

Optimizing Lower Limb Perfusion in Children With Diabetes Mellitus Through Buerger Allen Exercise

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Abstract

Background: The prevention of severe foot and lower limb complications in childhood diabetes mellitus requires close attention of nursing care and regular glycemic control.

Aim: To examine the influence of Buerger–Allen exercises on lower limb perfusion among diabetic children.

Methods: A quasi-experimental study was carried out in endocrinology and pediatric intermediate intensive care units at Assiut University Children's Hospital from November 2024 to July 2025. Sixty children with diabetes were recruited purposely and allocated to study and control groups. A structured questionnaire was used to gather demographic and medical history data, in addition to a tissue perfusion assessment tool which included biomarkers of local tissue perfusion (oxygen saturation, skin temperature and capillary refill time) and ankle brachial index scale

Results: Post-intervention showed statistically significant differences ($P < 0.001$) between the study and control groups in all the parameters measured including ABI, oxygen saturation , local skin temperature and capillary refill time.

Conclusion: Buerger-Allen exercises represent a beneficial nursing strategy to maximize the peripheral circulation and lower limb perfusion among pediatric diabetic patients.

Recommendation: Future research with larger sample sizes and extended follow-up duration is recommended to evaluate long-term vascular outcomes. Additionally, multicenter pediatric studies cross different healthcare settings are encouraged to enhance generalizability.

Keywords: Buerger Allen Exercise; Children; Diabetes Mellitus; Lower Limb Perfusion.

Introduction

Diabetes mellitus is a chronic metabolic disorder characterized by persistent hyperglycemia and associated with acute and chronic complications (Libman et al., 2022).The pathological effect is twofold, including both macro vascular problems, namely, stroke, peripheral arterial disease and coronary artery disease, and micro vascular ones, i.e., retinopathy, peripheral neuropathy and nephropathy. Mechanistically, persistent hyperglycemia leads to endothelial injury, which harms the microvasculature that supplies the peripheral nerves; it presents itself as pain, burning, numbness or tingling. Moreover, the impaired perfusion of lower limbs is a significant factor increasing the risk of infection, foot ulcer and potential amputation (Nugroho& Rosyid.,2026).

Clinical management of diabetes mellitus is a dualistic concept and it combines both pharmaceutical and lifestyle-based programs. Pharmacological therapy, including insulin and other hypoglycemic agents, plays a crucial role in controlling blood glucose levels. Non-pharmacological modalities include, weight control and dietary modification and are also crucial constituents of care. In this generalized approach to treatment, physical exercise is often mentioned as a pillar of effective disease management as a main principle of the treatment regimen (Ardika.,2026). One of the best non-pharmacological measures towards management of diabetes in children is the enhancement of lower limb circulation by means of therapeutic exercise. The different interventions such as relaxation techniques, warm-foot treatment and lower extremity exercises have been reported to increase collateral blood flow and improve tissue perfusion in the lower extremities (Lal & Kumar., 2025). The prevention of diabetic foot complications

has been a health concern around the world and Buerger Allen Exercises (BAE) are largely considered as a conservative and non-invasive nursing intervention to manage peripheral vascular impairment, it stimulate peripheral circulation, diminish venous stasis and enhance tissue oxygenation, and there are other effects of the exercises in aiding wound healing and alleviating the symptoms of peripheral neuropathy (Yammar et al., 2025).

Nurses have a central role in informing children with diabetes and their caregivers about the correct execution of BAE, proper positioning, sequencing and duration of the activity to ensure safety and effectiveness. Also the nurses have the task of following up on physiological reactions, evaluating the outcomes of lower limb perfusion and ensuring the exercise is an integral inseparable part of the overall diabetes treatment (Jannah et al., 2024).

