

Effect of Buerger's Exercises on Improving Peripheral Circulation: A Systematic Review

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Abstract

The aim of this study was to systematically review the evidence for the effectiveness of Buerger's exercise on the peripheral circulation or diabetic foot ulceration. A systematic search and 18 electronic databases were conducted. The intervention was predominantly focused on Buerger's exercise as an outcome. Due to high heterogeneity, data were synthesized in a narrative format rather than by statistical methods. Nine studies that covered 592 participants were selected in the analysis, of which 8 of the 9 found an effect of Buerger's exercise on peripheral circulation. The positive effects were indicative of improving blood flow, walking ability, reducing necrosis, reducing venous embolism, pain, swelling, cyanosis and the bed-rest times. However, the study design and quality appraisal were limited to Jadad score 2 and the sample size was small. Findings provide some evidence of the beneficial effects of Buerger's exercises. It was seen as a low cost and low risk physical activity that most diabetic patients could undertake at home. This review highlighted a need for further investigation of standardized procedures of Buerger's exercises. More high quality studies on the prevention of diabetic foot are required regarding Buerger's exercises.

Keywords

Buerger's Exercises, Diabetic Foot Ulceration, Lower Extremity Circulation, Systematic Review

1. Introduction

The global prevalence of diabetes mellitus (DM) in adults has been estimated at 8.3% in 2011 and will rise to 9.9% by 2030, affecting over 350 million individuals [1]. Diabetic foot complication is a major cause of disability, reduced quality of life, prolonged hospitalization, financial loss, lower limb amputation, and mortality rate [2]

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[3]. People with diabetes develop foot ulcers because of neuropathy, vascular insufficiency, and impaired wound healing [4]. Nearly 90% of diabetes-related lower limb amputations were preceded by foot ulcers [5]. In addition, conventional treatments—such as operation and infection control to cure diabetic foot ulcers are often ineffective [6].

Before and after World War II, medical experts did not know how to operate or treat the patient suffering from atherosclerosis or vessel occlusion, as well as stiffening in their peripheral arteries. Some medical genius at that time developed postural treatment to improve circulation in the lower extremities [7]-[12]. Buerger's exercises or Buerger-Allen exercises were proposed by Leo Buerger [11] and modified by Arthur Allen [7]. The value of these exercises had frequently been emphasized by Allen, and many medical experts considered them as important adjuvant treatment and postoperative care for circulatory disturbances in the extremities [8] [13] [14].

The mechanism of Buerger's exercises use gravitational changes in positions that are applied to the smooth musculature of vessels and to the vascular [15]. Gravity helps alternately to empty and fill blood columns, which can eventually increase transportation of blood through them [16]. The exercises involve the individual lying flat in bed with the legs elevated at 45 degrees until blanching occurs or for a maximum of 2 minutes. The patient then sits on the edge of the bed with the feet hanging down. Further exercises include dorsiflex, plantarflex, then inward and outward movement of the feet, followed by flexing and extending of the toes. This second phase is maintained for a minimum of 2 minutes or until rubor has appeared. Finally, the individual lies supine with the feet covered with a warm blanket lasting 5 minutes. The whole cycle is repeated 3 to 6 times each session, and the complete sequence is repeated 2 - 4 times a day [1] [17].

Buerger's exercise has been included in nursing textbooks for the chapter on arterial occlusive disease for decades. It has been considered as a strategy for improving lower limbs circulation. However, lack of evidenced-based studies to support. It was recognized that they might increase the rate of blood flow, clear away stagnant blood and help establish collateral circulation to the ischemic area [18] [19]. Bottomley [17] and Ventura [20] stated that instructing a patient or his/her family about Buerger's exercises can prevent and treat diabetic foot problems, shortened any period of hospitalization, and delayed morbidity [13] [21]. Furthermore, several reports support the beneficial effects of Buerger's exercises in patients with diabetic foot problems [10] [20]. These effects are due to improving neuropathy, infection, pain, and arteriosclerosis with or without gangrene [12] [22]. However, Buerger's exercises gradually have been dropped in recent decades, and few studies have investigated the evidence-based effect on diabetes care [23]. These phenomena might be due to lack of evidence, the changing healthcare payment system focus on medical oriented reimbursement, and/or neglect of the prevention the diabetic foot by our nursing staff. Preventing diabetic foot is a critical issue worldwide. Buerger's exercises are seen as a conservative treatment of the peripheral vascular disease, low cost and low risk physical activity that most diabetes patients could undertake at home [17] [23] [24]. Therefore, the objective of this study was to systematically review the evidence for the effectiveness of Buerger's exercise on the peripheral circulation or diabetic foot ulceration.

