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ANALYSIS OF FACTORS INFLUENCING ANKLE-BRACHIAL INDEX VALUES IN PATIENTS WITH DIABETES MELLITUS

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ABSTRACT
Peripheral artery disease (PAD) is one of the chronic complications that frequently occurs in patients with diabetes mellitus (DM). PAD can be detected early using the non-invasive Ankle-Brachial Index (ABI) method. An abnormal ABI value may indicate impaired peripheral blood flow and serves as an important indicator of the risk of amputation and cardiovascular morbidity. The aim of this study was to analyze the factors affecting ABI values in patients with DM, namely age, sex, Body Mass Index (BMI), duration of DM, smoking status, physical activity, foot care status, history of DM complications, adherence to DM therapy, and blood glucose levels. This research employed a quantitative descriptive non-experimental approach with a cross-sectional design. The sample was obtained through accidental sampling, resulting in 106 respondents. Data were analyzed using the Spearman's rho correlation test. The findings revealed that factors significantly associated with ABI values included duration of DM (p = 0.000), smoking status (p = 0.029), foot care status (p = 0.000), history of DM complications (p = 0.000), adherence to DM therapy (p = 0.000), and blood glucose levels (p = 0.000). The results of this study are expected to encourage respondents, particularly DM patients, to improve their overall adherence to diabetes therapy.

Keywords: ABI; diabetes mellitus; PAD

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INTRODUCTION

Diabetes mellitus (DM) is a group of metabolic disorders characterized by elevated blood glucose levels (hyperglycemia) resulting from defects in insulin secretion, insulin action, or both (Huether et al., 2019). DM is a chronic metabolic disease that affects the metabolism of carbohydrates, proteins, and fats, leading to an imbalance between the body's insulin requirements and insulin availability (Sommers, 2018). Prolonged hyperglycemia can trigger chronic microvascular complications such as nephropathy, retinopathy, and neuropathy. In addition, diabetes increases the risk of macrovascular complications, including coronary artery disease (heart attack), cerebrovascular disease (stroke), and peripheral arterial disease (PAD) (Smeltzer et al., 2015).

According to data from the International Diabetes Federation (IDF), 540 million adults are currently living with DM, and more than 90% of them have type 2 DM. IDF projections estimate that by 2045, one in eight adults—approximately 783 million people—will be living with diabetes, representing a 46% increase compared to the present. The majority (three out of four) of people with DM live in low- and middle-income countries, and in 2021 alone, there were 6.7 million diabetes-related deaths (IDF, 2023). At Tajinan Primary Health Center (Puskesmas Tajinan), there are 388 people with DM, with foot pain during physical activity being one of the most frequently reported problems. Data from one of the community health posts (Posyandu) showed that 6 out of 12 people with DM had diabetic ulcers, and 4 of them had undergone amputation.

One of the most common chronic complications in people with DM is peripheral arterial disease (PAD). Although often asymptomatic in its early stages, PAD can lead to ulcers, gangrene, and even amputation. Therefore, early detection plays a crucial role in preventing more severe complications (Huether et al., 2019; Smeltzer et al., 2015). Globally, PAD affects more than 200 million people, with symptoms ranging from no complaints to severe conditions (Gerhard-Herman et al., 2017; Song et al., 2019). The disease is caused by narrowing or blockage of large- and medium-sized arteries outside the coronary and cerebrovascular circulation.

In symptomatic cases, PAD is often associated with reduced functional capacity and increased risk of morbidity and mortality due to cardiovascular disease, making it an important marker of systemic atherosclerosis (McDermott et al., 2005). The relationship between PAD and DM is complex, as diabetes has long been identified as a major risk factor for the development of PAD. However, in patients with DM, PAD is often difficult to detect due to altered pain thresholds, microcirculatory disturbances, and impaired tissue regeneration (Shu & Santulli, 2018; Wilcox et al., 2018). One of the widely used non-invasive screening methods for early detection of PAD is Ankle-Brachial Index (ABI) measurement. A low ABI value indicates impaired blood flow to the lower extremities and serves as an important indicator of PAD severity.

