Effect of foot-ankle flexibility and resistance exercise in the secondary prevention of plantar foot diabetic ulcer

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Effect of foot-ankle flexibility and resistance exercise in the secondary prevention of plantar foot diabetic ulcer

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ABSTRACT

Aims: The study aimed to evaluate the effects of foot-ankle flexibility and resistance exercises on the recurrence rate of plantar foot diabetic ulcers, HbA1c levels, diabetic neuropathy examination (DNE) scores, ankle brachial index (ABI), and walking speed within 12 and 24 weeks.

Methods: We conducted a double-blind randomized clinical trial. Fifty patients with recently healed plantar foot diabetic ulcers were randomized to an intervention group that performed foot-ankle flexibility and resistance exercise three times a week in their home ($n = 25$) or a control group ($n = 25$). Both groups were given foot care education. Outcomes were assessed at plantar foot diabetic ulcer recurrence or at 12 and 24 weeks whichever came first. Outcome measures included plantar foot diabetic ulcer recurrence, changes of HbA1c levels, DNE scores, ankle brachial index ABI, and walking speed.

Results: There were significant difference between groups in ulcer recurrence at either 12 weeks (intervention 8%, control 68%, RR 0.288; 95% CI 0.156–0.534, P = 0.000) within 12 weeks, or 24 weeks (intervention 16%, control 72%, RR 0.222; 95% CI 0.088–0.564, P = 0.000).). There were significant differences in the DNE score delta (P = 0.000) and walking speed delta (P = 0.000), but there were no significant differences in the HbA1c delta and ABI delta between groups at either 12 or 24 weeks.

Conclusions: Foot-ankle flexibility and resistance exercises can reduce the recurrence of plantar foot diabetic ulcer incidence and improve diabetic neuropathy and walking speed.

Clinical trial number: NCT04624516

1. Introduction

Diabetic foot ulcer is a break of the foot skin that includes minimally the epidermis and part of the dermis in diabetic patients.[1] Diabetic foot ulcer is the common, complex, and costly complication of diabetes that affect in the lower extremities.[2] It is the most frequently complication of diabetes.[2] Globally, about 16% of diabetic patients live with diabetic foot ulcers.[3] The prevalence of diabetic foot ulcer is higher in type 2 diabetic patients than in type 1 diabetic patients.[3] Plantar foot is the most location of diabetic foot ulcers.[2]

Plantar foot diabetic ulcers have a high risk of recurrence.[4,5] The ulcer may recur within 14 days after healing.[6] The ulcer recurrence rate within one year is up to 40%, which places a large burden on patients.[2] Thus, the prevention of diabetic foot ulcer recurrence is very important.[7,8] Many factors are associated with diabetic foot ulcer recurrences, such as diabetic neuropathy,[9] peripheral arterial disease,[5] poor glycemic status,[4] preulcerative lesions,[10] previous foot ulcer duration,[10] walking activity variation,[10] and high plantar pressure.[10] Preventive measures should modify these factors.

Exercise is recommended to prevent the complication of diabetes.[11] Exercise is planned and structured of any bodily movement produced by skeletal muscles that result in any energy expenditure above resting levels.[12,13] In accordance with exercise guidelines of diabetic patients that each type of exercise has its own objectives.[12–14] Several forms of exercise can combine several types of exercises.[12]

Evidence has demonstrated that foot exercise can improve the risk

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factors for diabetic foot ulcers, such as diabetic neuropathy symptoms, plantar pressure distribution, foot-ankle joint mobility, and strength in diabetic patients.[15–18] Systematic reviews have shown that foot exercise significantly improves nerve velocity conduction, peripheral sensory function, and plantar pressure distribution.[11] Moreover, a randomized controlled trial showed that the incidence rate per year was lower in the foot exercise group than in the control group in diabetic patients, but the foot ulcer rate did not differ significantly between groups.[19] As diabetic exercise guidance, flexibility exercise can improve joint mobility, and resistance exercise can improve blood glucose and muscle strength.[13] Whereas foot exercise plays an important role in decreasing diabetic foot risk factors, foot exercise is not a part of diabetic foot ulcer prevention guidance.[20]

