J. Phys. Ther. Sci. 29: 651–653, 2017

The Journal of Physical Therapy Science

Original Article

Comparison of accelerometer-based and treadmill-based analysis systems for measuring gait parameters in healthy adults

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Abstract. [Purpose] This study aimed to determine the correlation between accelerometer-based and treadmill-based analysis systems for measuring gait parameters during comfortable walking in healthy young adults. [Subjects and Methods] Twenty-three healthy adults participated in this study. Gait parameters were measured with simultaneous use of accelerometer-based and treadmill-based gait analysis systems, while participants walked for 30 s. [Results] There was a highly-significant correlation between the two systems with respect to cadence and velocity. The cadence, speed, and stride measured with the accelerometer system were significantly and highly correlated with the cadence, velocity, and number of steps measured with the treadmill-based system. The gait cycle duration measured with the accelerometer system was significantly and highly correlated with the step time and stride time measured with the treadmill-based gait system. [Conclusion] Gait analysis using an accelerometer system is a valid method for assessment of the effectiveness of therapeutic interventions in a clinical setting.

Keywords: Accelerometer, Treadmill, Gait analysis

(This article was submitted Nov. 30, 2016, and was accepted Dec. 25, 2016)

INTRODUCTION

Gait analysis systematically evaluates human movement during walking, and enables quantitative analysis of gait patterns and kinematic characteristics[1)]. Gait analysis is important in clinical practice, and is used to determine whether a patient needs surgery, to evaluate postoperative outcomes, and to determine when outcomes need to be monitored[2, 3)].

Pressure sensor systems (PSS) or motion capture systems (MCS) are used to obtain kinematic information after gait analysis. However, these conventional methods require special laboratories and expensive equipment, as well as technically skilled experts and long post-processing time to obtain results. Moreover, due to limited measurement space, it can be difficult to acquire a large number of gait cycles.

Recently, accelerometer-based gait analysis (AGA) systems have been widely used due to their ability to overcome the limitations of existing methods. AGA offers several advantages compared to conventional methods. First, the accelerometer is portable, due to its small size and light weight. Second, AGA only requires an accelerometer and a computer, with no restriction of location. Third, the setup process is very simple, and AGA can even be implemented by beginners. Fourth, the accelerometer does not interfere with walking motion, enabling accurate data collection. These advantages of AGA make it appropriate for use in clinical practice[4)]. Various studies have tested the reliability of AGA results and compared them with the results of direct gait analysis. The reliability and validity of AGA results have been demonstrated by a study on the consistency of repeated measurements, a study on the correlation with results using the Walkway PSS, and a study comparing the results with those using a 3-dimensional (3D) infrared camera[5–7)]. However, there has been little research on the correlation between AGA and treadmill-based gait analysis (TGA) systems. Therefore, this study aimed to analyze the correlation between gait parameters measured using an AGA system and a TGA system.

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Table 1. General characteristics of the participants

Characteristics	Subjects[a] (N=23)
Gender (N, males/females)	9/14
Age (yrs)	30.2 ± 5.8
Height (cm)	165.5 ± 6.8
Weight (kg)	61.3 ± 11.6
Leg length (cm)	85.3 ± 4.3

[a]Data are presented as means ± SD, unless otherwise indicated

Table 2. Comparison of acceleration-based and treadmill-based analysis system for measuring gait parameter in healthy young adults

	Cadence[a]	Speed[a]	Strides elaborated[a]
Cadence	0.995***	0.643**	0.799***
Velocity	0.792***	0.838***	0.640**
Number of steps	0.983***	0.593**	0.777***

[a]r-value, ***p<0.001, **p<0.01

Table 3. Comparison of acceleration-based and treadmill-based analysis system for measuring spatiotemporal gait parameter in healthy young adults

	Gait cycle duration[a]	Speed[a]	% Stride length/height[a]
Step time (Lt/Rt)	0.983***/0.975***	−0.586**/−0.608**	−0.236/−0.268
Stride time	0.994***	−0.632**	−0.287
Stance phase (Lt/Rt)	0.385/0.420*	−0.546**/−0.559**	−0.583**/−0.547**
Swing phase (Lt/Rt)	−0.385/−0.420*	0.546**/0.559**	0.583**/0.547**
Double support	0.416*	−0.574**	−0.589**

[a]r-value, ***p<0.001, **p<0.01, *p<0.05. Lt: left side; Rt: right side

SUBJECTS AND METHODS

Twenty-three healthy adults (9 males, 14 females) participated in this study. Healthy young adults in their 20s or 30s who were capable of voluntary and independent walking, who had no musculoskeletal disease within the prior three months, and who did not have any diseases that could influence the study outcome, were included. Table 1 describes the general characteristics of the participants (Table 1). The study protocol was approved by the institutional review board of Sahmyook University in Seoul (2-1040781-AB-N-01-2016070HR). Participants provided signed consent after receiving verbal and written information about the study.

