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Test-retest reliability of temporal and spatial gait characteristics measured with an instrumented walkway system (GAITRite®)

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Abstract

Background: The purpose of this study was to determine the test-retest reliability of temporal and spatial gait measurements over a one-week period as measured using an instrumented walkway system (GAITRite®).

Methods: Subjects were tested on two occasions one week apart. Measurements were made at preferred and fast walking speeds using the GAITRite® system. Measurements tested included walking speed, step length, stride length, base of support, step time, stride time, swing time, stance time, single and double support times, and toe in-toe out angle.

Results: Twenty-one healthy subjects participated in this study. The group consisted of 12 men and 9 women, with an average age of 34 years (range: 19 – 59 years). At preferred walking speed, all gait measurements had ICC's of 0.92 and higher, except *base of support* which had an ICC of 0.80. At fast walking speed all gait measurements had ICC's above 0.89 except *base of support* (ICC = 0.79),

Conclusions: Spatial-temporal gait measurements demonstrate good to excellent test-retest reliability over a one-week time span.

Background

Observational gait analysis is regularly performed by physical therapists to determine treatment goals and is used as an evaluation tool during rehabilitation. However, subjective gait analysis has only poor to moderate reliability and validity [1,2]. Objective assessments can supply the clinician with highly reliable and valid data, but are usually time consuming, expensive, and they demand specific expertise. Instrumented walkways, however, can supply the clinician with quick objective measurements of a patient's gait. In addition, no specific expertise is needed. Such instrumentation is becoming more common in the clinical environment, and quantitative measures of gait are being used as outcome measures to evaluate treatment efficacy and function [2]. However, when using an objective gait assessment for the evaluation of an intervention it is necessary to know if the detected changes are genuine (that is, caused by the treatment) or if they are caused by the instrumentation system's measurement errors or normal variation of a person's gait. Therefore it is of great importance to have insight into both reliability and validity of the instrument being used,

as well as the test-retest reliability of spatial – temporal gait measurements.

Many instrumentation systems for quantitative gait analysis have been evaluated for reliability and validity. However, test-retest reliability over time for spatial and temporal gait measurements has not been studied to the same extent. Bilney et al. [3] investigated the test-retest reliability of spatial and temporal gait measurements using the GAITRite® system between three consecutive measurements on one day. They reported that the system was reliable for measuring temporal and spatial gait characteristics. However, until now no studies have been performed that investigated test-retest reliability with an interval of at least a week, using such a system.

In the field of physical therapy, patients often are treated over periods lasting several weeks. If variability in normal gait is significant from week to week, then measurements of changes in gait can not be attributed to treatment effects. Since repeated evaluations of a person's gait in the clinic are routinely performed with intervals of several days or weeks, insight in this test-retest reliability over a longer period of time is essential. The consistency of gait has also been investigated by Urquhart et al. [4] who showed, using a computerized stride analyzer, that gait of Parkinson's patients was stable over a seven-day interval.

The objective of this study was to determine the test-retest reliability of spatial and temporal gait measurements at preferred and fast walking speeds, as measured using an instrumented walkway (GAITRite®) over a one-week period. We chose a population of healthy adults to be able to characterize the normal week-to-week variation one would expect to see, without the confounding situation of improvement that one would see in a clinical population.

Methods

Subjects

Twenty-one healthy subjects volunteered for this study. Subjects were free of any orthopedic disorder of the lower limb that might affect their gait, and did not report acute pain or any other complaint likely to influence walking. The group consisted of 12 men and 9 women, with a mean age of 34 years (range: 19 – 59 years). This healthy group was chosen as their gait would not be considered likely to change clinically over a one-week period. All subjects gave informed consent. This study protocol was ruled exempt from review by the Medical Ethics Board of the University Medical Center Nijmegen.

Instrumentation: GAITRite®

In order to assess temporal-spatial characteristics we used the GAITRite® system (SMS Technologies Ltd., Elizabeth Way, Harlow Essex, UK). The GAITRite® system is a computer based instrumented walkway that has been developed to measure spatial and temporal gait characteristics. It includes a roll-up walkway available in various lengths with embedded pressure sensors. The mat used for this study is 6 m long with 18,432 pressure sensors. The walkway's active measurement area is 61 cm wide and 488 cm long. Sensors are arranged in a grid pattern (48 × 384) and placed 1.27 cm on center. The sampling rate of the system used varies between 32.2 and 38.4 Hz. Data are uploaded to a computer, and automatic footstep identification and parameter calculations are made. This system directly supplies the clinician with quantitative information about the patient's gait. Studies have investigated the reliability and validity of the GAITRite® system for measuring spatial and temporal gait characteristics. To validate the system's measurements, concurrent validity was assessed using a video-based analysis system, direct measures of chalk footfall imprints, a stopwatch, and a footswitch system [3,5,6]. Cutlip et al. [5] reported the GAITRite® system to be highly valid in measuring temporal characteristics, and McDonough et al. [6] and Bilney et al. [3] reported high validity of the system on both spatial and temporal measurements.