Significance of the research

The rising trend of diabetes mellitus is a strategic world health crisis as the prevalence has increased threefold since 1980 to 422 million in 2014 and 3% in the period between 2000 and 2019 (Vaishya et al., 2024). This weight is especially increasing among the children populations with Type 1 and Type 2 diabetes rates increasing by about 2 percent and 5.3 percent per year, respectively (Wagenknecht et al., 2023). These tendencies increase the vulnerability of children with diabetes to impaired lower limb circulation, which is the antecedent of neuropathy, infection and possible amputation (Goyal & Vanita, 2025).

Buerger–Allen exercises have been extensively studied among adults with diabetes and have demonstrated beneficial effects on peripheral circulation. (Susiana et al., 2026). However, evidence regarding their effectiveness in pediatric remains limited. This gap in the literature highlights the need for further investigation within the context of pediatric diabetic care. Therefore; this study aims to examine the influence of BAE on lower-limb perfusion among diabetic children, contributing evidence to support preventive vascular care in this vulnerable population.

Aim of the study

To examine the influence of Buerger–Allen exercises on lower limb perfusion among diabetic children

Research Hypothesis

H₀: There are no statistically significant differences in ankle-brachial index, capillary refill time, local skin temperature and toe oxygen saturation between children with diabetes mellitus who receive Buerger Allen Exercise and those who receive routine care after the intervention.

H₁: There are statistically significant differences in ankle-brachial index, capillary refill time, local skin temperature and toe oxygen saturation between children with diabetes mellitus who receive Buerger Allen Exercise and those who receive routine care after the intervention.

METHODOLOGY

Study Design and Setting

The study followed a quasi-experimental design with random allocation of participant. The study was carried out at Assiut University Children Hospital in endocrinology and pediatric intermediate intensive care units.

Sample and Sampling Technique

A purposive sample of sixty children diagnosed with diabetes mellitus and meeting the inclusion criteria was recruited. G*Power (version 3.1.9.7) was utilized to calculate the sample size. With an independent-samples t-test model for comparing two groups, parameters of an effect size (f) of 0.65, a significance level $\alpha = 0.05$, and power (1 - β) of 0.89, a minimum baseline of 57 subjects was determined. In order to account for possible attrition 60 diabetic children were included and divided equally between the control and study group. Due to strict eligibility criteria and possible participant dropout due to intervention length, the number of eligible participants was limited.

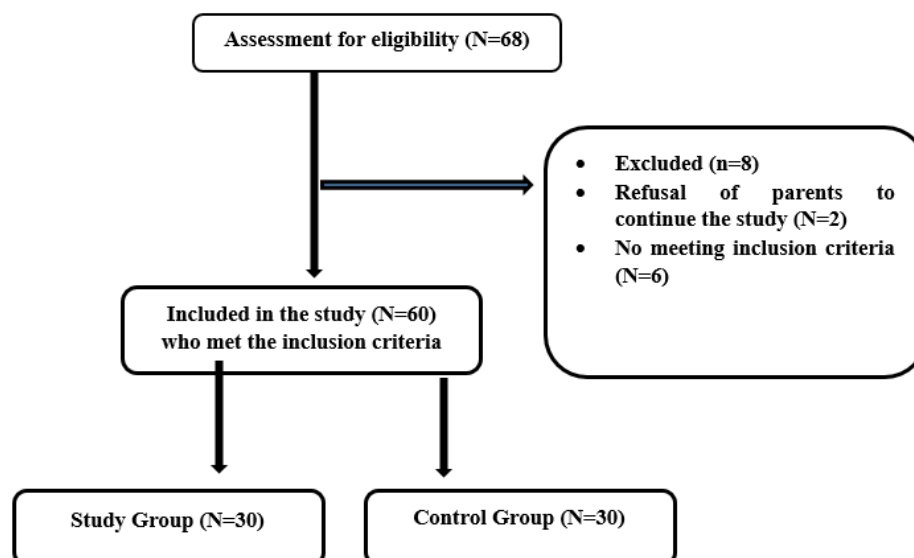


Figure: Flow diagram of the participants through the study

Randomization Procedure

To have an unbiased grouping we used a simple randomization protocol where we used a manual coin toss to allocate subjects at 1:1 ratios. According to this binary approach a score of tails would put a participant in the study group and a score of heads would put them in the control group.

