

Meta-Analysis on the Effect of Buerger Exercise on Lower Extremity Perfusion in Diabetic Patients

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Abstract

Diabetes Mellitus (DM) is a grave lifelong metabolic condition that poses a significant threat to the health of individuals worldwide. The aim of this article is to systematically evaluate the effect of Buerger-Allen Exercise (BAE) on low extremity perfusion among patient with diabetes mellitus (DM) through meta-analysis. Computer retrieval of patients with diabetes in PubMed, Web of Science, The Cochrane Library, Embase, CNKI, Wanfang Database, Weipu Chinese Science and Technology Journal Database and China Biomedical Literature Database. Randomized controlled and experimental studies of Buerger motion were both retrieved since the literature establishment on October 2022. Two researchers screened the literature and extracted data according to the inclusion and exclusion criteria. Cochrane collaboration tools and ROBINS-I tools were used to evaluate the quality of randomized controlled trials and class experiments respectively. RevMan 5.4 software was carried out for Meta-analysis. Finally, 12 literatures were extracted, including 5 randomized controlled trials, 7 types of experiments and 742 diabetes patients. The meta-analysis showed that the BAE was significantly effective in the improvement of Ankle/brachial index (ABI) scores [MD=0.14, 95%CI (0.10, 0.18) , P<0.01]. In conclusion, our results demonstrate that BAE effectively improves foot perfusion among patients with diabetes mellitus.

Keywords: Diabetes mellitus; Buerger Allen Exercise; Low extremity perfusion; Meta-Analysis

1. INTRODUCTION

Diabetes Mellitus (DM) is a grave lifelong metabolic condition that poses a significant threat to the health of individuals worldwide. In China alone, the prevalence of diabetes is estimated to be as high as 141 million, with approximately one in every 14 Chinese individuals affected by the disease ^[1]. A nationwide epidemiological study conducted across 31 provinces and cities between 2015 and 2017 has revealed that the standardized prevalence of diabetes among adults aged 18 years and older in China is 12.8% (based on the American Diabetes Association criteria for 2018) or 11.2% (based on the World Health Organization criteria from 1999), and this figure is on an annual rise ^[2]. With the global increase in the prevalence and incidence of diabetes, the associated complications are also multiplying. Lower extremity vascular disease is a common complication of diabetes and a leading cause of disability and mortality. In severe cases, it can

lead to chronic and refractory diabetic foot, which may necessitate amputation. This not only increases the economic burden on DM patients but also greatly reduces their quality of life ^[3].

Buerger's exercise, also known as Buerger Allen exercise (BAE), is an exercise regimen developed by Leo and refined by Arthur Allen. It is predominantly used in clinical settings to alleviate symptoms in patients with lower extremity ischemia. The exercise involves the following steps: ①The patient lies flat and elevates their lower extremity to approximately 45-60 degrees for about 2 minutes; ②The patient sits and dangles their feet, performing dorsiflexion and plantar flexion, along with curling and straightening their toes, for a duration of 3 minutes ^[4]; ③The patient lies flat and warms their feet with a blanket for about 5 minutes. Each session typically involves 3-6 cycles and is repeated 2-4 times a day. Buerger's exercise is extensively utilized in the

treatment of lower extremity vascular disease patients and has been demonstrated to be effective in enhancing lower extremity perfusion and improving ankle-brachial index (ABI) indicators [5-6].

However, some studies have indicated that short-term BAE exercise (lasting 4 weeks) does not exhibit statistical significance in improving lower extremity ischemia, ABI, and blood flow dynamics in the dorsalis pedis artery and tibial artery of patients with diabetic foot [7]. Moreover, the sample sizes of these studies are limited, and few are based on comprehensive research. There has been no systematic meta-analysis conducted to date. Therefore, this study aims to evaluate the impact of Buerger's exercise on lower extremity perfusion in diabetic patients through meta-analysis, with the goal of providing evidence-based support for clinical practice.

