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SHORT COMMUNICATION

Between-day test–retest reliability of gait variability in older individuals improves with a familiarization trial

Dennis Hamacher[1] · Daniel Hamacher[2] · Martin Krowicki[1] · Lutz Schega[1]

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Abstract Gait variability is an important measure in clinical settings to diagnose older individuals with fall risk. This study examines whether a familiarization trial improves test–retest reliability of gait variability. Twenty-two older participants walked twice at 1 day and twice 7 days later. The standard deviations of stride length, swing time, stance time, stride time and minimum foot clearance were calculated. The test–retest reliability of (1) between-day comparison of the first trials and (2) between-day comparison of the second trials of all gait variability measures was quantified with the intraclass-correlation coefficient (ICC), the smallest detectable differences (SDD) and the bias and the limits of agreement (LoA). The between-day comparison of the second trials per day showed higher ICC values, lower LoA values and lower SDD values in all analyzed parameters. Our data suggest that the reliability of gait variability in an older population can be considerably improved just with the aid of one familiarization trial.

Keywords Gait analysis · Reproducibility · Repeatability · Motor control

✉ Dennis Hamacher
dennis.hamacher@ovgu.de

[1] Department of Sport Science, Otto von Guericke University Magdeburg, Zschokkestr. 32, 39104 Magdeburg, Germany

[2] Department of Exercise Physiology, Friedrich Schiller University Jena, Seidelstr. 20, 07749 Jena, Germany

Introduction

Gait variability could display an important measure in clinical settings for example to diagnose old individuals with high fall risk [1], to understand the motor-cognitive dual task capabilities in patients suffering from chronic pain [2] or to control the success of intervention programs on motor control in older cohorts [3]. However, the test–retest reliability significantly varies as a function of different testing protocols and measurement systems [4]. Especially, the number of measured strides is critical to receive precise and sensitive results whereas more strides yield more reliable estimates regarding the variability of gait parameters [5]. Because common daily-life routines comprise walks on level grounds, a comparable testing protocol might be appropriate. Thus, to address feasibility in clinical settings, gait variability should be assessed on a conventional corridor involving sufficient strides. An appropriate algorithm calculating gait parameters based on single inertial sensors is already evaluated, and good to excellent intra-day reliability regarding gait variability was observed. However, the between-day reliability was found to be considerably worse (poor to excellent reliability depending on the gait parameter assessed) [6]. This displays a meaningful limitation as reassessment in therapy programs routinely take place in rather a weakly interval period [7] but not within 1 day. Looking for solutions with respect to that problem, we postulated that a simple familiarization walking trial might be helpful for subjects participating in an experiment or for patients receiving a clinical diagnosis to customize oneself to the measurement system and/or the testing situation. Measuring subjects/patients which are customized to a higher degree to the specific measuring conditions could enhance the robustness of the measure itself. While the influence of

different testing protocols and measurement systems on the gait variability parameters is relatively well investigated, the effect of a familiarization trial on the reliability of these parameters is not assessed, yet. Consequently, the purpose of the current study is to examine whether a familiarization trial improves test–retest reliability of gait variability parameters.

Methods

Twenty-two older adults without any known functional and cognitive impairments (7 male and 15 female subjects, mean age 70.5 years, standard deviation 4 years) were recruited from a local health-related sport club. The research protocol complied with the principles of the Declaration of Helsinki and the study was approved by the local the local ethics committee of the Otto von Guericke University, Magdeburg. Furthermore, an Informed consent was obtained from all individual participants included in the study. All subjects walked twice at 1 day and twice at another day with a between-day test–retest interval of exactly 1 week on a 130 m long level corridor continuously back and forth. To collect gait data, we used an inertial sensor (MTw, Xsens Technologies B.V., Enschede, The Netherlands) which was attached to each of the subjects' forefeet. The variability (standard deviation) of 100 strides was calculated for five gait parameters using an evaluated algorithm: stride length, swing time, stance time, stride time and minimum foot clearance [6].