Procedure

Testing was performed in the gymnasium of the Department of Physical Therapy of the University Medical Center Nijmegen. The GAITRite® mat was positioned in the gym to allow the subject to begin walking 2 meters before the mat, and to continue walking two meters past the end of the mat without slowing. By starting before the mat and continuing past its end, we assured that the subject would be walking at his/her steady-state speed over the instrumented section of the mat. Each subject was instructed to walk at a self-selected comfortable speed. Data were collected for eight trials at the subject's self selected pace. This assured collection of at least eight right and eight left strides. Eight strides has been shown to be appropriate for representing gait characteristics by mean values as representative of normal gait [7].

After completing these eight trials subjects were asked to walk the same distance at a self-selected higher speed. Eight trials were collected for this condition as well. Before data collection every subject practiced walking over the GAITRite® mat in order to familiarize themselves with the test procedure.

In order to assess the test-retest reliability of the spatial and temporal gait measurements, each subject was evaluated again one week later. Subjects wore the same pair of shoes on both test days.

The following eleven spatial and temporal gait measurements were evaluated: Walking speed (cm/s), Step length

Table 1: Overview of spatial and temporal gait parameters during preferred and fast walking speeds for 21 subjects. Values represent means over the trial (standard deviation). Left and Right sides for unilateral parameters were treated separately.

	Preferred walking speed				Fast walking speed			
	Week 1	Week 2	Change		Week 1	Week 2	Change	
Gait variables	Mean (SD)	Mean (SD)	Mean (95% CI)*	ICC (95% CI)*	Mean (SD)	Mean (SD)	Mean (95% CI)*	ICC (95% CI)*
Walking speed (cm/s)	142.49 (19.58)	147.14 (20.32)	4.65 (1.27 – 8.03)	0.96 (0.91 – 0.99)	176.73 (17.11)	179.69 (15.98)	2.96 (-0.47 – 6.39)	0.95 (0.87 – 0.98)
Step length (cm)	77.83 (8.48)	79.40 (8.30)	1.57 (0.68 – 2.46)	0.97 (0.95 – 0.98)	86.92 (8.04)	87.82 (7.43)	0.89 (0.13 – 1.66)	0.97 (0.95 – 0.99)
Stride length (cm)	155.83 (17.09)	159.00 (16.62)	3.17 (1.36 – 4.98)	0.97 (0.94 – 0.98)	173.72 (15.96)	175.83 (14.74)	2.11 (0.49 – 3.74)	0.97 (0.95 – 0.98)
Base of support (cm)	8.27 (1.82)	8.94 (1.83)	0.66 (0.19 – 1.14)	0.80 (0.50 – 0.92)	8.81 (1.94)	9.58 (1.88)	0.78 (0.27 – 1.29)	0.79 (0.47 – 0.91)
Step time (s)	0.55 (0.034)	0.54 (0.036)	-0.01 (-0.01 – -0.002)	0.95 (0.91 – 0.97)	0.50 (0.032)	0.49 (0.029)	-0.01 (-0.01 – -0.002)	0.96 (0.92 – 0.98)
Stride time (s)	1.10 (0.068)	1.09 (0.071)	-0.01 (-0.02 – -0.003)	0.96 (0.92 – 0.98)	0.99 (0.066)	0.98 (0.056)	-0.01 (-0.02 – -0.001)	0.96 (0.92 – 0.98)
Swing time (s)	0.45 (0.025)	0.44 (0.022)	-0.01 (-0.01 – -0.003)	0.93 (0.87 – 0.96)	0.41 (0.024)	0.41 (0.019)	-0.01 (-0.01 – -0.001)	0.89 (0.80 – 0.94)
Stance time (s)	0.65 (0.050)	0.65 (0.053)	-0.01 (-0.01 – 0.002)	0.94 (0.89 – 0.97)	0.57 (0.047)	0.57 (0.042)	-0.002 (-0.01 – 0.001)	0.95 (0.90 – 0.97)
Single support time (s)	0.45 (0.026)	0.44 (0.022)	-0.01 (-0.01 – -0.002)	0.92 (0.84 – 0.95)	0.41 (0.025)	0.41 (0.019)	-0.001 (-0.01 – -0.001)	0.89 (0.80 – 0.94)
Double support time (s)	0.21 (0.040)	0.21 (0.037)	< 0.001 (-0.01 – 0.01)	0.93 (0.87 – 0.96)	0.17 (0.028)	0.17 (0.031)	-0.001 (-0.01 – 0.004)	0.91 (0.83 – 0.95)
Toe in toe out (deg)	5.09 (5.83)	5.28 (5.74)	0.20 (-0.30 – 0.70)	0.98 (0.96 – 0.99)	4.69 (6.07)	4.70 (5.74)	-0.02 (-0.56 – 0.59)	0.98 (0.95 – 0.99)

