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Comparison of Walking with Poles and Traditional Walking for Peripheral Arterial Disease Rehabilitation

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Abstract

PURPOSE—The purpose of this study was to compare the effects of a 24-week walking with poles rehabilitation program with a traditional 24-week walking program on physical function in patients with peripheral arterial disease (PAD).

METHODS—Patients with PAD (n=103, age = 69.7±8.9 years, ankle-brachial index <0.90 or evidence of calcified vessels) were randomized into a rehabilitation program of traditional walking (n=52) or walking with poles (n=51). Patients exercised 3 times per week for 24 weeks. Exercise endurance was measured by time walked on a constant workrate treadmill test at 6, 12, and 24 weeks. Perceived physical function was measured by the SF-36 and Walking Impairment Questionnaire. Tissue oxygenation was measured using near-infrared spectroscopy.

RESULTS—Patients assigned to the traditional walking group walked longer at 24 weeks than those assigned to the pole walking group (21.10±17.07 min and 15.02±12.32 respectively, P=.037). There were no differences between the groups in tissue oxygenation. However, there was a significant lengthening of time for which it took to reach minimum tissue oxygenation values (P <0.001) within the groups on the constant workrate test. There were no differences between the groups in perceived physical function as measured by the physical function subscale on the Short-Form 36 or perceived walking distance as measured by the walking distance subscale on the Walking Impairment Scale.

CONCLUSIONS—Traditional walking was superior to walking with poles in increasing walking endurance on a constant workrate treadmill test for patients with peripheral arterial disease.

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Keywords

peripheral arterial disease; walking exercise; rehabilitation

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Patients with peripheral arterial disease of the lower extremities are subject to periods of intermittent claudication pain causing ischemic muscle pain with ambulation. The ability of patients with peripheral arterial disease to walk on level ground for more than a short distance is variably impaired. Walking exercise has been prescribed as the primary mode of rehabilitative treatment in patients with peripheral arterial disease[1] and walking with poles has been shown to increase stride length, cadence, and walking speed and decrease ground reaction forces on the joints.[2] The purpose of this study was to compare the effects of a 24-week walking with poles rehabilitation program with a traditional 24-week walking program on physical function (defined as exercise endurance on a constant work rate (CWR) treadmill test and self-reported physical function from the Medical Outcomes Study Short-Form 36). We hypothesized that walking with poles would be superior to traditional walking in improving exercise performance in a CWR treadmill test.

METHODS

The study was approved by the appropriate institutional review boards and written informed consent was obtained from all subjects. Criteria for inclusion in the study were that subjects had an ankle-brachial index (ABI) in their most affected leg of ≤0.90 or had documented calcification of vessels, were 21 years or older, and had a positive response on the Edinburgh Claudication Questionnaire. Subjects were excluded if they had ischemic ulcerations in their legs or feet, had a frozen shoulder, had unstable coronary arterial disease, amputation, were unable to walk on a treadmill, participated in a formal exercise program within 12 weeks of this program, or stopped exercise due to arthritic knee or hip pain at baseline.

A total of 2296 subjects were screened for eligibility in the study. Of these, 146 subjects were enrolled and 103 were randomized (see Figure 1). Fifty-one subjects were randomized to the walking with poles program and 52 subjects were randomized to the traditional walking program.

Research Design

This study was a randomized, controlled clinical trial. After baseline testing was completed, subjects were randomized into 1 of 2 groups: exercise training with Exerstrider™ poles or a standard (traditional) walking exercise-training program.

Peripheral Arterial Disease Testing

Peripheral arterial disease was confirmed using the ankle-brachial index (ABI) or vascular laboratory doppler evaluation. The ABI is the ratio of systolic blood pressure in the ankle to that in the arm. The ABI was measured at baseline in both legs and in the more severely affected leg thereafter. The dorsalis pedis or posterior tibial arteries were used for measurement. The location of the signal was recorded and used consistently throughout the study for that individual subject. After the subject rested comfortably in a supine position for 15 minutes, Doppler ultrasound was used to measure the systolic pressure in the right and left arms and in the ankle of the most severely affected leg. For patients with an ABI ≥1.2, vessel calcification was confirmed by the vascular laboratory.