2. Methods

2.1. Search Strategy

Over 18 of English and Chinese electronic databases from 1937 to March, 2013, were used and different terms (e.g. Buerger's exercise, Buerger-Allen exercise) were involved to search for relevant articles (Table 1). We also searched references with relevance in Google Scholar in all fields (no title or abstract restrictions) to filter the retrieved references. This was to ensure the search strategy was wide enough to recover all studies potentially relevant for the review. Studies of reference lists that seemed relevant were assessed based on the information provided in the title. The Cochrane Library search retrieved no systematic reviews.

2.2. Study Criteria

Two reviewers independently screened the full text of the references selected that could not initially be excluded based on their titles and abstracts. To obtain as many relevant reports as possible, broad inclusion criteria were adopted: 1) Intervention studies, those focused on Buerger's exercises. 2) Papers published in English and Chinese. The selection was not restricted by methodological quality, population and outcomes. Electronic search results were downloaded into the End Note bibliographic program, from which duplicates were deleted.

Table 1. Search strategy.**English database**

- Age Line (1978-March 2012).
- CINAHL Plus with Full Text (1937-March 2012).
- Cochrane Library (1966-March 2012).
- MEDLINE (1966-March 2012).
- OVID (1966-March 2012).
- ProQuest Nursing and Allied Health Source (1986-March 2012).
- ProQuest Health & Medical Complete (1994-March 2012).
- PubMed (1966-March 2012).
- Science Direct (1995-March 2012).
- Springer Link (1990-March 2012).

Chinese database (Traditional)

- Chinese Electronic Periodical Services (CEPS) (1991-March 2012).
- Nation Central Library (NCL) (1970-March 2012).
- National Digital Library of Theses and Dissertations (NDLTD) (1956-March 2012).

Chinese database (Simplified)

- China Doctor Dissertation Full-text Database (CDFD) (1999-March 2012).
- China Master Theses Full-text Database (CMTD) (1999-March 2012).
- China National Knowledge Infrastructure (CNKI) (1979-March 2012).
- China Yearbook Full-text Database (CYFD) (1912-March 2012).
- Wan Fang Data (1997-March 2012).

Website

- Google Scholar.

Search terms used

- Buerger's exercises, Buerger-Allen exercises, Buerger.
- Used different terms in Chinese traditional text for Buerger's exercises.
- Used different terms in Chinese simplified text for Buerger's exercises.

2.3. Data Extraction

One reviewer extracted data from included studies about first author; year of publication; country of study; location; duration of study; sample; population characteristics; variable; outcome measures; quality indicators; interventions; characteristics of interventions and results. The second reviewer checked the accuracy of the extracted data.

2.4. Quality Appraisal

Two reviewers independently assessed the eligibility of the study, quality appraisal and carried out the analysis. The quality appraisal of the included studies was assessed using criteria based on the Jadad scale [25]. The quality questions checked were the following: 1) Was the study described as randomized? 2) Was the study described as double blind? 3) Was there a description of withdrawals and dropouts? 4) Was the method to generate the sequence of randomization described and it was appropriate? 5) Was the method of double blinding described and it was appropriate? 6) Was the method to generate the sequence of randomization described and it was inappropriate? 7) Was the study described as double blind but the method of blinding was inappropriate?

