Measurement of Walking Distance and Speed in Patients With Peripheral Arterial Disease
A Novel Method Using a Global Positioning System

Alexis Le Faucheur, PhD; Pierre Abraham, PhD, MD; Vincent Jaquinandi, MD; Philippe Bouyé, PhD, MD; Jean Louis Saumet, PhD, MD; Bénédicte Noury-Desvaux, PhD

Background—The maximal walking distance (MWD) performed on a treadmill test remains the “gold standard” in estimating the walking capacity of patients who have peripheral arterial disease with intermittent claudication, although treadmills are not accessible to most physicians. We hypothesized that global positioning system (GPS) recordings could monitor community-based outdoor walking and provide valid information on walking capacity in patients with peripheral arterial disease.

Methods and Results—We studied 24 patients (6 women) with arterial claudication (median [25th to 75th percentile] values: 57 years old [48 to 67 years], 169 cm tall [164 to 172 cm], weight 81 kg [71 to 86 kg], and ankle-brachial index 0.64 [0.56 to 0.74]). MWD on the treadmill was 184 m (144 to 246 m), which was compared with the results of self-reported MWD, the distance score from the Walking Impairment Questionnaire, MWD observed during a 6-minute walking test, and MWD measured over a GPS-recorded unconstrained outdoor walk in a public park. Self-reported MWD, Walking Impairment Questionnaire distance score, 6-minute walking test score, and GPS-measured MWD were 300 m (163 to 500 m), 28% (15% to 47%), 405 m (338 to 441 m), and 609 m (283 to 1287 m), respectively. The best correlation with MWD on the treadmill test was obtained with the MWD measured by the GPS (Spearman \( r = 0.81, P < 0.001 \)).

Conclusions—Outdoor walking capacity measured by a low-cost GPS is a potentially innovative way to study the walking capacity of patients with peripheral arterial disease. It opens new perspectives in the study of walking capacity for vascular patients with claudication under free-living conditions or for physicians who do not have a treadmill. (Circulation. 2008;117:897-904.)

Key Words: peripheral vascular disease • claudication • diagnosis • tests • exercise

During lower-extremity peripheral arterial disease (PAD), slow aggravation of arterial lesions leads to claudication and progressively reduces walking capacity. The most common estimation of walking capacity impairment is the relative claudication distance (distance until pain occurs) and the maximal walking distance (MWD), the distance walked at a usual pace and on a flat surface until pain forces one to stop. The MWD is a major index for the classification of the severity of PAD according to the Fontaine or Rutherford classifications. These classifications are guidelines for the therapeutic choices to be proposed to patients with PAD. Because no easy way exists to record MWD while patients walk at their usual pace in daily living, MWD on a treadmill is currently the “gold standard” method used to measure MWD in patients with PAD. MWD is generally preferred to the relative claudication distance because it has been shown to provide better reliability over a wide range of treadmill speeds and grades. Recent guidelines recommend the use of the walking treadmill test to “provide the most objective evidence of the magnitude of the functional limitation of claudication.” As underscored by Summer, in vascular evaluations, “measurements should be accurate, reproducible, and, preferably, simple. Above all, they should provide information that is demonstrably pertinent to clinical evaluation or to scientific studies.” To this first group of criteria, a second group of criteria should be considered, such as tolerability, cost, accessibility, and feasibility (minimal technical requirements). Treadmill evaluation of MWD fulfills most of the criteria listed by Summer but remains protocol dependent, technically demanding, time-consuming, and limited to vascular laboratories. Furthermore, treadmill MWD may not be correlated with the “true” free-living MWD at

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From the Laboratory of Physiology (A.L.F., P.A., J.L.S.), CNRS, UMR6214, INSERM U771, Medical School, University of Angers, and Laboratory for Vascular Investigations (P.A., V.J., P.B., J.L.S.). University Hospital, Angers, France; and Institute of Physical Education and Sports Sciences (IFEPSA; B.N.-D.), UCO, Les ponts de Cé, France.
Correspondence to Dr Pierre Abraham, Laboratory for Vascular Investigations, University Hospital, 4 rue Larrey, Angers Cedex, 09, F-49033 France. E-mail Piabraham@chu-angers.fr
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usual pace and on a flat surface\textsuperscript{5} and does not correlate with the patient’s perception of disability.\textsuperscript{6} Various methods that do not require a treadmill have been proposed to estimate walking capacity, including “unguided” self-estimated MWD, estimation of walking impairment by standardized questionnaires, and the 6-minute walking test.

