

A quantitative real-time assessment of Buerger exercise on dorsal foot peripheral skin circulation in patients with diabetes foot

Chang-Cheng Chang, MD^{a,b,c}, Men-Yen Chen, PhD^d, Jen-Hsiang Shen, MD^e, Yen Bin Lin, MD^a, Wen-Wei Hsu, MD^f, Bor-Shyh Lin, PhD^{c,*}

Abstract

Buerger exercise can improve the peripheral circulation of lower extremities. However, the evidence and a quantitative assessment of skin perfusion immediately after this exercise in patients with diabetes feet are still rare.

We recruited 30 patients with unilateral or bilateral diabetic ulcerated feet in Chang Gung Memorial Hospital, Chia-Yi Branch, from October 2012 to December 2013. Real-time dorsal foot skin perfusion pressures (SPPs) before and after Buerger exercise were measured and analyzed. In addition, the severity of ischemia and the presence of ulcers before exercise were also stratified.

A total of 30 patients with a mean age of 63.4 ± 13.7 years old were enrolled in this study. Their mean duration of diabetes was 13.6 ± 8.2 years. Among them, 26 patients had unilateral and 4 patients had bilateral diabetes foot ulcers. Of the 34 wounded feet, 23 (68%) and 9 (27%) feet were classified as Wagner class II and III, respectively. The real-time SPP measurement indicated that Buerger exercise significantly increased the level of SPP by more than 10 mm Hg ($n = 46$, 58.3 vs 70.0 mm Hg, $P < 0.001$). In terms of pre-exercise dorsal foot circulation condition, the results showed that Buerger exercise increased the level of SPP in severe ischemia ($n = 5$, 22.1 vs 37.3 mm Hg, $P = 0.043$), moderate ischemia ($n = 14$, 42.2 vs 64.4 mm Hg, $P = 0.001$), and borderline-normal ($n = 7$, 52.9 vs 65.4 mm Hg, $P = 0.028$) groups, respectively. However, the 20 feet with SPP levels more than 60 mm Hg were not improved significantly after exercise ($n = 20$, 58.3 vs 71.5 mm Hg, $P = 0.239$). As to the presence of ulcers, Buerger exercise increased the level of SPP in either unwounded feet ($n = 12$, 58.5 vs 66.0 mm Hg, $P = 0.012$) or wounded feet ($n = 34$, 58.3 vs 71.5 mm Hg, $P < 0.001$). The majority of the ulcers was either completely healed ($9/34 = 27\%$) or still improving ($14/34 = 41\%$).

This study quantitatively demonstrates the evidence of dorsal foot peripheral circulation improvement after Buerger exercise in patients with diabetes.

Abbreviations: CLI = critical limb ischemia, DFU = diabetes foot ulcer, PAD = peripheral artery disease, SPP = skin perfusion pressure.

Keywords: Buerger exercise, diabetic foot, peripheral skin circulation

1. Introduction

Foot problems are common in diabetic patients, 15% to 25% of whom develop diabetes foot ulcers (DFU) in their lifetime.^[1]

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C-CC and M-YC contributed equally to this work.

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^a Department of Plastic Surgery, Chang Gung Memorial Hospital, Chiayi, ^b School of Medicine, College of Medicine, China Medical University, Taichung, ^c Institute of Imaging and Biomedical Photonics, National Chiao Tung University, Guiren, Tainan, ^d Department of Nursing, Chang Gung University of Science and Technology, Kwei-Shan Taoyuan, ^e Department of Ophthalmology, Chang Gung Memorial Hospital, Kueishan, Taoyuan, ^f Department of Orthopedics, Chang Gung Memorial Hospital, Chiayi, Taiwan.

* Correspondence: Bor-Shyh Lin, Institute of Imaging and Biomedical Photonics, National Chiao Tung University, No. 301, Gaotie 3rd Road, Guiren, Tainan 71150, Taiwan (e-mail: borshyhlin@gmail.com).

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Eighty-five percent of lower limb amputations in diabetes patients results from DFU,^[2–4] which is commonly seen with the following 3 conditions: peripheral neuropathy, vasculopathy, and immunopathy.^[5] After 10 years, about half of the patients with diabetes develop peripheral artery disease (PAD).^[6] Patients with PAD can be asymptomatic or have symptoms such as intermittent claudication and rest pain, as well as ischemia ulcer and foot gangrene. Increasing foot peripheral circulation in patients with diabetes is important not only in symptom relief, but also in ulcer and amputation prevention.

