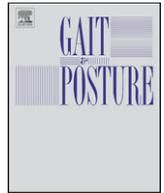




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The Gait Variability Index: A new way to quantify fluctuation magnitude of spatiotemporal parameters during gait[☆]

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ABSTRACT

This article describes a conglomerate measure of gait variability based on nine spatiotemporal parameters: the Gait Variability Index (GVI). Concurrent validity, inter-session reliability and minimum detectable change (MDC) were evaluated in 31 patients with Friedreich's Ataxia (FRDA), through comparisons with classically used evaluation tools such as the International Cooperative Ataxia Rating Scale (ICARS).

GVI scores for the healthy population were 100.3 ± 8.6 and were significantly reduced in FRDA patients (70.4 ± 7.9). The GVI was correlated with the global ICARS score and was sensitive enough to differentiate between groups of FRDA patients categorized by the Posture and Gait Disturbances sub-score. The GVI was found to have a high inter-session reliability with an intraclass correlation coefficient of 0.91. A MDC of 8.6 points was found necessary to ensure that a change in GVI reflects a true change rather than measurement error.

The GVI provides a quantitative measure of variability which behaves well statistically in both HP and patients with FRDA. It can be easily implemented using the supplemental data provided with this article. Complementary work is necessary to strengthen the GVI validation.

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1. Introduction

Balance control during gait can be affected by different pathologies which alter stability (capacity to recover from perturbations), thus leading to falls. Because this is an important public health issue, many studies have attempted to identify markers relating to fall risk.

Gait analysis techniques provide objective data including spatiotemporal parameters (STP). Two approaches have been used

to assess fall risk from STP. The most classical approach is based on comparison of mean values between healthy subjects and patients; it has caused a paradox which has been well described. The same characteristics are associated with an increased risk of falls and have also been explained as the adoption of a safer, more stable gait strategy [1]. The second approach is based on the measure of reproducibility of coordinated limb movements from one step or one stride to the next. This within-trial variability could be assessed using an analysis of the fluctuation magnitude (the variance, the size of fluctuations) [2]. There are indications that fall risk can be more precisely evaluated by the STP variability rather than by mean values [2,3]. Although gait variability was originally considered to represent noise, more recent research suggests that it reflects the underlying motor control and may be relevant to quantify age-related and pathological alterations in locomotor control-system, as well as to provide a clinical measure of mobility and functional status [2]. Subtle changes in variability have been reported among identified older fallers [4] and in future fallers [3]. Variability has also been reported to increase under dual-task conditions, when walking on irregular surfaces or with the eyes

[☆] Clinical trial registration: Data are parts of the following clinical trial: NCT00811681 (<http://clinicaltrials.gov/>).

Abbreviations: CV, coefficient of variation; FAPS, Functional Ambulation Performance Score; FRDA, Friedreich's Ataxia; GDI, Gait Deviation Index; GVI, Gait Variability Index; HP, healthy population; ICARS, International Cooperative Ataxia Rating Scale; ICC, intraclass correlation coefficient; MDC, minimum detectable change; PCA, principal component analysis; PGD, ICARS "Posture and Gait Disturbances" sub-score; STP, spatiotemporal parameters.

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Table 3Intraclass correlation coefficient (ICC), standard error of measurement (SEM) and minimum detectable change (MDC) for D1–D2 FRDA's GVI ($n = 31$).

Mean (SD)		Difference	p (t -test)	ICC (3,1) (95% CI)	SEM	MDC
D1	D2					
68.7 (9.6)	70.1 (10.8)	3.9 (2.4)	0.08	0.91 (0.82–0.96)	3.1	8.6

MDC suggests that a change of 9 points in GVI is necessary in FRDA patients.

The present study has limitations with regard to the number of strides used to compute the index. Owing and Grabiner found that accurate estimation of step kinematic variability required at least 400 steps while walking on a treadmill [27]. Hollman found that 60 strides were required to calculate variability in stride velocity during normal walking in elderly subjects [28]. In our work, each GVI was calculated from minimum of five absolute differences, which corresponds to 13 consecutive steps. Furthermore, the raw STP were obtained from several walks on GAITRite™. Paterson showed that STP variability differs depending if data are obtained from single, continuous trial or multiple short trials [29]. This was taken into consideration in the conception of GVI by trying to reduce inter-trial variability. We recommend the use of the highest number of cycles possible but, based on the recommendations of the European GAITRite™ Network Group about clinical evaluation of cycle-to-cycle variability [30], three values for each alternative parameter is the minimum requirement for GVI calculation. In our opinion, the most important consideration for use of GVI (or for measurement of gait variability) in the clinical assessment is to make sure that the conditions are always similar.

We proposed an index to improve the quantification of gait variability. The results obtained in FRDA patients seem to support the use of GVI. Future studies should continue to validate the measure; however, the GVI provides a useful method for many studies of variability and stability.

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Conflict of interest statement

The authors of this manuscript have no financial or personal relationships with other people or organizations that could inappropriately bias this work.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at <http://dx.doi.org/10.1016/j.gaitpost.2013.01.013>.