**Clinical Perspective p 904**

Global positioning system (GPS) recorders are now available at low cost. A simple spreadsheet analysis with an Excel file can help to retrieve information on walking-or-stopping bouts and estimate the walking distance between 2 stops in normal subjects.\textsuperscript{7} Nevertheless, the ability of GPS recordings to assess the walking ability of patients with claudication has never been tested. We aimed to compare the results obtained with various nontreadmill methods, specifically the GPS technique, with the MWD observed in the laboratory on a treadmill. The purpose was not to analyze gait parameters or physical activity; rather, the goal was to define how nontreadmill methods compare with the “gold standard” treadmill analysis to estimate walking capacity in patients who have arterial claudication and to discuss the potential advantages and limitations of each approach.

**Methods**

**PAD Participant Recruitment**

A prospective study was conducted among patients with lower-extremity PAD who were recruited from the departments of vascular investigations of our institutions or who were referred by their physicians for exercise treadmill tests. The protocol was approved by the local scientific and ethics committees and registered with the American National Institutes of Health database under reference No. NCT00485147. All patients gave their written informed consent to participate.

**Inclusion Criteria**

Patients with Fontaine stage II lower-extremity PAD were selected for participation according to the following criteria: (1) vascular-type intermittent claudication based on the San Diego Claudication Questionnaire;\textsuperscript{8} (2) a resting ankle–brachial index $<0.95$; (3) age $>18$ years old; (4) ability to walk on a treadmill; and (5) clinical stability of PAD in the last 3 months. Patients with any ongoing symptomatic disease that limited exercise other than PAD (eg, lumbar spine syndrome, limiting exertional dyspnea, or symptomatic arthritis), patients at risk for exercise tests (myocardial infarction in the last 6 months, uncontrolled angina pectoris, sustained cardiac arrhythmias, abdominal aortic aneurysm $>40$ mm), and those who were unable to participate in the study for logistical reasons were not included. A wide range of estimated claudication distances were accepted for inclusion to be representative of patients who may be entered into a clinical trial of walking capacity.

All included patients underwent functional evaluation with (1) walking impairment assessment with the Walking Impairment Questionnaire (WIQ), (2) self-reported MWD (MWD\textsubscript{SRT}), (3) symptom-limited treadmill testing, (4) a 6-minute walking test (6MT), and (5) a minimum of 45 minutes of GPS-recorded unconstrained, unsupervised outdoor walking in a public park. No change to the treatment regularly prescribed to the patients was proposed.

**Exclusion Criteria**

Patients were excluded from analysis if self-reported limitations or claudication was not confirmed during the treadmill test or if external events interfered with the outdoor walking in the designated public park (because of the risk of underestimating the MWD by GPS).

**Measurements of Walking Capacity**

**Walking Impairment Questionnaire**

Self-reported ambulatory ability was assessed by use of a French translation of the WIQ.\textsuperscript{9,10} The WIQ is a valid tool for measuring walking ability in PAD patients. It is divided into 3 components to estimate walking distance, walking speed, and stair-climbing abilities.\textsuperscript{9,10} For each component, patients rank the degree of difficulty for the corresponding task they were supposed to perform on a Likert scale, which ranges from 4 (no difficulty) to 0 (completely unable to perform the task). Each component of the WIQ was scored according to the procedure described previously.\textsuperscript{9,10} Specifically, for the WIQ distance score, the distances assessed ranged from walking indoors around the home to walking 5 blocks ($\sim500$ m).

**Self-Reported MWD**

At inclusion in the study and before performing the treadmill test, patients were asked to estimate their MWD as the maximal distance they may walk all at once at their usual pace on a flat surface before limb pain forces them to stop.

