Increasing exercise tolerance of persons limited by claudication pain using polestriding

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Objective: The efficacy of polestriding exercise (walking with modified ski poles with a movement pattern similar to cross-country skiing) to increase exercise tolerance of persons with intermittent claudication pain caused by peripheral arterial disease was tested in this 24-week prospective randomized clinical trial.

Methods: The study was conducted in a Department of Veterans Affairs Hospital with 52 individuals who gave written informed consent and were randomized into either a polestriding exercise (n = 27; age, 65.5 ± 7.0 years; ankle brachial index, 0.64 ± 0.25) or nonexercise control (n = 25; age, 68.6 ± 8.9 years; ankle brachial index, 0.69 ± 0.14) group (P > .05 for all comparisons). The polestriding exercise program consisted of supervised training three times per week for 4 weeks, two times per week for 8 weeks, one time per week for 4 weeks, biweekly for 4 weeks and unsupervised training for 4 weeks. Starting in week 5, subjects took their poles home with instructions to repeat the most recent supervised training walk at an appropriate and convenient location near their residence. This was referred to as unsupervised but directed exercise. Subjects were provided with a personal log book for documenting unsupervised exercise sessions. With both supervised and unsupervised exercise, subjects were expected to complete a total of four 30-minute to 45-minute polestriding exercise sessions per week. The main outcome measures were exercise duration on symptom-limited incremental treadmill test, Walking Impairment Questionnaire, rating of perceived leg pain at baseline, 4, 8, 12, 16, and 24 weeks, and constant work-rate treadmill exercise tests at baseline and at 4, 12, and 24 weeks.

Results: Polestriding significantly (P < .001) improved exercise tolerance on the constant work-rate and incremental treadmill tests. Ratings of perceived claudication pain were significantly less after the polestriding training program. Subject perceived distance and walking speed scores on the Walking Impairment Questionnaire improved in the polestriding trained group only (P < .001 and .022, respectively).

Conclusion: This randomized clinical trial provides empirical evidence that 24 weeks of polestriding training significantly improves quantitative and qualitative measures of the exercise tolerance of persons limited by intermittent claudication pain. (J Vasc Surg 2002;35:887-93.)

Patients with atherosclerotic peripheral arterial disease (PAD) of the lower extremities are subject to periods of intermittent claudication (IC) caused by the formation of atherosclerotic plaques that narrow or occlude arteries. This condition results in an inadequate blood flow that causes ischemic muscle pain. The ability of patients with PAD to walk on level ground for more than a short distance is variably impaired. Moreover, the peak exercise capacity of these individuals, measured during treadmill walking, is well below that expected for age-matched and gender-matched cohorts. Disability may result when the patient can no longer meet the daily demands of personal, social, or occupational activities.1 The purpose of this prospective, randomized clinical trial was to evaluate the efficacy of polestriding exercise to increase exercise tolerance of persons with IC pain caused by PAD. The total walking time/distance on a constant workload treadmill (CWT) exercise test by subjects randomized to polestriding was hypothesized to be significantly greater and rating of perceived claudication pain to be less than with nonexercise control group subjects. Polestriding is walking/striding with modified ski poles while coordinating the upper and lower extremities in a sequence of movements that are similar to the poling mechanics used in classic style cross-country skiing. This report uses data collected in a randomized double-blind (medication only) study design in which one of the purposes, in addition to that stated previously, was to evaluate the effect of vitamin E (α-tocopherol) supplementation on exercise tolerance and claudication. Because vitamin E did not influence exercise tolerance, the groups were merged.