Exercise Testing

Symptom-limited treadmill test protocol—Subjects were tested using a gentle treadmill protocol that was developed for patients with peripheral arterial disease.[3,4] Increases in percent grade occur every 30 seconds, and, after the first 6 minutes, speed increases every 3 minutes. Validity and reliability of the treadmill protocol has been previously shown.[3] Electrocardiogram and tissue oxygenation (StO_2) of the gastrocnemius muscle were monitored continuously throughout the test.

Constant work rate sub maximal treadmill test protocol—Exercise endurance was measured as exercise time on a CWR treadmill test. The CWR treadmill test consisted of a 2-minute warm-up and then the grade and speed of the treadmill were increased to the level in effect when the patient achieved 85% of his/her peak oxygen uptake on the baseline progressive treadmill test. Two baseline CWR tests were completed and the best performance was used in the analysis.

Tissue oxygenation—Tissue oxygenation of the most severely affected leg was measured using near-infrared spectroscopy. The near-infrared spectroscopy probe was placed on the widest part of the gastrocnemius muscle of the leg with the lowest ABI or most symptomatic for those subjects with stiff vessels. Tissue oxygenation measures were recorded continuously during 5 minutes of sitting pre-exercise, 2 minutes of standing pre-exercise, during exercise, and for 5 minutes postexercise. Spectroscopy data were analyzed using an isotime (spectroscopy measures recorded at a time consistent across all testing). Measurements were also recorded for the time it took for the oxygen values to drop to their minimum level after initiation of exercise.

Gait Analysis

The motions of 22 passive reflective markers were recorded by an 8-camera motion capture system recording at 120 Hz (Motion Analysis, Santa Rosa, CA). Ground reaction forces were acquired at 1200 Hz from 2 force plates (AMTI, Newton, MA) embedded within the laboratory walkway. Compression forces within the poles were measured by instrumenting them with a half-bridge arrangement of strain gauges (Entran Devices, Inc. Fairfield, NJ). Strain gauges were mounted approximately 1.5 inches below the handgrip of the pole: 1 strain gauge on the anterior surface of the pole, the other on the posterior surface. Gait analysis was completed for patients at baseline and 6 weeks. Those patients assigned to the walking with poles groups completed additional walking tests using the poles at the 6-week measurement time.

Quality of Life

The Medical Outcomes Study Short Form-36 v2 was used to measure perceived physical function.[5] Physical and emotional function component subscales derived from responses on the Short Form-36 have high levels of reliability and stability of scores when the Short Form-36 is administered to groups of medically stable individuals.[5,6]

The Walking Impairment Questionnaire was used to evaluate the subject self-reported walking limitations in walking distance, walking speed, and stair climbing.[7,8] Responses to the 18 questions are ranked on a 0 – 3 Likert-like scale (0 = did not do, 3 = no difficulty). Each domain is scored on a 0–100 scale with 0 representing extreme limitations and 100 no limitations or difficulties.

Comorbidities

The Index of Coexistent Diseases[9] was used to measure comorbidities at baseline. The Index of Coexistent Diseases has two major dimensions: the physiologic severity of each chronic comorbid condition and an assessment of the impairment or disability caused by comorbidity at a specific point in time.