Several risk factors are known to contribute to the development of PAD, including age, sex, duration of DM, treatment adherence, Body Mass Index (BMI), smoking status, blood glucose level, foot care status, physical activity, and history of complications. Research findings show that the mean BMI of respondents was 27.7 ± 5.8 kg/m^2, with 27.8% classified as obese (BMI ≥ 30 kg/m^2): 27.6% of women and 28.1% of men. Interestingly, individuals who were overweight (BMI 25–29.9 kg/m^2) had the lowest prevalence of PAD. There was a J-shaped relationship between BMI and PAD prevalence, where underweight status was also associated with increased PAD risk (1.72 vs. 1.39 for women and men, respectively). The association between obesity and PAD was stronger in women, whereas in men the relationship between increased BMI and PAD was relatively weaker (OR = 2.98 vs. 1.37 for BMI ≥ 40 kg/m^2) (Heffron et al., 2020).

Based on the above background, this study aims to identify the factors influencing ABI values in patients with DM. The results are expected to contribute to the early detection of peripheral vascular complications in patients with DM and serve as a foundation for developing more effective prevention and management strategies. Based on the aforementioned background, this study aims to identify the factors influencing the Ankle-Brachial Index (ABI) values in patients with Diabetes Mellitus (DM). The findings are expected to contribute to the early detection of peripheral vascular complications in DM patients and serve as a foundation for developing more effective prevention and management strategies. Therefore, the objective of this study is to determine the factors that affect the Ankle-Brachial Index (ABI) values among patients with Diabetes Mellitus.

METHOD

This study employed a quantitative non-experimental approach with a cross-sectional design, aiming to analyze the factors influencing Ankle-Brachial Index (ABI) values in patients with diabetes mellitus (DM). This design allows simultaneous measurement of independent and dependent variables at a single point in time. The study population consisted of patients with DM in the working area of Tajinan Primary Health Center (Puskesmas Tajinan), Malang Regency, totaling 388 individuals. The sampling technique used was accidental sampling, with a total of 106 respondents obtained during the study period in July 2025. Accidental sampling is a technique in which researchers select respondents who meet the inclusion and exclusion criteria among DM patients visiting the primary health center or community health posts (Posyandu).

The research instruments consisted of a structured questionnaire to collect demographic data and factors influencing ABI values, including name, age, sex, body weight, height, duration of DM, smoking status, daily activities, foot care practices, history of complications, treatment adherence, blood glucose levels, and ABI scores. Treatment adherence among DM patients was measured using the Morisky, Green, Levine Adherence Scale (MGLS). The MGLS demonstrated moderate internal and test–retest reliability (Cronbach's $\alpha = 0.651$; Spearman's rank correlation = 0.425; $p < 0.001$), and moderate convergent validity with the Medication Adherence Report Scale ($r = 0.58$; $p < 0.01$). Furthermore, the MGLS showed good known-group validity with a significant association to fasting blood glucose levels ($p < 0.001$) (Kristina et al., 2019). Data analysis was divided into univariate and bivariate analyses. Univariate analysis was performed using frequency distribution for each variable, whereas bivariate analysis was conducted using Spearman's rank correlation test with the assistance of SPSS version 26. This study obtained ethical clearance (Research Ethics Approval) from the Health Research Ethics Committee of Hafshawaty Zainul Hasan University, with approval number 510/KEPK-UNHASA/VII/2025, dated July 2, 2025.

RESULT

The univariate analysis was used to describe the characteristics of the respondents, which included ABI values, age, sex, BMI, duration of DM, smoking status, physical activity, foot care status, history of DM complications, and blood glucose levels. The characteristics of the respondents are presented in the table below:

Table 1
Frequency Distribution of Respondent Characteristics (n = 106)

Characteristics	f	(%)
Sex		
Male	19	17.9
Female	87	82.1
BMI		
Underweight (<18.5)	8	7.5
Normal (≥18.5-25)	51	48.1
Overweight (≥25-27)	38	35.8
Obese (>27)	9	8.5
Duration DM		
New (<5 tahun)	60	56.6
Intermediate (5-10 tahun)	28	26.4
Long (>10)	18	17
Smoking Status		
Active smoker	9	8.5
Passsive smoker	24	22.6
Non-Smoker	73	68.9
Physical Activity		
Light	69	65.1
Moderate	33	31.1
Heavy	4	3.8
Foot Care Status		
Good	33	31.1
Fair	38	35.8
Poor	26	24.5
Very Poor	9	8.5
History of DM Complications		
None	32	30.2
Microvascular	34	32.1
Macrovascular	35	33
Acute	5	4.7
	Mean	Std. Deviation
Age (years)	61.07	0.38538
Blood Glucose (mg/dL)	225.31	87.26865
ABI Value	0.96	0.07260

Table 1, almost all respondents were female (82.1%), and nearly half (48.1%) had a normal BMI. The majority of respondents had been diagnosed with DM for less than 5 years (56.6%), most were non-smokers (68.9%), and 65.1% reported light physical activity. Regarding foot care, almost half (35.8%) had a fair level of foot care. For DM complications, nearly one-third (33%) had macrovascular complications. The mean age of respondents was 61.07 years, the mean random blood glucose level was 225.31 mg/dL, and the mean ABI value was 0.96.