METHODS

Subjects. Volunteers were recruited from the hospital’s Peripheral Vascular and Outpatient Clinics, through contact with local physician groups, participation in health fairs, and veteran publications. Seventy-three individuals satisfied the inclusion criteria and gave written informed consent and were randomized into either a polestriding exercise (n = 27; age, 65.5 ± 7.0 years; ankle brachial index, 0.64 ± 0.25) or nonexercise control (n = 25; age, 68.6 ± 8.9 years; ankle brachial index, 0.69 ± 0.14) group (P > .05 for all comparisons). The polestriding exercise program consisted of supervised training three times per week for 4 weeks, two times per week for 8 weeks, one time per week for 4 weeks, biweekly for 4 weeks and unsupervised training for 4 weeks. Starting in week 5, subjects took their poles home with instructions to repeat the most recent supervised training walk at an appropriate and convenient location near their residence. This was referred to as unsupervised but directed exercise. Subjects were provided with a personal log book for documenting unsupervised exercise sessions. With both supervised and unsupervised exercise, subjects were expected to complete a total of four 30-minute to 45-minute polestriding exercise sessions per week. The main outcome measures were exercise duration on symptom-limited incremental treadmill test, Walking Impairment Questionnaire, rating of perceived leg pain at baseline, 4, 8, 12, 16, and 24 weeks, and constant work-rate treadmill exercise tests at baseline and at 4, 12, and 24 weeks.

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with Borg's ratio scale.3 After 72 hours, the second baseline pain and exertion was determined every 60 seconds walking. During exercise, subject perception of claudication was assessed. Supine ABI was determined before and after treadmill testing. Metabolic and hemodynamic measures were taken before, during, and after each test. Subjects in the polestriding exercise group received polestriding instruction and training. Individuals in the control group came to the laboratory biweekly for ABI measurements.

Physiologic and psychophysical measurements. In addition to walking duration and distance, the following measures were taken/recorded during all exercise tests. Expired gases were collected breath-by-breath and analyzed with a SensorMedics 2900 metabolic cart (Yorba Linda, Calif) to determine oxygen uptake. Measures were averaged every 30 seconds. Before and after each test, the analyzers were calibrated with reference gases and room air. Heart rate (HR) was derived from a 12-lead electrocardiogram every minute. Blood pressure (BP) was measured before exercise, every 2 minutes during exercise, and every minute after exercise until BP approached baseline values. After a standardized procedure, ratings of perceived leg claudication pain and exertion were obtained during the last 30 seconds of each stage of exercise with Borg's ratio scale.3 Doppler ultrasound scan was used to measure the supine ankle to arm systolic BP ratio, or ABI, for the most severely affected leg before exercise, within 120 to 150 seconds after exercise, and every 2 minutes up to 20 minutes or until ABI returned to the preexercise level. The Walking Impairment Questionnaire (WIQ)1 was administered via interview by a trained member of the research team. The WIQ was used to quantify patient perceived degree of difficulty regarding walking distance and speed.

Incremental symptom-limited treadmill test. With Hiatt et al's4 recommendations for optimizing treadmill tests for patients with PAD, a new protocol was developed for this study.5 Exercise began at 0% grade and speed of 1.8 mph (~3.0 km/h). Grade increased by 0.5% every 30 seconds. After 6 minutes, speed was increased 0.2 mph (~0.3 km/h) every 3 minutes. The protocol was designed so that the estimated metabolic requirements increased by one metabolic equivalent every 3 minutes.6

Constant work-rate treadmill test. Treadmill speed and grade were held constant at 1.8 mph and 12%, respectively. No metabolic measures were taken during the CWT test. Subjects walked until forced to stop by IC pain or a time limit of 45 minutes.

Polestriding exercise program. The polestriding exercise program consisted of supervised training three times per week for 4 weeks, twice per week for 8 weeks, once per week for 4 weeks, biweekly for 4 weeks, and unsupervised training for 4 weeks. Subjects completed a 1-hour instruction/orientation that included a videotape, demonstration, and practice. EXERSTRIDER poles (EXERSTRIDER Products Inc, Madison, Wis) were purchased in different lengths (weight, ~369 to 397 g) and issued to participants.