Little is known about the role of foot exercise in plantar foot diabetic ulcer recurrence. We hypothesized that foot-ankle flexibility and resistance exercise could decrease diabetic foot ulcer incidence and improve diabetic neuropathy, ankle brachial index (ABI), HbA1c, and walking speed. This study aimed to evaluate the effects of foot-ankle flexibility and resistance exercise on the recurrence rate of plantar foot diabetic ulcers within 12 and 24 weeks. The study also evaluated the effect of foot-ankle exercise on the changes of HbA1c levels, walking speed, diabetic neuropathy examination (DNE) score, and ABI at 12 and 24 weeks.

2. Subjects, material, and methods

This study was approved by the local ethics committee of the Medicine Faculty of Diponegoro University and was performed following the principles expressed in the Declaration of Helsinki. All subjects gave written informed consent before participation in the study.

In this prospective clinical trial, 50 patients were eligible and were randomized to an intervention group (n = 25) or a control group (n = 25) using a simple random allocation program that prepared in advance of the study. Patients were consecutively recruited from two hospitals in Semarang, Indonesia. All patients were type 2 diabetes based on diagnosis of the doctor in the hospital. The inclusion criteria were recently healed plantar foot diabetic ulcers (≤ 12 months before study entry) and age 40–60 years. The exclusion criteria were an active plantar foot ulcer, inability to walk, osteomyelitis history, Parkinson's disease, and contracture.

The data were assessed by observer and assessor blinding. The plantar foot ulcer was defined as a full-thickness lesion of the skin, i.e., wound penetration through the dermis at the plantar foot, without reference to the time present. Patients were asked to inform the researcher whenever the ulcer occurred as soon as possible. Photographs of the plantar foot were taken when an ulcer occurred and were assessed for outcomes by diabetic foot expert blinding.

Diabetic neuropathy examination (DNE) scores were defined as a composite score of 8 elements in the diabetic neuropathy examination.[21,22] Each score was in a range of 0–2, where 0 was normal, 1 was decreased, and 2 was abnormal/absent.[22] The total score range was 0–16.[22] Walking speed was defined as the ratio of distance to time. Walking speed test was performed by asking the patients to walk as fast as they could within 5 m in straight line, smooth floor and indoor. The observer measured the walking time in seconds using a stopwatch. The ankle brachial index (ABI) was defined as the ratio of the highest systolic pressure of the ankle and brachialis. ABI was measured using a hand held doppler with 8 MHz probe. HbA1c levels were analyzed in the clinical laboratory with the National Glycohemoglobin Standardization Program (NGSP) certification. Blood samples were taken from a vein in patient's arm using a small needle. A small amount of blood was collected into a test tube and sent to clinical laboratory to measure the HbA1c levels. All measurements were carried out on the same day and the measurement of walking speed was the last taken. At study entry, demographic and disease-related data were collected, as were DNE score, ABI, walking speed, and blood samples to check the HbA1c levels. DNE score, ABI, and walking speed were measured by observer blinding. The measurements of and the collection of blood samples to evaluate the HbA1c levels were repeated until a plantar foot ulcer occurred or until 12 and 24 weeks, whichever came first. The evaluations were made a total of 2 time in the study (12 and 24 weeks).

Patients in control and intervention groups were given foot care education in the hospital and were re-educated by the researcher in their home. They were encouraged to perform foot care every day, take their medicines regularly, and visit the doctor every 1–3 months. Patients in control groups were monitored every three weeks by phone to ensure the emergence of recurrence. During the monitoring, the patients were asked if doing exercise inside and outside the house independently.