2. DATA AND METHODS

2.1. Inclusion and Exclusion Criteria

The inclusion criteria are as follows: ① Study type: randomized controlled trials (RCTs) and quasi-experimental studies (CCTs) on the effect of BAE on diabetic patients' lower extremity perfusion; Study subjects: patients aged ≥ 18 years with a definite diagnosis of diabetes (type 1 or type 2 diabetes); Intervention measures: BAE group received Buerger exercise, control group received routine care; ④ Outcome measures: ABI; ⑤ Language: Chinese or English. Exclusion criteria: ① Literature without control group; ② Only abstracts or unable to obtain full text; ③ Duplicate publications.

2.2. Search Strategy

The computer conducted a comprehensive search across multiple databases, including PubMed, Web of Science, The Cochrane Library, Embase, China National Knowledge Infrastructure, WanFang Database, VIP Chinese Science and Technology Journal Database, and China Biomedical Literature Database. The search employed a combination of subject headings and free text terms. The Chinese search terms are "Diabetes/Diabetic Foot/Diabetic Foot Ulcer," "Buerger Movement/BAE," and "lower extremity perfusion." In English, the search terms were "Diabetes/Diabetic Foot/Diabetic Foot Ulcer," "Buerger Allen Exercise/BAE," and "lower extremity perfusion." For example, in the Embase database, the search formula used was (diabetes OR diabetic OR diabetic foot OR diabetic foot ulcer) AND (Buerger Allen

Exercise OR BAE) AND (lower extremity perfusion). The search timeframe was from the inception of the databases up to October 20, 2022. Additionally, the literature cited within the included studies was traced.

For literature screening and data extraction, two postgraduate students who had been trained in evidence-based nursing methodology independently reviewed the literature against predefined inclusion and exclusion criteria. The screening process involved reading the titles, abstracts, and full texts of all the retrieved literature, utilizing Endnote literature management software to assist in the organization. In the event of discrepancies, the two researchers would discuss and resolve them, or seek a third researcher's input for final decisions. The data extracted from the studies included details such as the author, publication year, country of origin, study design, sample size, intervention measures, and outcome indicators.

2.3. Literature Quality Evaluation

Two researchers independently assessed the risk of bias in the randomized controlled trials by applying the quality assessment criteria developed by the Cochrane Collaboration. This involved examining seven specific items for each study included in the review. For the quasi-experimental studies, the researchers utilized the ROBINS-I (Risk of Bias in Non-randomized Studies of Interventions) tool, which consists of nine items to evaluate the quality of these studies. In the event of disagreements, a third researcher was consulted to resolve the disputes and make a final decision.

2.4. Statistical Methods

RevMan 5.4 software was used for Meta-analysis. The continuous variables involved in this study were expressed by mean difference (MD) or standardized mean difference (SMD) and a 95% confidence interval (95% CI). A chi-square test was used to assess heterogeneity. If $P > 0.05$ and $I^2 < 50\%$, there was no significant statistical heterogeneity between the studies, and a fixed effect model was used for Meta-analysis. If $P < 0.05$ and $I^2 > 50\%$, there was significant statistical heterogeneity between the studies, and a random effect model was used to calculate the combined effect. $P < 0.05$ was considered statistically significant.

3. RESULTS

3.1. Literature Search Results

A total of 509 articles were initially retrieved, including 432 in English and 77 in Chinese, and

after removing duplicates, 237 articles were remaining. After reading the titles, abstracts, and full text, 12 articles were finally included, of

which 10 were in English and 2 were in Chinese, for a total of 742 diabetic patients. The literature screening process is shown in Figure 1.