### Table I. Characteristics of 52 subjects randomized to the PoleStriding (n = 27) and nonexercise control (n = 25) groups. Some data are based on the subjects' self-report (eg, smoking, blocks walked before intermittent claudication pain)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>PoleStriding exercise group</th>
<th>Nonexercise control group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>65.5 ± 6.8</td>
<td>68.7 ± 8.8</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>173.2 ± 7.1</td>
<td>177.2 ± 4.7</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>85.8 ± 16.7</td>
<td>88.9 ± 16.8</td>
</tr>
<tr>
<td>Body mass index</td>
<td>28.6 ± 4.9</td>
<td>28.4 ± 5.4</td>
</tr>
<tr>
<td>Ankle brachial index</td>
<td>0.64 ± 0.25</td>
<td>0.69 ± 0.14</td>
</tr>
<tr>
<td>Education (highest grade)</td>
<td>12.0 ± 2.7</td>
<td>13.0 ± 2.7</td>
</tr>
<tr>
<td>Smoking (pack y)</td>
<td>61.5 ± 36.4</td>
<td>53.9 ± 36.0</td>
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<td>Employment status (%)</td>
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<td>22</td>
</tr>
<tr>
<td>Unemployed</td>
<td>76</td>
<td>78</td>
</tr>
</tbody>
</table>

Body mass index = body weight (kg) ÷ height (m²).
in accordance with published sizing guidelines. All polestriding training sessions included warm up, range of motion exercises, polestriding interval training, cool down, and postexercise range of motion exercises. Subject training programs were individualized on the basis of the results of the most recent incremental treadmill exercise test. During training, subject HR, BP, ratings of effort, and perceived leg pain/discomfort were recorded at appropriate intervals. In week 5, subjects began taking their poles home with instructions to repeat the last training walk at a location near their residence. The objectives of this unsupervised exercise were to increase the weekly volume of exercise to 4 to 5 day·week−1 and to habituate subjects to a daily routine that included exercise. Subjects used a personal log book to record/report information similar to that collected during supervised training sessions.

Interval training was used throughout the program. Intermittent bouts of exercise allow for a higher total volume of more intense work. Before each training session, the subject was familiarized with the workout and changes were explained. Training was varied by the amount of upper body effort used during poling, increasing or decreasing walking speed, combined changes in walking speed and poling effort, the amount of time allowed for rest intervals, and changes in terrain. Frequent measures of HR and exertion served as indicators of exercise strain.

Much of the training was conducted out-of-doors; however, seasonal variation in the weather forced the program indoors for a number of months. A Trackmaster TM500-E AC treadmill (JAS Manufacturing, Carrollton, Tex) with a belt size of 6 × 3 feet (1.83 × 0.91 m) was used for indoor training.

Nonexercise control group. Subjects in the control group continued to receive standard medical care. To control for attention bias, subjects were seen biweekly by the study staff for the first 3 months and monthly thereafter. During each visit, body weight, HR, BP, and ABI were measured.

Statistical analysis. The longest time walked on the two baseline symptom-limited incremental treadmill tests that were within 10% of each other was used as the pretraining (baseline) walking endurance time in all analyses. The change in WIQ aggregate scores from baseline to the end of the study was calculated for each patient, and the difference between the polestriding and control groups was evaluated with a one-way analysis of variance (ANOVA). Differences between aggregate scores at baseline, 4, 12, and 24 weeks within groups were analyzed with a paired t test with a Bonferroni correction for multiple comparisons. One-way ANOVA was used to determine the significance of the differences in duration of exercise on the incremental and CWT tests and peak oxygen uptake on the incremental treadmill test.

The slope of the relationship between rating of perceived leg pain and time of exercise on the CWT test was determined for each subject with linear regression procedures. Differences in derived slopes between the polestriding and control groups were tested with Student indepen-

RESULTS

Baseline symptom-limited incremental treadmill exercise testing. To establish a stable baseline for treadmill testing, subjects completed the incremental treadmill test protocol at least twice. If the duration on the second test was within 10% of the first, the subject continued with other baseline testing. If the difference exceeded 10%, the subject’s metabolic values (VO2, mL·kg−1·min−1) were compared to find whether they differed by more than 5%. If the variation of both duration and peak oxygen uptake exceeded the a priori limits, the subject completed a third test. Of the randomized subjects, the percent difference in duration was 5.8% ± 3.1% in 42 subjects. Metabolic values were used to compare treadmill tests in the eight remaining subjects. The average difference between tests in these cases was 3.5% ± 2.8%. Seventeen randomized subjects needed a third test. After repeated testing, one volunteer was removed from the study because a stable baseline could not be established. Two subjects who participated in the study did not complete a repeat baseline treadmill test for the following reasons: (1) at the time of enrollment, the patient’s doctor requested he only complete one maximal exercise test; and (2) a volunteer was accidentally randomized to a treatment group before completing the second exercise test.

