

# Lower sensitivity of ankle-brachial index measurements among people suffering with diabetes-associated vascular disorders: A systematic review

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## Abstract

*Diabetes mellitus* is a systemic disease affecting microvascular and macrovascular systems and is considered as the strongest risk factor for peripheral arterial disease. Although the prevalence of the peripheral arterial disease is high among people living with diabetes, its severity is not accurately detected with the prevalent diagnostic methodologies. The ankle-brachial index measurement is a simple, objective, and reliable tool for diagnosis of peripheral arterial disease. However, it is of limited value in the diagnosis of peripheral arterial disease among diabetic patients due to its low sensitivity among diabetic individuals. *Diabetes mellitus* results in atherosclerosis and calcification of peripheral arterial walls leading to false normal ankle-brachial index values. Therefore, healthcare practitioners should be careful not to misinterpret ankle-brachial index results among diabetic patients. A literature search was conducted using the keywords “ankle-brachial index,” “interpretation,” “limitations,” “diabetic foot,” and “peripheral arterial disease” on different medical search engines. The results were manually scanned and then further reviewed to select the articles related to our topic of discussion. This article will review the use of ankle-brachial index measurement among diabetic patients, its limitations and its prognostic value. In Conclusion, Ankle-brachial index can be used for diagnosis of peripheral arterial disease with some precautions (e.g. raising the threshold of diagnosis or using the lowest systolic pressure value measured at the ankle) and can also be a prognostic indicator for cardiovascular morbidity and mortality.

## Keywords

Ankle-brachial index, diabetic foot, false readings, interpretation, limitations, peripheral arterial disease

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## Introduction

Peripheral arterial disease (PAD) and *diabetes mellitus* are highly correlated. Diabetes is considered one of the strongest risk factors, and the presence of symptomatic PAD among diabetic patients is an indicator of poor outcomes.<sup>1</sup> The most common clinical manifestation of PAD is claudication that worsens upon walking or activity. In advanced stages, the PAD may manifest with resting limb pain and critical ischemia. Most diabetic-like non-diabetic individuals suffering with PAD remain asymptomatic for years. Therefore, the actual prevalence of the disease is not known.<sup>2</sup> It is estimated that about 27 million individuals in America and Europe have symptomatic PAD, and 20% of them have diabetes. In diabetes, the PAD is more common with increasing age, the existence of diabetic peripheral neuropathy, and a longer duration of *diabetes mellitus*. Diabetes commonly affects

distal arteries (e.g. femoral, popliteal, and tibial arteries) rather than proximal iliac and aortoiliac vessels.<sup>3,4</sup>

The prevalence and pathogenesis of PAD among diabetic patients is not well-established. This is because many diabetic patients remain asymptomatic until advanced stages of limb ischemia when ulcers and gangrene evolve. This is primarily attributed to the peripheral neuropathy associated with pain that masks the claudication pain of limb ischemia.<sup>4</sup> Diagnosis of PAD is often carried out on a clinical basis

