From the Canadian Society for Vascular Surgery

Google Maps offers a new way to evaluate claudication

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ABSTRACT

Background: Accurate determination of walking capacity is important for the clinical diagnosis and management plan for patients with peripheral arterial disease. The current "gold standard" of measurement is walking distance on a treadmill. However, treadmill testing is not always reflective of the patient's natural walking conditions, and it may not be fully accessible in every vascular clinic. The objective of this study was to determine whether Google Maps, the readily available GPS-based mapping tool, offers an accurate and accessible method of evaluating walking distances in vascular claudication patients.

Methods: Patients presenting to the outpatient vascular surgery clinic between November 2013 and April 2014 at the Ottawa Hospital with vasculogenic calf, buttock, and thigh claudication symptoms were identified and prospectively enrolled in our study. Onset of claudication symptoms and maximal walking distance (MWD) were evaluated using four tools: history; Walking Impairment Questionnaire (WIQ), a validated claudication survey; Google Maps distance calculator (patients were asked to report their daily walking routes on the Google Maps-based tool *runningmap.com*, and walking distances were calculated accordingly); and treadmill testing for onset of symptoms and MWD, recorded in a double-blinded fashion.

Results: Fifteen patients were recruited for the study. Determination of walking distances using Google Maps proved to be more accurate than by both clinical history and WIQ, correlating highly with the gold standard of treadmill testing for both claudication onset ($r = .805$; $P < .001$) and MWD ($r = .928$; $P < .0001$). In addition, distances were generally under-reported on history and WIQ. The Google Maps tool was also efficient, with reporting times averaging below 4 minutes.

Conclusions: For vascular claudicants with no other walking limitations, Google Maps is a promising new tool that combines the objective strengths of the treadmill test and incorporates real-world walking environments. It offers an accurate, efficient, inexpensive, and readily accessible way to assess walking distances in patients with peripheral vascular disease. (J Vasc Surg 2017;65:1467-72.)

The prevalence of symptomatic peripheral arterial disease increases with age. In the United States, 6% to 7% of individuals aged 60 years and older are affected with intermittent claudication.[1,2] Whereas claudication is defined as reproducible fatigue, pain, or cramping in the lower extremities brought on during exercise and relieved with rest, establishing the diagnosis of claudication is more complex.[3] Patient factors such as baseline functional mobility, existing comorbidities, and effects of the disease on quality of life are all important considerations in formulating a management plan.

Walking distances—to claudication onset and maximal walking distance (MWD)—have been established as one of the primary measures in assessment of the patient.[4] Treadmill testing is the current "gold standard" for measurement of walking distance because of its strong reproducibility and reliability.[5] Although it is useful as an objective measure, it is widely accepted that the treadmill's artificial conditions may not be representative of real-world walking environments, with changing elevations and varying walking paces. A survey of vascular surgeons during the Canadian Society for Vascular Surgery annual meeting (H. Khambati and P. Jetty, 2015) revealed that 93% of respondents do not rely on treadmill testing as part of their diagnostic algorithm.

The Walking Impairment Questionnaire (WIQ) was developed as an alternative to treadmill testing, relying on the patient's estimates to determine walking distance. It has been widely tested and validated in multiple languages around the world as a useful guide for direct patient-centered management.[6-10] Because of its subjective nature, however, there is a wide discrepancy between the estimated distance obtained from the questionnaire and the actual walking distance, making interpretation difficult and decreasing its effectiveness as an assessment tool.[11,12]

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Given the problems associated with current quantitative and qualitative measures, we propose an alternative Google Maps-based approach that is aimed at combining the reproducibility and accuracy of treadmill testing with the real-world data capture of the WIQ. Whereas previous GPS-based studies relied on actual patient-worn devices, this study proposes the use of the free Google Maps mapping service to determine real-world walking distances at the time of the patient's visit and consultation.[13,14]

ARTICLE HIGHLIGHTS

- **Type of Research:** Prospective cohort study
- **Take Home Message:** In 15 patients, walking distances determined by Google Maps correlated highly with treadmill testing and were more accurate than by history or the Walking Impairment Questionnaire (WIQ).
- **Recommendation:** The authors suggest using a GPS-based mapping tool to measure walking distance for patients with claudication.