The bivariate analysis aimed to determine the factors influencing ABI values in patients with DM using Spearman's rank correlation test. The variables analyzed included age, sex, BMI, duration of DM, smoking status, physical activity, foot care status, history of DM complications, treatment adherence, and blood glucose levels. The results are presented in the following table:

Table 2
Results of Bivariate Analysis of Factors Influencing ABI Values (n = 106)

Variable	*P-Value (Sig. 2-tailed)*	Correlation Coefficient
Age	0.289	-0.104
Sex	0.301	0.101
BMI	0.167	-0.135
Duration of DM	0.000	-0.379
Smoking Status	0.029	0.212
Physical Activity	0.443	-0.075
Foot Care Status	0.000	-0.602
History of DM Complications	0.000	-0.463
Treatment Adherence	0.000	-0.547
Blood Glucose Level	0.000	-0.585

The factors found to be significantly associated with ABI values in patients with DM were : Duration of DM ($p = 0.000$, $r = -0.379$), Smoking status ($p = 0.029$, $r = 0.212$), Foot care status ($p = 0.000$, $r = -0.602$), History of DM complications ($p = 0.000$, $r = -0.463$), Treatment adherence ($p = 0.000$, $r = -0.547$), Blood glucose level ($p = 0.000$, $r = -0.585$).

DISCUSSION

Ankle-Brachial Index (ABI) is the ratio between ankle and brachial systolic blood pressure, which serves as a key indicator of peripheral arterial disease (PAD) in patients with Diabetes Mellitus (DM). A low ABI value indicates impaired peripheral blood flow, whereas a high ABI value may suggest vascular calcification. This study analyzed several factors influencing ABI values in patients with DM. Based on the results of Spearman's correlation analysis (Table 2), the variables significantly associated with ABI values were duration of DM, smoking status, foot care status, history of DM complications, treatment adherence, and blood glucose levels.

The first factor associated with ABI values was duration of DM. There was a moderate negative correlation between the duration of DM and ABI values (Table 2). This indicates that the longer a person has diabetes, the lower their ABI value tends to be, reflecting impaired blood flow to the lower extremities and an increased risk of PAD. Physiologically, prolonged exposure to chronic hyperglycemia leads to endothelial dysfunction, increased oxidative stress, and chronic inflammation, which accelerate atherosclerosis and reduce vascular elasticity. Over time, these mechanisms contribute to progressive peripheral vascular damage, which is reflected in decreased ABI values. This finding is consistent with previous studies indicating that longer disease duration is a significant risk factor for PAD, along with older age, sedentary lifestyle, smoking, poor glycemic control, and dyslipidemia (Allison et al., 2023). This highlights that the duration of diabetes is associated not only with microvascular complications but also with macrovascular complications such as PAD.

The second factor was smoking status, which showed a weak positive correlation with ABI values. Although the strength of this correlation was weak, the relationship remains clinically

relevant because smoking is a well-established major risk factor for PAD development. Smoking leads to endothelial injury, narrowing of the arterial lumen, increased blood viscosity, and chronic inflammatory activation, all of which accelerate atherosclerosis and impair blood flow, especially in the lower extremities, thereby influencing ABI values. The weak positive correlation observed in this study may be due to the complex interplay of other factors, such as smoking frequency, duration, and metabolic status. These findings are in line with existing literature, which reports that active smokers tend to exhibit severe ischemia of the toes (grade 3, <30 mmHg), indicating impaired blood flow to the lower limbs (Bechara et al., 2024). Other studies have also confirmed smoking, along with older age, sedentary lifestyle, long disease duration, poor glycemic control, and dyslipidemia, as significant risk factors for PAD (Allison et al., 2023).