The exercise intervention was given after the education and the first data measured on the following day. Patients in the intervention group received foot exercises incorporating flexibility and resistance training using an elastic band with a thickness of 0.5 mm in the first 12 weeks and 0,65 mm in the second 12 weeks in sitting position with the help of modules and videos. The elastic band was tied at a tool that was made from bengkirai wood, so the patient could perform the exercise without handling an elastic band in sitting position on the chair. Patients were asked to perform flexibility and resistance exercises independently at home according to the protocol at a frequency of 3 times a week with a non-consecutive day. The patients performed exercises that stretched and strengthened the muscles, tendons, ligaments around the ankle joint, metatarsophalangeal joint, and interphalangeal joint. Patients performed plantarflexion, dorsiflexion, inversion, eversion of the ankle joint, flexion and extension of the interphalangeal joint, and adduction, abduction, flexion, and extension of the metatarsophalangeal joint during flexibility and resistance exercise. The flexibility or stretching exercise was held for about 15 min and continued by strengthening or resistance exercise. During each exercise, they performed 30 repetitions of flexibility exercise, but they performed a number of repetitions of resistance exercise until felt tired (there was no number of minimum or maximum of repetitions). The repetition could be increased in each session. Before each exercise session, the patients performed the warming exercise in sitting position by tapping their feet to the floor slowly like a person walking for 30 times, and after each exercise, the patients cooled down by taking 10 deep breaths. Patients completed the exercise logbook after they performed the exercise. Patients were monitored every three weeks to ensure foot exercises were performed by checking the logbook.

Intention to treat analysis was used in the study. The last data observation was used to fill the missing data collection. Comparisons of categorical data at the end of the follow-up period were performed using the chi-square test, and the relative risk was reported. The study also used intergroup analysis (independent *t*-test and Mann-Whitney *U* test) to evaluate the effects of exercise on the HbA1c delta, DNE score delta, ABI delta, and walking speed delta.

3. Results

Fifty patients with a recently healed plantar foot diabetic ulcer (≤12 months) participated in the trial, but six patients couldn't complete the outcomes and were still alive with no ulcer (Fig. 1). The intervention and control groups were good matches for age, sex, diabetes type, diabetic severity, strength and range of motions of the great toe and ankle joint, diabetic duration, medication usage, body mass index, HbA1c level, DNE score, ABI and walking speed in the baseline (Table 1).

The patients were followed until a plantar foot ulcer occurred or until the end of the observation period. Thus, the range of timepoints actually taken in the result was 1 to 24 weeks. Based on logbook, all patients in intervention group had very good compliance. Patients performed the exercise (Fig. 2) 3 times a week with 30 repetitions of flexibility exercise and 5–50 repetitions of resistance exercise using elastic band. Table 2. In the intervention group, ulceration recurred in 2 patients (4%), whereas 17 patients (68%) experienced recurrence in the control group (RR

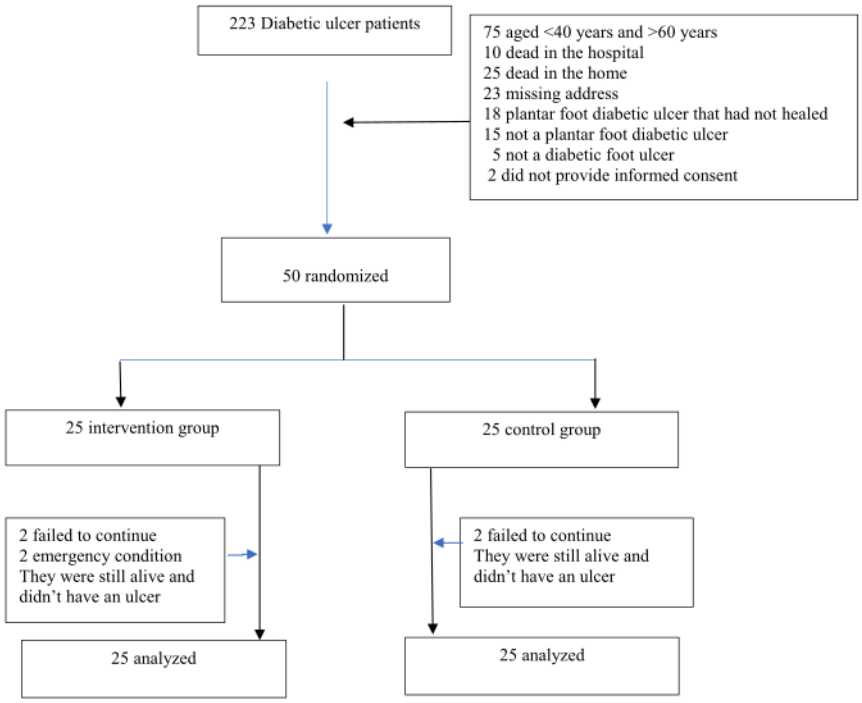

Fig. 1. Consort diagram.