METHODS

Patients presenting to the outpatient vascular surgery clinic between November 2013 and April 2014 at the Ottawa Hospital with vasculogenic calf, buttock, and thigh claudication symptoms were identified and prospectively recruited on the basis of the following inclusion criteria: diagnosis of mild to severe claudication (Rutherford class 1-3) established by a qualified vascular surgeon; age ≥18 years; resting ankle-brachial index <0.9; and ability to undergo treadmill testing.

Patients were also screened on the basis of the following exclusion criteria: suffering from any other symptomatic exercise-limiting comorbid condition (eg, angina pectoris, congestive heart failure, osteoarthritis, spinal stenosis, chronic obstructive pulmonary disease, Parkinson disease); contraindications to walking; lower limb tissue necrosis; lower limb amputations; walking-aid requirements; non-English or non-French speaking; inability to give informed consent; and cognitive limitations to completing the WIQ.

The project was reviewed and approved by the Research Ethics Board, and informed consent was obtained from each patient.

Evaluation modalities

Onset of claudication symptoms and MWD were evaluated using four separate evaluation tools.

Clinical history. A detailed medical history and physical examination were performed by a qualified vascular surgeon as part of initial diagnostic evaluation. Patients were asked to report their walking distances (onset of claudication and MWD); all reported distances were converted to meters to allow comparison.

WIQ. Patients were asked to complete the WIQ by a blinded observer (Appendix, online only). The distance score was calculated per the standard methodology.[6] The first instance of a score <4 in the Walking Distance section was defined as distance to claudication onset. First score of 0 (inability to function) was defined as MWD. Note that the Stair Climbing section was eliminated as it was not the focus of the study.

Google mapping claudication quantification. Patients were asked to report walking distances by plotting their daily walking routes on a computer terminal using the Google Maps-based tool *runningmap.com*. This was done in the clinic in front of a computer terminal using Google Map view as well as satellite imagery. Familiar landmarks in the neighborhood were used to estimate distance to claudication onset and MWD. Assistance with the website was provided by a blinded observer, particularly for elderly patients who were unfamiliar with online mapping tools. The observer was present to help identify the home and workplace on the map and to assist in switching from map to satellite views to allow patients to identify local landmarks and walking routes.

Treadmill testing. Participants underwent treadmill testing to determine their intermittent claudication and MWD per standard vascular blood flow laboratory protocols. Tests were performed at 0% grade and titrated to each patient's walking speed (between 1.5 and 2.5 kph). Symptom onset and MWD were reported. Patients were blinded to the distance walked. Data were excluded if participants had to stop walking for any other reason than claudication-type pain.

Outcomes

Differences in distance to claudication onset and MWDs between the tested modalities and the gold standard of treadmill testing were the primary outcomes of the study. Time to completion of the WIQ and Google Maps reporting time for each patient were recorded as secondary outcomes.

Analyses

Walking distances obtained through history, WIQ, and Google Maps were compared against the gold standard, treadmill testing. Spearman rank correlations, defined as nonparametric measures of dependence between variables, were calculated using MedCalc software; values of +1 or −1 indicate perfect positive or negative correlations, respectively, whereas values in between indicate partial correlation. Two-sample *t*-tests for continuous variables were used to assess for differences between groups, and a two-tailed probability level of $P < .05$ was used to indicate statistical significance.

Table. Characteristics of patients in the study population

Study population	15
General	
Age, years	69 (59-80)
Male	80%
MWD, meters	187 (40-380)
Ankle-brachial indices (lowest)	0.58 (0.38-0.75)
Comorbid conditions	
Smoker (current or former)	15
Diabetes mellitus	2
Hyperlipidemia	9
Hypertension	11
Myocardial infarction or previous CABG or PCI	6
Cerebrovascular disease	1
Malignant disease	1
Medications	
Antiplatelet agents or anticoagulants	10
Statins	10
Beta blockers	6
Antihypertensives	13

CABG, Coronary artery bypass graft; *MWD*, maximal walking distance; *PCI*, percutaneous coronary intervention.
Categorical variables are presented as number. Continuous variables are presented as mean (range).