Inclusion criteria

Recruitment of children was done on the basis of certain inclusion criteria so as to have the right participation. The criteria that qualified the participants included the following: 6-18 years old, diagnosed with diabetes mellitus over six months and who were conscious, cooperative and capable of following verbal instructions. Only children with ankle brachial index from 0.4 to 0.9 .

Exclusion Criteria

The children were excluded if they had any disabilities or conditions of the lower limbs such as amputation, neuropathy or peripheral vascular conditions such as a deep vein thrombosis (DVT).

Study Tool

Data collection relied on two structured tools

Tool I: A researcher-designed structured tool that addressed participants' demographic details (age, gender, residence, and educational level) and other pertinent medical history, such as family history of diabetes mellitus, disease duration, length of hospitalization and past causes of hospitalization.

Tool II: lower limb tissue perfusion assessment tool consisting of two parts.

The first part assessed biomarkers of local tissue perfusion adopted from Hegazy et al. (2023), including capillary refill time (CRT) which is considered normal at less than 2 seconds and indicative of impaired perfusion when exceeding 2 seconds; local skin temperature determined through palpation as an indicator of peripheral vasoconstriction; and oxygen saturation assessed at the great toe using a pulse oximeter. We used ABI scale provided by Zahran et al. (2018) to assess the status of peripheral vascularity. This index is computed as a quotient, the highest systolic pressure measured at the ankle (of either the dorsalis pedis or posterior tibial artery) and divided by the highest brachial systolic pressure measured at either arm, using an appropriately sized blood pressure cuff. The cuff size was selected according to the circumference of the limb. Before measurement, the child was placed in the supine position and allowed to rest for 5–10 minutes.

Scoring system:

ABI values were classified as normal (>0.90), mild impairment ($0.71-0.90$), moderate impairment ($0.41-0.70$) and severe impairment (≤ 0.40).

Procedure

The study followed four phases: preparatory phase, assessment, implementation and evaluation.

The preparatory phase.

-During the preparatory phase necessary approvals were obtained from hospital authorities and faculty of nursing.

- A pilot study was conducted on 10 % (6) of participant children to assess tool clarity and usability, requiring no modifications.
- Content validity was evaluated using contents validity index by 5 professionals with expertise in pediatrics and pediatric nursing and it was 97%.
- **Reliability:** The study tools' reliability was assessed using Cronbach's alpha. Tool I demonstrated a reliability coefficient of 0.88. Tool II showed high reliability, with coefficients of 0.895 for the biomarkers of local tissue perfusion and 0.912 for (ABI) scale
- **Ethical Consideration:** Ethical approval was obtained from the Research Ethics Committee of the Faculty of Nursing, Assiut University, Egypt (Approval No. 1120240906) on 27 October 2025.

Assessment phase

- The researcher went to the pediatric intermediate care and the endocrinology unit, where all eligible children meeting the inclusion criteria were selected. The children were subsequently allocated at random to the study or control groups. The study group underwent the intervention and routine care, while the control group received routine care.
- The Demographic and medical information of the children were obtained from their medical records.
- The researcher clarified the study purpose to the selected children and their parents.
- Initial assessment of lower limb perfusion was carried out individually for all children in the study and control groups using Tool II.