Randomization and Study Intervention

Permuted block randomization was computer-generated and group assignment was managed by the study statistician. Exercise training was conducted 3 times weekly for 24 weeks. Interval training was used with exercise intensity and duration increasing according to an established protocol designed for this study. Patients began walking for 30 minutes with 20% of the workout at light intensity, 60% at moderate intensity, and 20% at hard intensity. By week 24, the goals were that patients would exercise for 60 minutes with 10% at light intensity, 35% at moderate intensity, 50% at hard intensity, and 5% at very hard intensity. Exercise protocols were adjusted when patients were unable to reach established targets. Patients trained on indoor treadmills or outside when weather permitted. Exercise training parameters were identical with 1 group exercising with Exerstrider™ poles and one group without. Patients were trained on proper use of the Exerstrider™ poles.[10]

Statistical Analysis

Data were examined using frequency distributions whenever applicable to facilitate data interpretation. Data were summarized using appropriate descriptive statistics. Repeated-measures analysis of variance (ANOVA) and covariance (ANCOVA), using intent-to-treat procedures, were used for the outcome variables. Initial power calculations using a two-tailed t-test for independent samples, indicated that 50 subjects would be needed in each group to achieve a power of 0.80 ($\alpha = 0.05$, ES=0.56). The study was powered on a change in exercise endurance on the CWR test.

RESULTS

Sample characteristics and baseline data for the 103 randomized subjects are summarized in Tables 1–3. The majority of subjects were male (94%), Caucasian (80%), and older with a mean age of 69.7 ± 8.9 years. Subjects assigned to the pole walking group were older than subjects assigned to the traditional walking group (pole walking = 71.4 ± 9.1 yr, traditional walking = 68.0 ± 8.5 yr, $P<.05$). There were no significant differences with respect to gender, body mass index, smoking status, ABI, or comorbid diseases. Eighty-nine percent of subjects (n=91) had compressible vessels and 12% (n=12) had calcified vessels.

Exercise endurance was measured as exercise time on a CWR treadmill test. Since the pole walking group was older than the traditional walking group, subject age was entered into the analysis as a covariate. Intent-to-treat analyses were used. The last measurement taken for all subjects with at least 1 followup test was carried forward (n=97). Those patients assigned to the traditional walking group walked longer (21.10±17.07 min, 164% change from baseline) at 24 weeks than those assigned to the pole walking group (15.02±12.32, 103% change from baseline) (P=.037) (Table 4). However, when data were analyzed including only those who completed the protocol, there were no differences between the groups (traditional walking group, 22.10±16.35 min, 170% change from baseline; pole walking group, 17.06±13.57, 127% change from baseline) (Figure 2).

Tissue oxygenation data are presented in Table 5. Using repeated measures ANOVA, there were no differences between the groups in isotime measures (F = 0.06, P=.81) or the time it took to reach minimum values (F = 0.38, P=.54). However there was a significant lengthening of time for which it took to reach minimum oxygenation values (F=14.12, *P*<.001) within the groups on the CWR test. This finding indicates that with traditional walking or pole walking exercise training, subjects maintained higher oxygen saturation levels in the gastrocnemius muscle for longer periods of time while walking. The increase in walking time before reaching minimal values was 1.1 min for the CWR treadmill test.

Perceived leg pain onset was recorded during the CWR test. Values for time of pain onset are in Table 6. There were no between-group differences in onset of pain (*P*=.109). There was, however, a significant lengthening of pain onset over time within the groups (*P*<.001).

There were no differences between the groups in perceived physical function as measured by the physical function subscale on the Short-Form 36 or perceived walking distance as measured by the walking distance subscale on the Walking Impairment Scale. Data in Table 7 summarize scores at each measurement time point.

Adherence to exercise training was examined to determine if it influenced the study outcomes. Adherence was defined as the number of study sessions attended/number of study sessions expected to attend. Adherence values were restricted to the 97 subjects included in the intent to treat analysis. For the 97 subjects in the intent to treat analysis, adherence was computed based on a potential of 72 sessions (completing the study) and based upon point of drop out. Adherence to the exercise training sessions was 73±24% and 73±22% for the pole walkers and traditional walkers respectively (*P*=.96). When the number of sessions expected to attend ended at the point of study withdrawal, adherence for the pole walkers was 84±18% and the walkers was 79±20% (*P*=.13).