RESULTS

In total, 20 claudication patients were assessed during the study period. Two of them were excluded at the onset; one was unable to walk without the assistance of a walker, and another had advanced tissue necrosis in the leg. Three others did not show up to the required treadmill testing and so were omitted from the study. Demographic information, comorbidities, and current medications for the 15 enrolled patients are listed in the Table. All patients were either current smokers or ex-smokers.

MWDs on the treadmill test were all below 400 m. The median distances reported were as follows: clinical history, 61 m; WIQ, 46 m, Google Maps, 130 m; treadmill testing, 120 m.

Unlike with the WIQ and Google Maps tools, patients reported only a single number for claudication distance, being unable to differentiate claudication onset and MWD; when probed, individuals reported stopping and resting at the first onset of symptoms.

Claudication onset distances and MWD were extrapolated from the WIQ as patients were able to describe escalating symptoms from *difficulty* in walking to *complete impairment*. The first score in the Walking Distance section <4 was defined as symptom onset, and the first score of 0 (inability to function) was defined as MWD (Appendix, online only).

Satellite view was most helpful in Google Maps to allow patients to easily identify landmarks to describe their usual walking routes. Differences in elevations were also obtained along with distances and are not reported; all patients reported walking on relatively flat terrain with the maximum elevation change of 0.23 m/100 m walked.

Correlation of the three tested modalities with treadmill testing (TT) is shown in Fig 1, with comparisons made to both claudication onset (TT_{onset}) and MWD (TT_{MWD}). Correlation to TT_{onset} is superior to TT_{MWD} for clinical history, in keeping with preferences of the patients in reporting only a single walking distance, which usually corresponded to first onset of symptoms. Similarly, WIQ distance scores correlated significantly with TT_{onset} but not with TT_{MWD}. Google Maps had the best correlation with both onset ($r = .80$) and maximal ($r = .93$) treadmill distances, with a Spearman coefficient >0.8.

Fig 2 shows the differences in reported distances compared with the gold standard, treadmill testing. Both clinical history and WIQ distances have primarily negative distributions, suggesting that distances are under-reported when these two modalities are used. This phenomenon is not seen in Google Maps, where the difference plot has a more heterogeneous distribution.

On average, Google Maps reporting times were shorter at 3:45 (min:sec) compared with 4:48 for WIQ, although the difference was not statistically significant ($P = .065$). There was considerable variability in using the *runningmap.com* tool, depending on the familiarity of patients with online mapping systems.

DISCUSSION

Assessment of claudication is a complex problem that should include both a quantitative measure of the patient's walking distance and a qualitative assessment of functional impairment in real-world environments.[15] These measures are important in determining when to intervene on claudicants.

Clinical history, despite being the most widely used method, is inconsistent and highly variable, with patients being unable to accurately report their true capabilities (Fig 1).[16] The WIQ, on the other hand, is a validated tool for claudication assessment. In this study population, the WIQ correlated statistically with claudication onset distances on the treadmill but performed poorly compared with MWDs. Although this may be because of the small sample size in this study, the results are not widely different from existing literature on the questionnaire, with WIQ correlation ranging from 0.41 to 0.56.[6,15,17] Google Maps reported distances correlated highly with treadmill testing, for both claudication onset ($r = .80$) and MWD ($r = .93$), making it superior to the first two modalities.