The methodological quality of included studies was evaluated by two reviewers. The 1 - 5 questions were scored as "Yes" (1), "No" (0), and 6 - 7 were scored deduct 1 point if as "Yes". Therefore, each study could score 0 to 5. Disagreements between the two reviewers were resolved by discussed until consensus.

2.5. Data Synthesis

The participants, intervention, study design, outcomes, measures and intervention characteristics were summarized with a narrative and tabular synthesis. The limited data and use of divergent variables within the studies did not allow meta-analysis.

3. Results

3.1. Study Search

A total of 95 potentially relevant papers were identified, of which 15 articles were identified by the systematic search in electronic database, and 79 papers were selected from the Google Scholar Website. One further study

was found from a reference list. There were 86 papers that failed to reach our selection criteria, which left on 9 that could be included in the final review (**Figure 1**).

3.2. Study Characteristics

Table 2 showed that of the 9 studies reviewed, 6 randomized were controlled trials, two were pre-test studies with control group, and one was a prospective control study. Three of the studies were published before 1996 and 6 after 2005. Six of the studies were conducted in Mainland China, with one study each from Denmark, the United States and Taiwan. Five studies were lead by registered nurses, 3 by medical doctors and one by a physical therapist. Three papers were published in English [23] [26] [27] and 6 in Simplified Chinese [28]-[33]. These studies were conducted in a variety of settings, including vascular clinics, surgical, Chinese medicine, orthopedic, and gynecology units.

3.3. Participant Characteristics

The 9 studies involved a total of 592 participants; most of whom were hospitalized patients (66.7%). Four of the studies patients were related to peripheral arterial occlusive disease (PAOD), 4 to orthopedics, and 1 to a gynecology problem. Two of the studies included diabetic patients [23] [26]. Sample size ranged from 14 [26] to 233 [31]. All studies did not calculate the sample size (power) required to see an effect. Seven studies gave the range age of participants from 10 to 83 years. Five studies recruited both male and female participants, but 2 did not mention gender. Only 2 studies mentioned informed consent and one study reported a drop-out rate [23] [26].

3.4. Measurement

Measurement variances of the selected studies were to assess Buerger's exercises with regard to several physiological outcomes or clinical symptoms. The variables of physiological indicators included Na [24] clearance rate (Geiger counter); ^{133}Xe washout rate (NaI scintillation detector); blood flux (DRT4 Laser Doppler); walking time (treadmill); skin temperature (DRT4 Laser Doppler); hemorheology (packed cell volume, fibrinogen); and bed-rest times (days). Clinical symptoms that were measured included foot necrosis (years); degree of swelling; pain (Wong-Baker Faces Pain Rating Scale, Numeric Pain Rating Scale), and degree of cyanosis (**Table 2**). Most of the select studies did not investigate or report on the reliability, stability and validity of their instruments. Even when using the observational study design, 5 studies did not include an operational definition, observer training and inter-rate reliability [28]-[31] [33].

3.5. Intervention Characteristics

All the studies had 2 intervention and comparison groups. Six of the 9 studies assessed the benefit of Buerger's exercises compared with usual care, and one compared them with arterial reconstruction [26]. Two compared the same intervention, but used different participant characteristics (**Table 3**) [23] [27]. Two studies had certified

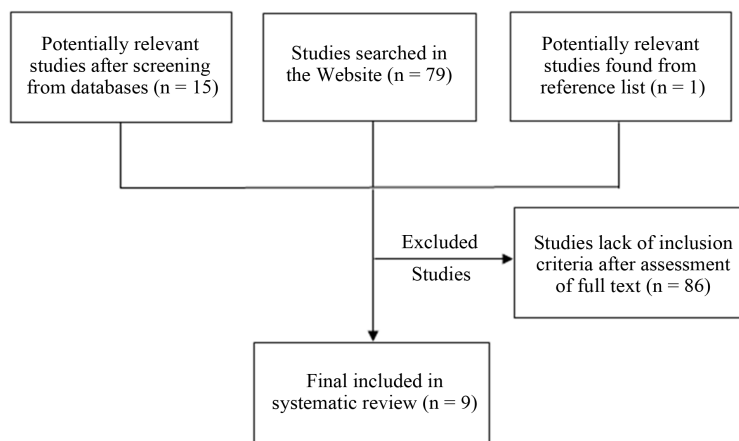


Figure 1. Flowchart of the inclusion process.

