ORIGINAL ARTICLE

# Correlation between ankle-brachial index before and after shuttle walk test

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## ABSTRACT

**Background:** Patients with peripheral occlusive artery disease (POAD) show changes in blood flow that may impair their walking ability. However, variability between inferential measurements of blood flow and walking performance is still high.

**Objective:** To correlate the ankle-brachial index (ABI) before and after performing the shuttle walk test (SWT).

**Methods:** Twenty-one patients with claudication due to POAD had their ABI values registered before and after walking based on a progressive external controlled speed walking protocol.

**Results:** Distance (261.07±160.63 m), time (292.30±122.61 seconds) and speed (1.23±0.34 m/s) obtained at claudication onset and when the limiting walking symptom started (369.52±157.97 m, 377.71±104.60 seconds, 1.46±0.29 m/s, respectively) were registered. Mean ABI before and after the SWT was 0.66±0.14 and 0.42±0.19, respectively. There was no substantial correlation between ABI pre- and post-walking and the variables obtained with the SWT (distance, time and speed).

**Conclusion:** Time, speed and distance for claudication onset and walking limiting symptom during a progressive speed walking protocol are independent of inferential blood flow measurements obtained by ABI before and after exercise.

**Keywords:** Claudication, walking test, flow.

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## RESUMO

**Contexto:** A alteração de fluxo sangüíneo observada nos pacientes com doença arterial obstrutiva periférica (DAOP) contribui para a redução da capacidade deambulatórida. Entretanto, ainda existe uma grande variabilidade nas correlações entre medidas inferenciais de comprometimento de fluxo e testes de deslocamento.

Objetivo: Estabelecer o nível de correlação entre as medidas do índice tornozelo-braço (ITB), pré e pós-esforço, com um novo teste de deambulação chamado teste de deslocamento bidirecional progressivo (TDBP).

Métodos: Vinte e um pacientes claudicantes, com diagnóstico de DAOP, tiveram registrados o ITB antes e após a realização de um teste de caminhada no solo, com controle externo e progressivo de velocidade (TDBP).

Resultados: Foram registrados a distância (261,07±160,63 metros), o tempo (292,30±122,61 segundos) e a velocidade (1,23±0,34 m/s) obtidos no início do surgimento de sintoma claudicante, bem como durante o surgimento de sintoma limitante (369,52±157,97 metros, 377,71±104,60 segundos, 1,46±0,29 m/s, respectivamente). A média do ITB de repouso foi de 0,66±0,14, e de pós-esforço foi de 0,42±0,19. Não se observou nenhuma correlação importante entre as variáveis do teste (distância, tempo e velocidade) com o ITB de repouso e nem após esforço.

Conclusão: O tempo, velocidade e distância de surgimento de sintoma claudicante e de sintoma claudicante limitante durante o teste de caminhada progressiva são independentes da medida inferencial de fluxo sangüíneo através do ITB de repouso e pós-exercício.

Palavras-chave: Claudicação, caminhada, fluxo.

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## Introduction

Combination of ankle-brachial indexes (ABI) and walking tests has been used to better understand the degree of patient impairment due to peripheral occlusive artery disease (POAD), since it associates inferential measurement of blood flow integrity and functional capacity.[1] Due to vasodilatation and inability to increase flow after the level of atherosclerotic obstruction, the ABI measured after physical activity (ABI-e) tends to drop in relation to rest levels. Thus, ABI-e is considered as having better prognostic value than resting ABI (ABI-r).[2,3] In addition, ABI-e has an additive value in the diagnosis of peripheral artery obstruction for individuals whose ABI-r is normal, but has a major fall with effort.[4] Reduction in systolic pressure after exercises is considered one of the most sensitive indicators to detect hemodynamically significant stenosis.[5]

However, if on the one hand the ABI-r is universally accepted as a clinical indicator of blood flow impairment, it does not always have satisfactory or significant correlations with performance in functional tests.[6] The correlation level between ABI-r and walking distance until start of claudication ($r = 0.17$) and with maximum claudication ($r = 0.24$), during the protocol in treadmill with constant load is quite low.[7] However, when the protocol is for maximum progressive load, such levels rise to 0.48 and 0.61, respectively.[8,9]

ABI-e can potentially have better correlation levels with performance, since individuals with POAD usually have a reduction in ABI during effort. However, further investigation is required to establish usefulness and feasibility of ABI-e in walking tests.

The treadmill test (TT) provides an objective measurement in walking performance. However, it is expensive, often requires specialized personnel, is not always available in clinics and does not reproduce a usual form of walking. Test-retest reliability for time of pain onset and limiting pain is low and quite variable.[8,9] Such variability in stability of distance measurements using the treadmill naturally reflects, in principle, the multiple protocols and/or forms how tests are conducted.