Implementation phase:

- The researcher individually educated each child and their parents about the Buerger Allen Exercises, including their benefits, the correct method of performing them, the duration and frequency of the exercises, as well as the timing of the demonstrations.
- The researcher used illustrated pictures to demonstrate the Burger Allen Exercises.
- The children performed the exercises under the researcher's supervision for 30–45 minutes, twice daily, with a six-hour interval between sessions, five days per week over a two-week period (20 sessions).
- Prior to the exercise sessions, children were instructed to wear comfortable clothing, avoid strenuous activity, and report any unusual symptoms. Children were closely observed for signs of pain, dizziness, or fatigue, and any adverse events were promptly documented and addressed. No adverse events occurred during intervention.
- The sessions were conducted in the pediatric intermediate care unit and the endocrinology unit, in the children's room, during the morning shift (9 a.m.) and evening shift (3 p.m.). Each session included three main steps.
- **Step 1 Elevation;** the children lay in a supine position, and their lower limbs were raised to a 45–90° angle supported until blanching of the skin occurred approximately two to three minutes.
- **Step 2 Dependency;** the legs and feet were lowered till redness appeared, taking about three to five minutes.
- **Step 3 Horizontal;** the legs were positioned horizontally on the bed for three to five minutes.

Evaluation phase

Children's lower limb perfusion was evaluated using tool II following the completion of the twenty sessions.

Statistical Analysis

The Statistical Package for Social Sciences (SPSS), version 23, was used to analyze the data. The results were summarized using means, standard deviations, frequencies, and percentages. The chi-square test was applied to investigate the relationships among categorical variables. Mean values were compared using independent t-tests. The threshold for statistical significance was $p < 0.05$.

Results

Table 1: Demographic characteristics of the studied children (n=60)

	Study (n=30)	Control (n=30)	X²	P. value

	No.	%	No.	%		
Age						
6 – <9 years	1	3.3	2	6.7	0.578	0.902
9 – <12 years	4	13.3	5	16.7		
12 – <15 years	9	30	9	30		
15 – 18 years	16	53.3	14	46.7		
Mean±SD (range)	14.2±3.1(6-18)		13.8±3.1 (7-18)		t = 0.503	0.617
Gender						
Male	9	30	15	50	2.50	0.114
Female	21	70	15	50		
Residence						
Urban	11	36.7	15	50	1.086	0.297
Rural	19	63.3	15	50		
Education level						
Read and write	3	10	4	13.3	0.693	0.875
Primary education	4	13.3	5	16.7		
Preparatory education	10	33.3	11	36.7		
Secondary education	13	43.3	10	33.3		

The t-test and Chi-square test were used

Table 1: Presents no statistically significant differences between both groups before intervention. About half of children were aged 15–18 years (study: 53.3%, control: 46.7%), and females predominated in the study group (70% vs. 50%). Among the study group, 63.3% lived in rural areas, compared with 50% in the control group.

Table 2: Medical characteristics of the studied children (n=60)

	Study (n=30)		Control (n=30)		X ²	P. value
	No.	%	No.	%		
Family history of DM						
Yes	30	100	29	96.7	0.950	0.330
No	0	0	1	3.3		
Duration of disease						
> 6: < 12 months	0	0	0	0	1.017	0.313
12: < 18 months	1	3.3	0	0		
≥ 18 months	29	96.7	30	100		
Duration of hospital stays						
4:5 days	1	3.3	0	0	3.158	0.206
6:7 days	2	6.7	0	0		
>7 days	27	90	30	100		
Past hospitalization						
Yes	30	100	30	100	-	-
If yes the cause						
Cardiac problem	5	16.7	4	13.3	1.706	0.636
Diabetic ketoacidosis	22	73.3	21	66.7		
Renal problem	3	10	5	16.7		

Chi-square test

Table 2: Indicates a high prevalence of positive family history of diabetes mellitus in both groups (100% in the study group and 96.7% in control group). The disease duration was greater than 18 months in 96.7% of the study group and 100% of the control group. In addition, all children in both groups (100%) having a history of hospitalization. Furthermore, diabetic ketoacidosis was the primary reason for prior hospitalization representing 73.3% of the study group and 66.7% of the control group.