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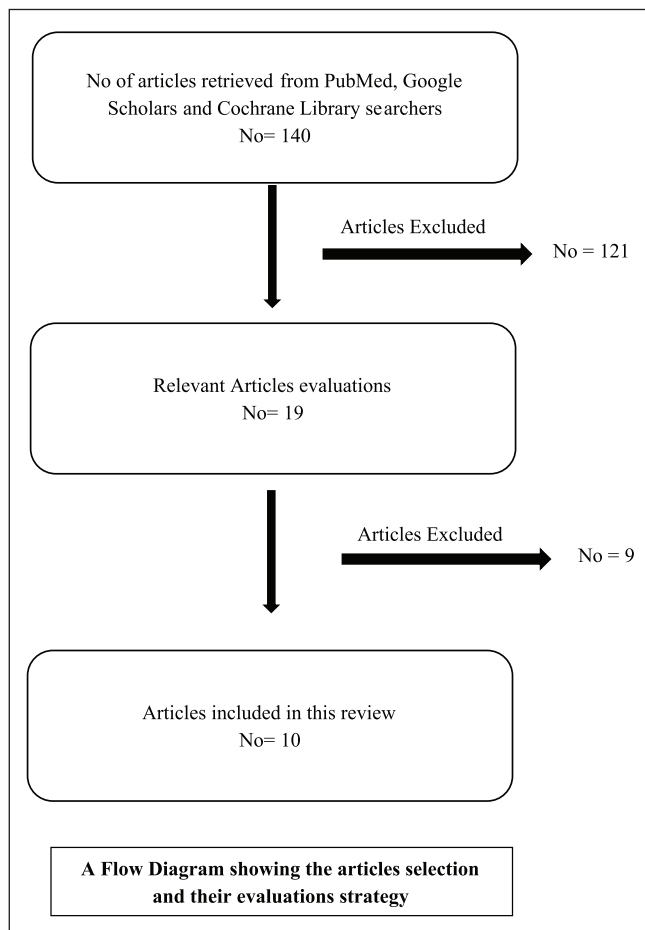
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(claudication and absent peripheral pulsations). However, these signs and symptoms may go mostly undetected, especially among diabetic patients. Hence, a more accurate and easier bedside test for the diagnosis of PAD is ankle-brachial index (ABI) measurement. This article reviews the usefulness of ABI measurement for vascular disorders among diabetes individuals, its advantages, limitations, and fallacies.<sup>5</sup>

## Methods

To write this review, a research was carried out on April 2017 via using the keywords by utilizing “AND” operator. The search term included ankle-brachial index AND diabetic foot AND false readings OR interpretation OR limitations OR peripheral arterial disease on Google Scholar, PubMed website, and Cochrane library. In the advanced research options, the time frame of publication was limited to the studies published in the past 15 years, and the title of the paper was adjusted to include at least two of the keywords as mentioned above.

Papers were selected according to their relevance to the topic reviewed in this research. We examined the titles of the retrieved papers to manually choose the manuscripts closely related to our research question of review. Among the articles meeting the inclusion criteria, we evaluated the abstract of each article to



filter them further to include only those describing the details of the ABI use and limitations in patients with diabetic foot.

## Results and discussion

### ABI usefulness in diabetic foot

Measurement of the ABI is a widely utilized test for the diagnosis of peripheral arterial insufficiency worldwide. Despite its popularity, ease of use, reliability, and various other advantages, many practitioners are not fully aware of its limitations. Furthermore, the ABI findings are often insufficient to describe the disease. Therefore, this section aims to review the basis of ABI measurement, its advantages, limitations, and proper interpretation.

**ABI measurement.** The principle of ABI measurement is to compare blood pressure in the lower extremities to central blood pressure. This is conducted by comparing systolic blood pressure between the arm (which represents an approximation of the aortic central pressure) and lower limbs. The ABI is calculated by measuring the systolic blood pressure via using a hand-held Doppler on the arms (at brachial artery) and legs (at posterior tibial and dorsalis pedis arteries). The patient is put into a supine position and allowed to rest for 10 min before starting the measurements. Systolic blood pressure is measured at the brachial arteries on both arms using an appropriately sized sphygmomanometer cuff and hand-held Doppler, and the higher value is taken. The same is applied to the lower extremities to measure the dorsalis pedis or posterior tibial artery systolic blood pressure.

Both values are then divided over each other to get a ratio. The formula for calculation of the ABI is

$$ABI = \frac{\text{Dorsalis pedis[or posterior tibial] systolic blood pressure}}{\text{Brachial systolic blood pressure}}$$

Values between 1.0 and 1.4 are considered normal according to the Inter-Society Consensus for the Management of Peripheral Arterial Disease (TASC II).