Buerger exercise intended to improve feet and legs circulation was first described by Buerger in 1926 and then modified by Allen in 1930.^[7,8] To relieve the symptoms in patients with lower limbs arterial insufficiency, Buerger exercises drained engorged vessels by using postural changes and stimulated peripheral circulation by modulating gravity and applying muscle contractions.^[9] The duration of each position varies in accordance with patient's tolerance and the velocity of color changes.^[10] However, the applications of this exercise to patients with diabetes feet are very rare, and the clinical significance of peripheral circulation improvement is still limited due to the lack of measuring tools. Various methods were used to objectively assess limb ischemia. The LASER Doppler technique was used for skin perfusion pressure (SPP) measurements. To evaluate skin tissue viability, the proximal pressure was measured by completely blocking the distal blood reperfusion.^[11,12] Lower extremity SPP values with normal perfusion is >50 mm Hg. The SPP measurement is

correlated with the severity of arterial disease while the SPP is <30 mm Hg and considered as a severe PAD or critical limb ischemia (CLI).^[13,14] It also has been reported that if the SPP is 30 to 40 mm Hg or below, the viability is poor; an improvement of SPP indicates a better peripheral skin and tissue circulation in ischemic limbs.^[15] SPP with values ≥ 30 mm Hg is a useful positive independent predictor of wound healing potential.^[16] Herein, we used LASER-Doppler flow sensors to measure the same point of SPP responses immediately before and after exercise, to reflect the peripheral circulation condition by recording the local pressure while minimal microcirculation starts to be detected.

2. Patients and methods

2.1. Patients

We recruited patients with unilateral or bilateral DFU from our outpatient clinics in the wound care center of Chang Gung Memorial Hospital, Chia-Yi Branch, from October 2012 to December 2013 (Chang Gung Medical Foundation institutional review board passed: 102-4973B). All of these patients had professional and timely wound assessment, debridement if needed, wound care education, and modern wound dressings with adequate moisture. (Our wound care center and wound care management are described in detail in our previous publication.^[17]) Exclusion criteria included end-stage renal disease, severe anemia (hemoglobin <9 g/dL), previous lower limb amputation, and heart failure (New York functional class $>II$). Also, some patients in our wound care center received negative pressure wound therapy or revascularization therapy, but they are not included in this study. Patients' basic demographic data including sex, age, duration of diabetes, and wound condition after 3 months follow-up were recorded.

Buerger exercise was taught to the patients in our clinic sessions. First, the lower extremities are elevated to a 45° angle and supported in this position until the skin became pale. Second, patients sat in a relaxed position with their feet and legs rested below the level of the remaining parts of the body, and performed individual foot flexion/extension and then pronation/supination for 3 min until redness appears. Finally, patients lay quietly for 5 min with both legs rested on the bed in a warm blanket for a few minutes (Fig. 1A–C).^[10]

Real-time SPP was measured before and immediately after exercise, and the data were analyzed by using statistical software SPSS 15 (SPSS Inc, Chicago, IL). Further comparisons of pre-exercise dorsal foot peripheral circulation (the initial SPP values) and the presence of ulcers were also analyzed.

2.2. Real-time SPP measurements and wound reassessment

We used the LASERDOPP (Vasamedics, St Paul, MN) model to measure SPP. Patients first rested in a supine position for 10 min. A blood pressure cuff was placed around the patient's foot and a laser Doppler probe was applied to the dorsum of the foot. The cuff contained a transparent polyvinyl chloride window, through which we could make the perfusion measurements.

The cuff was inflated to suprasystolic pressure (up to 200 mm Hg) and deflated in 10 mm Hg intervals. Each pressure was maintained for 15 s. If the Doppler scan flux sensed 2 consecutive increases, the first measurement indicated the start of blood reperfusion and was recorded as the pre-exercise SPP (Fig. 2A and B). Postexercise real-time SPP was immediately measured after Buerger exercise.

Patients were advised to perform Buerger exercise 3 times daily. Educational pamphlets and self-record booklet were provided. Wound conditions were recorded after 3 months follow-ups (Fig. 2C). We defined healed as "complete epithelization of the wound," and healing as "the reduction of the wound size and depth but the epithelization is not complete."

2.3. Statistical analysis

Patients' basic demographic data were presented as either a number and percentage or mean and standard deviation (SD). The comparisons of SPP levels before and after exercise were made by using Wilcoxon signed-rank test. The correlation between pre-exercise SPP and improvement of SPP after exercise was analyzed using Spearman rank correlation. All the analyses were performed by using statistical software SPSS 15 (SPSS Inc, Chicago, IL).