Constant work-rate treadmill test. By 6 months, the polestriding exercise group improved baseline exercise time by 18 minutes 18 seconds (181%) or a distance of 0.88 kilometers, whereas the control group decreased walking time by 7 seconds (−1%). Polestriding training significantly affected duration (F = 29.42; P < .001). Observed power for the polestriding exercise effect was 1.51 and for the control condition was 0.02.

At baseline, no significant between-group difference in duration on the CWT test was found (polestriding: 10:06 ± 8:39 min:s; control: 11:00 ± 8:44 min:s; P = .72). Significant differences were found between the groups as early as 4 weeks (polestriding: 19:11 ± 16:49 min:s; control: 10:23 ± 5:59 min:s; P = .029) and continued to increase at 12 weeks (polestriding: 20:42 ± 18:53 min:s; control: 11:11 ± 8:41 min:s; P = .039) and 24 weeks (polestriding: 28:24 ± 19:16 min:s; control: 10:54 ± 11:48 min:s; P < .0001).

Symptom-limited incremental treadmill exercise test. Significant differences in exercise time from baseline were found after 12 weeks of polestriding training (Table II). The polestriding group improved duration on the incremental treadmill test by 23% at 4 weeks, 31% at 8 weeks, 40% at 12 weeks, 47% at 16 weeks, and 51% at 24 weeks. Conversely, the control group’s duration of exercise declined by 9% at 4 weeks, 7% at 8 weeks, 9% at 12 weeks, 14% at 16 weeks, and 7% at 24 weeks.

Peak oxygen uptake consistently increased after the baseline assessment in the polestriding group but not in the
control group. The mean increases in peak oxygen uptake during the 24-week training period were significant in the polestriding group (mean increase, 2.76 mL · kg⁻¹ · min⁻¹; \( P < .0001 \)) but not in the control group (mean increase, 0.28 mL · kg⁻¹ · min⁻¹; \( P = .389 \)).

**Arterial blood flow in the legs.** Repeated measures ANOVA was used to test the effect of the experimental conditions on subject resting preexercise ABI and 2-minute postexercise ABI for the CWT test at baseline, 1, 3 and 6 months. No training effect was seen on resting ABI (\( F = 1.02; \ P = .40 \)) or 2-minute postexercise ABI (\( F = 0.41; \ P = .74 \)).

**Rating of perceived leg claudication pain.** The slope of the relationship between perceived leg pain and exercise time during the CWT test was determined for each subject for all CWT tests with the least squares method. At baseline, the average slope of the regression lines for perceived leg pain in the polestriding and control groups were equivalent (polestriding: 1.30 ± 1.25; control: 1.08 ± 0.91; \( P = .51 \)). Significant differences in mean slope were found at the time of the last CWT test (polestriding, 0.27 ± 0.30; control, 0.95 ± 0.73; \( P < .001 \)). During a 6-month period, mean slope decreased only 12% in the control group versus 79% in the polestriding group (Fig).

**Walking impairment questionnaire.** On the basis of an analysis of change scores, the polestriding group reported significantly greater perceived ability to walk distance than the control group at 4 (\( P = .05 \)), 12 (\( P = .001 \)), and 24 (\( P = .002 \)) weeks. Moreover, the polestriding group rated their perceived ability to walk faster to be significantly greater than the control group at 4 (\( P = .03 \)), 12 (\( P = .19 \)), and 24 (\( P = .02 \)) weeks. The groups’ ratings were equivalent at baseline (\( P > .05 \)). In the polestriding group, the polestriding aggregate scores for both distance and speed improved significantly between baseline and 12 weeks (\( P < .0001 \)) and baseline and 24 weeks (\( P < .0001 \)) but not between 12 and 24 weeks (\( P > .015 \)). The perception of walking speed and distance did not improve in the control group.

**DISCUSSION**

**Subject adherence and compliance.** Only six subjects failed to complete the study. Three withdrew for nonmedical reasons and three for medical reasons, including severe exacerbation of osteoarthritis, frequent hospitalizations for psychologic instability, and an accident resulting in injuries.