Gait biomechanics were completed on a subset of patients (36 patients assigned to pole walking and 25 patients assigned to the traditional walking group). There were no differences in the change in step length (*P*=.18), forward velocity (*P*=.96), or cadence (*P*=.14) between the groups at baseline and the 6-week measurement period. For those assigned to the pole walking group, gait characteristics were compared at 6-weeks while walking with and without the poles. Table 8 summarizes these findings. Lastly, pole compression force was not significantly correlated with any gait measures but was moderately correlated to improvement in duration on the CWR treadmill test at six weeks (r=.42, *P*=.014).

DISCUSSION

Data from this study indicate that a traditional walking program is superior to walking with poles in improving exercise duration in patients with peripheral arterial disease. Second, there were no differences between the 2 groups in onset of claudication pain, tissue oxygenation or perceived physical function; however, both groups showed improvements in all of these parameters.

To our knowledge, this is the first randomized trial to compare the effects of pole walking with traditional walking training in patients with peripheral arterial disease. Our group previously demonstrated that pole walking increases cardiovascular fitness in patients with peripheral arterial disease.[10, 11] Other investigators have also shown that using poles during aerobic exercise increases the cardiovascular work when compared to walking.[10, 12–16] We hypothesized that those assigned to the pole walking group would walk longer at 24 weeks than those who participated in a traditional walking program. Anecdotally, our patients relayed that they could walk further and longer before experiencing intermittent claudication pain when they walked with the poles. Oakley et al[16] demonstrated claudication distance, maximal walking distance and perceived pain improved when patients with peripheral arterial disease walked with Nordic poles compared to traditional walking on a treadmill.

Accordingly, one would expect that training with poles, compared to traditional walking would increase exercise tolerance.

Although both groups increased their walking endurance on the CWR treadmill test, contrary to our hypothesis, traditional walking was superior to pole walking in improving exercise endurance on a CWR test. In the one additional training study that compared pole walking to a traditional walking training program, investigators in Finland identified no differences in cardiovascular training response between middle-aged, non-obese women who participated in 13 weeks of pole walking as compared to 13 weeks of traditional walking.[17] In addition to cardiovascular responses, the Finnish investigators also measured neuromuscular fitness. The only parameter that differed between the groups was that leg strength was greater after training in the traditional walking groups as compared to the pole-walking group.[17]

We initially reasoned that by using the poles, individuals would increase their stride length, and walking speed as well as reduce vertical ground reaction and knee joint forces as posited by Wilson et al[2] Other investigators have failed to show these biomechanical benefits of pole walking.[18,19] Indeed, in a subset of patients, we found no difference in mean vertical or peak propulsive ground reaction forces between walking with or without poles.

Our training was based on intensity of exercise as determined by percent of maximal heart rate achieved on our symptom-limited treadmill test. Exercise intensity and duration in both groups were similar and held to protocol. Since more muscle groups were contributing to workload for those who participated in pole walking, exercise intensity was higher even though the workload on the exercising leg muscles may have been lower. Thus, the use of the poles may have reduced lower extremity oxygen demands subsequently reducing exercise-induced metabolic effects on the calf muscle.

There was a lengthening of the time calf muscle StO_2 took to reach its minimal value from baseline to 24 weeks in both groups although there was no difference between the groups. Failure to detect a between group difference may be due to the nature of the CWR treadmill test. After a 2-minute warm-up, the grade and speed of the treadmill was increased to the level in effect when the patient reached 85% of his/her peak oxygen uptake on the progressive treadmill test. At baseline, StO_2 levels dropped within about one minute of this increase in grade and speed; at 24 weeks, this decrease occurred about two minutes after the increase in grade and speed. This dramatic increase in workload may not have allowed for capturing fine differences between the groups.