* 95% CI = 95% Confidence Interval

(cm), Stride length (cm), Base of support (cm), Step time (s), Stride time (s), Swing time (s), Stance time (s), Single support time (s), Double support time (s), and Toe in toe out (deg).

Data analysis

Footsteps which did not fall entirely on the GAITRite® mat were deleted. Mean values for each gait parameter were calculated using the first ten complete steps derived from the eight trials at each speed: self-selected pace and fast walking speed. Data for individual steps were averaged, not averages for each trial, to avoid situations where one trial had more complete steps than another. Mean values were used as this is common practice when evaluating these measurements in the clinic.

Statistics

To determine test-retest reliability, intraclass correlation coefficients (ICC) were used (Model 2, k) [8]. Although the 3, k model is often used in intrarater and test-retest reliability studies, we chose the 2, k model because this statistical technique is more conservative and therefore more generalizable [8].

Results

Test-retest reliability at preferred walking speed

At preferred walking speed, ICC's for all gait measurements tested were 0.92 and higher, with the exception of base of support, which had an ICC of 0.80 (see Table 1). Preferred walking speed also proved to be highly reproducible (ICC = 0.96).

Test-retest reliability at fast walking speed

Fast walking speed also proved to be highly reproducible (ICC = 0.95). The *base of support* during fast walking had the lowest ICC (0.79). Swing time and single support time each had ICC's of 0.89. ICC's for all other gait measurements were 0.91 and higher.

Differences in gait measurements between week 1 and 2

Change scores in Table 1 show several of the gait measurements to have increased or decreased. We believe that this is more an artifact of the statistical analysis than it is an indication of change from Week 1 to Week 2. As within-week variability of certain of these parameters is very low, small changes between-week may present as 'statistically significant'. However, we do not consider these small changes clinically relevant in most cases.

Discussion

It is essential that any measurements used for evaluation of an intervention are not subject to significant intra-individual variability over time. While instrumentation is often evaluated for reliability and validity, this alone is not enough. When evaluating an intervention one must be able to rely on the fact that observed changes are genuine and not caused by normal variation in task performance. Therefore it is important to investigate the test-retest reliability over time of performance measures that are used as diagnostic tools or to evaluate interventions.

In this study we used ICC's to evaluate test-retest reliability. A major advantage of ICC analysis over standard correlation analysis is that the ICC also accounts for differences between the data sets by using analysis of variance between and within data sets [8].

Almost all of the gait measurements tested at preferred and fast walking speeds had ICC's above 0.90. Portney and Watkins have indicated that clinical measurements should show reliability of at least 0.90 [8]. Only the *base of support* showed somewhat lower test-retest reliability at both the preferred and fast walking speed. From previous studies using the GAITRite system, we suspect that this lower reliability is a result of the spatial resolution of the instrumentation, and not increased normal variation in walking patterns week-to-week [7].

In conclusion, all spatial and temporal gait measurements investigated in this study demonstrated good to excellent test-retest reliability in an adult population without pathology. Thus, changes in gait observed after treatment can likely be attributed to that treatment, and not to test-retest variability. This makes the GAITRite a good instrument to evaluate treatment effects using spatial and temporal gait measurements. Some caution might be appropriate for considering changes in base of support as measured using the GAITRite® system. Future research should address natural changes or variability over time of spatial and temporal gait measurements in pediatric and geriatric populations, as well as populations with specific pathologies.

Authors' contributions

CU participated in the study design, supervised the data collection, and performed statistical analysis. MB participated in the study design. Both authors contributed equally to the final manuscript and approve its content.

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