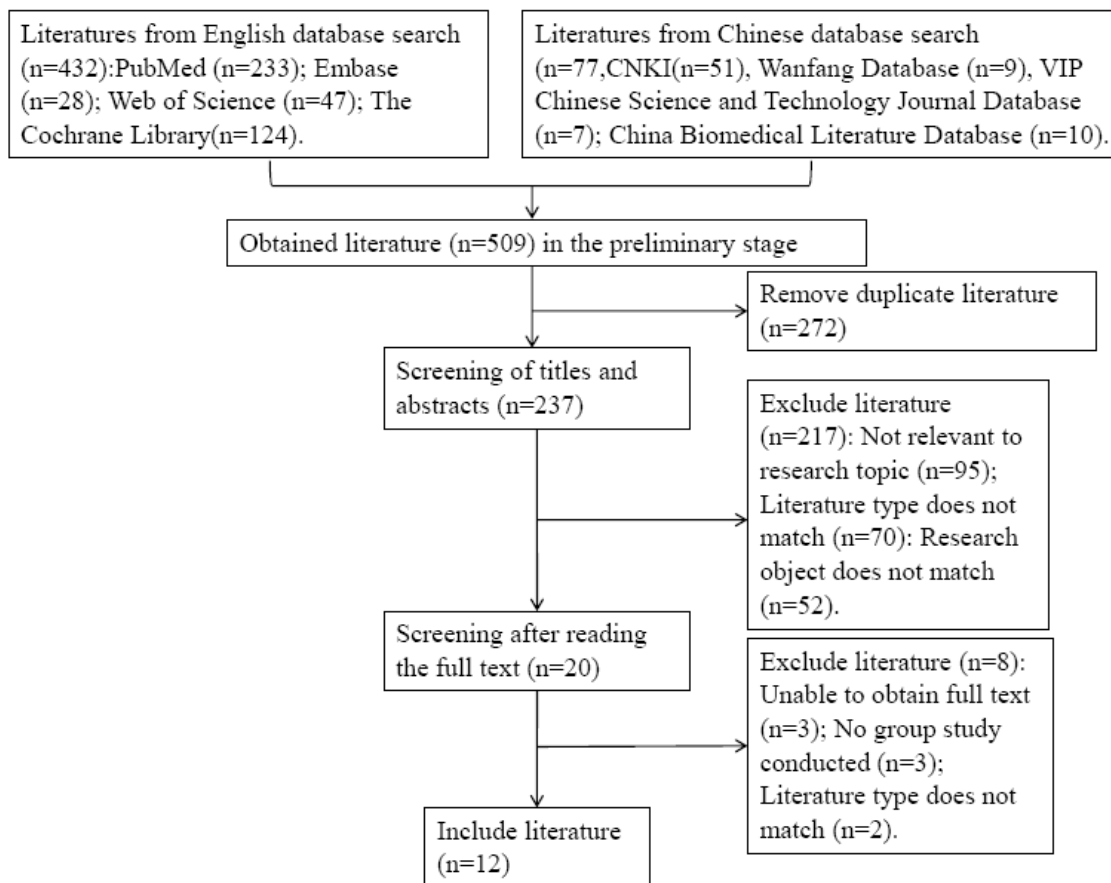


Figure1. Flow chart of literature screening

3.2. Basic Characteristics of Inclusive Literature and Methodological Quality Evaluation Results

In the 12 included articles, all study groups received Buerger exercise, and the control groups received standard nursing (ST). Among the 11 articles, the specific steps, exercise periods, and exercise time of Buerger exercise were described. The other basic characteristics of the included literature are shown in Table 1. The methodological quality evaluation results of the 5 RCTs included are shown in Table 2, and the results of the 7 CCTs included are shown in Table 3.

3.2.1. Effect of Buerger Exercise on ABI in Diabetic Patients

In this study, a total of 12 studies were included, of which 7 [10-13,15,16,18] could be combined for Meta-analysis, and the outcome measure was ABI. Other outcome measures such as diabetic foot screening scale score (In low's score) [14], diameter (D), time average mean velocity (TAMEAN), blood flow volume (FV), toe brachial index (TBI), and average blood flow

velocity of the dorsal artery (DAMV) were only assessed by a single study [7,20], so Meta-analysis could not be performed and descriptive analysis was performed.

Five studies [10-12,16-18] included 300 diabetic patients who reported the effect of Buerger exercise on ABI in diabetic patients. There was significant heterogeneity between the studies ($P = 0.001$, $I^2 = 77\%$), and a random effect model was used for Meta-analysis. The results are shown in Figure 2. Compared with the ST group, the ABI of the BAE group improved, and the ABI of the BAE group was higher than that of the ST group, with a statistically significant difference [MD = 0.14, 95%CI (0.10, 0.18), $P < 0.01$].