However, walking exercise, with or without the use of walking poles, significantly prolonged the deoxygenation of the exercising muscle. These findings may be due to increased capillary density post-exercise training. Duscha et al[20] have demonstrated that the greatest increase in angiogenesis in the gastrocnemius muscle of patients with peripheral arterial disease occurs at 3 weeks postexercise training. We did not test patients at three weeks but also saw the greatest prolongation of muscle deoxygenation at the first followup exercise test at 6 weeks. Additionally, Gardner et al[21] have shown that patients who have shorter times reaching minimal values in StO_2 also experience shorter initial and absolute claudication distances. Thus, lengthening of this window may result in longer initial and absolute walking distances in patients with peripheral arterial disease.

As with tissue deoxygenation, we also noted a significant prolongation in time of onset of initial claudication pain. These findings have been supported by previous meta-analyses.[1,22] Onset of claudication pain occurred about 1 minute after patients reached their minimal StO_2 value and prolongation of perceived pain followed a similar pattern of prolonging the minimal StO_2 values.

We measured gait characteristics in a subset of patients at baseline and after 6-weeks of training with the walking poles. No differences in gait were identified between the groups. Although others have demonstrated differences in gait biomechanics when walking with poles versus not walking with the poles, we failed to identify such differences. Interestingly, we noted a moderate correlation with force on the poles and improved exercise duration on the 6-week CWR treadmill test. However, since we did not measure pole force during training, it is difficult to know whether this influenced the training outcomes. Similar to other investigators, we identified improved perceived physical function as measured by the Short Form-36 and Walking Impairment Questionnaire in both groups[3,4,23–25]

Limitations

The study sample was composed of primarily older men. Thus, our results cannot necessarily be generalized to younger populations with higher female representation. Additionally, our sample size may not have been large enough to detect other differences between groups in secondary outcomes such as gait characteristics.

CONCLUSIONS

Traditional walking was superior to walking with poles in increasing walking endurance on a CWR treadmill test. Both training programs, however, prolonged calf muscle deoxygenation and initial claudication pain, and improved physical functioning. This study further supports the importance of walking exercise in patients with peripheral arterial disease.

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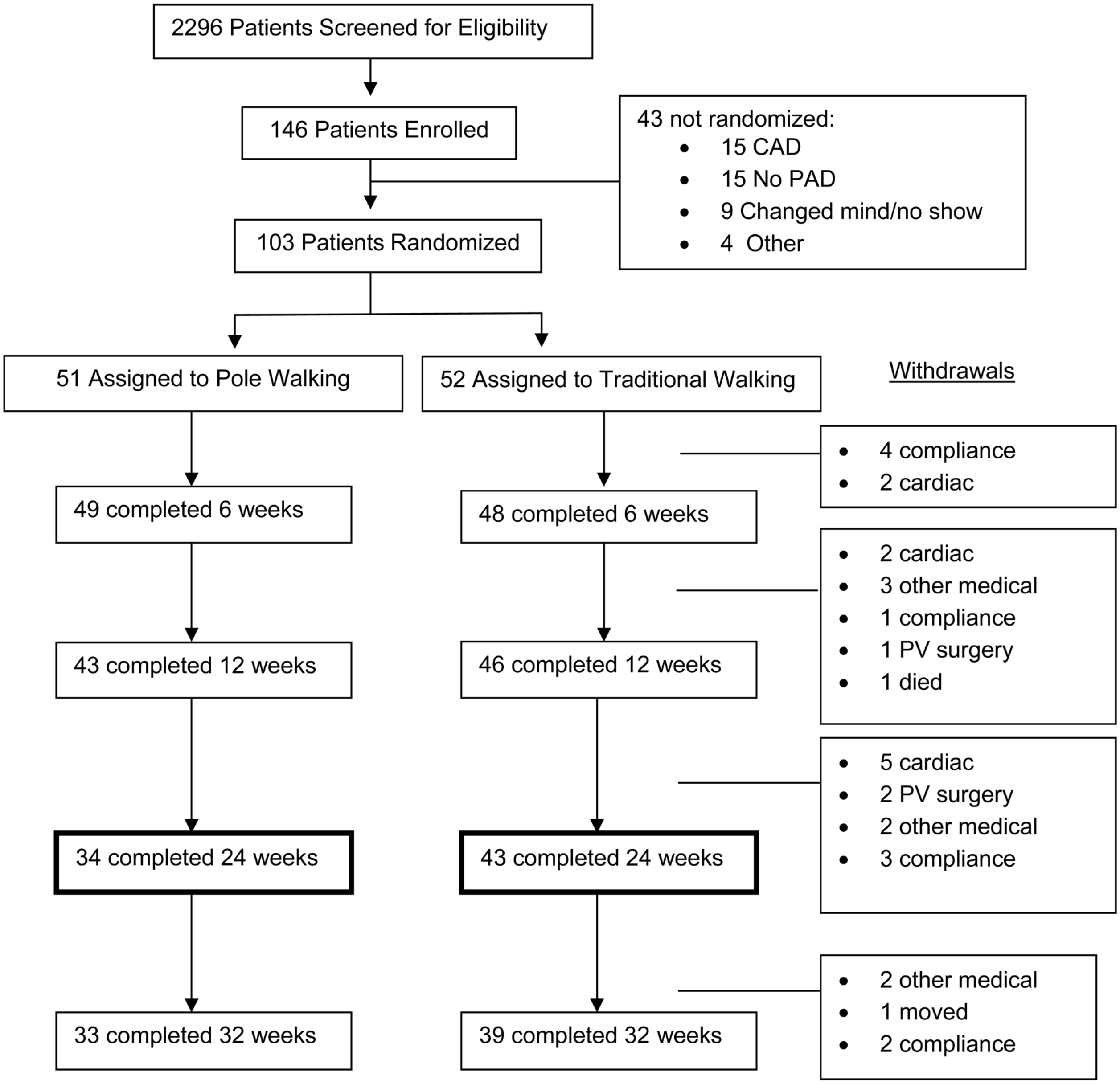