**Treadmill Exercise Test**

The treadmill test was performed as described previously with a 10% grade.\textsuperscript{11,12} Treadmill speed was increased progressively over 4 minutes up to 3.2 km/h and then maintained at this speed for a maximum of 16 minutes. Throughout the test, a 12-lead ECG was used to control the heart rate and to detect arrhythmias or abnormal depolarization events. Patients were encouraged to perform the test for as long as they could. If not ended on the patient’s request or for medical reasons, the test was stopped after a total walking duration of 20 minutes ($\sim1000$ m). On the treadmill, all patients were blinded to the distance and time walked. MWD on the treadmill (MWD\textsubscript{TT}) was noted at the end of the test.

**Six-Minute Walking Test**

The 6MT is a valid test that yields reliable measurements related to the functional and hemodynamic severity of PAD populations.\textsuperscript{13} The 6MT took place in an indoor, 30-m–long hallway with marks on the wall every 5 m. Patients were asked to walk up and down the hallway, covering as many laps as possible in 6 minutes. Patients were permitted to stop walking if their claudication became intolerable; however, the time clock continued to run during the rest period, and patients who stopped walking were encouraged to resume walking as soon as possible. The procedure was performed under technical supervision, with recording of the time to the first stop, the number of nonwalking periods when patients stopped because of claudication, and the total distance walked during the test. The investigator provided verbal encouragement every 2 minutes during the test.

**GPS Recording**

A single, commercially available, low-cost (approximately $450 US) GPS device (Garmin GPS 60, Garmin Ltd, Olathe, Kan), which included the European Geostationary Navigation Overlay Service (EGNOS) function, was used to record an unsupervised, unconstrained outdoor walk in a designated public park. The principles of GPS and the EGNOS-enabled GPS technique have been well described elsewhere.\textsuperscript{14,15} In the present study, the GPS receiver (15.5-cm height by 6.1-cm width by 3.3-cm depth; weight 198 g with 2 batteries) was started at the hospital and placed in the external pocket of a backpack. An external receiving antenna was placed over the backpack to improve signal reception. The chosen recording rate was 0.5 Hz.

The procedure to be followed at the public park was explained clearly and precisely to each patient at the laboratory. Patients were given a handout that contained detailed information for further reference if necessary. The geographic location of the public park and the itinerary from the hospital were explained carefully to all subjects, and a map projection of the public park was shown to them. The designated public park for the present study is flat (no hills) and free of motorized vehicle traffic, buildings, and compact trees.
The investigator emphasized that the aim of this unconstrained walking was to reproduce their daily walking limitation during an outdoor, unsupervised walk at their usual pace. Patients were instructed as follows: (1) To wait for \(\approx\)10 minutes on arrival at the designated public park to allow for initialization of the system. This duration is \(>\)2 times the maximal time required for detection by satellites and avoids adding the effects of previous walks to the recorded MWD. (2) Next, they were to walk at their usual walking speed for at least 45 minutes, including eventual rest periods due to leg pain. (3) They were instructed to stop at maximal claudication pain rather than voluntarily slowing down to avoid pain when walking discomfort occurred (onset of pain). No recommendation was provided about the duration of the stops. (4) Finally, they were asked to wait for an additional 10 minutes at the end of the 45-minute walk before returning to the hospital. This allowed the investigator to detect the end of the walking period more easily.

The GPS device was stopped when the patient returned to the hospital. Raw data were downloaded from the GPS receiver after each experiment and converted to indicate speed and distance with Mapsource software (version 6, Garmin Ltd), and data analysis was performed on a personal computer with a spreadsheet (Microsoft Excel 2000, Microsoft Corp, Redmond, Wash) as described previously.

Data Analysis

Walking Impairment Questionnaire
Each distance walked (expressed in meters) was multiplied by the Likert score that was selected for that distance. The products were summed and divided by the maximum possible score to obtain the percent score. Because the present study focused on walking distance capacity, only the distance score was used for further analysis.

Six-Minute Walking Test
A single parameter was used for further analysis: the total distance walked in 6 minutes (MWD6MT).

Global Positioning System
The methodology used has been described extensively elsewhere. With this methodology, accuracy for walking-and-resting-bout detection was 97.1%, and the estimation of walking distance was highly accurate \((r=1\) between actual and processed distance). Reproducibility of the GPS-measured walking distances was tested among healthy subjects on test-retest prescribed walking protocols. The Pearson correlation coefficient and the coefficient of variation of the GPS-measured walking distances were 97.1% and 4.1%, respectively (A.L.F., P.A., and B.N.-D., unpublished data, 2007).