3. Results

Thirty patients consisted of 16 male and 14 female with a mean age of 63.4 years old (SD = 13.7 years) were enrolled in this study. Among them, 26 patients had unilateral and 4 patients had bilateral DFU. We measured and collected SPP data of 46 feet, including 34 wounded feet and 12 unwounded feet. The mean duration of diabetes was 13.6 years (SD = 8.7 years). Of the 34 wounded feet, 23 (68%) and 9 (27%) feet were classified as Wagner class II and III, respectively. The status of wound was monitored 3 months after they were first instructed to do the Buerger exercise in our outpatient clinics. The majority of the ulcers were either completely healed ($n=9$, 27%) (Fig. 2A–C) or still improving ($n=14$, 41%). Six ulcers (18%) were static, 3 ulcers (9%) were progressed, and 2 (6%) suffered from toe amputation (Table 1).



Figure 1. (A) Step 1 of Buerger exercise. (B) Step 2 of Buerger exercise. (C) Step 3 of Buerger exercise.



Figure 2. (A) This is a 62-year-old female patient with 12 years of type 2 diabetes mellitus. The Wagner Gr. III deep diabetes foot ulcer over the left 2nd toe was as demonstrated. (B) Modalities for skin perfusion pressure measurements. (C) The completely healed wound after 3 months of follow-up.

Table 2 demonstrated the comparison of SPP before and after Buerger exercise. The result showed that Buerger exercise significantly increased the level of SPP by more than 10 mm Hg (58.3 vs 70.0 mm Hg, $P < 0.001$). We further analyzed the initial dorsal foot SPP values and the presence of ulcer. In terms of pre-exercise dorsal foot peripheral circulation, the result from initial SPP values indicated that Buerger exercise increased the level of SPP in severe ischemia ($n = 5$, 22.1 vs 37.3 mm Hg, $P = 0.043$), moderate ischemia ($n = 14$, 42.2 vs 64.4 mm Hg, $P = 0.001$), and borderline-normal ($n = 7$, 52.9 vs 65.4 mm Hg, $P = 0.028$) groups, respectively. However, the 20 feet with SPP levels more than 60 mm Hg were not improved significantly after exercise ($P = 0.239$). As to the presence of ulcer, the results revealed that Buerger exercise increased the level of SPP in either unwounded feet (58.5 vs 66.0 mm Hg, $P = 0.012$) or wounded feet (58.3 vs 71.5 mm Hg, $P < 0.001$). We also drawn Table 2 to Fig. 3A and B.

Furthermore, we investigated the correlation between pre-exercise SPP and the improvement of SPP before and after exercise (expressed by percentage). The Spearman rank correlation indicated that the improvement of SPP was moderately and negatively correlated to pre-exercise SPP values ($\rho = -0.68$, $P < 0.001$) (Fig. 4).

Table 1
Patient's characteristics at baseline (N=30).

Variables	Number, % or mean \pm SD
Age, y	63.4 \pm 13.7
<65	15 (50.0)
\geq 65	15 (50.0)
Gender	
Female	14 (46.7)
Male	16 (53.3)
Duration of diabetes, y	13.6 \pm 8.2
The Wagner wound classification ($n = 34$ wounded feet)*	
I	1 (2.9)
II	23 (67.6)
III	9 (26.5)
IV	1 (2.9)
Status of wound in 3 mo ($n = 34$ wounded feet)*	
Healed	9 (26.5)
Improving	14 (41.2)
Stasis	6 (17.6)
Progression	3 (8.8)
Toe amputation	2 (5.9)

* Four patients had wounds in both feet, thus resulting in a total of 34 feet with wound. SD = standard deviation.

4. Discussion

Buerger exercise has been used for 80 years as a strategy to improve peripheral circulation.^[7,8] However, only scant evidence has shown the effect of Buerger exercise on peripheral circulation improvement or the healing of DFU. Although numerous selected studies indicated that Buerger exercises is beneficial to patients with PAD and postoperative patients with orthopedic and gynecology problems by improving local circulation, study methodologies were still limited.^[7,8,18,19]

