Validity of the Intelligent Device for Energy Expenditure and Activity Accelerometry System for Quantitative Gait Analysis in Patients With Hip Osteoarthritis

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Objective: To evaluate the concurrent validity of an accelerometry-based system (Intelligent Device for Energy Expenditure and Activity) with a criterion instrument (Gaitrite) for the evaluation of spatiotemporal gait variables in orthopedic patients.

Design: Validity study.

Setting: Research laboratory in an orthopedic hospital.

Participants: Men with unilateral hip osteoarthritis (N=26; mean age ± SD, 54±9y).

Interventions: Not applicable.

Main Outcome Measures: Patients were asked to walk at normal and fast velocities while gait cycle, swing, double support, step length, cadence, and speed were concomitantly recorded with the 2 instruments. Concurrent criterion-related validity was examined using intraclass correlation coefficients and Bland-Altman limits of agreement.

Results: Intraclass correlation coefficients were acceptable for all gait parameters (range, .815–.997), except step length (.783). Limits of agreement were low for gait cycle, swing, and cadence, though relatively high for double support, step length, and speed. A significant bias between the 2 measuring instruments was consistently observed.

Conclusions: In patients with hip osteoarthritis, quantitative gait analysis with the IDEEA accelerometry system was satisfactory for the main temporal gait parameters, while double support, step length, and walking speed quantifications were invalid. The IDEEA system should be used with caution, and modifications of the system are recommended for improved use in clinical practice and research.

Key Words: Osteoarthritis, hip; Rehabilitation; Walking.

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SIMPLE INSTRUMENTS and straightforward techniques are needed to objectively measure gait characteristics in the clinic, in order to provide useful information for effective diagnosis and treatment. In the last few years, wearable accelerometry systems have been increasingly used for quantitative gait analysis, because they are cheaper, lightweight, and portable compared with the traditional laboratory instruments.

A body-mounted system composed of 5 biaxial accelerometers has recently been introduced (Intelligent Device for Energy Expenditure and Activity [IDEEA]), which can concurrently provide spatiotemporal estimates of walking, energy expenditure, and posture allocation. Concurrent validity of gait variables provided by the IDEEA system was found to be good in a small group of healthy individuals, even though step length and walking speed were lower (~7%) compared with the criterion measure (forceplates). In patient populations, the validity of the IDEEA system has only been examined in pediatric neurology but never in orthopedics, despite the fact that this instrument has been employed to investigate gait characteristics of patients with knee and hip osteoarthritis (OA), both before and after joint replacement. Orthopedic-specific validation of this instrument is therefore necessary before further clinical and research applications.

The aim of this study was to evaluate the concurrent validity of the IDEEA accelerometry system with a criterion instrument for spatial and temporal gait parameters in patients with hip OA.

METHODS

Participants

A total of 26 men with unilateral hip OA volunteered to participate in this study. Their mean age ± SD was 54±9 years, body mass ± SD was 84±11kg, and height ± SD was 176±6cm. The study protocol was approved by the local ethical committee. The data collection was carried out in accordance with the directives given in the Declaration of Helsinki.

Equipment and Procedure

Patients were fitted with IDEEA accelerometers and were asked to walk over a validated electronic walkway (Gaitrite), therefore the gait characteristics were collected simultaneously (concurrent criterion-related validity). We used the Gaitrite mat as the criterion instrument, because it was previously shown to have high validity for the assessment of spatiotemporal gait.

List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
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<tr>
<td>ICC</td>
<td>intraclass correlation coefficient</td>
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<tr>
<td>LOA</td>
<td>limit of agreement</td>
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<td>OA</td>
<td>osteoarthritis</td>
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</table>
Fig 1. Bland-Altman plots of gait parameters provided by IDEEA against Gaitrite. The different panels show: gait cycle (A), swing (B), double support (C), step length (D), cadence (E), and speed (F). The solid line within the graph represents the bias, and the broken lines represent the upper and lower 95% LOAs. Each data point represents the mean individual value obtained at normal (black circles) and fast (white circles) velocity.
The IDEEA system consists of 5 biaxial accelerometers that are connected to a microprocessor. Sensors were placed according to the recommendations of the manufacturer. The IDEEA system uses proprietary algorithms based on subject height and thigh and foot acceleration recorded during the swing phase (sampling rate, 32Hz) to compute spatiotemporal gait variables. The Gaitrite mat used in this study contains a network of 13-mm pressure sensors distributed over an area of 7.3 \times 0.6m. Pressure data from the activated sensors were sampled at 80Hz. Patients were asked to complete 1 familiarization trial followed by 3 experimental trials at 2 self-selected velocities: normal then fast.

Spatiotemporal gait parameters provided by Gaitrite software (Gaitrite Gold, Version 3.2b) were compared with those calculated by the IDEEA software (Gaitview software, Version 2.2a). For each instrument (IDEEA and Gaitrite) and parameter: gait cycle, swing, double support, step length, cadence, and speed.

**Statistical Analysis**

The concurrent validity of IDEEA with Gaitrite was assessed using intraclass correlation coefficients (ICC$_{2,1}$) with 95% confidence intervals, 95% limits of agreement (LOAs) by Bland and Altman, and paired $t$ tests. LOAs ratios were calculated in the presence of heteroscedasticity ($R^2<.1$). ICCs greater than .80 were arbitrarily considered as acceptable. A Bonferroni-adjusted alpha level of $P<.008$ was used, because there were 6 dependent variables.

