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Agreement between temporal and spatial gait parameters from an instrumented walkway and treadmill system at matched walking speed

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ABSTRACT

Background: Commercially available instrumented treadmill systems that provide continuous measures of temporospatial gait parameters have recently become available for clinical gait analysis. This study evaluated the level of agreement between temporospatial gait parameters derived from a new instrumented treadmill, which incorporated a capacitance-based pressure array, with those measured by a conventional instrumented walkway (criterion standard).

Methods: Temporospatial gait parameters were estimated from 39 healthy adults while walking over an instrumented walkway (GAITRite®) and instrumented treadmill system (Zebris) at matched speed. Differences in temporospatial parameters derived from the two systems were evaluated using repeated measures ANOVA models. Pearson-product-moment correlations were used to investigate relationships between variables measured by each system. Agreement was assessed by calculating the bias and 95% limits of agreement.

Results: All temporospatial parameters measured via the instrumented walkway were significantly different from those obtained from the instrumented treadmill ($P < .01$). Temporospatial parameters derived from the two systems were highly correlated (r, 0.79–0.95). The 95% limits of agreement for temporal parameters were typically less than ±2% of gait cycle duration. However, 95% limits of agreement for spatial measures were as much as ±5 cm.

Conclusions: Differences in temporospatial parameters between systems were small but statistically significant and of similar magnitude to changes reported between shod and unshod gait in healthy young adults. Temporospatial parameters derived from an instrumented treadmill, therefore, are not representative of those obtained from an instrumented walkway and should not be interpreted with reference to literature on overground walking.

1. Introduction

With the advent of modern instrumented walkway systems, basic temporospatial gait parameters have been increasingly used by clinicians to define the characteristics of normal and pathological gait and to assess interventions aimed at improving gait [1]. These portable devices typically permit rapid determination of temporospatial parameters during overground walking and have been shown to have good agreement with parameters derived from three-dimensional motional analysis systems [2,3]. However, length restrictions of commercial instrumented walkways render them suboptimal for the investigation of long-distance locomotion and they are not suitable for use in locations with limited working space. Recently, instrumented treadmills that provide rapid measures of temporospatial gait parameters have become commercially available and overcome the spatial limitations of instrumented walkways. Moreover, treadmill walking is now considered a viable intervention for treating gait impairments associated with neurological disorders, such as Parkinson's disease, though the duration of improvements is unclear [4]. Instrumented treadmills, therefore, provide the clinicians with a relatively simple method for monitoring the progress of training, and have recently been used as outcome measures in the evaluation of various clinical treatments, such as footwear [5] and ongoing neurorehabilitation trials [6]. However, no study to date has evaluated the concurrent validity of these new commercially available treadmill systems relative to a conventional instrumented walkway or criterion standard.

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Protocols using instrumented treadmills have commonly matched treadmill speeds to comfortable self-selected walking speeds determined during independent overground walking trials [7–9]. Implicit to these studies, therefore, is the assumption that temporospatial parameters obtained during treadmill and overground walking at a common speed are comparable. While treadmill walking has been shown to alter neuromuscular control and co-ordination, and subsequent lower extremity joint moments and powers [10,11], the effect on basic temporospatial parameters is less clear. For instance, some studies have noted that treadmill walking in healthy individuals was associated with a higher cadence [12,13], decreased stance phase duration [12,13], shorter step/stride length [12,14], and a shorter double support period [12,15] when compared to overground walking at matched speeds. However, these parameters have not been consistently identified across studies and others have reported opposite effects, i.e. a decrease in cadence and an increase in stance phase duration [16] or found no significant change in temporospatial parameters between the two modes of walking [17,18].

The purpose of this study, therefore, was to compare temporospatial parameters measured during walking at preferred speed on an instrumented walkway system with those derived from a new instrumented treadmill system, which incorporated a capacitance-based foot pressure array.

2. Methods

2.1. Participants

A convenience sample of 39 (11 female and 28 male) healthy adults was recruited from University faculty to participate in the study. The mean (±SD) age, height, weight and body mass index of participants was 21.6 ± 3.0 years, 168.6 ± 9.6 cm, 67.4 ± 17.7 kg, and 23.7 ± 5.7 kg m^{-2}, respectively. No participant reported a medical history of balance disorders or musculoskeletal conditions likely to affect their ability to walk on a treadmill. All participants gave written informed consent prior to participation in the research. The study received approval from the university human research ethics committee and was undertaken according to the principles outlined in the Declaration of Helsinki.