Table 1
Baseline characteristics.

Characteristics	Intervention group	Control group	P
Subject	25	25	
Sex			1000
Male	13 (50)	13 (50)	
Female	12 (50)	12 (50)	
Age (years)	54.00 ± 5,96	56,00 ± 5,89	0,619
Body mass index (kg/m^2)	25.00 ± 5,37	24.00 ± 5,99	0,647
Type 2 diabetes	25 (100)	25 (100)	1.000
Diabetic duration (years)	9.60 ± 8,59	9.16 ± 5,13	0,380
Medication usage			0,713
Antidiabetic oral	21 (51,2)	20 (48,8)	
Insulin + antidiabetic oral	4 (44,4)	5 (55,6)	
Diabetic severity			1.000
Diabetic neuropathy	23 (92)	23 (92)	
Peripheral arterial disease	2 (8)	2 (8)	
Hypertension	25 (100)	25 (100)	
Range of motion			
Great toe (dorsiflexion)	22,62 ± 8.17	23.52 ± 8.64	0.734
Ankle (plantarflexion)	18.78 ± 6.89	18.50 ± 7.46	0.740
Ankle Strength (MRC scale)	4.00 ± 0.00	4.00 ± 0.00	1.000
HbA1c (%)	10,11 ± 2,04	9,48 ± 1,99	0,276
ABI	1,10 ± 0,15	1,11 ± 0,16	0,861
DNE	7,60 ± 3,22	7,76 ± 2,79	0,840
Waking speed (m/s)	0,59 ± 0,17	0,61 ± 0,21	0,831

Data are the mean ± SD, and frequency (%).

0.288; 95% CI 0.156–0.534, P = 0.000) within 12 weeks. Within 24 weeks, plantar foot diabetic ulceration recurred in 4 patients (16%) in the intervention group and in 18 patients (72%) in the control group (RR 0.222; 95% CI 0.088–0.564, P = 0.000).

Table 3. The differences in the DNE score and walking speed changes between the two groups were significant at 12 and 24 weeks. In the intervention group, mean DNE score decreased up to 3.62 ± 1.58 at 12 weeks and 4.38 ± 3.13at 24 weeks, but mean walking speed

Fig. 2. Patient perform the exercise.

increased up to 0.06 ± 0.12 at 12 weeks and 0.11 ± 0.16 at 24 weeks. There were no significant differences in the HbA1c level or ABI changes between two groups at 12 and 24 weeks.

4. Discussion

For the first time, a randomized controlled trial demonstrated that foot-ankle flexibility and resistance exercise can reduce the recurrence rate of plantar foot diabetic ulcers in patients with a history of plantar foot diabetic ulcers significantly. Difference to a previous randomized

Table 2
Results for the recurrence of plantar foot diabetic ulcer.

	12 weeks			24 weeks		
	n (%)	RR (95%CI)	P	n (%)	RR (95%CI)	P
Intervention group	2 (8)	0.288 (0.156–0.534)	0.000	4 (16)	0.222 (0.088–0.564)	0.000
Control group	17 (68)			18 (72)		

Table 3
Results for DNE score, walking speed, ABI, HbA1c.

	Delta 12–0 weeks	Delta 24–0 weeks
DNE		
Intervention group	−3.62 ± 1.58	−4.38 ± 3.13
Control group	0.09 ± 2.94	0.04 ± 2.96
P	0.000	0.000
Walking speed		
Intervention group	0.06 ± 0.12	0.11 ± 0.16
Control group	−0.02 ± 0.11	−0.04 ± 0.12
P	0.000	0.000
ABI		
Intervention group	0.02 ± 0.09	0.03 ± 0.12
Control group	−0.02 ± 0.12	−0.02 ± 0.14
P	0.192	0.296
HbA1c		
Intervention group	0.23 ± 1.23	0.57 ± 2.29
Control group	0.07 ± 1.43	0.36 ± 1.32
P	0.685	0.801

Data are the mean ± SD. P difference in the changes between the groups.

controlled trial study that the incidence rate per year was lower in the foot exercise group than in the control group in diabetic patients, but the foot ulcer rate did not differ significantly between groups.[19] The previous study used weight bearing exercise.[19] These types of exercise may explain the difference result of the study.