**RESULTS**

Bland-Altman plots of gait parameters provided by IDEEA versus Gaitrite are shown in figure 1. All variables differed significantly between the 2 instruments (table 1): gait cycle and swing showed a small positive bias (IDEEA>Gaitrite), while double support, step length, cadence, and speed showed a negative bias. ICCs were acceptable for all the parameters, except for step length (.783). LOAs or LOAs ratios were low for gait cycle, swing, and cadence, though relatively high for double support, step length, and speed.

**DISCUSSION**

When compared with a criterion instrument (Gaitrite), the IDEEA accelerometry-based system provided a valid quantification of the main temporal gait parameters (gait cycle, swing, and cadence) in patients with hip OA, while double support, step length, and walking speed estimates were considered invalid.

The Gaitrite manual contains all relevant information about postacquisition processing of the different spatiotemporal gait parameters. This is not the case with the IDEEA manual, which does not provide algorithm and filter characteristics or a description of how the principal walking variables are quantified. Therefore, we can only speculate about the systematic biases observed between the 2 instruments. Possible reasons for the underestimation of step length and walking speed with IDEEA have already been evoked in our previous study. For example, it is unclear if the gravitational component of the thigh and foot acceleration, as well as if soft tissue artifacts, is taken into account by the IDEEA proprietary algorithms. In the same way, we previously suggested that the real problem for the quantification of spatial gait parameters with IDEEA is that lateral (side-to-side) acceleration is not measured, and therefore movements in the horizontal plane are ignored. This inevitably causes large errors in the computation of step length to occur, which in turn affects the calculation of speed. Discrepancies in step length estimates between IDEEA and criterion instruments other than Gaitrite have indeed already been reported.

The largest difference between the 2 instruments was found for double support, given that IDEEA measured approximately half of the time compared with Gaitrite. The most likely reason for this discrepancy is that IDEEA would only take into account initial or terminal double support, whereas the Gaitrite software always calculated double support as the sum of initial and terminal phases. Gait cycle and swing phase were slightly overestimated by the IDEEA system. Our data show that the difference in gait cycle is because of the swing component, because stance was similar for the 2 systems (data not reported). This could be because the 2 systems have different measuring principles: Gaitrite measures foot pressure, whereas IDEEA detects acceleration of foot sensors, which could result in anticipated swing onset and/or delayed swing offset.

**Study Limitations**

The main limitation of this study is that the observed differences between Gaitrite and IDEEA cannot be satisfactorily discussed, because IDEEA manufacturers do not specify important details regarding quantification of spatiotemporal gait parameters. However, because the IDEEA system is commercially available and has been employed to characterize gait characteristics of patient populations, we believe its comparison against a criterion instrument is valuable. There are other limitations that need to be acknowledged regarding the present study. Only men with unilateral hip OA were evaluated, and the sample size was relatively small, which limit the generalizability and interpretation of our findings (particularly for LOA). Finally, we did not verify the test-retest reliability of IDEEA measurements, although previous results obtained in healthy subjects were highly reliable.

### Table 1: Concurrent Validity of Gait Parameters Provided by Gaitrite and IDEEA (N=26)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Gaitrite</th>
<th>IDEEA</th>
<th>ICC$_{2,1}$ (95% CI)</th>
<th>LOA or LOA Ratio</th>
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<tr>
<td>Gait cycle (s)</td>
<td>1.022±0.109</td>
<td>1.029±0.109</td>
<td>0.997 (0.996–0.999)</td>
<td>0.007±0.016</td>
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<tr>
<td>Swing (s)</td>
<td>0.397±0.037</td>
<td>0.405±0.031</td>
<td>0.928 (0.878–0.958)</td>
<td>0.022±0.064</td>
</tr>
<tr>
<td>Double support (s)</td>
<td>0.240±0.051</td>
<td>0.109±0.031</td>
<td>0.815 (0.698–0.889)</td>
<td>−0.806±0.230</td>
</tr>
<tr>
<td>Step length (cm)</td>
<td>78.0±8.4</td>
<td>70.7±8.6</td>
<td>0.783 (0.650–0.869)</td>
<td>−7.3±11.2</td>
</tr>
<tr>
<td>Cadence (steps/min)</td>
<td>118.8±12.5</td>
<td>118.3±12.4</td>
<td>0.997 (0.996–0.998)</td>
<td>−0.5±1.9</td>
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<tr>
<td>Speed (m/s)</td>
<td>1.53±0.28</td>
<td>1.37±0.25</td>
<td>0.934 (0.889–0.962)</td>
<td>−0.18±0.19</td>
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</table>

**NOTE:** Values are mean ± SD or as otherwise indicated.

Abbreviation: CI, confidence interval.

*Significant difference between Gaitrite and IDEEA ($P<.008$; Bonferroni correction).
CONCLUSIONS

The IDEEA accelerometry system, which allows quantitative gait analysis outside the laboratory, is valid for the main temporal parameters but not for double support, step length, and speed evaluation in men with unilateral hip OA. Therefore, this system should be used with caution in orthopedic settings, and modifications of its hardware and software are strongly recommended for an improved use in clinical practice and research.

References

Suppliers
a. MiniSun LLC, 935 E Mill Creek Dr, Fresno, CA 93720.
b. CIR Systems Inc, 60 Garlor Dr, Havertown, PA 19083.