We previously reported that all false bouts (of walking and resting) that were detected incorrectly lasted 6 to 15 seconds. Thus, as in our previous experiments, a manual postprocessing analysis was performed on all bouts that lasted from 6 to 15 seconds. This methodology was used in the present study to detect the end of the walking period more easily.

Sample-Size Estimation
The statistical power calculation for the end point of the correlation of treadmill MWD with nontreadmill walking capacity estimation revealed a power of 0.80 to detect \(r>0.80\) for the coefficient of correlation at the 5% significance level with 20 patients completing the study.

Statistical Analysis
Data are expressed as medians (25th to 75th percentiles). The Friedman test with Dunn post hoc test was performed to compare MWD6MT with MWD6MT, and MWDGPS with Prism 4.01 (GraphPad Software; San Diego, Calif). Spearman rank correlation coefficients with Bonferroni correction (with 95% confidence intervals) were calculated to assess the relationships between MWD6MT and other measurements of walking capacity (MWD6MT, WIQ distance score, MWDGPS, and MWDGPS) with SPSS version 13.0 (SPSS Inc, Chicago, Ill). For all statistical tests, a 2-tailed probability level of \(P<0.05\) was used to indicate statistical significance.

The authors had full access to and take full responsibility for the integrity of the data. All authors have read and accepted the manuscript as written.

Results
A total of 28 PAD patients who met the inclusion criteria were included in the study. Four patients were excluded because of nontypical symptoms \((n=1)\) or nonlimiting claudication \((n=2)\) during the treadmill test or because of multiple external events that had interfered with the unsupervised, unconstrained outdoor walking test (initiation of a diuretic treatment on the day of the study with multiple stops for urinating, \(n=1)\). As a result, a total of 24 white PAD patients \((6\) women) were analyzed. Demographic information, comorbid conditions, and medications used are presented in Table 1.

<table>
<thead>
<tr>
<th>Table 1. Characteristics of Studied PAD Patients ((n=24))</th>
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<tbody>
<tr>
<td><strong>General</strong></td>
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<tr>
<td>Age, y</td>
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<tr>
<td>Height, cm</td>
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<tr>
<td>Weight, kg</td>
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<tr>
<td>Body mass index, kg/m²</td>
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<tr>
<td>Ankle–brachial index</td>
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<tr>
<td>Current or former smokers, n</td>
</tr>
<tr>
<td>Comorbid conditions, n</td>
</tr>
<tr>
<td>Previous lower-extremity revascularization</td>
</tr>
<tr>
<td>History of myocardial infarction/stable angina</td>
</tr>
<tr>
<td>History of minor stroke</td>
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<tr>
<td>Chronic bronchitis</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
</tr>
<tr>
<td>Past history of knee or hip arthritis</td>
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<tr>
<td>Past history of sciatica</td>
</tr>
<tr>
<td>Medications used, n</td>
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<tr>
<td>Antiplatelet agents/vitamin K inhibitors</td>
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<tr>
<td>Statins</td>
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<tr>
<td>(\beta)-Blockers</td>
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<tr>
<td>Vasodilators for PAD</td>
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<td>Antihypertensive drugs</td>
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<td>Medications used, n</td>
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<td>Antihypertensive drugs</td>
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</tbody>
</table>

Data are expressed as median (25th–75th percentiles) for continuous variables. Numbers of subjects are reported for categorical variables.

Median MWD6MT was 184 m \((144\) to \(246\) m). Figure 1 depicts the distribution of MWD among studied PAD patients. As shown, most \((83\%\) of the patients had treadmill MWD inferior to 300 m. Median MWD for nontreadmill tests and the WIQ distance score are presented in Table 2. Other scores for WIQ were 33% \((23\%\) to \(49\%\) for speed and 42% \((35\%\) to \(64\%\) for stair climbing. It is of interest to note that among the 24 subjects who performed the 6MT, 50% stopped...
at least once during the test. For these subjects, the median walking distance to the first stop was 240 m (155 to 294 m).