Foot-ankle flexibility and resistance exercises can protect patients from the recurrence rate of plantar foot diabetic ulcers with an efficacy of 72% in 12 weeks and 78% in 24 weeks. Exercise can prevent the plantar diabetic foot ulcer recurrence. Some of risk factors of diabetic foot ulcer significantly improved after a few weeks of exercise therapy.[23] Exercise can decrease the risk of neuropathic plantar diabetic foot ulcer risk such as limited joint mobility that induce abnormal walking.[23] Additionally, it seems that there were improvements in diabetic neuropathy and walking speed but not in HbA1c and the ABI of the patients who performed the exercises within 12 and 24 weeks. These improvements may explain the success of foot-ankle flexibility and resistance exercises.

The study showed that patients had poor diabetic neuropathy score, HbA1c, and walking speed, except ABI in the baseline. The higher the DNE score is, the higher the diabetic neuropathy severity.[21,22] Patients with more severe diabetic neuropathy will have decreased or absent sensation sensitivity, ankle reflex, and muscle strength in a diabetic neuropathy examination.[21,22] Foot exercise has been frequently reported to improve diabetic neuropathy symptoms, plantar pressure, range of motion, and muscle strength in diabetic patients.[15–18] Foot-ankle exercise decreased the DNE score up to 3.62 within 12 weeks and 4.38 within 24 weeks. According to Kluding et al., exercise could induce nerve protection or recovery by reducing oxidative stress and increasing neurotrophic factors,[24] but the study didn't analyze it. Regular foot exercises also increase the conductivity of peripheral nerves so that peripheral nerve function improves.[24] The sensation sensitivity function is very important to protect patients from trauma that causes diabetic foot ulcers.[2,20,25] Thus, the improvement in sensitivity sensation may protect patients from plantar diabetic foot ulcer recurrence.

Diabetic neuropathy causes musculoskeletal dysfunction that decreases walking speed.[26] Peripheral nerve dysfunction can decrease mobility and muscle strength.[26] Thus, the walking speed will be decreased, and plantar pressure will be increased.[26] The lower the musculoskeletal function is, the greater the plantar overload under the respective segment during walking.[26] The improvement in walking speed may protect patients from plantar diabetic foot ulcer recurrence. Foot exercise increased the walking speed up to 0.06 m/s within 12 weeks and 0.11 m/s within 24 weeks.

Patients performed the exercise using elastic band with different thickness within first 12 weeks and second 12 weeks. The repetition was increased in each session of exercise. Patients had difference number of repetitions. It could be that the more repetitions of the exercise the better the changes in the outcomes such as walking speed and diabetic neuropathy scores that interfere the recurrence of plantar foot diabetic ulcer. The intensity and duration of exercise may explain the difference outcomes between 12 and 24 weeks. However, the medication, daily activities, diet could interfere the outcomes also. All patients in control group didn't perform the exercise inside and outside the house. They just did the daily activities like usually they did.

There were several limitations of study. First, not all the patients could complete the outcomes, so we used the last observation data to fill the missing outcomes data. Second, daily activities, kind of medication, and diet that could influence the outcomes were not controlled in the study.

5. Conclusions

Foot-ankle flexibility and resistance exercise can prevent plantar foot diabetic ulcer recurrence. In conclusion, patients with a history of plantar foot diabetic ulcers can perform foot-ankle flexibility and resistance exercises individually to prevent recurrence. Patients may continue the exercise, increasing its intensity as they progress, to prevent plantar diabetic foot ulcers for a longer period of time. More studies with controlling the factors that can influence the outcomes are needed.