Table 2. Characteristics of the main results.

1 st author and title	Country, study design, setting, and sample sizes	Design	Outcomes	Results
Wisham (1953) MD	USA, N = 29, arterial disease of lower extremities patients, intermittent claudication of varying degree but no gangrene, at vascular clinic.	Pre-post control group	Blood flow (Na ²⁴ clearance rate (%))	EG: ↑ 17% - 84%, CG: ↑ 33% - 114%
Bjerre-Jepsen (1984) MD	Denmark, N = 14, severe leg ischemia due to occlusive arterial disease; All patients had severe rest pain, at surgery unit	Design: RCT, pre-post	Subcutaneous blood flow (¹³³ Xe washout rate) Measures: NaI (Te)	NS
Wu (1996) PT	Taiwan, N = 30, peripheral arterial insufficiency patients, 18 patients had ulceration and/or gangrene, at vascular clinic	Pre-post control group	Skin temperature, blood flux, walking time	Blood flux ($p < 0.05$), walking time ($p < 0.05$)
Fan (2005) MD	China, N = 60, arteriosclerosis obliterans patients, at medicine unit	Prospective control group	Foot necrosis periods	Foot necrosis periods ($p < 0.01$)
Ou (2006) RN	China, N = 233, Gynecology patients postoperative, at gynecology unit	Design: RCT, post	Hemorheology, swelling, pain	Hemorheology ($p < 0.01$)
Zhu (2006) RN	China, N = 96, low limb trauma patients, at orthopedic unit	Design: RCT, post	Pain, swelling, cyanosis, bed rest	Pain ($p < 0.01$), swelling ($p < 0.01$), cyanosis ($p < 0.01$), bed rest times ($p < 0.05$)
Guan (2007) RN	China, N = 30, above knee fracture after internal fixation patients, at orthopedic unit	Design: RCT, post	Pain, cyanosis, swelling	Pain ($p < 0.005$), cyanosis ($p < 0.005$), swelling ($p < 0.005$)
Jiang (2009) RN	China, N = 60, lower limb fractures patients post-surgery, at orthopedic unit	RCT, pre-post	Pain, swelling	Pain ($p < 0.01$), swelling ($p < 0.01$)
Zhang (2009) RN	China, N = 40, multiple fractures patients in low extremities after internal fixation, at orthopedic unit	RCT, post	Hemorheology, *HBV, LBV, PCV	After surgery 14 th , 21 st and 28 th day ($p < 0.05$, $p < 0.01$, $p < 0.001$)

*HBV = high blood viscosity, LBV = low blood viscosity, PCV = packed cell volume, EG = experimental group, CG = control group, NS = not significant.

nurse as intervener, one a physiotherapist. Most of the studies did not mention the background of interveners (Table 3).

The intervention time (period) of the 4 selected studies ranged from 3 - 14 days, 3 ranging from 28 days to one month. The 9 studies contained a divergent range of exercising programs, such as intensity, duration, frequency and procedure. Most of the exercises were undertaken each day ($n = 6$), the intensity ranging from 2 - 4 sections a day, with each section repeated 3 - 10 times. Regarding the duration for each step, 6 studies used 1 - 3 minutes and 3 used 1 - 5 minutes. Most of the procedures of Buerger's exercises were inconsistent, e.g., the angle of legs, duration of each step and each section.