Overground walking tests have been proposed for functional assessment of claudicating patients, considering the variability of results observed with TT, lack of consensus between definition of the best protocol for the treadmill and technical difficulties, and cost associated with this instrument. The 6-minute walking test (6MWT) was developed as a cheaper and alternative form of measuring functional capacity, and its objective is measuring the distance the patient is able to walk over a 6-minute period.[10] However, the protocol also has standardization problems and higher susceptibility to variation, since the test speed is not controlled and the performance can be influenced by patient's motivation and encouragement.[10]

Another walking test to assess aerobic resistance has been recently presented in the literature, called shuttle walking test (SWT).[11] This test allows individuals to develop a more familiar walking activity, i.e., walking on the ground instead of walking on a treadmill, and speed is controlled externally by a previously recorded sound signal. Speed increases every minute and the test is only interrupted when the patient cannot follow the previously established velocity for a specific stage. This test has a low cost and progressive speed, therefore it is more likely to reveal the patient's functional capacity more reliably. Thus, SWT aggregates values present in treadmills (external speed control) and in the 6MWT (walking on a stable surface that is more representative of daily walking). SWT also has better psychometric properties than the 6MWT and TT.[10,12]

Considering that there has been no consensus on which ABI (rest vs. effort) is more adequate to assess the level of blood flow impairment for the lower limbs, and that protocols of functional tests involving walking for assessment of claudicating patients are variable, there should be more studies on the association of inferential flow measurements with more functional performance protocols.

Therefore, this study aims at investigating the degree of association of ABI after effort with a walking test that is closer to functional activity and that has more stability in relation to occurrence of symptoms.

## Methods

Individuals of both genders, independent of ethnic group or age, with POAD confirmed clinically or by ultrasound were contacted to participate in the study. The patients were part of a vascular rehabilitation program at the Center of Studies of Peripheral Vascular Diseases of Clínica Escola do Centro Universitário de Belo Horizonte (UNI-BH). The study started after approval by the Human Research Ethics Committee of Hospital SOCOR and each participant joined the program after signing a consent form containing all information regarding the study.

Inclusion criteria were adult patients with POAD who presented ABI-r between 0.9 and 0.4, with no pain at rest and with intermittent claudication.

Exclusion criteria were patients who had ABI-r > 0.9 or < 0.4, or those with pain at rest; patients unable to perform exercises, such as those with severe congestive heart failure, unstable angina, arrhythmias, who did not cooperate with performing the test; patients whose ABI was inaudible and, consequently, not measurable; and diabetic patients, except those who had symptoms of pain.

### *Procedures*

#### ABI measurement

To measure the ABI-r, the patient remained in the supine position for a 5-minute period before measurements. A specific cuff for upper limbs was used to assess systolic pressures of both limbs. The cuff was inflated at 20 mmHg above systolic arterial pressure (SAP). Pressure was recorded using a portable Doppler device (MEDPEJ model DV-2001, Brazil), placed on the brachial arterial in the cubital fossa.

A specific cuff for lower limbs was placed above the malleolus and inflated at 20 mmHg above the SAP to measure systolic pressures of each limb. A Doppler probe was placed on the posterior tibial and dorsal foot arteries. Although ABI is usually obtained through the ratio between the highest systolic pressure values recorded for the lower and upper limb, this study used the lowest systolic pressure value in the lower limb, because the authors consider that the largest obstruction had a greater impact on the functioning of the lower limb.[2] The lower limb that generated the lowest ABI was used as a reference limb to record the ABI after the walking test.

After the walking test, the patient was immediately placed in a supine position and the pressures in the lower and upper limbs were recorded in that order. However, at that moment, only the limb previously identified with the lowest ABI was assessed.

Shuttle walking test (SWT)

For this test, each participant walked a 10-meter distance, limited by two cones placed on the ground. The participant made consecutive laps around both cones, with speeds that increased progressively until exhaustion, presence of claudicating symptom or inability to maintain the previously established rhythm. Speed was increased at every minute (0.17 m/s) and controlled by audio signals, generated by a portable sound device. The SWT consisted of 12 levels lasting 1 minute each, and initial speed was 0.5 m/s until a maximum speed of 2.37 m/s.[11]

During the SWT, the patient used a belt over his chest that contained a portable transmitter. A Polar ™ (model Sport Tester, USA) heart rate monitor captured all signals emitted by the transmitter attached to the patient's chest to record heart rate (HR) during the whole walking test. By the end of each minute, HR was recorded.

The variables of interest in this test were distance, time and speed recorded at the pain onset and at the limiting symptom at which the patient could no longer follow the protocol.