Subject adherence to supervised training (weeks 1 to 12) was nearly perfect. Exceptions were primarily related to illness. Compliance with unsupervised but directed exercise was less successful. Fewer than 50% of subjects maintained a regular program of exercise without supervision. Analysis of the subject exercise logs showed noncompliance with unsupervised training, and concurrent decrements were seen in work tolerance during supervised sessions. Because adherence to unsupervised training was not a primary outcome in this study, subjects were offered the option of returning to a schedule of 2 to 3 supervised sessions per week. A 100% acceptance of this option was found when it was offered. As a result, the program was transformed into 24 weeks of supervised polestriding training. Reasons for not training on their own included: 1, inclement weather; 2, neighborhood not conducive to exercising safely; and 3, uncomfortable walking with poles in public. In a substantial number of subjects, motivation to exercise independently without regular supervision/encouragement was low. This was a disappointing, although not unanticipated, outcome. Given the success of supervised polestriding exercise in improving exercise tolerance, the development of alternative strategies to promote adherence to unsupervised exercise should be investigated further.

**Appropriateness of polestriding exercise in the rehabilitation of patients with peripheral artery disease: a hypothesis.** “Walking pole/sticks” have long been used by walkers (hikers, mountainiers) for several reasons (eg, increased base of support and improved balance when walking over uneven terrain and a decrease in lower extremity loading and strain). Recently, people have begun using poles during aerobic exercise because of mounting evidence that HR and oxygen consumption (caloric expen-
diture) are markedly greater when walking with poles. In our laboratory, six individuals completed repeated 5-minute bouts of treadmill walking (grade and no grade conditions) with and without poles. Subjects rested 5 minutes before exercise, exercised for 5 minutes, and were given 5 minutes for recovery or longer as needed (± 10 beats · min⁻¹ of preexercise HR). Testing order was not randomized, and polestriding trials always followed walking. The percentage increase in oxygen uptake, HR, and kcal · min⁻¹ with walking with poles compared with walking without poles was 29 ± 16, 13 ± 10, and 32 ± 17 for the no grade condition and 24 ± 12, 12 ± 8, and 26 ± 13 with grade, respectively (unpublished data). On the basis of the available literature and observations made during this study, the addition of the pole-to-ground contact experienced during polestriding is hypothesized to provide beneficial changes in walking that afford the individual with PAD mechanical and physiologic advantages. Wilson et al have shown that walking poles enable the individual to walk at increased speed and stride length, that vertical ground and knee joint reaction forces are reduced, and that knee extensor angular impulse is greater (“more flexed knee position through stance, reducing the bone on bone forces and increasing the internal [muscular] knee extensor kinetics”). They posit, “This reduction of lower extremity stress during a faster walking velocity may symbolize a less harmful mode of exercise for healthy and pathologic populations alike.” For individuals with PAD who use good poling mechanics, better perfusion of the leg muscles may exist as a result of the longer period of time the leg muscles are relaxed between the toe off to heel strike phase of the recovering (nonweight bearing) leg. Moreover, with reduced effect of ground reaction forces on the leg, less tension may be created in the antigravity muscles contracting to balance the forces. As a result, the accumulation of metabolic byproducts, such as lactic acid, may be slowed, thus extending the period of time the muscles of the lower legs can perform aerobically and delaying the onset of claudication pain caused by ischemia. This may explain why most subjects in this study were able to walk further and for longer on the first day of training.

This investigation methodology differs from previous exercise studies in that repeated testing was conducted at baseline to establish a stable initial assessment of exercise tolerance before proceeding with the intervention protocol. Seventeen subjects (33%) needed a third test to establish a stable baseline (ie, within 10% on duration or 5% on metabolic values). Repeated measures ANOVA was used to establish that the differences between the three tests in these 17 subjects were significant (F = 6.12; P = .01). Post hoc pairwise comparisons were completed with Tukey test. Significant differences were found between the first and second tests (P = .008) and the first and third tests (P = .003). No significant difference was found between the second and third tests (P = .79). This finding strongly suggests that when subjects with PAD are given only one test at baseline, investigators may be underestimating the individual’s true initial walking ability.