In addition to relatively poor correlation, the WIQ fails to capture the subjectivity and qualitative nature of functional assessment, which is one of the main reasons that physicians continue to rely on clinical history. A patient's

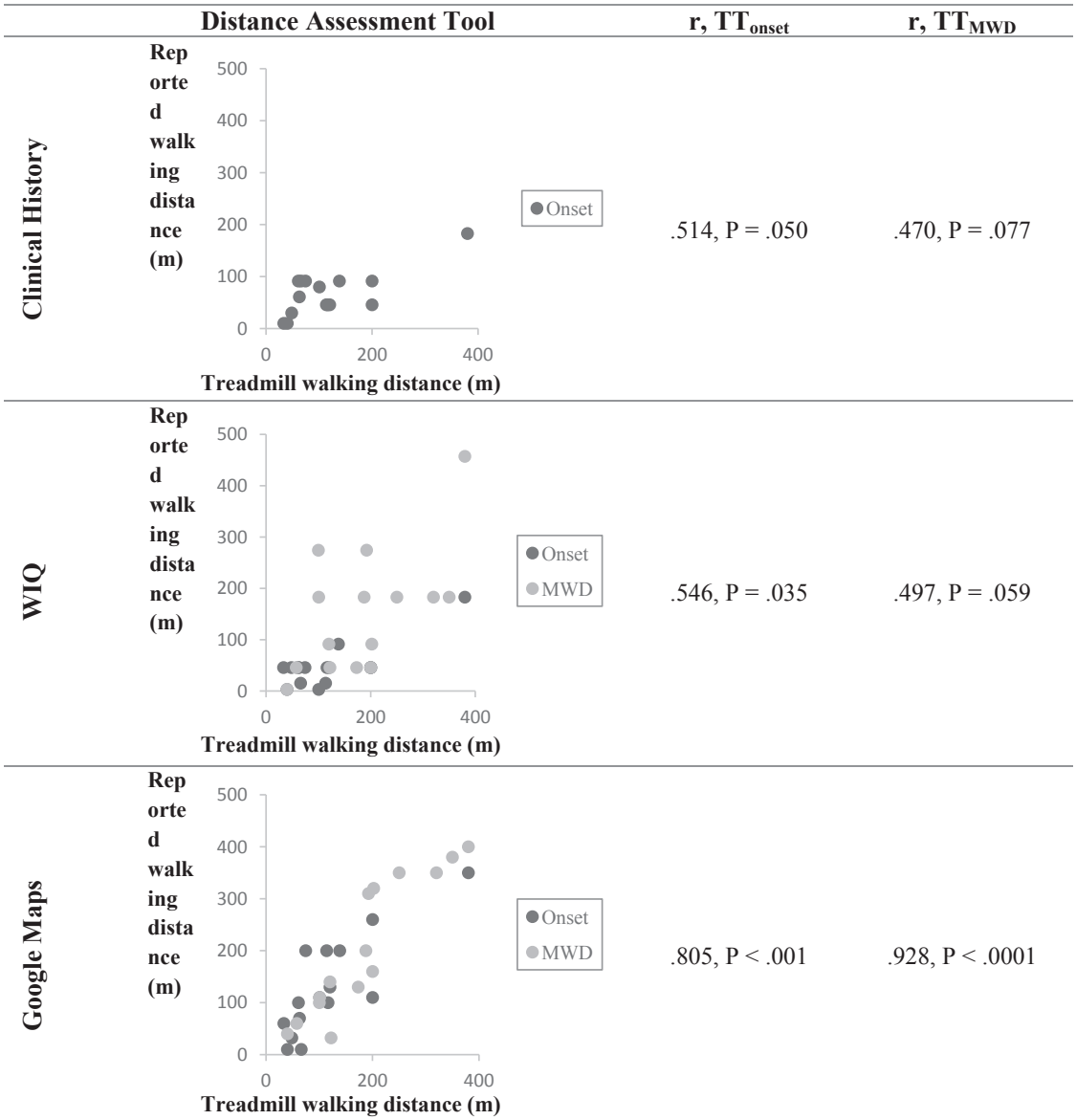

Fig 1. Correlation of walking distance assessment tools (y-axis) with gold standard treadmill testing (*TT*; *x*-axis) in claudication patients. Distances reported through clinical history are compared with maximal walking distance (*MWD*) on treadmill testing. Walking Impairment Questionnaire (*WIQ*) and Google Maps scatter plots are aggregates of both claudication onset and MWD compared with treadmill testing. To estimate the WIQ distances in the scatter plot, the first instance of a score <4 in the Walking Distance section was defined as distance to claudication onset, and the first score of 0 (inability to function) was defined as MWD. WIQ scores were calculated per standard described methodology and are used for correlation testing. Spearman rank correlation coefficients (*r*) were calculated using both claudication onset distances and MWD as obtained during the treadmill testing.[6]