Figure 2 presents a typical result of a GPS recording in 1 patient, with the corresponding signal processing and results for both walking speed and distance. As shown (upper left panel), although the public park (Parc de Balzac) has various pathways, this patient used only 1 of them. The initial and final resting periods that were performed by this patient enabled the investigator to clearly identify the scope of the outdoor walk in the public park (right panels). This was also made easier with the use of the map projection and the location of the place of the beginning and end of the unconstrained walking exercise (upper left panel). Raw data show typical speed signal instabilities (upper right panel) that were corrected after signal processing (lower left panel), which enabled the investigator to identify 10 walking bouts and 9 resting bouts in this patient. For this patient, the walking distances ranged from 166 to 281 m, and walking speeds ranged from 3.97 to 4.56 km/h (lower left panel).

Thus, the MWDGPS retained for further analysis for this patient was 281 m. This MWDGPS was the distance until the first stop for this patient; this was not the case for all patients.

After the unconstrained outdoor walking exercise, the median total distance walked and duration of outdoor walking were 2840 m (1960 to 3461 m) and 56.9 minutes (47.3 to 63.8 min), respectively. Median speed of walking was 3.62 km/h (3.44 to 4.24 km/h), which was significantly higher than the maximal speed achieved on the treadmill ($P < 0.001$). Median MWDGPS (609 m) was on average 3 times higher than MWDTT; however, the general trend was that the ratio of MWDGPS to MWDTT was higher for high MWDTT than for low MWDTT values. As shown in Table 2, all measurements of

![Figure 1. Distribution of MWDTT for PAD patients studied.](image)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Median (25th–75th Percentiles)</th>
<th>Difference From MWDTT*</th>
<th>Correlation Coefficient With MWDTT (95% CI); $P$†</th>
</tr>
</thead>
<tbody>
<tr>
<td>MWDGPS, m</td>
<td>609 (283–1287)</td>
<td>$P &lt; 0.001$</td>
<td>0.81 (0.60–0.92); $&lt; 0.001$</td>
</tr>
<tr>
<td>WIQ distance score, %</td>
<td>405 (338–441)</td>
<td>$P &lt; 0.001$</td>
<td>0.74 (0.47–0.88); $&lt; 0.001$</td>
</tr>
<tr>
<td>MWDSR,m</td>
<td>300 (163–500)</td>
<td>$P = 0.05$</td>
<td>0.52 (0.13–0.77); 0.038</td>
</tr>
<tr>
<td>MWD6MT,m</td>
<td>405 (338–441)</td>
<td>$P &lt; 0.001$</td>
<td>0.74 (0.47–0.88); $&lt; 0.001$</td>
</tr>
</tbody>
</table>

CI indicates confidence interval.

* $P$ for Friedman test with Dunn post hoc test.

† $P$ for Spearman test with Bonferroni correction.
walking capacity were significantly correlated with the MWD<sub>TT</sub>; however, the best correlation was obtained with the MWD<sub>GPS</sub>.

**Discussion**

We demonstrated that during unconstrained and unsupervised outdoor walking, MWD<sub>GPS</sub> was highly correlated to MWD<sub>TT</sub>, although median MWD<sub>GPS</sub> was on average 3 times higher than median MDW<sub>TT</sub>. Therefore, GPS recordings may provide valid information on walking capacity in PAD patients.

Apparently, the easiest way to assess the walking capacity of a patient without the use of a treadmill is to interview the patient (MWDSR). The correlation coefficient found in the present study for MWDSR was low. Various studies have shown that MWDSR was highly inaccurate compared with MWD<sub>TT</sub>.<sup>5,17,18</sup> Only Giantomaso et al<sup>19</sup> found that the MWDSR of 31 patients was correlated with their MWD<sub>TT</sub> (Pearson correlation coefficient 0.79), but most (67%) of the patients in that study overestimated their MWD. Conversely, Walker et al<sup>18</sup> who studied PAD patients and normal control subjects, and Watson et al<sup>5,17</sup> found no correlation between MWD<sub>TT</sub> on a fixed-speed treadmill and MWDSR.