Table 3: Distribution of Biomarkers of local tissue perfusion among the study and control groups before and after intervention

Biomarkers of local tissue perfusion assessment before and after intervention						
	Study (n=30)		Control (n=30)		X ²	P. value
	No.	%	No.	%		
Before intervention						
Capillary refill time						
Less than 2 seconds	0	0	1	3.3	4.023	0.134
2 second	3	10	8	26.7		
longer than 2 seconds	27	90	21	70		
local skin temperature						
Cold	29	96.7	29	96.7	0.000	1.00
Hot	1	3.3	1	3.3		
Oxygen saturation						
70: < 80	1	3.3	1	3.3	0.000	1.00
80 :< 90	28	93.3	28	93.3		
≥90	1	3.3	1	3.3		
After intervention						
Capillary refill time						
Less than 2 seconds	29	96.7	0	0	59.250	<0.001**
2 second	0	0	15	50		
longer than2 seconds	1	3.3	15	50		
local skin temperature						
Cold	0	0	27	90	52.500	<0.001**
Hot	0	0	1	3.3		
Warm	30	100	2	6.7		
Oxygen saturation						
70: < 80	0	0	0	0	43.866	<0.001**
80 :< 90	0	0	26	86.7		
≥90	30	100	4	13.3		

Chi-square test ** Highly statistically significant difference $p < 0.001$.

Table 3: Displays that, prior to the intervention, there was no statistically significant change in terms of capillary refill time, local skin temperature and oxygen saturation between the children in the study and the control groups. Additionally, results showed that children in both groups showed highly statistically significant changes post-application of the Buerger–Allen exercise (BAE) ($p < 0.001$).

Table 4: Distribution of ankle brachial index levels among children in the study and control groups before and after intervention (n = 60)

(ABIs) before and after intervention						
	Study (n=30)		Control (n=30)		X ²	P. value
	No.	%	No.	%		
Before intervention						
Ankle Brachial Index Scale						
Above 0.90 normal tissue perfusion)	0	0	0	0	5.496	0.064
(0.71 – 0.90 mildly impaired tissue perfusion)	6	20	11	36.7		
(0.41 – 0.70 moderately impaired tissue perfusion	20	66.7	19	63.3		
(0.0 – 0.40 severely impaired tissue perfusion).	4	13.3	0	0		
After intervention						
Ankle Brachial Index Scale						
(Above 0.90 normal tissue perfusion)	29	96.7	1	3.3	6.573	<0.001**
(0.71 – 0.90 mildly impaired tissue perfusion)	1	3.3	13	43.3		
(0.41 – 0.70 moderately impaired tissue perfusion	0	0	16	53.3		
(0.0 – 0.40 severely impaired tissue perfusion).	0	0	0	0		

Chi-square test ** Highly statistically significant difference $p < 0.001$.