3.2.2. Effect of Buerger Exercise on ABI in the Left Leg of Diabetic Patients

Two studies [13,15] included 90 diabetic patients who reported the effect of Buerger exercise on ABI in the left leg of diabetic patients. There was no significant heterogeneity between the two studies ($P = 0.28$, $I^2 = 14\%$), and a fixed effect model was used for Meta-analysis. The

results are shown in Figure 3. Compared with the ST group, the ABI of the left leg of the BAE group improved significantly, with a statistically significant difference [MD = 0.16, 95% CI (0.11, 0.21), P < 0.01].

3.2.3. Effect of Buerger Exercise on ABI in the Right Leg of Diabetic Patients

Two studies [13,15] included 90 diabetic patients who reported the effect of Buerger exercise on

ABI in the right leg of diabetic patients. There was no significant heterogeneity between the two studies (P = 0.25, I2 = 24%), and a fixed effect model was used for Meta-analysis. The results are shown in Figure 4. Compared with the ST group, the ABI of the right leg of the BAE group improved, and the difference was statistically significant [MD = 0.17, 95% CI (0.10, 0.25), P < 0.01].

Table1. Characteristics of included studies (n=12)

Article	Country	Type	Age (Year)	Samples BAE/ST	Sex (%)		Procedure	Test group	Control group	Outcome indicators
					BAE	ST				
John J 2015 ^[10]	India	CCT	40~80	30/30	M : 60% F : 40%	M : 27% F : 73%	1~20	Tid, 6min/per interval, 6h, 5d	ST	ABI
Towar M 2017 ^[11]	India	CCT	>35	30/30	M : 66.67% F : 33.33%	M : 70% F : 30%	5~20	Tid, 12~13min/per, 5d	ST	ABI
Bhuvaneshwari S 2018 ^[12]	India	RCT	31~65	30/30	M : 36.67% F : 63.33%	M : 40% F : 60%	≥0	Qid, 15min/per, 5d	ST	ABI
Kumari A 2019 ^[13]	India	RCT	≥18	30/30	M : 50% F : 50%	M : 26.7% F : 73.3%	Not mentioned	Tid, 7~11min/per, 5d	ST	ABI, CRT
Thakur P 2019 ^[14]	India	CCT	>39	30/30	Not mentioned	Not mentioned	Not mentioned	Tid, 20min/per, 2d	ST	ABI In low's score
Digal PE 2019 ^[15]	India	RCT	>30	15/15	M : 66.67% F : 33.33%		Not mentioned	Not mentioned	ST	ABI
Sathya K 2019 ^[16]	India	CCT	≥30	30/30	Not mentioned	Not mentioned	Not mentioned	Tid, interval 6h, 30min/per, 5d	ST	ABI
Meizhen Lai 2019 ^[7]	China	RCT	BAE : 62.85 ± 6.18 ST : 64.20 ± 8.64	20/20	M : 50% F : 50%	M : 50% F : 50%	10.72 ± 7.83	Tid, 20min/per, 12w	ST	ABI, D, TAMEAN, FV, TBI
Sasi RK 2020 ^[17]	India	CCT	55.30 ± 4.58	50/50	M : 72% F : 28%	M : 82% F : 18%	Not mentioned	12~13min/per, 3d	ST	ABI,

Table1. Characteristics of included studies (n=12)

Article	Country	Type	Age (Year)	Samples BAE/ST	Sex(%)		Procedure	Test Group	Control Group	Outcome indicators
					BAE	ST				
Margret 2021 ^[18]	India	CCT	Not mentioned	30/30	M : 50% F : 50%	M : 57% F : 43%	Not mentioned	Tid, 30min/per, 5d	ST	ABI
Gavit Pritam V 2021 ^[19]	Not mentioned	CCT	40~70	30/30	M : 73.33% F : 26.67%		≥1	17~23min/per	ST	ABI
Jinlan Zhao 2022 ^[20]	China	RCT	BAE : 61.3 ± 11.7 ST : 61.5 ± 12.3	46/46	M : 54.35% F : 45.65%	M : 60.87% F : 39.13%	Not mentioned	Oid, 10min/per, 7d	ST	ABI DAMV

Table2. Methodological quality evaluation of 5 included randomized controlled trials (n=5)