Figure 1.
Consort Flow Diagram for study. Abbreviations: CAD, coronary arterial disease; PAD, peripheral arterial disease; PV, peripheral vascular

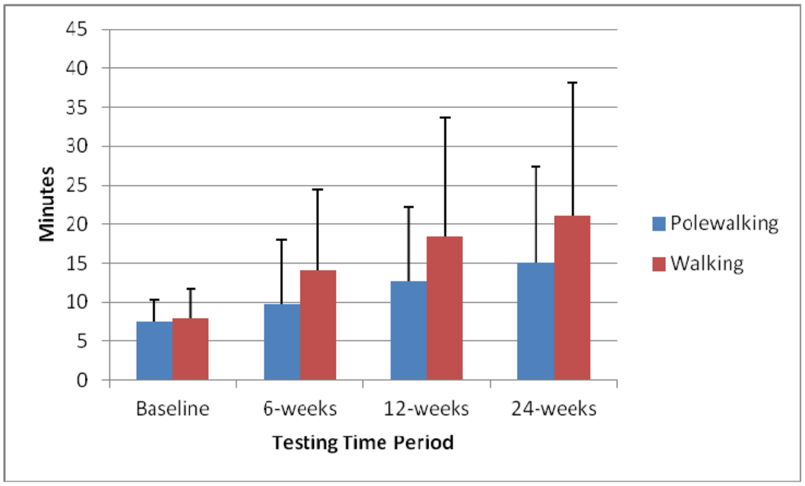

Figure 2a.