3.6. Outcomes

Most of the studies ($N = 8$) reported a positive effect of Buerger's exercises. Only one study showed no significant effect on PAOD patients [26]. More than half of the studies indicated significantly improved blood flow of the lower extremities and walking ability ($p < 0.05$), decreased hemorheology indices after operation ($p < 0.05$), reduced bed-rest times ($p < 0.05$). Six studies indicated that the exercises significantly reducing swelling, cyanosis and pain ($p < 0.001$) [29] [30] [33], reduced venous embolism ($p < 0.001$) [31] [32], and delayed the occurrence of foot ulcers and gangrene [28]. There was no significant effect on skin temperature [23].

3.7. Quality Assessment

Total Jadad quality score among the 9 studies ranged from 0 to 2 (Table 4). They scored less than or equal to 2 points, including 4 studies of 0 point, 4 studies of 1 point and 1 study of 2. While 6 studies used randomized

Table 3. Characteristics of the Buerger's exercises.

Author/year	Length	Angle/degree	Intensity/frequency	Procedure and duration (minutes)
Wisham (1953)	Unclear	60	6, 1-5/NA	Passive: Supine, leg elevated (2) → sit, feet lowered (3) → supine (5) Active: Supine, leg elevated and movement feet (30 times a min) → sit, feet lowered and movement feet (30 times a min) → supine (5) Resistance: Supine, resistance to active plantar flexion (30 times a min for 20 min)
Bjerre-Jepsen (1984)	5 days	60 - 90	5-6, 3/1-3/3 cycle a day for 5 days	Supine, leg elevated (1) → sit, feet lowered (1-2) → supine (3)
Wu (1996)	1month	45 - 60	3, 2/1-5/5-7 days per week	Supine, leg elevated (1-3) → sit, feet lowered and movement feet and toe (3) → supine (5)
Fan (2005)	Follow-up until feet necrosis	45	5, 3/1-5/7 days per week	Supine, leg elevated (1-2) → sit, feet lowered and movement feet and toe (5) → supine, leg elevated (2)
Ou (2006)	3 days	45	Several times/1-3/ for 3 days	Supine, leg elevated (1-2) → sit, feet lowered (2-3) → supine and movement feet and toe (2)
Zhu (2006)	7 days	45	Several times/1-3/7 days per week	Supine, leg elevated (1-2) → sit, feet lowered (2-3) → supine and movement feet and toe (2)
Guan (2007)	14 days	45	10, 3/1-3/7 days per week	Sit, feet lowered (2-3) → supine and movement feet and toe (2) → supine, leg elevated (1-2)
Jiang (2009)	28 days	45	5-6, 3-4/1-3/7 days per week	Supine, leg elevated (1-2) → sit, feet lowered (2-3) → Supine and movement feet and toe (2)
Zhang (2009)	28 days	45	Several times/1-3/7 days per week	Supine, leg elevated (1-2) → sit, feet lowered (2-3) → Supine and movement feet and toe (2)

Note. N/A = not applicable, N/R = not reported.

Table 4. Quality assessment of included studies.

Studies	Jadad questions							Total score
	1	2	3	4	5	6	7	
Wisham (1953)	0	0	0	0	0	0	0	0
Bjerre-Jepsen (1984)	1	0	0	0	0	0	0	1
Wu (1996)	0	0	0	0	0	0	0	0
Fan (2005)	0	0	0	0	0	0	0	0
Ou (2006)	1	0	0	0	0	0	0	1
Zhu (2006)	1	0	0	0	0	0	0	1
Guan (2007)	1	0	0	0	0	0	0	1
Jiang (2009)	1	0	0	0	0	-1	0	0
Zhang (2009)	1	0	0	1	0	0	0	2

controlled trials, only 2 gave their method of randomization. One of these studies used table random numbers generated by a Stochastic [32]. One enrolled subjects according to their admission order, and was deducted 1 point. One study had withdrawal numbers, but no reason was given.

4. Discussion

This systematic review of the value of Buerger's exercises in improving peripheral circulation selected 9 studies,

with most of the participants of PAOD and having orthopedic problems. In general, the results suggest that this conservative treatment positively influences blood flow, walking ability, and venous embolism. They significantly reduced necrosis periods, pain, swelling, cyanosis, and bed-rest times.

