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Concurrent Validity of the VirtuSense® Gait Analysis System for the Quantification of Spatial and Temporal Parameters of Gait

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ABSTRACT

International Journal of Exercise Science 11(1): 934-940, 2018. The VirtuSense (VS) is a new single camera 3D movement-capturing device that has gait analysis capabilities in its arsenal of functional programs. The Gait Analysis System with the VS has not been formally validated. The purpose of the study was to assess the concurrent validity of the VirtuSense (VS) Gait Analysis System by comparing it to two standards, the GAITRite (GR) computerized gait mat and manual pedograph (PG). Twenty-seven healthy, young adults performed 4 walking trials at a self-selected pace on a level surface. In 3 trials, stride length, step length, and velocity were collected simultaneously from the VS and GR. In the first trial, stride length and step length data were collected simultaneously by the VS, GR, and PG. A high inter-class correlation coefficient was found between all 3 methods for each gait parameter measured: left stride length (ICC=.987), right stride length (ICC=.983), left step length (ICC=.983), right step length (ICC=.971). A significant correlation ($p<.001$) was found among each gait parameter mean (trials 1-4) for the VS and GR. The mean difference between VS-GR foot fall parameters revealed a small difference of no more than 1.56 cm. VS-GR velocity revealed a 14.8 cm/sec mean difference which can be explained by the difference when the devices captured the velocity. The VirtuSense Gait Analysis System, as compared to the GAITRite and pedograph, demonstrates good concurrent validity for measuring gait parameters (stride length, step length, and velocity). Clinicians using this device for clinical gait assessment should have an assurance the data collected for these parameters are valid.

KEY WORDS: Gait assessment, GAITRite, step length, stride length, gait velocity

INTRODUCTION

Contemporary clinical gait analysis provides clinicians with quantifiable measures which can assist in making clinical decisions (1,6,8,13,14). In order for this to occur the measures must be valid and reliable. The reliability and validity of these measures has improved over time with the aid of computerized analysis (3,4,10). The GAITRite (GR) system is a mat of sensors and computer software that is capable of quantifying the spatial and temporal parameters of gait. The system is considered to be highly valid and reliable (11,16,17). Manual pedograph, a traditional paper and ink method of measuring footfalls, has been shown to be a reliable method of measuring spatial parameters of gait (7,9).

The VirtuSense (VS) is a motion capturing system that uses a single remote camera, without applied reflectors, to quantify movement. Among its capabilities is software to analyze balance, functional movements and gait. This system was designed with the clinician in mind. Instead of having a single system for measuring aspects of gait and another system for measuring balance or function, this system can measure multiple motions in a relatively small space of a single camera. While the validity of the VS balance system has been explored (5), no similar studies have been conducted for the VS clinical Gait Analysis System. Studies using other single camera systems have shown high correlation for standing broad jump, vertical jump and broad jump (2,12).

The purpose of this study was to explore the concurrent validity of the VS Gait Analysis System for capturing basic spatial and temporal parameters. We hypothesized that a high correlation would be found between step length and stride length as measured by the VS, the GR, and manual pedographs (PG), and there would be a high correlation between gait velocity as measured by the VS and the GR. We also hypothesized there would not be a difference in the mean gait measures. Studies have confirmed the reliability of the GR, however out pilot studies have shown number of suspicious outlying values, thus the manual PG data was collected concurrently for one of the trials. Even though the PG is subject to measurement error, it is not subject to electronic-technological glitches.

METHODS

Participants

Institutional Review Board (IRB) approval was obtained prior to collecting data. Subjects were recruited via word of mouth to graduate students in physical therapy and undergraduates in health science. Adult participants were included if they had no major medical issues and no gait impairments, and could walk at least 90 meters at a self-selected pace. Twenty-seven participants (13 males/14 females) were recruited with an age range of 22-35 and a mean age of 25.6 years. Van Uden and Besser studied the reliability of the GAITRite over time with young adults and calculated the mean differences and standard deviation of the mean difference (16). Inputting these values from this study in the G*Power application (v. 3.1, Kiel, Germany) an effect size of 0.76 was calculated and a minimum of 25 participants was determined to be necessary for statistical significance ($p < 0.05$).

