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Effectiveness of Foot Exercise on Improving Ankle-Brachial Pressure Index (ABPI) in Young Adults at Risk of Peripheral Artery Disease (PAD)

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ABSTRACT

Background: Peripheral artery disease (PAD) is a vascular complication associated with cardiovascular disease or diabetes mellitus and, if not adequately managed, may progress to severe morbidity and increased mortality risk. The prevalence of PAD, based on an Ankle-Brachial Pressure Index (ABPI) value of ≤ 0.89, among students of the Faculty of Medicine at Mulawarman University is approximately 44.7%. Foot exercise is a simple physical activity that, when performed sequentially and regularly, can enhance peripheral blood circulation and improve lipid metabolism, including increasing HDL cholesterol and reducing total cholesterol and triglyceride levels.

Purpose: To evaluate the effectiveness of foot exercise in improving the Ankle-Brachial Pressure Index (ABPI) among young adults at risk of peripheral arterial disease.

Methods: This study employed a quasi-experimental design using a pre-test and post-test non-equivalent control group approach. Forty respondents with an ABPI value of ≤ 0.89 were randomly assigned to two groups (intervention and control), with 20 participants in each group. The intervention group performed foot exercises three times per week for one month, while the control group did not receive any intervention. Data analysis was conducted using the paired t-test.

Results: The mean ABPI value increased after foot exercise, from 0.75 (SD = 0.83) to 0.97 (SD = 0.70). This difference was statistically significant ($p < 0.05$).

Conclusion: Foot exercise is effective in increasing ABPI values among young adults at risk of peripheral artery disease (PAD).

Keywords: ankle brachial pressure index, foot exercise, peripheral artery disease

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BACKGROUND

Non-communicable diseases (NCDs) have become a major global health concern, accounting for a significant proportion of mortality worldwide. According to the World Health Organization (WHO), NCDs were responsible for 38 million deaths out of 56 million global deaths in 2012 (Balakumar et al., 2016). Among these, cardiovascular diseases ranked first, causing 17.5 million deaths, followed by cancer (8.2 million), respiratory diseases (4 million), and diabetes mellitus (1.5 million) (Balakumar et al., 2016). Cardiovascular disease is further exacerbated by risk factors such as insulin resistance in diabetes mellitus. The prevalence of cardiovascular disease continues to rise annually. Data from the Indonesian Ministry of Health indicate that East Kalimantan ranked fifth in coronary heart disease cases, with 137,130 cases reported in 2013. In terms of diabetes mellitus, the province was ranked fourth in 2013 and rose to second place in 2018, with a prevalence of 3.1%. (Kementerian Kesehatan RI, 2020).

Cardiovascular disease and diabetes mellitus, if not properly managed, can lead to various complications, one of which is Peripheral Artery Disease (PAD). More than 50% of PAD patients are asymptomatic, while less than 50% present with typical symptoms such as intermittent claudication (pain or cramps in the legs during walking that improve with rest) and, in severe cases, critical limb ischemia (Beckman et al., 2015; Conte & Vale, 2018). PAD is an important marker of cardiovascular disease and significantly increases morbidity and mortality among patients with type 2 diabetes mellitus (Dewi et al., 2016; Weerarathna et al., 2019). Approximately 20% of individuals with diabetes mellitus develop PAD, with the risk increasing among those aged 41–60 years (50%) and over 60 years (46%) (Weerarathna et al., 2019). Globally, the prevalence of clinically symptomatic peripheral artery disease (PAD) among individuals aged 35 years remains relatively low, at less than 0.4% per 1000 individuals (Criqui & Aboyans, 2015). However, recent evidence shows that young adults are increasingly at risk of developing mild to moderate PAD, with a reported prevalence of 44.7%. This emerging pattern underscores the need for early preventive strategies targeting this age group (Aminuddin, 2021).