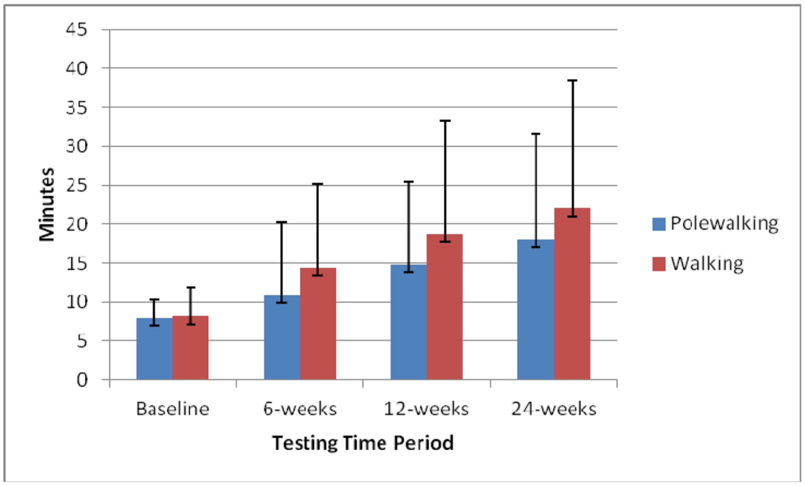

Figure 2b.

Figure 2.

Figure 2a. Exercise duration for all subjects (intent to treat, n=97).

Figure 2b. Exercise duration for all subjects (those who completed the protocol only, n=77)

Table 1

Demographic information for randomized subjects (n=103).

Parameter	**Combined (n=103)**	**Pole Walking (n=51)**	**Traditional Walking (n=52)**	***P*-value**
Age, y	69.7±8.9	71.4±9.1	68.0±8.5	.047
BMI	28.8±5.0	29.0±4.4	28.6±5.5	.67
Smoking (pack year)	43.2±34.2	37.4±25.9	48.9±40.2	.093
Smoking presently (%)	35	35	35	.45
Gender (n)				.45
Male	96	47	49	
Female	7	4	3	
Race (n)				.44
Black	18	9	9	
Caucasian	82	40	42	
Other	3	2	1	
ABI	0.63±0.17	0.62±0.20	0.65±0.36	.62
Index of comorbid disease	7.2±3.3	7.5±3.2	6.9±3.4	.42
Peak oxygen uptake ($ml^{-1}·kg^{-1}·min^{-1}$)	14.63±3.08	14.39±2.89	14.86±3.27	.44

Abbreviations: BMI, body mass index; ABI, ankle-brachial index.

Table 2

Outcome variables at baseline for randomized subjects (n=103).

Parameter	**Combined (n=103)**	**Pole Walking (n=51)**	**Traditional Walking (n=52)**	***P*-value**
Constant workrate treadmill test				
Exercise duration, min	7.74±3.25	7.41±2.85	8.06±3.59	.31
Rating of perceived leg pain at peak exercise (0–10, 10=maximum)	5.04±3.35	5.23±3.30	4.87±3.41	.58
Onset of claudication pain, min	3.96±2.36	3.82±2.27	4.10±2.45	.56
Gastrocnemius tissue oxygenation at rest, %	58.72±15.89	57.43±5.14	59.96±16.54	.43
Gastrocnemius tissue oxygenation at peak exercise, %	17.74±19.01	20.04±20.77	15.53±17.05	.24
Gait	n=61	n=34	n=25	
Step length, cm	61.02±7.75	60.38±7.37	62.73±7.51	.24
Forward velocity, cm/s	102.49±17.18	101.24±16.49	106.06±16.18	.27
Cadence, steps/min	100.46±9.27	100.41±8.45	101.24±9.96	.73

Table 3

Self-reported variables at baseline for randomized subjects (n=103).

Parameter	**Combined (n=103)**	**Pole Walking (n=51)**	**Traditional Walking (n=52)**	***P*- value**
Short-Form 36				
Physical Component Score	35.92±7.52	35.96±7.88	35.88±7.23	.96
Mental Component Score	52.64±10.26	51.82±11.29	53.44±9.20	.43
Walking Impairment Questionnaire				
Distance	34.20±27.68	33.16±28.35	35.22±27.24	.71
Speed	32.05±22.09	28.01±21.43	36.02±22.20	.065
Stair climbing	45.43±27.78	39.71±25.71	51.04±28.81	.038

Table 4

Mean exercise time on CWR tests at measurement timepoints (ITT, n=97)

Exercise time on CWR test, min	Pole Walking	% change	Traditional Walking	% change
Baseline	7.39±2.89	--	7.98±3.60	--
6-weeks	9.83±8.16	33	14.09±10.40	77
12-weeks	12.67±9.52	71	18.39±15.34	133
24-weeks	15.02±12.32	103	21.10±17.07	164

Repeated measures analysis of co-variance, age = covariate, F=4.47 *P*=.037 group effect (% change is from baseline)

Abbreviations: CWR, constant workrate treadmill test; ITT, intent to treat.