Protocol

Standardized gait assessment included the VS Gait Analysis system (Virtusense Technologies, 801 W Main St, Peoria IL), the GR mat (CIR Systems Inc. 12 Cork Hill RD, BLDG 2, Franklin, NJ), and a manual pedograph — the manual pedograph only collected data regarding the spatial parameters of the gait cycle. The GR is a 0.61m x 4.88m mat embedded with 1.27cm x 1.27cm pressure sensors throughout the length of the mat. As participants walk over the mat, the individual pressure sensors activate and record their time of activation. The information gathered from these individual pressure sensors, in relation to one another, can collectively give information regarding the spatial-temporal parameters of a subject's gait. The VS is a 20cm x 10cm x 10cm motion-capture system that uses a single camera to collect data during movement. Gait data is gathered within a distance of 3.81 meters and includes similar measures to the GR such as step length, stride length, distance covered, and velocity. The VS also collects sway and lean. We chose not to include these in the analysis because these cannot be detected by the GR. The VS does not require wearable sensors in order to collect this data. All data collected through the VS is stored on an external laptop. To create the pedograph, a sheet of butcher paper was laid over the length of the GR in order to apply both measurement tools during the same trial. A paint sponge apparatus was strapped onto the participant's shoes in order to denote footfall as the participant walked across the pedograph — red and blue paint was used to identify the right and left foot, respectively.

One student researcher was trained by an expert user during a 10-subject pilot study to operate the GR. Similarly, another student researcher was trained by an expert user during the pilot study to operate the VS. One researcher applied the sponges and paint for the pedograph. Only one student researcher measured the step length and stride length manually on the pedograph after being trained and observed for consistency by the other researchers during the pilot study.

After informed consent was obtained, participants were seated 1 meter in front of the GR mat. At the other end of the mat, the VS device was positioned 80 cm off the ground (approximate midsection of someone with average height) and 1 meter away from the mat and positioned to capture the movement of the participants walking. For the first trial, small sponges with tempera water-based paint were secured to the bottom of the participant's shoe at the toe and heel. Butcher paper was put down over the GR mat to create the manual pedograph. The participants were asked to walk on the paper at their preferred, comfortable pace while both devices collected data simultaneously. The paper was removed from the GR, the ink was allowed to dry, and the stride and step length were measured at a later time. The pedograph was only taken once due to the expense of the paper, the space required to move the paper for the ink to dry, and the time consumption to measure of the step and stride length. For the second, third, and fourth trials, the participants were instructed to walk at a comfortable normal pace on the GR mat while both devices collected data. From trial one, the average step length and stride length were calculated from the measured number of steps on the butcher paper. From trials 1, 2, 3, and 4, the average step length, stride length, and velocity were calculated from the data produced by the respective devices.

Statistical Analysis

SPSS version 16.0 (SPSS Inc., Chicago, IL) was used to perform the statistical analyses. Significance levels were set at $p < 0.05$. For the foot fall measures in trial 1 among the three methods (VS, GR, PG), interclass correlation coefficient (ICC) estimates and the 95% confidence intervals were calculated based on a mean-rating (k=3), absolute-agreement, 2-way mixed–effects model. Pearson *r* correlation coefficients were calculated on the mean values for the VS and GR for trials 1-4. Paired *t*-tests were calculated for the mean measures of trials 1-4 between the VS and GR. Mean difference of the VS-GR was also calculated with 95% confidence intervals calculated on the mean difference. Cohen's *d* was calculated to determine effect sizes.

RESULTS

With this group of young adults, there was excellent correlation of the foot fall measures (stride length and step length) among the three measures. ICC values for step length and stride length were very high (.971 - .987). The most difference in the means length was 2.3 cm, less than 2% of that value. See Table 1 for the specific test results.

Table 1. ICC estimates among stride length and step length for the VS, GR and PG during Trial 1.

Variable	Measure	Mean	SD	ICC	95% Confidence Interval
LSDL	VS	135.8	11.5	.987	.97-99
(cm)	GR	135.1	11.1		
	PG	133.8	11.4		
RSDL	VS	136.0	11.6	.983	.97-.99
(cm)	GR	135.3	11.6		
	PG	133.7	12.4		
LSPL	VS	67.9	5.9	.983	.94-.98
(cm)	GR	67.5	5.9		
	PG	67.5	7.0		
RSPL	VS	67.4	6.2	.971	.93-.99
(cm)	GR	67.3	5.7		
	PG	65.8	5.5		

(LSDL = left stride length, RSDL = right stride length, LSPL = left step length, RSPL = right step length)

The data analysis indicates a high and significant correlation between the VS and GR for the footfall measures of step and stride length. The correlation was significant for velocity between the VS and GR, however the magnitude of that r value for velocity was not as high as the other parameters. The overall mean difference was relatively small, with 1.56 cm being the greatest difference. The effect sizes of the differences were small (except for velocity) indicating that the practical differences between the measures were not great. See table 2 for the specific results.