PAD can be detected through invasive and non-invasive methods. One recommended non-invasive method, considered the gold standard for detection, diagnosis, and monitoring of PAD, is the Ankle-Brachial Pressure Index (ABPI) measurement(Armstrong, 2017; Weller et al., 2019). ABPI is calculated by dividing the systolic pressure at the ankle by the systolic pressure at the brachial artery. An ABPI value of ≤ 0.89 indicates PAD (Weragoda et al., 2016). A preliminary study among medical students revealed that 6 out of 10 students had ABPI values ≤ 0.89, indicating that 60% were at risk of PAD. This complication can be prevented through early detection and identification of risk factors.

Cardiovascular disease, diabetes mellitus, and PAD are influenced by various factors. Non-modifiable risk factors include age, gender, and family history, while modifiable risk factors include hypertension, tobacco use, diabetes mellitus, physical inactivity, unhealthy diet, dyslipidemia, and stress (Kementerian Kesehatan RI, 2020). These modifiable risk factors are increasingly prevalent among young adults, particularly due to sedentary lifestyles. Although the effect of physical activity on blood circulation in healthy individuals has been widely studied, its impact on individuals at risk of PAD remains limited. One simple physical activity that can be performed is foot exercise, which has been shown to improve blood flow and increase ABPI values in patients with type 2 diabetes mellitus when performed three times per week for one month (Febrianti & Aini, 2024; Indarti & Palupi, 2018; Tehan et al., 2018). Despite evidence supporting the benefits of foot exercise in diabetic patients, there is limited research on its effectiveness among young adults at risk of PAD.

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OBJECTIVE

This study aims to determine the effectiveness of foot exercise in improving ABPI values among young adults who are at risk of PAD.

METHODS

This study employed a quasi-experimental design using a one-group pre-test and post-test with control design to examine differences in ABPI values before and after foot exercise among respondents at risk of PAD. The research was conducted at the Mini Hospital and the Medical Skills Laboratory of the Faculty of Medicine, Mulawarman University. ABPI values were measured using a vascular Doppler and a sphygmomanometer. The ABPI was calculated by dividing the systolic pressure at the ankle by the systolic pressure at the brachial artery.

A total of 40 respondents were recruited using purposive sampling based on the criterion of having an ABPI value ≤ 0.89. The respondents were then randomly assigned into two groups (intervention and control), with 20 participants in each group selected through simple random sampling. The intervention group received structured diabetic foot exercises comprising a series of range-of-motion and strengthening movements for the toes, forefoot, and ankle. The exercise protocol included toe flexion-extension, toe spreading, ankle dorsiflexion-plantarflexion, ankle inversion-eversion, and heel-toe raises. Each session lasted 15–20 minutes and was led by a trained instructor, conducted three times per week (Mondays, Wednesdays, and Fridays) for four consecutive weeks. The control group did not receive any foot-related intervention.

Data were analyzed using paired t-tests to compare pre-test and post-test ABPI values within the intervention group. Statistical significance was set at $p < 0.05$. Descriptive statistics, including mean and standard deviation (SD), were used to summarize participant characteristics and ABPI values. This study obtained ethical clearance from the Health Research Ethics Committee of the Faculty of Medicine, Mulawarman University (Approval No. 168/KEPK-FK/XII/2019).

RESULTS

Characteristics of participants

The study included 40 participants, consisting of first- and third-semester students from the Faculty of Medicine, Mulawarman University, Samarinda. The majority of respondents were female (n = 32; 80%), with an age range of 17–20 years. Most participants had a Body Mass Index (BMI) within the normal range (18.5–25).

Table 1. Characteristics of participants

Characteristics	Frequency	Percentage
Gender		
Female	32	80
Male	8	20
Age		
17 years	3	7.5
18 years	21	52.5
19 years	13	32.5
20 years	3	7.5
Body mass index		
Underweight	16	40
Normal weight	21	52.5

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Overweight	2	5
Obesity Class 1	1	2.5
Salt Intake (2–3 tsp/day or >3 tsp/day)		
Yes	38	95.5
No	2	4.5
Sweet Food/Drink Intake (2–3 tsp/day or >3 tsp/day)		
Yes	40	100
Coffee Consumption		
Yes	21	52.5
No	19	47.5
Smoking		
Yes	3	7.5
No	37	92.5
Physical Activity		
Regular	28	70
No Regular	12	30

In terms of lifestyle (Table 1), 95% of respondents reported consuming salty foods (2–3 teaspoons/day or >3 teaspoons/day), and 100% consumed sweet foods or drinks (2–3 teaspoons/day or >3 teaspoons/day). Additionally, 52.5% reported coffee consumption. The majority of respondents were non-smokers (n = 37; 92.5%), while 3 respondents (7.5%) reported smoking. Regarding physical activity, 70% engaged in regular physical activity, whereas 30% did not.