Borderline PAD is diagnosed when the ABI values are between 0.91 and 0.99. A value below 0.9 indicates stenosis in the arteries between the ankle and the aorta. Values below 0.4 indicate severe PAD, and values above 1.4 suggest calcified rigid and non-compressible arterial walls.<sup>6</sup>

**Basis of ABI test.** Theoretical basis for measuring the ABI is simple. The test is based on the fact that, under normal circumstances, the systolic blood pressure in the lower extremities should be equal to the central systolic blood pressure in the aorta, as well as to the systolic blood pressure in the upper extremities. This means that the ratio

between the two values should be 1.0. In cases of peripheral arterial stenosis or insufficiency, the systolic blood pressure in the lower extremities will be lower than the central or upper extremities' blood pressure. Thus, the ratio will be less than 1.<sup>7</sup>

This simple, non-invasive bedside test was proved later on by many researchers to have a high sensitivity and specificity. Literature studies concluded that an ABI value of 0.9 or less is 100% sensitive and 95% specific to PAD.<sup>8</sup>

**Advantages and limitations of ABI measurement.** To date, the ABI measurement is considered one of the most reliable tests for diagnosis of PAD. Although many clinical criteria had been proposed for the diagnosis of PAD, none of them was found to be reliable.<sup>9</sup> This is attributed partly to a large number of patients with asymptomatic disease and partly due to the variety of clinical presentations of the disease. Therefore, most of the clinical criteria have low sensitivity. Thus, the ABI represents a reliable, simple, and easy-to-perform objective test to aid in confirming the diagnosis of peripheral arterial ischemia.

However, some limitations exist that make the ABI measurement not a reliable tool for assessment of PAD on certain occasions. Risk factors that lead to rigidity and atherosclerosis of the arterial vessels wall were identified to give false normals or even high ABI values.<sup>10</sup> These risk factors are probably the reason behind the variations in the literature when it comes to the ABI. Although most of the researchers report ABI sensitivity above 90%, some studies report sensitivity as low as 38%.<sup>11,12</sup> This is probably attributed to the different sample characteristics and risk factors. The significant risk factors that may lead to wrong ABI values are *diabetes mellitus*, old age, mild arterial stenosis, and distal stenosis. The ABI values between 0.9 and 1.4 would be falsely considered as normal and could underestimate the prevalence of PAD, especially in patients with neuropathy, diabetic foot ulcers, or radiographic arterial calcification. The next section will detail the ABI false readings in diabetes mellitus.<sup>10</sup>

### ***Inaccurate reading of ABI in diabetic foot***

*Diabetes mellitus* is a systemic disease that is associated with grave macrovascular and microvascular complications. This disease accelerates arteriopathy and atherosclerosis, and is associated with increased prevalence of PAD. Although peripheral arterial ischemia is very common among diabetic patients, only one-third of them are symptomatic. Furthermore, pain associated with diabetic peripheral neuropathy mimics the painful claudication of PAD.<sup>13</sup> This makes the diagnosis of PAD difficult among patients with diabetes.

Diabetes-associated PAD often affects the distal vessels such as dorsalis pedis, posterior tibial, and tibioperoneal arteries.<sup>14</sup> It is also usually associated with calcification of vascular tunica media which results in vessel stiffness and rigidity. Tunica media calcification was reported to be more prevalent among diabetic patients with diabetic nephropathy

and hyperparathyroidism, suggesting a role of calcium metabolism disturbance in the occurrence of these vessel wall calcifications.<sup>15</sup> If left untreated, the PAD can lead to serious chronic limb ischemia and amputation. Therefore, early identification of this disease among diabetic patients is critical. To date, however, it remains a significant challenge for healthcare practitioners, partly due to the prevalence of asymptomatic disease and partly due to the masking of symptoms due to associated peripheral neuropathy. Although ABI measurement is a reliable, non-invasive objective test for early diagnosis of peripheral vascular disease, its usefulness for diabetic patients is very limited. Diabetes-associated atherosclerosis and vessel wall calcification result in false ABI results. Diabetic patients with significant levels of peripheral arterial stenosis may reveal normal or even high values in ABI measurements.<sup>16</sup>