Article	Random selection	Allocation Concealment	Blinding of Participants and Personnel	Blinding of Outcome Assessment	Completeness of Outcome Measures	Selective Reporting	Other Bias	Quality Rating
Bhuvaneshwari S 2018 ^[12]	Obscure	Obscure	Obscure	Obscure	Low	Low	Low	B
Kumari A 2019 ^[13]	Low	Obscure	Obscure	Obscure	Low	Low	Low	B
Digal PE 2019 ^[15]	Obscure	Obscure	Obscure	Obscure	Low	Low	Low	B
Meizhen Lai 2019 ^[7]	Low	Low	Low	Low	Low	Low	Low	A
Jinlan Zhao 2022 ^[20]	Obscure	Obscure	Obscure	Obscure	Low	Low	Low	B

Table3. Methodological quality evaluation of 7 included quasi-experimental studies (n=7)

Article	①	②	③	④	⑤	⑥	⑦	⑧	⑨
John J 2015 ^[10]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Towar M 2017 ^[11]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Obscure	Yes
Thakur P 2019 ^[14]	Yes	Obscure	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sathya K 2019 ^[16]	Yes	Yes	Yes	Yes	Obscure	Yes	Yes	Yes	Yes
Sasi RK 2020 ^[17]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Margret 2021 ^[18]	Yes	Yes	Yes	Yes	Obscure	Yes	Yes	Yes	Yes
Gavit Pritam V 2021 ^[19]	Yes	Yes	Yes	Yes	Yes	Obscure	Yes	Yes	Yes

Note:

- ① Whether the causal relationship in the study is clearly stated;
- ② Whether the baselines of each group are comparable;
- ③ Whether the other measures accepted by each group except for the intervention to be verified are the same;
- ③ Whether a control group has been established;
- ⑤ Whether multi-dimensional measurements of the outcome indicators are performed before and after the intervention;

- ⑥ Whether the follow-up is complete, and if not, whether the loss to follow-up is reported and measures are taken to deal with it;
- ⑦ Whether the same method is used to measure the outcome indicators of each group of research subjects;
- ⑧ Whether the measurement method of the outcome indicators is credible;
- ⑨ Whether the data analysis method is appropriate"