Statistical analysis

For the descriptive statistics, the data were presented as mean and standard deviation. Pearson's correlation coefficient was used to establish a correlation between ABI values and the variables evaluated in the SWT. A significance level equal or higher than 5% was used to determine whether the association between measurements differed from zero. Student's *t* test was used to compare SWT variables at the start of claudicating symptoms and during limiting claudicating symptoms.

## Results

Twenty-nine patients were contacted to participate in the study, but only 21 were included. The other eight patients did not show up for the procedures. Out of 21 participants, 15 were males and six were females, aged between 35-80 years (mean 61.95±10.21 years). Mean height was 163.00±7.00 cm and mean body weight was 70.16±14.68 kg. All patients tolerated the procedures and there were no complications or medical emergency during the study.

The patients had their diagnosis of POAD confirmed clinically (presence of intermittent claudication) and by ultrasound examination (Doppler scan). Five patients had obstructive lesion in one limb and 16 had it in both lower limbs. Mean diagnostic time of POAD was 54.4 months (12-216 months).

Fifteen patients were taking part in a rehabilitation program for peripheral vascular disease or were performing scheduled walks. Mean participation time in a rehabilitation program was 15.2 months (1-36 months). The HR of one patient during the limiting symptom was not recorded due to technical problems. Eleven patients were smokers, eight ex-smokers and two patients had never smoked cigarettes. Hypertension and diabetes mellitus were the most frequently found associated diseases among the participants (Table 1). Drugs in use are listed in Table 1.

Table 1 - Associated diseases and drugs in use

| Associated diseases | (n) | Drugs | (n) |
|---|---|---|---|
| Hypertension | 16 | Anticoagulants | 3 |
| Dyslipidemia | 4 | Nitrate | 3 |
| Diabetes | 5 | ACE inhibitor | 7 |
| Stable angina | 2 | Beta-blocker | 5 |
| Thromboangiitis obliterans | 1 | Hemorheologic agents | 1 |
| Chronic heart failure | 1 | Antithrombotic agent | 9 |
| Infarction | 1 | Cholesterol and triglyceride reducers | 9 |
| Stroke | 1 | Cilostazol | 6 |
| Smoking | 11 | Diuretics | 8 |
| Ex-smoker | 8 | Calcium channel antagonist | 5 |
| | | Antiarrhythmics | 1 |
| | | Oral hypoglycemic agents | 2 |
| | | Central alpha-agonist | 1 |

Of the 21 patients included in the study, only one could not have his ABI after effort recorded. Mean ABI-r value was 0.66±0.14 (95% CI 0.38-0.94); and mean ABI-e value was 0.42±0.19 (95% CI 0.24-0.61). There was a reduction of 0.24±0.14 in mean ABI obtained after effort in relation to resting ABI ($p < 0.0005$). Mean values of distance, time, speed and HR of claudicating pain onset, as well as occurrence of limiting claudicating symptom are described in Table 2. One patient did not report initial claudicating symptom and, therefore, was not included in correlation statistics.

The correlation between ABI-r with distance, time and speed of claudicating symptom onset and limiting claudicating symptom was small and not significant, ranging from 0.19 to 0.25. The ABI-e did not show major correlation with any of the variables obtained, both at claudicating symptom onset and during limiting claudicating symptom (ranging from -0.01 to 0.12).

Functional variables had more significant correlations between themselves when claudicating symptom onset was compared with limiting claudicating symptom. The correlations between distance, time and speed at claudicating symptom onset with total distance, time and speed achieved at the limiting symptom were 0.92 ($p < 0.0005$), 0.91 ($p < 0.0005$), and 0.89 ($p < 0.0005$), respectively.

Table 2 - Distance, time, speed and heart rate observed at symptom onset and during limiting symptoms in the shuttle walk test

| | Symptom onset | | | | Limiting symptom | | | |
|---|---|---|---|---|---|---|---|---|
| | Distance (m) | Time (s) | Speed (m/s) | HR (bpm) | Distance (m)* | Time (s)* | Speed (m/s)* | HR (bpm) |
| n | 20 | 20 | 20 | 20 | 21 | 21 | 21 | 20 |
| Mean | 261,07 | 292,30 | 1,23 | 111,35 | 369,52 | 377,71 | 1,46 | 116,80 |
| SD | 160,63 | 122,61 | 0,34 | 19,39 | 157,97 | 104,60 | 0,29 | 21,15 |
| CI95% | 146,65 | 164,20 | 0,69 | 62,55 | 211,48 | 216,17 | 0,83 | 65,61 |
| | 375,49 | 420,40 | 1,77 | 160,15 | 527,57 | 539,26 | 2,08 | 167,99 |

CI95% = 95% confidence interval; HR = heart rate; n = number of individuals tested; SD = standard deviation.
* $p < 0.05$ (symptom onset vs. limiting symptom).