Noninvasive measurement of limb systolic pressure and calculation of the ankle-brachial index are the standard assessment for the severity of vasculopathy in lower limbs. However, the medial calcification-associated arterial rigidity may interfere with the measurement of ankle pressure.^[20–22] These phenomena are more commonly observed in patients with diabetes mellitus and those undergoing dialysis. Transcutaneous oxygen monitoring (TCOM/TcPO₂) is a well-documented technique reflecting the flow in the capillaries that applied for wound healing assessment, hyperbaric medicine, and amputation determinations.^[23] The measuring procedures require warming up the skin, and thus the differences of temperature may interfere the accuracy of comparison between pre- and post-exercise. In contrast, SPP is not affected by arterial wall calcification or skin temperature, which has been shown to be useful for diabetic patients in the assessment of PAD severity,^[13,14] and ulcers tend to be cured when the SPP is ≥ 30 to 40 mm Hg.^[16,20,24] In our study, it is an optimal index for quantitative measurement immediately after Buerger exercise.

According to our results, the real-time measurement indicated that SPP significantly improved not only wounded but also unwounded feet on both sides after Buerger exercise. In the first step of Buerger exercise, gravity causes an emptying of the veins and increases the inflow of the right atrium, which subsequently promotes cardiac output. In the second step, gravity still plays a role in increasing inflows of the arterioles. The following ankle movement may reinforce distal circulation due to the force of muscle contraction. The dorsal-plantar foot flexion can also help the patients to exercise their Achilles tendon to avoid contracture or joint stiffness that leads to further foot deformity. The final step is to lie down on supine position, which can improve leg reperfusion when the gravity effects are withdrawn.

The treatment of DFU combined with PAD is usually a challenge. Although revascularization such as percutaneous transluminal angioplasty or bypass surgery has become the prime therapy to decrease major amputations and promote ulcer healing,^[24,25] sometimes the applications are limited because of the poor tolerance of contrast medium resulting from poor

Table 2
Mean SPP (mm Hg) before and after exercise according to severity of PAD and the presence of ulcer.

Subgroup	n	Pre-exercise	Post-exercise	Improvement	Improvement, %	P*
All feet	46	58.3 (24.3)	70.0 (23.3)	11.7 (16.4)	29.1 (40.3)	<0.001
Severity of PAD†						
Severe (CLI)	5	22.1 (4.4)	37.3 (16.4)	15.2 (13.8)	66.5 (51.8)	0.043
Moderate	14	42.2 (4.3)	64.4 (19.9)	22.2 (20.0)	53.8 (47.6)	0.001
Borderline-normal	7	52.9 (2.7)	65.4 (9.1)	12.4 (8.4)	23.4 (16.3)	0.028
Normal	20	80.6 (17.5)	83.8 (20.5)	3.2 (11.7)	4.3 (12.9)	0.239
Ulcer foot						
No	12	58.5 (15.6)	66.0 (9.8)	7.6 (8.7)	17.8 (23.9)	0.012
Yes	34	58.3 (26.9)	71.5 (26.5)	13.2 (18.2)	33.0 (44.2)	<0.001

The Buerger exercise increased the level of SPP in severe (22.1 vs 37.3 mm Hg, $P=0.043$), moderate (42.2 vs 64.4 mm Hg, $P=0.001$), and borderline-normal (52.9 vs 65.4 mm Hg, $P=0.028$) groups, respectively. The level of SPP increased in either unwounded feet (58.5 vs 66.0 mm Hg, $P=0.012$) or wounded feet (58.3 vs 71.5 mm Hg, $P<0.001$).

CLI = critical limb ischemia, PAD = peripheral arterial disease, SPP = skin perfusion pressure.

*The difference in SPP values before and after exercise was compared by using Wilcoxon signed-rank test.

†Severity of PAD was determined by SPP at pre-exercise, where <30, 30–49, 50–59, and more than 60 mm Hg was classified as severe (critical limb ischemia), moderate, borderline-normal, and normal, respectively.

general conditions, infections, severe calcification, or poor renal function. Buerger exercise is a noninvasive physical therapy that is easy-to-learn and can be continuously executed at home by learning from drawings, videos, or live demonstrations. Some of the aged patients who cannot tolerate the elevation of 45° used

the modified instructions in the first step (elevate at maximal angle to attain blanching in the feet).

We demonstrated the immediate effects on foot peripheral circulation after Buerger exercise and a cohort follow-up that can help us to understand more about the long-term effects on patients with diabetic feet by continuing doing this exercise. Moreover, as a pilot-study evidence, we have quantitatively identified the immediate SPP increase after Buerger exercise and proved the physiologic hypothesis which easy-learning exercise can be beneficial to patients with diabetic feet. Our results also suggested that Buerger exercises could be an alternative or adjuvant procedure to improve peripheral circulation when other invasive procedures are limited, but further investigations regarding vasculature anatomy, and the benefits and risk assessments before receiving invasive procedures are still needed to be highlighted. In addition, we observed a trend of immediate positive effects in severe cases, but the practical treatment guidelines or algorithm based on the severity of the disease is still undetermined.