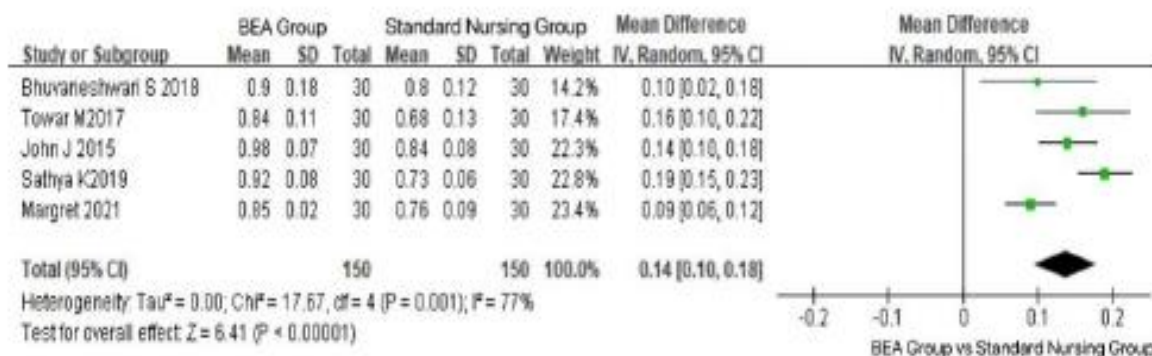


Figure2. Effect of BAE on ABI in diabetes patients

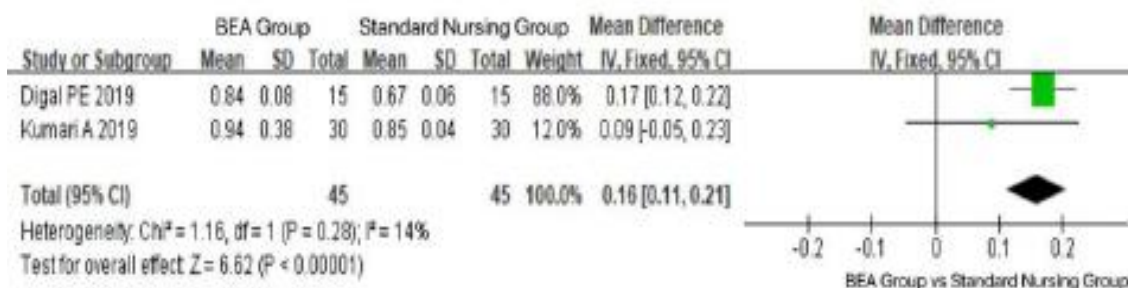


Figure3. Effect of BAE on ABI of left leg in patients with diabetes

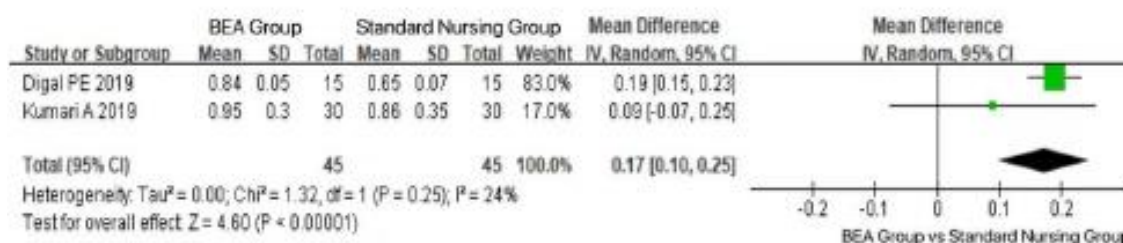


Figure4. Effect of BAE on ABI of right leg in patients with diabetes

3.2.4. Descriptive Analysis of Other Included Literature

According to the document, two additional randomized controlled trials have reported on the effectiveness of Buerger exercise on ABI in diabetic patients. Zhao Jinlan et al. [20] showed that 7 days of Buerger exercise significantly improved the prevention and treatment of lower extremity vascular disease in diabetic patients,

with their ABI and dorsal artery mean blood flow velocity significantly increased (P<0.05). Lai Meizheng [7] found that the differences in ABI, TBI, D, TAMEAN, FV and other values between the intervention 4 weeks and before the intervention were not statistically significant (P>0.05), but as the intervention time extended, the differences between the intervention 12 weeks and before the intervention were

statistically significant ($P < 0.05$), suggesting that Buerger exercise can improve related indicators of lower extremity hemodynamics and lower extremity ischemia in diabetic patients.

Sasi RK et al.^[17] and Gavit Pritam V et al.^[19] assessed the effectiveness of Buerger exercise on lower extremity perfusion in diabetic patients in other ways, and both studies showed that Buerger exercise can significantly improve lower extremity perfusion in diabetic patients. The standard deviation of ankle brachial pressure indices (ABPI) scores on the first day (0.07 ± 0.01), second day (0.05 ± 0.02), and third day (0.19 ± 0.01) was $p < 0.01$, indicating a statistically significant difference.

Thakur P et al.^[14] evaluated the effectiveness of Buerger Allen exercise on improving peripheral circulation in diabetic patients at Sharda Hospital, with the outcome measure being Inlow score. After Buerger Allen exercise, the average difference in Inlow score between the experimental group (1.1 ± 0.017) was higher than that of the control group (0.2 ± 0.005), with a statistically significant difference. This suggests that Buerger exercise can improve peripheral circulation in diabetic patients.

4. DISCUSSION

4.1. Performing Buerger exercises can effectively improve ABI in diabetic patients.

The ankle-brachial index (ABI) is a ratio that compares the systolic blood pressure measured at the ankle's tibial posterior or anterior artery to the pressure at the brachial artery. This measurement reflects the blood pressure and vascular health of the lower limbs. It is a commonly used, non-invasive method to detect narrowing or blockages in the peripheral arteries of the lower extremities and is frequently employed as a screening tool for peripheral arterial disease (PAD)^[21]. A decrease in ABI suggests the accumulation of plaque in the arteries and reduced blood flow to the lower extremities. The findings of this study indicate that engaging in Buerger exercises can significantly enhance ABI levels in diabetic patients, with the exercise group showing a notable increase in ABI compared to the conventional nursing group.