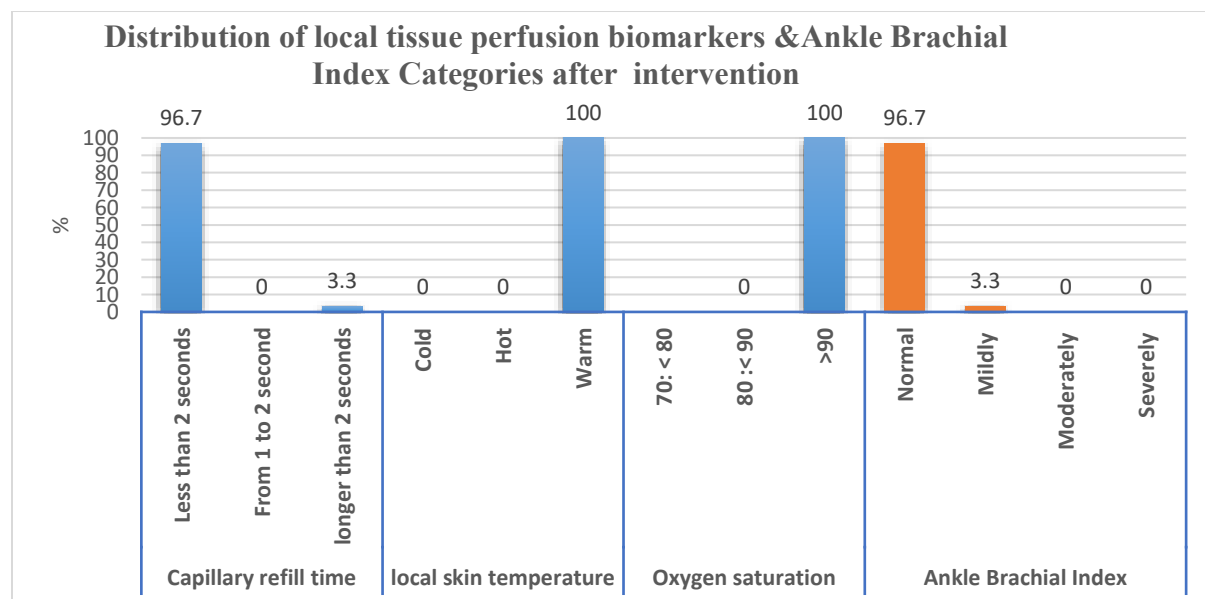


Figure: 1 Column chart showing the percentage distribution of local tissue perfusion biomarkers and ankle brachial index levels among the studied children after the intervention

Fig: 1 Shows improvement in local tissue perfusion biomarkers and ankle brachial index (ABI) categories following the intervention.

DISCUSSION

Non-pharmacological interventions such as BAE are recognized as safe, affordable, and easily implementable nursing techniques to improve blood flow to the limbs and overall well-being in patients with diabetes Susiana et al. (2026). In this context, the present study examined the influence of BAE on lower-limb perfusion among diabetic children.

The results presented that both groups were homogeneous at baseline in terms of age, gender, residence and educational attainment, without significant statistical differences between them. This comparison enhances the study's internal validity, consistent with Nguyen and Xie (2021), who emphasized that baseline comparability, is essential to avoid bias in intervention outcomes.

In the present study, the majority of participant was adolescents aged 15–18 years a population particularly sensitive to vascular problems. This could be explained by the fact that micro vascular problems were linked to the pubertal age group, most likely as a result of behavioral variables influencing adherence, elevated insulin demand and extended hyperglycemia. These findings align with Hovestadt et al. (2022) and Msanga et al. (2020), who reported higher HbA1c levels and higher rates of small-vessel complications were observed in older children and adolescents with diabetes. Irwandy et al. (2025) also showed that the risk of neurovascular problem of the lower limbs in children with diabetes is increased by age and length of disease.

Regarding child gender, more than two-thirds of the study group and half of the control group were female. This is consistent with Adege et al. (2025), who stated that female children represented the majority of their diabetic pediatric sample. This also in line with de Vries et al. (2023) who indicate that girls with diabetes are more vulnerable to complications than boys, however this finding opposed Madrigal et al. (2020) found that male children slightly predominated in children with diabetes. From the perspective of the researcher, the increased susceptibility of female children with diabetes to complications may be related to pubertal hormonal changes in girls that contribute to greater insulin resistance and poorer glycemic control. In addition, higher HbA1c levels and a greater prevalence of obesity and dyslipidemia among females may increase metabolic risk.

Based on the study results, more than half of the children in the study group were from rural areas, compared to half of them in the control group. From the perspective of the researcher, this can be explained by the fact that children in rural areas may be more likely to suffer from complications because they have less access to specialized care, use insulin pumps and continuous glucose monitoring less frequently and face socioeconomic obstacles as confirmed by Tilden et al. (2024).