To indicate possible differences in test–retest reliability induced by learning and/or habituation effects, the following two comparisons were made: (1) between-day comparison of the first trials and (2) between-day comparison of the second trials. Test–retest reliability was rated with the intraclass-correlation coefficient (ICC 2.1) [8], the smallest detectable differences (SDD) as well as the bias and the limits of agreement (LoA) [9]. Depending on ICC outcomes, the reliability was graded with values ranging from 0.00 to 0.40 indicating poor reliability, values from 0.40 to 0.59 indicating fair reliability, values from 0.60 to 0.74 indicating good reliability and values from 0.75 to 1.00 indicating excellent reliability [10].

Results

The between-day gait variability data regarding the second trials per day showed higher ICC-values, lower LoA values and lower SDD values in all analyzed parameters as compared to those of the between-day gait variability data comparing the first trials per day. In the comparison of data derived from the second trials per day, the reliability was good or excellent for the variability of stride length (ICC = 0.76), minimal foot clearance (ICC = 0.83), swing time (ICC = 0.74), gait velocity (0.67) and stride time (ICC = 0.83). The reliability of stance time, however, was only rated with fair (ICC = 0.55). All results are displayed in Table 1.

Discussion

We aimed to investigate whether a simple familiarization trial has the potential to increase the test retest–reliability of the variability of gait parameters measured with inertial sensors feasible for the use in clinical or scientific settings. Therefore, the between-day comparison of gait variability of the first trials and the between-day comparison of the second trials of each measurement day were analyzed. Regarding the ICC values, our data show that the reliability of the first walking trials per day must be considered poor or fair, except of the minimum foot clearance variability. This result corroborates data from [11] who also reported poor between-day reliability values for gait variability in older participants measured with inertial sensors. However, our data also indicate that the reliability of measures of gait variability in older individuals could mostly be considered good to excellent when a familiarization trial is conducted prior to the actual testing trial. In this case, the reliability values of gait variability measured with inertial sensors in older participants are even comparable with the reliability values of gait variability measures obtained from younger individuals measured with a camera-based system [5]. The SDD entail information about the smallest treatment effect that can be identified with a measurement system. The SDD are smaller regarding each second walking trial per day, as compared to the first trials, which also indicates that a familiarization trial improves the outcome's stability. These results could be of utmost interest for clinicians and scientist as, based on those, we offer a very easy and feasible way to improve the robustness of the measure of gait variability leading to more accurate diagnoses or experimental outcomes which helps to detect subtle but meaningful changes in gait control. We strongly suggest that clinicians and researchers should use a familiarization trial prior to the testing trial from which gait variability will be assessed. Further research should investigate if a familiarization trial also improves accuracy in assessments in dual-task gait analyses since cortical and subcortical processes are involved in gait control in particularly older individuals [12] and since in dual-task conditions, consistently larger measurement error has been reported [13]. In this line, it should be investigated if the same effect would occur in a diseased or frail population.

Table 1 Reliability scores of the between-day comparison of the first trials and the second trials per day in all gait variability parameters

Variability of gait parameters	Between-day-comparison of the first trials					Between-day-comparison of the second trials				
	Bias	LoA	SDD	ICC 2.1	Grade	Bias	LoA	SDD	ICC 2.1	Grade
Stride length (m)	−0.0005	0.0126	0.013	0.413	Fair	−0.0008	0.0089	0.009	0.762	Excellent
Minimum foot clearance (m)	0.0000	0.0019	0.002	0.634	Good	0.0000	0.0013	0.001	0.829	Excellent
Stance time (s)	−0.0017	0.0056	0.006	0.343	Poor	−0.0002	0.0042	0.004	0.549	Fair
Swing time (s)	−0.0004	0.0039	0.004	0.581	Fair	−0.0004	0.0034	0.003	0.737	Good
Gait velocity (m/s)	−0.0002	0.0268	0.028	0.212	Poor	0.0004	0.0148	0.015	0.671	Good
Stride time (s)	−0.0013	0.0089	0.009	0.337	Poor	0.0000	0.0043	0.004	0.827	Excellent

The grading was done based on ICC-values

LoA limits of agreement, *SDD* smallest detectable differences, *ICC* intraclass correlation coefficient

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the local ethics committee of the Otto von Guericke University Magdeburg and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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