The methodological procedures were generally of poor quality, some of which could have a bearing on the validity of the results. There were limited statistical analyses in two studies that were conducted more than 20 years ago [26] [27]. Power calculation was not used in any of the studies, and sample sizes in 2 of them were small. A small sample size can give a larger bias due to variations among the participants or, in some conditions, contribute to a positive result when the observed effect is much larger than the true difference [34]. Baseline characteristics of the participants were not compared in some studies. Although 4 studies used RCT design, and only have post-test data. Furthermore, most of the studies lacked scientific vigor, such as the validity, reliability and reproducibility of the instruments were not reported [28] [29] [31] [33]. Therefore, when the measurement errors were high, the effects of the intervention would be suspect.

Notably, the measurement variables in the 9 selected studies were somewhat different. For instance, 3 studies measured blood flow with significant improvement seen in the studies of Wisham *et al.* [27] and Wu and Wang [23]. The results of Bjerre-Jepsen *et al.* [26], however, did not show improve although their methodology was similar to Wisham *et al.* [27]. The reasons might be due to 1) the small sample size ($N = 14$), and 2) the procedure and intervention dose was different with others in the study of Bjerre-Jepsen *et al.* [26], e.g. they did not use dorsiflex, plantarflex, then inward and outward of the feet. Theoretically, when circulation increases in a limb, an increase in its skin temperature would be expected [19]. However, the Wu and Wang [23] reported no significant differences.

Regarding procedures, most of the included studies preferred elevation of the leg at 45 degrees ($N = 7$), 5 - 6 times/per section ($N = 4$), 3 sections/per day ($N = 4$), for 1 - 3 min/each duration ($N = 6$). However, many studies did not state their standardized of procedures [31]-[33]. Further study is necessary to establish the standardized of procedures for Buerger's exercises.

4.1. Strengths and Weakness

Despite some limitations in this study, we were able to make decisions about the strength and consistency of the evidence. To the best of our knowledge, our review is the first attempt to synthesize the evidence that Buerger's exercises improve peripheral circulation. The results may be biased by only screening publications in the English or Chinese; thus, important studies might have been missed. The reviewed studies varied in participants, interventions, samples, methods, measures, and outcomes, giving a heterogeneity that disallowed meta-analysis, making comparisons between them difficult.

4.2. Implications for Practice and Research

Some literatures indicate that many diabetic patients apparently had foot ulcer before their lower extremities were amputated [5] [35]. Hence, providing further diabetic care with Buerger's exercises would be beneficial for diabetic patients who have peripheral circulation insufficiency or peripheral neurovasculopathy, e.g. ankle brachial pressure index < 0.9 or Michigan Neuropath Screening Index > 2 . Therefore, it is necessary to investigate the effect of Buerger's exercises on diabetic-related peripheral disorder through evidence-based studies. Regarding the ethical consideration, only 2 studies mentioned informed consent [23] [26]. Notably, in more than half of the selected studies, the primary researchers and background of interveners were nurses, which implied that Buerger's exercises can be an important independent role for nurses to take care of hospitalized and community clients with lower extremity circulation disorders. However, the effect of Buerger's exercises and the standardization of the procedures involved ought to be subject to further more rigorous scientific researches.

5. Conclusion

Although most of the selected studies were not focused on diabetic foot patients, this review has found that Buerger's exercises can benefits for PAOD patients, post-operative patients with orthopedic and gynecology problems by improving local circulation, despite the studies having methodology limitations. We have found that some of the accumulated evidence supports the benefits of Buerger's exercises. It also suggests that Buerger's exercises could be an alternative procedure on improving peripheral circulation, but the need for further in-

investigation of optimal procedure of Buerger's exercises have been highlighted, particularly with high quality studies with optimized standard procedures being used.

Competing Interests

The authors hereby declare that there were no competing interests.

Author's Contribution

CFC, CCC and MYC designed the study conception and wrote the manuscript. All authors contributed to manuscript development, and read and approved the final manuscript.

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