This study also has some limitations. We did not further grouped patients based on their underlying comorbidities.

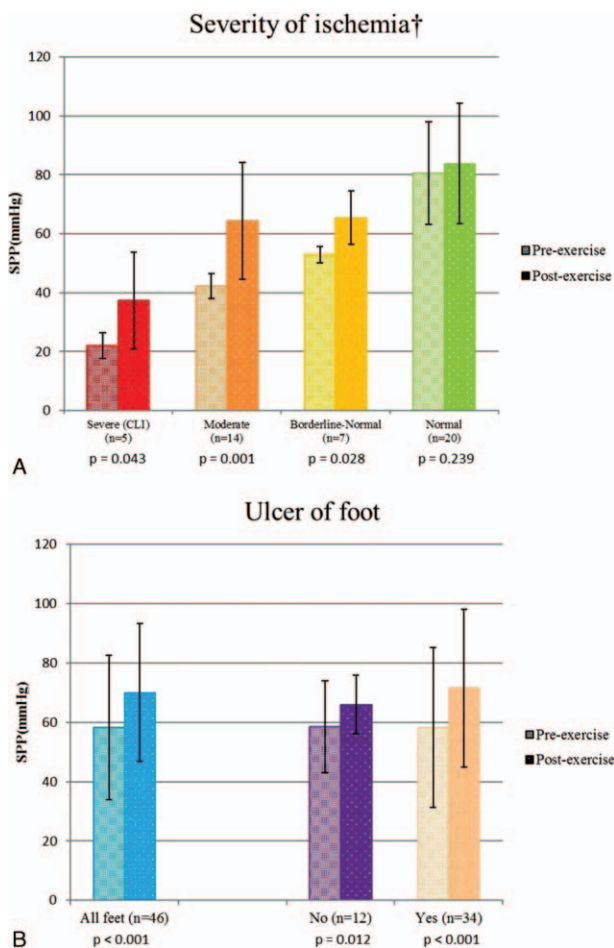


Figure 3. (A, B) Mean SPP (mm Hg) before and after exercise according to severity of dorsal foot ischemia and the presence of ulcer. SPP = skin perfusion pressure.

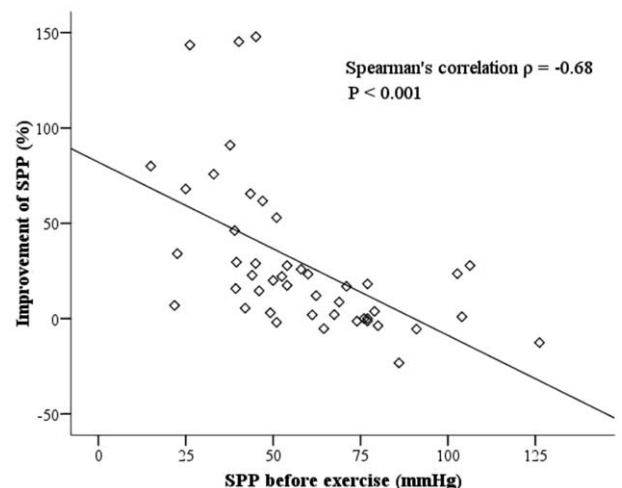


Figure 4. Correlation between the initial severity of dorsal foot ischemia and improvement of SPP. SPP = skin perfusion pressure.

Detailed stratification on the presence of respective comorbidities could yield further results. Secondly, we did not have a control cohort of comparable patients without Buerger exercise. Also, regular follow-up and exact completion of Buerger exercise at home could be limited due to its community-based nature. Further randomized cohort studies are required to identify the maximal effects or the “cut-point” for establishing treatment recommendation when doing Buerger exercise.

5. Conclusions

DFU are a common complication in patients with diabetes. PAD can deteriorate DFU and thus result in amputation. Significant increased SPP values in either wounded or unwounded diabetes feet immediately after Buerger exercise were observed, which indicated that Buerger exercise can improve foot peripheral circulation in subgroups of our study. We conclude that Buerger exercise is an ideal and noninvasive physical therapy for patients with diabetes combined with peripheral vascular disease as it is an easy-to-learn, repetitive, low-cost, and low-risk physical activity.

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