DISCUSSION

The VS Gait Analysis system overall demonstrated good concurrent validity when considering the statistical analysis. Inter-class correlation coefficients and Pearson r correlation coefficients were statistically significant and high. This indicates that the relative changes between subjects is consistently measured by the three methods of measurement. However, the correlational results only suggest the relative but not absolute relationship between these measures. Systematic and consistent differences between the three methods of measurement will not be reflected in correlational statistics. Thus, an analysis of the means is an important step in determining concurrent validity. The means and standard deviations were very similar for all three measures. Paired t-test for the spatial parameters results show no statistical difference between the two systems except for right step length. The effect size values were small suggesting very little practical difference between all the spatial parameters including the right step length. An absolute or perfect agreement may be improbable given that the distance captured by each method for parameter calculation is different. The VS collects data within a distance of 3.81 meters and the GR collects within a distance of 4.88 meters. Thus, the number of actual foot falls averaged by each device is different and could account for a less than perfect agreement. The PG measure was similar in length to the GR.

Table 2. Correlation for stride length, step length and velocity between the VS and GR trials 1-4. Paired t-test results for gait variables.

Variable	r	p	VS Mean (SD)	GR Mean (SD)	VS-GR Mean (SD)	95% CI of the mean difference	t	p	d
LSDL (cm)	.924	<.001	142.1 (9.98)	143.1 (11.7)	-1.07 (4.53)	-2.80 - .77	-1.17	.252	.05
RSDL (cm)	.986	<.001	142.8 (11.00)	143.4 (10.7)	-.65 (1.83)	-1.37-.08	-1.83	.079	.11
LSPL (cm)	.974	<.001	70.9 (5.4)	71.4 (5.6)	-.47 (1.25)	-.96-.03	-1.93	.064	.13
RSPL (cm)	.904	<.001	70.3 (5.4)	71.8 (5.3)	-.1.56 (2.36)	-2.49-.63	-3.43	.002	.31
Velocity (cm/sec)	.854	<.001	141.1 (13.5)	126.3 (10.4)	14.80 (7.12)	11.37-17.62	10.81	<.001	.82

Velocity measures had a lower, but significant correlation. The mean values of the velocity were significantly different. As stated above, there is a difference in the distance in which the data points are collected between the VS and GR, with the GR collecting distance being approximately 1.2 m greater than the VS. In this set-up, there may not have been adequate acceleration space for participants entering the GR leading to a systematic slower average gait speed for the GR compared to the VS. Specific testing protocols can impact the outcome of velocity measures. Sustakoski et al. found that gait speed on average was 0.17 m/sec faster with a walking start compared to a standing start (15). Subtracting 17 cm/sec from the mean VS gait speed leaves an average speed of 124.1 cm/s which is very close to the GR average speed of 126.3 cm/sec. Thus, it is plausible that the large difference in gait speed could be accounted for by the lack of acceleration in the data collection set-up.

One other study looked at the validity of the VS had similar results. This study was related to it balance measures (Functional Reach Test and the Modified Clinical Test of Sensory Integration on Balance) and compared the VS to a manual measure and a digital measure. This study found high correlations with r values greater than .92 for the Functional Reach Test. This compared the VS with a manual measure of length of reaching. The other balance measures compared the VS with force plate data. There were significant correlations but most r values were in the moderate range. This study did not analyze the difference in mean values.

The authors of this study acknowledged that the force plate data included a couple of subject values that were extreme outliers thus contributing to the lower r values (5).

A limitation of the study is the different lengths of the data capturing range leading to different number of average foot falls for each measure. Future research should consider eliminating the initial step lengths on the GR to capture close to the same steps. Secondarily, the difference in velocity could be minimized by giving an acceleration phase. The VS captures velocity when a body segment enters and exit the capture range, whereas the GS measures the distance/time from the first to the last step. Because of these technological difference, it may be improbable to get an absolute agreement in velocity. Future studies should also validate the VS against the data collected by multi-camera three-dimensional motion analysis systems.

The VS was designed for clinical application. The set-up and data collection with the VS is very easy requiring a single camera, laptop computer and relatively small space. The GR requires a large mat to roll out and a laptop. Of course, both are much easier than manual pedograph (inking sponges, paper and manual measures). With regard to this study, absolute agreement was not achieved, however the mean difference in the actual step and stride length measures was at the most 2% and at the least 0.5% of the total length. Also considering the confidence intervals of the mean differences, the difference seems to be within an acceptable range for clinical use. Even though there is a small data capture range, the clinician should include an acceleration phase to accurately capture velocity.

Considering quite different technologies for collecting the raw data (physical pressure sensors versus a single camera), the two systems have some agreement in the basic spatial parameters of gait and possibly the temporal parameters of gait. Future studies might look at concurrent validity in clinical settings with individuals with gait impairments. The clinical utility features such as time to set up and usefulness of all the data points could also be compared.

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