CRediT authorship contribution statement

Maria Suryani: conceptualization, methodology, validation, formal analysis, investigation, data curation, writing original draft, writing review and editing, project administration.**Widiastuti Samekto**: conceptualization, methodology, validation, formal analysis, review and editing.

Heri-Nugroho: conceptualization, methodology, validation, review, and editing.

Hardhono Susanto: conceptualization, review, and editing.

Luky Dwiantoro: conceptualization, review, and editing.

Declaration of competing interest

We confirm that potential conflict of interest for all authors that no conflicts exist are included in manuscript section.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jdiacomp.2021.107968.

References

1 Van Netten JJ, Bus SA, Apelqvist J, Lipsky BA, Hinchliffe RJ, Game F, et al. Definitions and criteria for diabetic foot disease. *Diabetes Metab Res Rev*. 2020;36, e3268. https://doi.org/10.1002/dmrr.3268.

2 Armstrong DG, Boulton AJM, Bus SA. Diabetic foot ulcers and their recurrence. *N Engl J Med*. 2017;376:2367–2375. https://doi.org/10.1056/NEJMra1615439.

3 Zhang P, Lu J, Jing Y, Tang S, Zhu D, Bi Y. Global epidemiology of diabetic foot ulceration: a systematic review and meta-analysis. *Ann Med*. 2017;49:106–116. https://doi.org/10.1080/07853890.2016.1231932/.

4 Dubsky M, Jirkovská A, Bem R, Fejfarová V, Skibová J, Schaper NC, et al. Risk factors for recurrence of diabetic foot ulcers: prospective follow-up analysis in the Eurodiale subgroup. *Int Wound J*. 2013;10:555–561. https://doi.org/10.1111/j.1742-481X.2012.01022.x.

5 Peters EJG, Armstrong DG, Lavery LA. Risk factors for recurrent diabetic foot ulcers: site matters. *Diabetes Care*. 2007;30:2077–2079. https://doi.org/10.2337/dc07-0445.

6 Pound N, Chipchase S, Treece K, Game F, Jeffcoate W. Ulcer-free survival following management of foot ulcers in diabetes. *Diabet Med*. 2005;22:1306–1309. https://doi.org/10.1111/j.1464-5491.2005.01640.x.

7 Van Netten JJ, Price PE, Lavery LA, Monteiro-Soares M, Rasmussen A, Jubiz Y, et al. Prevention of foot ulcers in the at-risk patient with diabetes: a systematic review. *Diabetes Metab Res Rev*. 2016;32:84–98. https://doi.org/10.1002/dmrr.2701.

8 Jeffcoate WJ, Vileikyte L, Boyko EJ, Armstrong DG, Boulton AJM. Current challenges and opportunities in the prevention and management of diabetic foot ulcers. *Diabetes Care*. 2018;41:645–652. https://doi.org/10.2337/dc17-1836.

9 Bus SA, van Netten JJ. A shift in priority in diabetic foot care and research: 75% of foot ulcers are preventable. *Diabetes Metab Res Rev*. 2016;32:195–200. https://doi.org/10.1002/dmrr.2738.

10 Waaijman R, de Haart M, Arts MLJ, Wever D, Verlouw AJWE, Nollet F, et al. Risk factors for plantar foot ulcer recurrence in neuropathic diabetic patients. *Diabetes Care*. 2014;37:1697–1705. https://doi.org/10.2337/dc13-2470.

11 Matos M, Mendes R, Silva AB, Sousa N. Physical activity and exercise on diabetic foot related outcomes: a systematic review. *Diabetes Res Clin Pract*. 2018;139:81–90. https://doi.org/10.1016/j.diabres.2018.02.020.

12 Sigal RJ, Armstrong MJ, Bacon SL, Boulé NG, Dasgupta K, Kenny GP, et al. Physical activity and diabetes. *Can J Diabetes*. 2018;42:S54–S63. https://doi.org/10.1016/j.jcjd.2017.10.008.

13 Colberg SR, Sigal RJ, Yardley JE, Riddell MC, Dunstan DW, Dempsey PC, et al. Physical activity/exercise and diabetes: a position statement of the American Diabetes Association. *Diabetes Care*. 2016;39:2065–2079. https://doi.org/10.2337/dc16-1728.