There was no statistical difference between HR recorded at claudicating symptom onset and during the limiting symptom HR (Table 2). HR was not significantly correlated with distance, time and speed during occurrence of claudicating symptom. On the other hand, HR during limiting symptom had a 0.55, 0.55 and 0.49 ($p < 0.0005$) correlation with distance, time and speed during limiting claudication, respectively.

## Discussion

The main objective of this study was to determine the level of association of ABI-e with a new walking test, the SWT. Choice for ABI after performing physical activity was due to the fact that the literature has variable correlations between ABI-r and performance.[1] Other studies suggest that ABI-e could have better correlation levels, although its use has not been investigated from the perspective of an association with functional capacity and hemodynamic variables.[3,5] The SWT was chosen due to its standardization, less influence as to patient encouragement, advantages to develop ground walking at incremental speeds, besides presenting more stability in reproducibility measurements.[13]

McDermontt et al. suggested that the ABI measured after physical activity could potentially have better correlation levels with performance than the ABI-r, since individuals with POAD could have a fall of more than 25% in ABI-e.[5,14] In the present study, there was a reduction of around 36% in the index obtained after effort, but there was no substantial correlation between this index and measures of time, speed or distance of symptom onset or limiting symptom. Correlation between ABI-r and functional variables was small and not significant.

Stein et al. demonstrated that the association between ABI and function was strong when the ABI was calculated using the mean value between the dorsal foot and the posterior tibial arteries.[2] In this study, however, the lowest systolic pressure value measured in the lower limb was used, because we believe that the largest obstruction has a greater impact on the function of the limb. However, previous studies used the highest arm and leg pressures to calculate the ABI.[1,15] Therefore, it is possible that variations in ABI recording partly explain the variability of correlation values with functional measurements.

Another possible explanation for the weak correlation between ABI and functional variables can be due to the fact that all patients were using drugs that could change blood flow and irrigation of the affected limb. There were patients whose medication could facilitate blood flow (cilostazol, ACE inhibitor, calcium channel antagonists, hemorheologic agents) or compromise it (beta-blockers).

Another factor that may contribute to explain the low or lack of correlation between ABI-r and ABI-e and SWT is the level of physical activity by participants. It has been demonstrated that trained patients have better mechanisms for oxygen uptake and peripheral utilization. These factors possibly better explain symptom mitigation of claudicating symptoms in functional tests, despite not changing blood flow as estimated by ABI.[1] In the present study, 76% of patients were taking part of a physical activity program and, therefore, could already show peripheral adaptations that influenced the association between blood flow and performance. Gardner et al. demonstrated that the increase in blood flow assessed by means of hyperemic response (27%) and by ABI (1%) were much lower than the improvement in walking distance until pain onset (133%) and until occurrence of maximum claudicating pain (77%) after a training program.[3]

Chronotropic behavior also supports the hypothesis that there may be a peripheral adaptation. First, there was no statistically significant difference between symptom onset HR and limiting symptom HR, despite the statistically significant differences in test performance variables. Therefore, this suggests that performance during the test can be more related to ability of utilizing oxygen than to distribution mechanisms. In addition, there was no correlation between symptom onset HR and any variable in the walking test, whereas shared variance ($r^2$) between HR and variables during limiting symptom was only 30%.

If, on the one hand, there was no correlation between blood flow impairment indexes and performance with the SWT in this population, SWT proved to be consistent as to assessment of clinical symptoms. Time, distance and speed of symptom onset had strong and significant correlations with the variables obtained during limiting symptom (correlation coefficient ranging from 0.89 to 0.92, $p < 0.05$). Thus, SWT is a feasible instrument to assess symptoms in patients with POAD.

### *Study limitations*

Reduced number of patients, as well as use of drugs and lack of uniformity regarding level of physical activity are issues that should be considered in further studies, since they could have interfered with the results. The most adequate form of recording ABI also needs to be investigated.

## Conclusions

Further reduction in ABI seen after effort in this study corroborates flow impairment in patients with POAD. However, low or lack of correlation of ABI-r and ABI-e with SWT performance suggests that the claudicating patient is able to perform the walking test thanks to, in principle, an efficient mechanism for oxygen uptake. SWT proved to be consistent in assessing time, distance and speed during symptom onset and limiting claudicating symptom. Therefore, this walking test is an alternative for a consistent and practical assessment of patients in angiologic clinics. Our results suggest that assessment of the claudicating patient's level of impairment should not discard a functional assessment.

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