fall occurrences is also considered. Future results will provide additional information regarding the validity of this measure to detect an early increase risk of fall.

## References

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