The Buerger exercise regimen involves specific steps: initially, the lower limb is elevated at a 45-degree angle for 1-2 minutes, during which the skin color of the limb turns white, aiming to

promote venous reflux and increase the return blood volume through the effects of gravity. Next, the patient lowers their feet and performs dorsiflexion and plantar flexion, along with left and right foot swings and toe curls, for a duration of 3 minutes. These movements enhance the muscle contractility of the ankle, improving peripheral circulation. Dorsiflexion and plantar flexion also help patients exercise the Achilles tendon to prevent contracture or joint stiffness, which could lead to further foot deformities. Finally, the patient lies flat and rests with their lower limbs extended and covered with a blanket to maintain warmth. The transition from a hanging position to a flat position further improves blood flow reperfusion in the lower limb.^[22]

Research by Liu Meilan and colleagues^[23] suggests that Buerger exercises primarily facilitate the passive filling and emptying of the lower limb arteries and veins through body posture and gravity. These exercises also promote the establishment of collateral circulation in the affected limb and improve blood supply to the tissue at the site of distal vessel damage. Chang and others have confirmed through self-controlled studies that Buerger exercises can effectively enhance the dorsal foot skin perfusion pressure (SPP) and increase peripheral circulation in the foot.

4.2. Continuous and effective exercise provides insights for diabetic patient care

Compared to non-diabetic patients, diabetics are more susceptible to severe diffuse peripheral arterial disease. Appropriate exercise increases metabolic activity, decreases blood pH, and leads to the release of more oxygen by hemoglobin, thereby increasing oxygen delivery to muscles. Leg cycling, aerobic arm exercise, and 6-minute walk training are all helpful in improving lower extremity perfusion in patients with peripheral arterial disease. Buerger exercise, as a non-weight-bearing exercise, becomes more effective with prolonged intervention time. A study showed that 12 months of aerobic exercise combined with Buerger exercise intervention helped improve insulin resistance in diabetic patients and reduced the risk of diabetic foot^[24]. The "Chinese Expert Consensus on Risk Assessment and Management of Vascular Disease in Type 2 Diabetes (2022 Edition)" recommends that diabetic patients with peripheral disease should do flat-footed exercise or walking, which is the

most effective exercise. The exercise intensity should be suitable to cause intermittent claudication, and the exercise time should be 30-45 minutes per time, at least 3 times per week, and at least 3-6 months in duration^[25]. In this study, most of the exercises^[7,10-14,17,19-20] were less than 30 minutes per time, only a few^[16,18] were equal to or greater than 30 minutes, and the intervention time was mainly short-term within a week, with only one study^[7] continuing for 12 weeks. Therefore, healthcare workers should strengthen the health education of exercise therapy for diabetic patients, inform them of the importance of choosing the right and effective exercise method for diabetes treatment, and ultimately achieve long-term control of blood sugar, delay the occurrence and development of complications, and improve quality of life.

LIMITATIONS OF THE STUDY

The present study also has certain limitations: among the five RCTs included, most of the researchers mentioned little about the randomization process, whether the allocation was concealed, and the blinding method, which may indicate the presence of methodological heterogeneity; secondly, there are differences in the implementation of the intervention measures such as Buerger exercise in various studies, such as the frequency, duration, and intensity of the activity, whether it is under the guidance and supervision of professional medical personnel, which will also affect the clinical heterogeneity. In the future, more related studies are needed to enrich the outcome indicators and assess the lower extremity perfusion from multiple dimensions. The intervention time can be prolonged to further observe the effect of exercise intervention on the physiology, psychology, and quality of life of diabetic patients.

SUMMARY

This research has demonstrated that Buerger exercises can markedly enhance the ABI scores of individuals with diabetes and significantly improve lower limb perfusion to different extents. Given its simplicity, affordability, ease of execution, and low risk, this exercise regimen warrants further exploration. Healthcare professionals are encouraged to assess individual patient needs and promote the use of Buerger exercises in a quantifiable manner, taking into account patient tolerance and other relevant considerations. Moving forward,

additional high-quality, large-scale randomized controlled trials are needed to further assess the impact of Buerger exercises on the lower limb perfusion of diabetic patients.

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