The WIQ was developed to standardize patients’ perception of their walking performance and is largely used in prospective cohort and cross-sectional studies or studies evaluating PAD treatments.<sup>20,21</sup> In PAD patients, WIQ distance scores correlated both with MWD<sub>TT</sub> and MWD<sub>6MT</sub>, with a correlation coefficient that ranged from 0.42 to 0.56.<sup>10,22,23</sup> The Spearman rank correlation coefficient between MWD<sub>TT</sub> and the WIQ distance score found in the present study was in accordance with these previous studies. This weak correlation is within the same range as that observed with various other disease-specific or generic questionnaires.<sup>24–28</sup> Despite the eventual language problems that can be encountered with questionnaires or the difficulty some patients have in estimating their MWD, questionnaires are easy to use, inexpensive, and repeatable. They are useful tools for epidemiological studies but are of little interest for the precise, objective individual estimation of MWD.

Objective assessment of walking capacity through direct measurement of MWD without a treadmill has been attempted by various methods.<sup>13–29</sup> The 6MT can be performed rapidly and is largely used in clinical studies to assess performance in symptomatic patients reporting limitation or no limitation of walking capacity.<sup>13,20–22</sup> In groups of patients with PAD, mean MWD<sub>6MT</sub> is close to MWD<sub>TT</sub>, but correlation between MWD<sub>6MT</sub> and MWD<sub>TT</sub> is weak (r=0.53, P<0.001).<sup>13</sup> Furthermore, the relative concordance of mean MWD<sub>6MT</sub> to MWD<sub>TT</sub> may depend on the treadmill protocol used, because it has been shown that progressive graded treadmill testing at 2 mph allows for a greater MWD (462 m) than the 6MT.
Finally, the forced walking pace attained during the 6MT does not reproduce a free-living walking pace and may not be completely devoid of risk in patients who have cardiovascular disease, although it is reported to be a safe test even in the early phase after myocardial infarction.

Estimating MWD from “unconstrained” walking under technical supervision is theoretically the ideal approach in claudication. Many authors have had subjects perform a supervised walk on a flat surface at a freely chosen or constant moderate speed and found that MWD was higher than on a treadmill. These tests are well tolerated and generally preferred to treadmill testing by the patients.

Unfortunately, these studies are necessarily limited in time to shorten the duration of technical supervision. Thus, tools to eliminate the need for technical supervision and allow for prolonged recording are required. A specific ultrasound device (PADHOC, Peripheral Arterial Disease Holter Control) was developed to monitor the distance walked by measuring the distance between the ankles. With this device, MWD was correlated with MWDTT ($r=0.60, P<0.01$) in PAD patients, although the median PADHOC MWD until the first observed stop during flat walking at usual speed was on average $\approx 2$ times higher than the median MWDTT (2.5 km/h on a 10% grade) as also observed for supervised indoor tests. The PADHOC system is an interesting tool for vascular specialists but is not readily available to most physicians.

The use of GPS devices in human applications for research or clinical purposes is an emerging field. Compared with accelerometers, GPS devices do not require individual calibration but allow only outdoor recordings in areas relatively free of major buildings or trees. Once the satellite signals are detected (usually within 1 or 2 minutes), the geographic position can be memorized with high precision, particularly with Wide Area Augmentation System (WAAS)–enabled devices. Under optimal recording conditions, the GPS may also allow for altitude (vertical) measurements, although the precision is lower than for surface (horizontal) measurements. Positions are downloaded with specific software and converted to speed and distance values by algorithms that may differ from one manufacturer to another. The entire downloading and postprocessing that we applied lasted $\approx 15$ minutes per patient. Correlation with actual distance and walking speed was 1.00 and 0.95, respectively, during predefined walking protocols in normal subjects. To the best of our knowledge, this is the first study to use a GPS to assess free-living outdoor walking capacity by measuring MWD during a period of unconstrained outdoor walking. The correlation with MWDTT that we observed was the highest among other usual measurements of walking capacity. The fact that MWDGPS was higher than MWDTT is consistent with previous studies that showed that MWD determined from unconstrained walking was vastly greater than MWDTT. This does not suggest that reliance on MWDGPS estimation is flawed but rather that treadmill testing does not satisfactorily reflect unconstrained outdoor walking. GPS recording of unconstrained outdoor walking appears to be an attractive approach for future studies in PAD patients or patients who have nonvascular walking limitations (eg, cardiac insufficiency or bronchitis). Specifically with regard to PAD, the ability of GPS to monitor speed, distance, altitude, and duration of walking-and-resting bouts over a prolonged period of time opens the door for future original studies that focus on the effect of fatigue, environment (eg, temperature, uphill walking, and type of ground surface), or duration of resting intervals on walking capacity and that analyze the results of treatments with regard to not only maximal distance walked but also other GPS-derived parameters.