At baseline, the subject perceived walking ability score (0.31 ± 0.25) on the distance subscale of the WIQ was
We also thank the veterans who volunteered to participate in this investigation.

REFERENCES


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DISCUSSION

Dr Walter McCarthy (Chicago, Ill). This is an important study because of the large number of patients in the United States who have intermittent claudication, sometimes estimated to be as high as 70% of the population over 70 years old. I wondered if you could speculate on the advantage of the polestriding over a traditional trained exercise walking program quantitatively. Patients have been shown to increase their walking distance by a factor of 2 or so with an educated walking program. Does the polestriding really offer an advantage?

Dr W. Edwin Langbein. We believe that it does. Our results are comparable with what has been published in the literature. Based on a recent study by Wilson, when the poles are used properly, the stride length is increased so that the time from toe off to heel contact is increased. We believe that this increases the relaxation period sufficiently to allow for improved perfusion of the exercising muscles. Secondly, the ground reaction forces are reduced, which decreases the amount of muscle tension necessary to overcome the body weight. Theoretically, this should reduce the rate at which metabolic byproducts build up in the exercising muscles. We were surprised that once we gave the poles to the patients and taught them how to polestride properly that on the first day of training their comment frequently was “I haven’t walked this far in years.” Our impression is that a distinct advantage of the poles is that it gets the person up and moving quickly and success experiences come early in the training program. We encourage patients to walk without poles as well, but the poles I believe offer significant advantages. I think both walking and polestriding are important modes of exercise for persons with
peripheral artery disease. There is one disadvantage that we found associated with the poles, and that was that some of the subjects felt self-conscious when walking with the poles in public.

Moderator. Tell us, have you in any way compared walking with poles with walking without poles or with any type of supervised exercise program?

Dr Langbein. We did not compare them directly; however, as I noted, the poles were not used during exercise testing, so essentially the testing circumstances in our study were similar to the testing circumstances in other studies. We already knew that walking exercise was effective, and so there was no point in reproving that. We wanted to demonstrate the benefit of polestriding. In addition, we have had success with polestriding in other groups that have disabilities, such as osteoarthritis, Parkinson’s disease, and congestive heart failure. In each case, the poles have been effective in increasing the ability of the individual to sustain exercise.

Dr James McKinsey (Chicago, Ill). My question kind of goes along with Peter’s. It seems like the trial or study should be done comparing it with a straight well-organized exercise program. Is this really just a study? Because they are actively being followed and doing it, they are going to participate more in it. So, that is the first question.

The second question goes to your last statement: what was the overall physical ability of the patients? Because many of our patients, too, we see with either an other-sided amputation or severe osteoarthritis. Does this help stabilize the patient rather than just decreasing their work of walking?

Dr Langbein. I have already forgotten the first question.

Dr McKinsey. The simple question is, is this not just an organizational issue rather than a difference between an ambulatory program and pole walking? Because I think a lot of our patients we see improve when they really do the exercise program and so you need to compare an exercise program with pole walking. The question that was going to go with that is did you see an earlier improvement? Because generally with an exercise program it takes several weeks before they start seeing improvement. With this additional aide, are they up and walking quicker and further?

Dr Langbein. We saw a very significant improvement at 4 weeks in those who participated in the study. In answer to the more difficult question regarding organization, which I interpret to mean, what would happen if you just left people on their own to train? Our experience provides some insight into this question. We attempted to titrate subjects away from the three times per week supervised training program. We reduced the supervised sessions to two and then to one time per week. Fifty percent of our subjects were noncompliant in the absence of supervision. We offered these subjects the opportunity to return to the program and resume the supervised training. One hundred percent accepted the offer and became fully compliant again. The presence of our exercise physiologists who were very good had a marked effect on subjects’ participation in the study.

Moderator. What percentage of your patients could not participate in this type of exercise?

Dr Langbein. Of those that were randomized into the study, we lost six, or 10% of the patients. Of the six, three were removed from the study for medical reasons, one person because he moved to a different city, and the other two people chose, after randomization, to withdraw from the study before they began training. They left after they completed the baseline testing.