The third factor was foot care status, which showed a statistically significant strong negative correlation with ABI values. This indicates that better foot care practices are associated with higher ABI values, reflecting better peripheral circulation and lower risk of PAD. Foot care in diabetes includes regular foot hygiene, use of appropriate footwear, monitoring for wounds or infections, and education on early signs of circulatory or neuropathic disturbances. These practices help prevent diabetic foot ulcers, improve peripheral circulation, and enhance overall adherence to diabetes management. This result is supported by case studies in which foot care interventions in two patients with type 2 diabetes resulted in reduced blood glucose levels and increased ABI values. In the first patient, blood glucose decreased from 256 mg/dL to 197 mg/dL and ABI increased from 0.81 to 0.90. In the second patient, blood glucose decreased from 318 mg/dL to 195 mg/dL and ABI increased from 0.77 to 0.92 (Adam & Isytiaroh, 2021). These findings indicate that foot care has both local and systemic vascular benefits.

The fourth factor was history of DM complications, which showed a statistically significant moderate negative correlation with ABI values. Patients with more severe or complex complications tended to have lower ABI values, indicating greater peripheral arterial impairment. This aligns with previously reported patterns of macrovascular and microvascular complications, where ischemic stroke, nephropathy, and retinopathy were more frequent among patients with low ABI. In fact, nephropathy incidence was higher than all-cause mortality across all ABI categories, underscoring the strong relationship between low ABI and the progression of diabetic complications. A previous study titled “Levels of Ankle-Brachial Index and the Risk of Diabetes Mellitus Complications” found that complication rates were lowest among patients with normal ABI values (1.1 to <1.3). For macrovascular complications, ischemic stroke incidence was twice as high as acute myocardial infarction (AMI)—7.7 vs. 4.1 cases per 1,000 person-years in the normal ABI group. For microvascular complications, neuropathy had the lowest incidence (3.4 cases per 1,000 person-years), followed by retinopathy, whereas nephropathy had the highest incidence (24.4 cases per 1,000 person-years) (Alves-Cabratosa et al., 2020). Other studies have also found that patients with low ABI have significantly higher rates of stroke, myocardial infarction, and foot ulcers (Yang et al., 2021).

The fifth factor was treatment adherence. A statistically significant strong negative correlation was observed between treatment adherence and ABI values (Table 2). This indicates that patients with higher adherence to diabetes treatment tend to have better ABI values, even though the correlation direction is negative because lower adherence scores are coded with higher numerical values in certain scales. Non-adherence to therapy leads to chronic glycemic fluctuations, which cause endothelial damage, vascular inflammation, and atherosclerotic plaque formation, ultimately resulting in reduced peripheral blood flow and lower ABI values. Previous studies support this finding, reporting an average adherence score of 5.88 ± 1.74 based on the Morisky Medication Adherence Scale-8 (MMAS-8), with 50.8% of patients showing low adherence, 27.2% moderate adherence, and only 22% high adherence. Significant differences in ABI values

were also found between adherence categories, confirming the impact of adherence on peripheral circulation (Heidari et al., 2021).

The sixth factor was blood glucose levels, which showed a strong negative correlation with ABI values (Table 2). This indicates that higher blood glucose levels are associated with lower ABI values, highlighting the crucial role of hyperglycemia in peripheral circulatory impairment and PAD development. Uncontrolled hyperglycemia causes endothelial dysfunction, oxidative stress, and inflammatory activation, leading to atherosclerosis and reduced arterial elasticity. Large-scale studies have found that individuals with abnormal fasting blood glucose levels have a 1.79-fold higher risk of low ABI and a 2.05-fold higher risk of high ABI (Fadlilah et al., 2025). Both low ABI (indicating peripheral arterial narrowing) and high ABI (indicating arterial stiffness) are strongly linked to metabolic disturbances caused by chronic hyperglycemia.

CONCLUSION

The factors influencing Ankle-Brachial Index (ABI) values among patients with diabetes mellitus (DM) in the working area of Tajinan Primary Health Center, Malang Regency, include duration of DM, smoking status, foot care status, history of DM complications, treatment adherence, and blood glucose levels. Based on the findings of this study, it is expected that respondents, particularly patients with DM, will improve their overall adherence to diabetes therapy, including maintaining a healthy diet, taking medication regularly, and routinely monitoring blood glucose levels. In addition, respondents should enhance self-foot care practices at home, as the study revealed a strong association between foot care status and ABI values. Preventing DM complications can be achieved through adopting an active lifestyle and maintaining consistent glycemic control, which are essential for reducing the risk of peripheral arterial disease and improving vascular health.

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