14 Colberg SR. Key points from the updated guidelines on exercise and diabetes. *Front Endocrinol (Lausanne)*. 2017;8:33. https://doi.org/10.3389/fendo.2017.00033.

15 Cerrahoglu L, Kocsan U, Sirin TC, Ulusoy A. Range of motion and plantar pressure evaluation for the effects of self-care foot exercises on diabetic patients with and without neuropathy. *J Am Podiatr Med Assoc*. 2016;106:189–200. https://doi.org/10.7547/14-095.

16 Iunes DH, Rocha CBJ, Borges NCS, Marcon CO, Pereira VM, Carvalho LC. Self-care associated with home exercises in patients with type 2 diabetes mellitus. *PLoS One*. 2014;9, e114151. https://doi.org/10.1371/journal.pone.0114151.

17 Kluding PM, Pasnoor M, Singh R, Jernigan S, Farmer K, Rucker J, et al. The effect of exercise on neuropathic symptoms, nerve function, and cutaneous innervation in people with diabetic peripheral neuropathy. *J Diabetes Complications*. 2012;26:424–429. https://doi.org/10.1016/j.jdiacomp.2012.05.007.

18 Sartor CD, Hasue RH, Cacciari LP, Butugan MK, Watari R, Pássaro AC, et al. Effects of strengthening, stretching and functional training on foot function in patients with diabetic neuropathy: results of a randomized controlled trial. *BMC Musculoskelet Disord*. 2014;15:137. https://doi.org/10.1186/1471-2474-15-137.

19 LeMaster JW, Mueller MJ, Reiber GE, Mehr DR, Madsen RW, Conn VS. Effect of weight-bearing activity on foot ulcer incidence in people with diabetic peripheral neuropathy: feet first randomized controlled trial. *Phys Ther*. 2008;88:1385–1398. https://doi.org/10.2522/ptj.20080019.

20 Bus SA, Van Netten JJ, Lavery LA, Monteiro-Soares M, Rasmussen A, Jubiz Y, et al. IWGDF guidance on the prevention of foot ulcers in at-risk patients with diabetes. *Diabetes Metab Res Rev*. 2016;32:16–24 (doi:10.1002/dmrr.2696).

21 Meijer J-WG, Bosma E, Lefrandt JD, Links TP, Smit AJ, Stewart RE, et al. Clinical diagnosis of diabetic polyneuropathy with the diabetic neuropathy symptom and diabetic neuropathy examination scores. *Diabetes Care*. 2003;26:697–701. https://doi.org/10.2337/diacare.26.3.697.

22 Meijer J-W, van Sonderen E, Blaauwwiekel EE, Smit AJ, Groothoff JW, Eisma WH, et al. Diabetic neuropathy examination: a hierarchical scoring system to diagnose distal polyneuropathy in diabetes. *Diabetes Care*. 2000;23:750–753. https://doi.org/10.2337/diacare.23.6.750.

23 Francia P, Gulisano M, Anichini R, Seghieri G. Diabetic foot and exercise therapy: step by step the role of rigid posture and biomechanics treatment. *Curr Diabetes Rev*. 2014;10:86–99.

24 Kluding PM, Bareiss SK, Hastings M, Marcus RL, Sinacore DR, Mueller MJ. Physical training and activity in people with diabetic peripheral neuropathy: paradigm shift. *Phys Ther*. 2017;97:31–43. https://doi.org/10.2522/ptj.20160124.

25 Alavi A, Sibbald RG, Mayer D, Goodman L, Botros M, Armstrong DG, et al. Diabetic foot ulcers: part I. Pathophysiology and prevention. *J Am Acad Dermatol*. 2014;70:1–e1. https://doi.org/10.1016/j.jaad.2013.06.055.

26 Sacco ICN, Sartor CD. From treatment to preventive actions: improving function in patients with diabetic polyneuropathy. *Diabetes Metab Res Rev*. 2016;32:206–212. https://doi.org/10.1002/dmrr.2737.

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