description of the lifestyle limitations imposed by claudication as obtained through clinical history is a useful indicator of whether surgical intervention is warranted.[18] These may include inability to complete work activities that involve walking and difficulties in enjoying leisure time, such as golf or travel. A numerical quantification of walking distance as obtained through a WIQ score is unable to capture this real-world functional impairment. Google Maps is a representation of the real world and as such combines the quantitative strength of the WIQ with the qualitative information obtained through history. Because distances reported in Google Maps are based on patients' own walking routes, elements such as walking habits, work habits, and walking route specifics such as direction and elevation are all captured. In contrast to walking on a fixed-grade treadmill, patients are free to pick familiar routes where they may speed up or slow down during the walk or change direction. In this way,

Fig 2. Difference between walking distances obtained using the three assessment tools and treadmill testing. As each patient reported only a single distance number in the clinical history, differences were calculated using maximal walking distance (*MWD*) on treadmill testing. Walking Impairment Questionnaire (WIQ) and Google Maps scatter plots are aggregates of both claudication onset and MWD differences.

Google Maps may be a truer representation of walking assessment than the controlled treadmill test, making it a powerful tool in the assessment of claudication.

Also highlighted in this study is the patient's overestimation of claudication severity on clinical history and WIQ. Fig 2 illustrates this reporting bias, with many reported distances falling below the treadmill test results. In contrast, distances reported through Google Maps have no such discernible trend, suggesting that the landmarks-based method in Google Maps is a more accurate way of assessing walking distances.

From a pragmatic standpoint, Google Maps is easy to use, with every Internet computer or device having access to the service. Although not statistically significant, there was a trend toward shorter reporting times in comparison to the WIQ, with overall reporting times averaging <4 minutes. It also does not require the additional personnel, space, and equipment necessary to obtain a treadmill test assessment, and its widespread availability may make it useful in other specialties that assess a patient's walking abilities, such as orthopedics and physiatry.

Limitations. This study includes a limited number of participants; however, it adds to the growing number of publications that highlight the usefulness of GPS-based claudication evaluation tools.[13,14,19] To our knowledge, it is also the first to use a freely available mapping service such as Google Maps. The limited number of participants also does not detract from the conclusions of the study, proving Google Maps to be accurate in determining walking distances.

Second, the WIQ questions were administered by an observer who was blinded to the clinical history or treadmill test results. Deviation from the traditional self-reported format was intentional, as previous studies have shown that the WIQ is often error prone and needs observer intervention to make survey corrections.[11,20] However, this form of survey administration may lead to a systematic error, possibly resulting in the under-reported values.

In addition, the Google Maps reported distances do not include a time component and do not account for possible changes of pace or periodic stops. Routes were also mapped on the basis of familiar landmarks, probably resulting in rounding of distances. As discussed before, however, these real-world factors should not be eliminated but rather incorporated to more completely assess the functional lifestyle impairment due to claudication.

CONCLUSIONS

Google Maps offers an accurate, precise, efficient, inexpensive, and readily accessible way to assess walking distances in vascular claudicants, adding to the still-nascent field of GPS-based technologies used in the diagnosis and management of patients with peripheral arterial disease.

AUTHOR CONTRIBUTIONS

Conception and design: HK, KB, PJ
Analysis and interpretation: HK
Data collection: HK, KB, PJ
Writing the article: HK
Critical revision of the article: HK, PJ
Final approval of the article: HK, KB, PJ
Statistical analysis: HK
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Overall responsibility: PJ

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