REQUIRED NUMBER OF STRIDES AND TEST-RETEST RELIABILITY FOR GAIT STABILITY ASSESSMENT

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Introduction

Several nonlinear measures of gait variability and stability are proposed in the literature. Standardization of implementation parameters (e.g. number of strides) is necessary to perform a consistent evaluation. Moreover, measures must reproduce the same results in the same experimental conditions. The aim of the present study was to assess the minimum number of required strides and the test-retest reliability of 11 temporal variability/stability measures proposed in the literature.

Methods

Ten participants [28 ± 3 years, 174 ± 11 cm, 67 ± 13 kg] walked straight at self-selected natural speed on a 250 m long dead-end road wearing an accelerometer on the trunk. The first and the last ten strides were removed in order to exclude gait initiation-termination phases. Stride time was calculated and analysed through the following variability measures [Hausdorff, 2001; Khandoker, 2008]: Standard deviation (SD); Coefficent of variation (CV); Inconsistency of variance (IV); Nonstationary index (NI); Poincaré plots (PSD1, PSD2). Stability measures were calculated on trunk accelerations in vertical (V) medio-lateral (ML) and anterior-posterior (AP) directions [Dingwell, 2007; Sylos-Labini, 2012; Costa, 2003; Menz, 2003; Lamoth, 2002]: Maximum Floquet multipliers (maxFM tot, V, ML, AP); Short term / long term Lyapunov exponents (sLE / lLE tot, V, ML, AP); Recurrence quantification analysis (RQA rr, det, avg, max, diverg); Multiscale entropy (MSE τ = 1, …, 6); Harmonic ratio (HR); Index of harmonicity (IH). For the assessment of the required number of strides, each measure was estimated for windows of increasing size (from 10 to 150 strides) until a steady value was reached. The corresponding number of strides was considered as the amount of strides required. For test-retest reliability, measures were calculated on a window (sized 85 strides) sliding along the trial. Percentage interquartile/median ratio (*imr*) of measures across the windows was calculated. Reliability of measures was labeled from very poor (*imr* > 40%) to excellent (*imr* < 10%). Worst case inter-subjects scenario was considered in both analysis.

Results

lSE and maxFM showed a low number of strides requirement. Variability measures (SD, CV, IV, NI, PSD) required a number of strides ranging from 20 to 78. RQA and MSE measures showed a very broad range of required strides (Table 1). MSE and RQA (rr, det, avg) showed excellent reliability. HR and lSE demonstrated good to average reliability, with the exception of lSE tot that performed poorly. IH showed poor reliability. Variability measures showed from poor to good reliability. lLE, maxFM and RQA (max, diverg) showed very poor reliability.

< 10	10-50	> 50
MSE ML (τ = 1, 5)	HR AP, ML, V	PSD1
MSE V (τ = 1, …, 4)	IH V	MSE ML (τ = 3)
IH AP, ML	PSD2	RQA AP (diverg)
maxFM	MSE AP (τ = 1, …, 6)	RQA ML (det)
lSE	MSE ML (τ = 2, 4, 6)	RQA ML (avg)
RQA AP (rr)	MSE V (τ = 5, 6)	RQA V (max)
RQA AP (det)	RQA AP (max)	RQA V (diverg)
RQA AP (avg)	RQA ML (max)	NI
RQA ML (rr)	RQA ML (diverg)	lLE
RQA V (rr)	IV	
RQA V (det)	SD	
RQA V (avg)	CV	

Table 1: Required number of strides.

Discussion

In general, a larger number of required strides than what is conventionally used was found. Only MSE and RQA (rr, det, avg) showed excellent reliability. lLE, maxFM and RQA (max, diverg) performed poorly and their reliability is therefore questionable.

References

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