The sensitivity and accuracy of ABI measurement differ among diabetic patients with peripheral neuropathy and those without. Toursarkissian,<sup>11</sup> in their study of diabetic patients with moderate PAD and no peripheral neuropathy, reported that an ABI < 0.9 had an 88% specificity and a 100% sensitivity. Alnaeb et al.<sup>16</sup> reported similar results. Contrarily, the sensitivity of ABI < 0.9 was significantly lower (with reported values between 35% and 73%) when assessing diabetic patients with peripheral neuropathy or advanced vascular disease.<sup>11,17</sup> This low sensitivity is attributed to arterial wall calcification, and atherosclerotic changes that make the artery poorly compressible and subsequently high ABI values are acquired. Similarly, ABI values above 1.4 are common among diabetic patients for the same reasons. Hence, ABI measurement is of limited value in advanced states of peripheral arterial ischemia among patients with diabetes.

It is estimated that PAD occurs among more than 50% of diabetic patients who have peripheral neuropathy with ABI values between 0.9 and 1.3.<sup>18</sup> For those with ABI  $\geq$  1.4, the prevalence of PAD reaches 85%.<sup>18</sup> Therefore, values below 0.9 and values above 1.4 are currently considered indicators of PAD among diabetic patients, mainly when peripheral neuropathy exists.

To improve the diagnostic yield and sensitivity of ABI measurement among diabetes, a number of issues were considered. The threshold for the diagnosis of the PAD was suggested to be raised to 1 to 1.1.<sup>19</sup> Another suggestion was to use the lowest systolic pressure value measured at the ankle. In addition, toe pressure was recommended to replace ankle pressure because it was found that tunica media calcification affects peripheral arteries at the level of the ankle more than those at the level of the toes.<sup>20</sup> Literature studies reported that toe pressure was 100% sensitive to detect PAD, whereas ankle pressure was only 53% sensitive.<sup>11</sup>

### ***ABI and prognosis in diabetes***

If properly interpreted, the ABI can be used for the evaluation of vascular prognosis in diabetes.<sup>21</sup> Decreasing ABI

over time is a poor prognostic indicator; it indicates progressive arterial stenosis and is considered a risk factor for cardiovascular morbidity as well as mortality.<sup>22</sup> There is a U-shaped association between ABI and cardiovascular morbidity and mortality. ABI < 0.9 was found to be associated with a 67% increase in the risk of cardiac death.<sup>23</sup> Similarly, ABI > 1.4 was associated with high cardiovascular mortality rates.<sup>24</sup> Furthermore, ABI < 0.9 was revealed to be a direct and independent risk factor for lower limb amputation among diabetic patients. The ABIs < 0.9 and above 1.4 were significantly correlated with diabetic nephropathy, microalbuminuria, macroalbuminuria, and renal failure.<sup>25,26</sup> High ABI values (>1.4) were also found to be associated with diabetic neuropathy.<sup>27</sup> Data on the correlation between ABIs are still lacking. However, it is suggested that ABI can be a reliable predictor of diabetic macrovascular and microvascular complications if properly measured, interpreted, and regularly followed-up.

## Conclusion

The toe brachial index is considered as a method of choice by the clinicians for evaluating medial arterial calcification even among diabetic individuals based on their empirical usage. Latest literature suggests that among diabetic individuals, the utility of this method is limited. Although ABI measurement is a simple, objective, and reliable tool for diagnosis of PAD, its diagnostic sensitivity among diabetic patients is low. *Diabetes mellitus* results in atherosclerosis and calcification of peripheral arterial walls leading to false normal ABI values. Therefore, healthcare practitioners should take caution when interpreting the results of ABI among diabetic patients. ABI can be used for the diagnosis of PAD with some care and can also be a prognostic indicator of cardiovascular morbidity and mortality.

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