Medical history analysis revealed that nearly all participants had a family history of DM, supporting the strong hereditary influence reported by Hedlund et al. (2024) and Zahran et al. (2018). Also, the majority of children had disease duration longer than 18 months. From the perspective of the researcher the predominance of children with a diabetes duration longer than 18 months can be attributed to the progressive development of microvascular changes in type 1 diabetes or type 2, and this supported with Neubauer-Geryk et al. (2024) who reported that prolonged hyperglycemia leads to early endothelial dysfunction and reduced peripheral blood flow which usually emerge after the first year of disease.

In the present study, all children in both groups had a previous history of hospitalization, with diabetic ketoacidosis (DKA) identified as the primary cause. This result might be explained by the fact that DKA is an acute condition that can be fatal, which requires immediate inpatient management and close monitoring. This result corroborates the observations by Wankanit et al. (2025), who identified DKA as the most common cause of hospitalization among diabetic children.

The current investigation found no statistically significant variations in baseline oxygen saturation, local skin temperature and capillary refill time between the study and control groups. However, once the Buerger-Allen exercise was implemented, the study group showed a highly significant improvement over the control group. These results imply that BAE improves tissue oxygenation, capillary refill time and local skin temperature by increasing peripheral circulation through alternating postural shifts of venous return and arterial inflow. This is in agreement with Hegazy et al. (2023) who confirmed the efficiency of BAE in improving local skin temperature and color while

reducing capillary refill time in children with impaired circulation. Moreover, consistent with Nugroho and Rosyid. (2026) who asserted that patients performed BAE experienced marked enhancement in skin temperature, peripheral pulses, skin color, sensation, and capillary refill time. Similarly, Qomariah et al. (2023) showed that BAE dramatically enhances peripheral perfusion markers, such as oxygen saturation, capillary refill time and local skin temperature. In contrast, El Banna et al. (2021) reported that the study group continued to exhibit delayed capillary refill time compared with the control group.

Additionally, the post-intervention ankle-brachial index values showed a significant improvement ($p < 0.001$), reflecting enhanced blood flow to the limbs. These results are consistent with several previous investigations Dewi et al. (2025) who confirmed that BAE significantly improves ABI and overall peripheral circulation among diabetic patients. Similarly, Ahmed Saleh et al. (2024) and Ibrahim et al. (2024) reported that BAE leads to notable improvements in ABI values and enhances lower-extremity blood flow.

Notably, improvements were observed in both microcirculatory biomarkers and ABI measurements following the intervention. This finding is supported by Ahmed et al. (2025).

Based on the statistically significant findings observed after the intervention, the research hypothesis was supported and the null hypothesis (H_0) was rejected.

Implication

BAE is easily integrated into pediatric nursing practice to improve peripheral circulation, help maintain mobility and minimize the chances of diabetes-related complications such as peripheral neuropathy. In addition, the training of children and caregivers on how to use BAE at home to practice it can facilitate self-management, continuity of care, and long-term health of the lower limbs in hospital and community-based pediatric diabetes care environments.

Limitation

The study involved a small sample and a brief intervention period, which may limit generalizability. Future studies with longer follow up are recommended to assess sustained vascular and clinical effects.

CONCLUSION

Buerger–Allen exercises led to a marked improvement in lower limb perfusion in children with diabetes indicating their nursing value. Children in the study group exhibited statistically significant improvements in key indicators of peripheral perfusion, including oxygen saturation, skin temperature, capillary refill time and ABI scale relative to the control group ($P < 0.001$).

Recommendations

We propose the inclusion of the Buerger-Allen Exercises in the routine pediatric diabetes care as an adjunctive nursing intervention to promote peripheral circulation in the lower extremities. BAE is ideal in the routine management of diabetic feet due to its nature of being non-invasive, cost-effective and easy to manage. To promote consistent clinical nursing practice, a uniform standardized guideline handbook detailing the BAE approach and its benefits should be developed. Moreover, future research efforts ought to employ larger and more diverse samples to compare Buerger-Allen Exercises' efficacy in relation to other physical or pharmacological interventions.

Conflict of Interest

The authors confirm that they have no conflicting interests that might affect the study.

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