**Study Limitations**

It could be argued that MWDTT would be different if another treadmill speed and slope were used. The relationship of MWD to treadmill speed is not linear. Thus, the relationship of MWDGPS and MWDTT to a different treadmill protocol would not be the same as shown here. GPS results must be compared with other treadmill protocols.

In addition, the fact that the GPS test was not supervised and was performed outdoors may be a pitfall of this technique, although it was intended to facilitate the work of the healthcare provider or organization, better reproduce a real-life situation, and limit the time required for the physician to perform the test. Walking outdoors makes the walk dependent on weather (eg, rain, wind, and temperature) and ground conditions (eg, hills and stairs). Testing on windy days should be avoided, although wind speed and direction could be taken into account in the analyses. Indeed, with GPS, the walking direction can be determined. For ground levels, the present study was performed in a flat, designated area along a lake and a river (Figure 2; the river Maine) to homogenize the results. Finally, interference with unexpected personal or external events (eg, a stone in the shoe, untied laces, other pedestrians, dogs, and cyclists) cannot be avoided completely. These occasional interfering events may induce early stops unrelated to pain, but their influence on the results is reduced if the recording is prolonged and if the analysis focuses on searching for the maximal MWD instead of just the distance until the first stop. This further underscores the interest in prolonged recordings for these unsupervised situations.

Furthermore, although the number of patients studied was small, it was calculated according to the goal of the study. The present study confirms that GPS estimation of MWD is accurate and simple. Whether MWDGPS is reproducible and provides information that is pertinent to clinical evaluation or to scientific studies remains to be determined. Experiments in larger groups are required.

Treadmill tests are and will continue to be useful if one aims to record important hemodynamic parameters during walking in PAD patients. For example, a postexercise ankle–brachial index can not be obtained during unsupervised out-of-the-laboratory tests. Nevertheless, portable devices are available to record many other physiological parameters (eg, heart rate, ventilation, electromyography, and transcutaneous oxygen pressure) and could be used in association with GPS recording to retrieve physiological information in free-walking conditions in PAD patients.
Conclusions
The GPS technique, associated with a simple spreadsheet data analysis, is easy, simple to perform, low in cost, and accessible to all physicians. As such, it is of potential interest for the individual assessment of walking capacity in patients with claudication from PAD and for physicians who do not have a treadmill. The reproducibility of the MWD_{gps} and the ability of the GPS approach to detect changes that result from treatments in PAD patients must be determined before GPS use is introduced into clinical practice.

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Disclosures
None.

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**CLINICAL PERSPECTIVE**

Treadmill testing is the “gold standard” in the evaluation of maximal walking capacity in patients with Fontaine stage 2 claudication, although treadmills are not readily accessible to all physicians. Furthermore, walking on a treadmill imperfectly reflects unconstrained outdoor walking. In 24 patients with peripheral arterial disease, we compared the maximal walking distance measured on a treadmill with the maximal walking distance observed during a 1-hour community-based outdoor walk while the patient’s position was monitored with a global positioning system (GPS). Our data support the evidence that global positioning system–determined maximal walking distance is correlated with the maximal walking distance observed on a treadmill. To the best of our knowledge, this is the first report on the use of a global positioning system in vascular patients. Ultimately, we believe that the use of a global positioning system might lead to new insights in the evaluation of walking capacity in arterial claudication and specifically to approaches for measurement of new dimensions in the evaluation of these patients, such as walking speed, fatigue, and walking gait.
Measurement of Walking Distance and Speed in Patients With Peripheral Arterial Disease: A Novel Method Using a Global Positioning System
Alexis Le Faucheur, Pierre Abraham, Vincent Jaquinandi, Philippe Bouyé, Jean Louis Saumet and Bénédicte Noury-Desvaux

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