2.2. Equipment

Temporospatial gait data were collected via two commercially available systems; A GAITRite® instrumented mat (CIR Systems Inc., 60 Garlor Drive Havertown, PA 19083), and a Zebris instrumented gait analysis system (Zebris Medical GmbH, Max-Eyth-Weg 43, D-88316, Isny, Germany).

The GAITRite instrumented mat possessed a sensing area of 4.8 × 0.6 m and incorporated 18,432 sensors, each approximately 1 cm^2, with a spatial resolution of 1.27 cm. The GAITRite system derives measures of step and stride length, duration, velocity and cadence from the timing of sensor activation and the distance between activated sensors. Previous research has established the test–retest reliability of temporospatial parameters derived from the GAITRite system, with reports of good to excellent reliability, both within and between-days, in healthy adults [19]. The system has also been reported to have 'excellent' agreement with temporospatial parameters derived from 3-D motion analysis systems and have been shown to be accurate to within 1.5 cm and 0.02 s for individual step parameters on the majority (80–94%) of occasions [2,3].

The Zebris instrumented gait analysis system (FDM-THM-S, Zebris Medical GmbH) is comprised a capacitance-based foot pressure platform housed within a treadmill. The pressure platform had a sensing area of 108.4 × 47.4 cm and incorporated 7168 sensors, each approximately 0.85 × 0.85 cm. The treadmill has a contact surface of 150 × 50 cm and its speed could be adjusted between 0.2 and 22 km h^{-1}, at intervals of 0.1 km h^{-1}. Although the grade of the contact surface of the treadmill is adjustable in 1% increments up to 25%, it was maintained in a horizontal position (0%) throughout testing. High levels of between- and within-day reliability have been reported for the majority of temporospatial gait parameters recorded by the Zebris system during walking in healthy seniors, with coefficients of variation typically below 5% and 7%, respectively [20].

2.3. Protocol

Participants reported to the gait laboratory (thermoneutral environment) wearing lightweight, comfortable clothing and having abstained from vigorous physical activity. Following anthropometric assessment, participants were instructed to walk barefoot at their 'preferred' walking speed over a 10-m walkway in which the GAITRite instrumented mat was mounted at its midpoint. Temporospatial data were collected once the between-trial walking speed of each subject varied by less ± 10%. For each gait trial, temporospatial data for the first stride onto and off the mat were excluded from further analysis. In total, ten gait trials were recorded for each participant, equating to approximately 45 steps.

As outlined by Van de Putte et al. [21] participants were then afforded a treadmill acclimatization session, in which they were briefed regarding the safety procedures for treadmill walking, and undertook a minimum of 10 min practice. Following acclimatization, participants were requested to walk barefoot on the Zebris treadmill system. Treadmill speed was adjusted to match the self-selected walking speed determined during overground walking on the GAITRite system. Once participants were comfortable, a 30 s data capture period was used; equating to approximately 55 steps. Data for each system were sampled at 120 Hz and proprietary software was used to calculate temporospatial variables including cadence, step, stance and swing phase duration, and the duration of single and double limb support.

2.4. Statistical analysis

The SPSS™ statistical package (SPSS, Chicago, IL) was used for all statistical procedures. Kolmogorov-Smirnov tests were used to evaluate data for underlying assumptions of normality. Because outcome variables were determined to be normally distributed, means and SD have been used as summary statistics. Differences between measurements systems with respect to global gait parameters (cadence, and gait cycle duration) were evaluated using paired *t*-tests. For all other variables, differences between systems were assessed using repeated measures ANOVA within a generalized linear modeling framework. In each case, system (GAITRite and Zebris) and limb (left and right) were treated as within-subject factors. Underlying assumptions regarding the uniformity of the variance–covariance matrix were assessed using Mauchly's test of sphericity. When the assumption of uniformity was violated, an adjustment to the degrees of freedom of the *F*-ratio was made using Greenhouse–Geisser Epsilon, thereby making the *F*-test more conservative. Relationships between variables measured by each measurement system were investigated using Pearson-product-moment correlations, while agreement was assessed by calculating the bias and 95% limits of agreement.

3. Results

Despite walking at a common gait speed (1.3 ± 0.1 m s^{-1}), participants assumed a significantly faster cadence and shorter gait