Gait parameters were measured while participants comfortably walked for 30 s, with simultaneous use of two different measurement systems: an AGA system (G-Sensor, BTS Bioengineering S.p.A., Italy), and a TGA system (Zebris FDM-T, Zebris medical GmbH, Germany). Gait speed measured during initial comfortable ground walking was then applied to treadmill walking for assessment. Measurement was performed three times and averaged, with participants facing forward and walking comfortably according to the set speed. Cadence, speed, strides elaborated, gait cycle duration, and % stride length/height on each side (left and right) were calculated by the AGA system. Cadence, velocity, number of steps, step time, stride time, stance phase, swing phase, and double support on each side were calculated by the TGA system. All collected data were analyzed using SPSS version 18.0 (SPSS for Windows; SPSS Inc., Chicago, IL, USA). Descriptive statistics were used for the general characteristics of the participants and Pearson's analysis was used to determine the correlation between the AGA and TGA results for gait parameters. Alpha was set at 0.05 for all statistical tests.

RESULTS

The results of the study showed a strong correlation between AGA and TGA for cadence (r=0.995) and number of steps (r=0.983) (p<0.001). There was also a strong correlation between speed in AGA and velocity in TGA (r=0.838) (p<0.001). Moreover, there was a strong correlation between strides elaborated in AGA with cadence (r=0.799) and number of steps in TGA (r=0.777) (p<0.001) (Table 2). Correlations between AGA and TGA were also observed for spatiotemporal parameters. There were strong correlations between gait cycle duration in AGA and step time (left side r=0.983, right side r=0.975) and stride time in TGA (r=0.994) (p<0.001). Speed in AGA showed strong correlations with step time (left side r=−0.586, right side r=−0.608), stride length (r=−0.632), stance phase (left side r=−0.546, right side r=−0.559), swing phase (left side r=0.546, right side r=0.559), and double support in TGA (r=−0.574). Finally, % stride length/height in AGA was correlated with stance phase (left side r=−0.583, right side r=−0.547), swing phase (left side r=0.583, right side r=0.547), and double support (r=−0.589) in TGA (Table 3).

DISCUSSION

The purpose of this study was to analyze the correlation between an AGA system and a TGA system in healthy adults. The results confirmed a high correlation between major gait parameters measured in the two gait analysis systems.

In this study, we selected TGA as the direct measurement method. TGA is able to collect a large volume of gait data in a limited space. Moreover, TGA is often used in the rehabilitation and evaluation of patients, since it is possible to adjust the walking speed in steps of 0.1 km/h, and to perform walking training while maintaining a constant speed. The common use of TGA in clinical practice has prompted various studies on its effects. Alton et al.[8] reported that walking speed in stroke patients increased after gait training on treadmills. Miller et al.[9] reported that gait training on treadmills contributed more to improving walking ability than gait training on even ground. Thus, treadmill-based gait training and evaluation have been actively used in clinical practice for stroke patients and other patients with impaired gait[10]. However, treadmill-based gait evaluation requires data to be collected in a laboratory, with associated high costs. Consequently, AGA is used as a convenient and easy method in clinical practice. AGA systems are small and light, and they impede walking during measurement less than conventional systems. Mens et al.[11] reported that the highest reliability was achieved when the accelerometer was fixed at the level of the lower lumbar and sacral regions, which are at the same height as the center of mass of the body, and which also comprise the center of rotation of the pelvis and trunk.

We used a G-Sensor (BTS Bioengineering, Italy) for AGA. Hartmann et al.[6] and Park[7] studied the correlation between AGA results and those using a Walkway, and reported a high correlation between gait velocity and cadence. Mayagoitia et al.[12] and Liu et al.[13] reported a high correlation between 3D optical measuring equipment and AGA. Thus, combining the results of several previous studies demonstrated a strong correlation between the results for AGA with those for direct gait analysis. For these reasons, Bouten et al.[14] reported that accelerometers are appropriate for the evaluation of human motion. The present study also confirmed strong correlations between AGA and TGA, demonstrating that AGA can be used as a quantitative evaluation tool to evaluate gait in clinical practice.

This study had some limitations. The subjects were healthy adults, and it might be difficult to generalize the correlations to patients with an impaired gait. The small number of subjects was also a limitation.

AGA systems are portable, small, and lightweight, and can easily be used by beginners. Moreover, the results of AGA were shown to be strongly correlated with those of TGA. Therefore, AGA can be an effective evaluation tool for gait analysis in clinical practice.

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