ABPI Values

ABPI measurements were taken twice for each group: at baseline (pre-test) and after the intervention (post-test) (Figure 1). The initial mean ABPI value in the intervention group was 0.75 (SD = 0.08), while the control group had a mean value of 0.76 (SD = 0.08). After four weeks of foot exercise, the intervention group showed an increase in mean ABPI to 0.97 (SD = 0.07), whereas the control group remained relatively unchanged at 0.75 (SD = 0.07).

Statistical analysis using the paired t-test indicated that the improvement in ABPI values within the intervention group was statistically significant ($p < 0.05$), suggesting that foot exercise effectively enhanced peripheral arterial circulation among participants at risk of PAD. No significant difference was observed in the control group.

These findings demonstrate that regular foot exercise can serve as a simple and practical intervention to improve lower extremity blood flow and potentially reduce the risk of PAD in young adults.

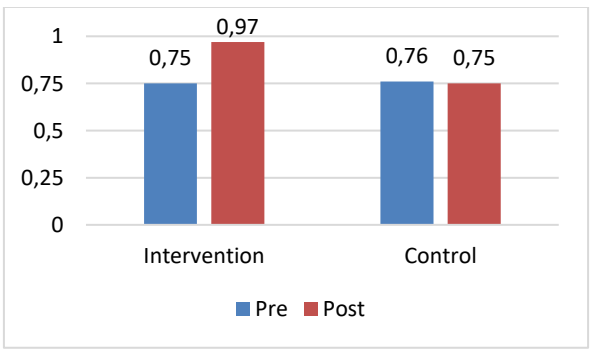

Figure 1. Comparison of Pre-test and Post-test ABPI Values

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Effect of Foot Exercise on ABPI Values

The effect of foot exercise on ABPI values was analyzed using the Wilcoxon test due to non-normal data distribution. In the intervention group, the test yielded a p-value < 0.001 (Table 2), indicating a statistically significant difference in mean ABPI values before and after foot exercise. The Wilcoxon signed-rank test showed a statistically significant increase in ABPI values after the foot exercise intervention ($p < 0.001$), indicating that the exercise program effectively improved peripheral arterial circulation among participants at risk of PAD. The observed difference followed a positive pattern across all respondents, meaning that the mean ABPI value after foot exercise was higher compared to the pre-intervention value. In the control group, the Wilcoxon signed-rank test indicated no significant difference between pre-test and post-test ABPI values ($p = 0.247$), suggesting that the absence of intervention did not lead to any improvement in peripheral arterial circulation (Table 3).

Table 2. Wilcoxon Test Results for the Intervention Group

variable	n	mean (min-max)	*p*-value
ABPI Pre-test	20	0.75 (0.58-0.83)	< 0.001
ABPI Post-test	20	0.97 (0.90-1.10)	

ABPI, ankle brachial pressure index

Table 3. Wilcoxon Test Results for the control Group

Variable	n	Mean (min-max)	*p*-value
ABPI Pre-test	20	0.76 (0.58-0.86)	< 0.001
ABPI Post-test	20	0.75 (0.62-0.90)	

ABPI, ankle brachial pressure index

DISCUSSION

Characteristics of participants

This study involved 40 participants with an initial ABPI value of ≤ 0.89. The majority of respondents were female (80%). Females are at a higher risk of developing diabetes mellitus (DM), which has implications for peripheral arterial disease (PAD), compared to males. This increased risk is attributed to a greater susceptibility to elevated body mass index and obesity among women. Central obesity is more prevalent in women (42%) compared to men (11.3%) (2). Additionally, hormonal factors and menstrual cycles contribute to fat accumulation, as fat tends to concentrate in specific areas more easily in women (Santosa & Listiono, 2017).