References

- [1] Winter DA, Patla AE, Frank JS, Walt SE. Biomechanical walking pattern changes in the fit and healthy elderly. *Physical Therapy* 1990;70(6):340–7.
- [2] Hausdorff JM. Gait variability: methods, modeling and meaning. *Journal of NeuroEngineering and Rehabilitation* 2005;2(1):19–28.
- [3] Maki BE. Gait changes in older adults: predictors of falls or indicators of fear. *Journal of the American Geriatrics Society* 1997;45(11):313–20.
- [4] Hausdorff JM, Edelberg HK, Mitchell SL, Goldberger AL, Wei JY. Increased gait unsteadiness in community-dwelling elderly fallers. *Archives of Physical Medicine and Rehabilitation* 1997;78(3):278–83.
- [5] Hollman JH, Kovash FM, Kubik JJ, Linbo RA. Age-related differences in spatio-temporal markers of gait stability during dual task walking. *Gait and Posture* 2007;26(1):113–9.
- [6] Menz HB, Lord SR, Fitzpatrick RC. Age-related differences in walking stability. *Age and Ageing* 2003;32(2):137–42.
- [7] Niechwiej-Szwedo E, Inness EL, Howe JA, Jaglal S, McIlroy WE, Verrier MC. Changes in gait variability during different challenges to mobility in patients with traumatic brain injury. *Gait and Posture* 2007;25(1):70–7.
- [8] Montero-Odasso M, Wells J, Borrie M, Speechley M. Can cognitive enhancers reduce the risk of falls in older people with mild cognitive impairment? A protocol for a randomised controlled double blind trial. *BMC Neurology* 2009;9:42.
- [9] Trombetti A, Hars M, Herrmann FR, Kressig RW, Ferrari S, Rizzoli R. Effect of music-based multitask training on gait, balance, and fall risk in elderly people: a randomized controlled trial. *Archives of Internal Medicine* 2011;171(6):525–33.
- [10] Lord S, Howe T, Greenland J, Simpson L, Rochester L. Gait variability in older adults: a structured review protocol and clinimetric properties. *Gait and Posture* 2011;34(4):443–50.
- [11] Brach J, Berlin J, VanSwearingen J, Newman A. Too much or too little step width variability is associated with a fall history in older persons who walk at or near normal gait speed. *Journal of NeuroEngineering and Rehabilitation* 2005;2(2):1.
- [12] Gabell A, Nayak US. The effect of age on variability in gait. *Journal of Gerontology* 1984;39(6):662–6.
- [13] Schutte LM, Narayanan U, Stout JL, Selber P, Gage JR, Schwartz MH. An index for quantifying deviations from normal gait. *Gait and Posture* 2000;11(1):25–31.
- [14] Schwartz MH, Rozumalski A. The gait deviation index: a new comprehensive index of gait pathology. *Gait and Posture* 2008;28(3):351–7.
- [15] Rozumalski A, Schwartz MH. The GDI-Kinetic: a new index for quantifying kinetic deviations from normal gait. *Gait and Posture* 2011;33(4):730–2.
- [16] Gouelle A, Mégrot F, Presedo A, Penneçot GF, Yelnik A. Validity of Functional Ambulation Performance Score for the evaluation of spatiotemporal parameters of children's gait. *Journal of Motor Behavior* 2011;43(2):95–100.
- [17] Beaton DE. Understanding the relevance of measured change through studies of responsiveness. *Spine* 2000;25(24):3192–9.
- [18] Plotnik M, Giladi N, Balash Y, Peretz C, Hausdorff JM. Is freezing of gait in Parkinson's disease related to asymmetric motor function? *Annals of Neurology* 2005;57(5):656–63.
- [19] Balasubramanian CK, Neptune RR, Kautz SA. Variability in spatiotemporal step characteristics and its relationship to walking performance post-stroke. *Gait and Posture* 2009;29(3):408–14.
- [20] Hausdorff JM, Zemany L, Peng CK, Goldberger AL. Maturation of gait dynamics: stride-to-stride variability and its temporal organization in children. *Journal of Applied Physiology* 1999;86(3):1040–7.
- [21] Daniels J, Worthingham C. *Le bilan musculaire Techniques de testing manuel*. Paris: Masson; 2006.
- [22] Trouillas P, Takayanagi T, Hallett M, Currier RD, Subramony SH, Wessel K, et al. International Cooperative Ataxia Rating Scale for pharmacological assessment of the cerebellar syndrome. The Ataxia Neuropharmacology Committee of the World Federation of Neurology. *Journal of the Neurological Sciences* 1997;145(2):205–11.
- [23] Shrout PE, Fleiss JL. Intraclass correlations: uses in assessing rater reliability. *Psychological Bulletin* 1979;86(2):420–8.
- [24] Schniepp R, Wuehr M, Neuhaeuser M, Kamenova M, Dimitriadis K, Klopstock T, et al. Locomotion speed determines gait variability in cerebellar ataxia and vestibular failure. *Movement Disorders* 2012;27(1):125–31.
- [25] Ilg W, Golla H, Their P, Giese MA. Specific influences of cerebellar dysfunctions on gait. *Brain* 2007;130:786–98.
- [26] Brach JS, Perera S, Studenski S, Newman AB. The reliability and validity of measures of gait variability in community-dwelling older adults. *Archives of Physical Medicine and Rehabilitation* 2008;89(12):2293–6.
- [27] Owings TM, Grabiner MD. Measuring step kinematic variability on an instrumented treadmill: how many steps are enough? *Journal of Biomechanics* 2003;36(8):1215–8.
- [28] Hollman JH, Childs KB, McNeil ML, Mueller AC, Quilter CM, Youdas JW. Number of strides required for reliable measurements of pace, rhythm and variability parameters of gait during normal and dual task walking in older individuals. *Gait and Posture* 2010;32(1):23–8.
- [29] Paterson KL, Lythgo ND, Hill KD. Gait variability in younger and older adult women is altered by overground walking protocol. *Age and Ageing* 2009;38(6):745–8.
- [30] Kressig RW, Beauchet O. Guidelines for clinical applications of spatio-temporal gait analysis in older adults. *Aging Clinical and Experimental Research* 2006;18(2):174–6.