Table 5

StO_2 measures during the CWR test (n=95).

Parameter	Combined (n=95)	Pole Walking (n=49)	Traditional Walking (n=46)
Isotime, % oxygenation			
Baseline	18.2±20.6	19.5±21.5	16.8±19.8
6 weeks	18.9±20.9	18.6±20.2	19.1±21.8
12 weeks	18.9±28.2	20.8±33.9	16.8±20.5
24 weeks	21.2±22.0	20.2±22.1	22.3±22.2
Time to minimum value, min			
Baseline	3.2±2.5	3.2±2.7	3.2±2.4
6 weeks	3.9±2.9	3.8±2.7	3.9±3.2
12 weeks	4.4±3.7	4.5±4.1	4.3±3.2
24 weeks	4.3±3.6	3.8±3.1	4.9±4.2

There were no significant differences between the groups on tissue oxygenation or time to reach minimal values using repeated measures analysis of variance. There was a significant time effect in time to reach minimal values between baseline and 24 weeks (F = 14.12, *P*<.001).

Abbreviations: StO_2, tissue oxygenation; CWR, constant work rate treadmill test.

Table 6

Onset of leg pain during the CWR test.

Pain onset, min	Combined	Pole Walking	Traditional Walking
Baseline	4.0±2.4	3.7±2.0	4.2±2.7
6 weeks	4.3±3.4	3.8±2.5	4.7±4.0
12 weeks	4.8±3.8	5.2±5.0	4.4±2.5
24 weeks	7.9±8.9	9.3±12.1	6.8±4.8

There were no significant differences between the groups.

CWR, constant work rate treadmill test.

Table 7

Perceived physical function at measurement timepoints (ITT, n=97)

Physical Function subscale, Short Form-36	**Pole Walking**	**% change**	**Traditional Walking**	**% change**
Baseline	49.29±20.94	--	50.10±21.15	--
6-weeks	50.82±20.19	3	60.00±20.91	20
12-weeks	54.18±19.72	10	59.48±22.22	19
24-weeks	55.51±21.27	13	60.42±21.75	21
Distance subscale, WIQ	**Pole Walking**	**% change**	**Traditional Walking**	**% change**
Baseline	33.26±28.82	--	37.25±27.36	--
6-weeks	38.86±30.44	17	43.42±27.31	17
12-weeks	43.12±32.39	30	46.79±32.00	26
24-weeks	45.51±31.74	37	47.78±30.24	28

Repeated measures analysis of covariance, age = co-variate, Physical Function: F=1.53, *P*=.22;

Distance: F=0.71 *P*=.68 group effect (% change is from baseline).

Abbreviations: ITT, intent to treat; WIQ, Walking Impairment Questionnaire.

Table 8

Gait characteristics of walking with and without poles (n=36)

Gait Characteristic	**Walking with poles**	**Walking without poles**	***P*- value**
Step length, cm	63.31±8.64	61.99±7.86	.06
Forward velocity, cm/sec	100.74±21.32	103.11±18.11	.10
Cadence, steps/min	94.91±11.77	99.62±9.95	<.001
Mean vertical GRF, BW	0.7915±0.0770	0.7976±0.7200	.15
Peak propulsive GRF, BW	0.1287±0.0411	0.1310±0.0375	.38
Vertical GRF peak 1	1.067±0.1351	1.0771±0.1314	.17
Vertical GRF peak 2	1.021±0.1019	1.021±0.1016	.94

Paired samples t-tests.

Abbreviations: GRF, ground reaction force; BW, body weight.