The respondents in this study were aged between 17 and 20 years, categorized as young adults (millennial age group). Although the risk of PAD due to diabetes mellitus typically occurs in individuals over 40 years old, millennials (>18 years) still exhibit an 11% risk of developing diabetes mellitus (Kementerian Kesehatan RI, 2020). The majority of respondents had a normal body mass index (18.5–25), accounting for 52.5%. However, 5% were classified as mildly obese and 2.5% as severely obese. Obesity is a well-established risk factor for diabetes mellitus. Hyperlipidemia, commonly associated with obesity, contributes to various health complications. It can impair blood flow and disrupt cellular and tissue function, particularly in the lower extremities, ultimately leading to PAD.

Effect of Foot Exercise on ABPI

The Ankle-Brachial Pressure Index (ABPI) is a key marker for assessing peripheral arterial disease, particularly in the lower extremities. An ABPI value of 0.89 is considered the optimal cutoff point for identifying PAD (Weragoda et al., 2016). In this study, the mean (min-max) ABPI value at baseline in intervention and control groups was recorded as 0.75 and 0.76,

respectively.

This study found that the exercise program effectively improved peripheral arterial circulation among participants at risk of PAD. Foot exercise is a nursing intervention categorized under Exercise Promoting: Stretching, performed sequentially and regularly using slow-stretch-hold movements aimed at enhancing muscle strength. During 15–20 minutes of foot exercise, muscle cells in the feet require energy supplied by blood flow from the heart through the femoral artery to the popliteal and dorsalis pedis arteries. This physiological response is evident from an increase in heart rate by 4–10 beats per minute post-exercise, indicating that the heart, as the central circulatory organ, provides additional energy to the muscle cells engaged during exercise. This is further supported by an observed rise in systolic blood pressure following the intervention (Malhotra & Moshal, 2024; Nayor et al., 2023).

Foot exercise involves movements targeting small muscles in the feet and improving blood circulation in various positions sitting, standing, or lying down. Its objectives include restoring muscle work capacity, accelerating wound healing, increasing mitochondrial volume density and oxidative capacity in muscle tissue, enhancing peripheral oxygen extraction, promoting peripheral vasodilation, improving muscle capacity and cardiac output, reducing restenosis incidence, and lowering end-diastolic pressure.

Moreover, resistance-based exercise can increase lean body mass, thereby boosting resting metabolic rate. This contributes to weight reduction, stress alleviation, and overall physical fitness. Exercise also positively modifies blood lipid profiles by increasing HDL cholesterol and reducing total cholesterol and triglyceride levels. These benefits are particularly significant for individuals at risk of PAD due to diabetes mellitus or cardiovascular conditions.

After 12 sessions of foot exercise over one-month, improved blood flow in the extremities is likely attributable to enhanced antioxidant activity (reduced oxidative stress), increased nitric oxide availability, elevated arterial pressure, arterial wall dilation, and reduced peripheral vascular resistance (Nayor et al., 2023).

This study has several limitations. First, participants were recruited from a single institution, which restricts the generalizability of the findings. Future research should include participants from diverse settings and demographic backgrounds to enhance external validity. Despite these limitations, this study represents the first evidence on the effectiveness of foot exercise in improving ABPI values among young adults at risk of PAD. Therefore, foot exercise can be recommended as a preventive strategy for this population group.

CONCLUSION

Foot exercise is effective in increasing ABPI values among adolescents at risk of PAD. The findings of this study provide evidence that structured foot exercise can serve as an effective preventive strategy against complications of PAD, particularly among young adults. Incorporating such exercise into routine health promotion programs may help improve peripheral circulation and reduce early vascular risk factors associated with diabetes mellitus and obesity

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CONFLICTS OF INTEREST

The authors declare that there are no relevant conflicts of interest.

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