Resistance Training for Patients with Peripheral Arterial Disease: A Model of Exercise Rehabilitation

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CARDIOVASCULAR DISEASE IS the most significant health problem in Australia and is responsible for approximately 42% of all deaths (15). Peripheral arterial disease (PAD) is a condition that results from occlusion (blockage) or stenosis (narrowing) of the arteries that supply blood to the extremities (22). This results in inadequate blood flow in the arteries and is primarily caused by atherosclerosis (3). PAD affects up to 20% of older people (4) and greatly increases the risk of other cardiovascular diseases (12, 17). In patients with PAD, the limited blood supply cannot meet the metabolic demands of the muscles of the lower extremity during exercise. Therefore, normal walking results in pain in the legs due to muscle ischaemia, which is known as intermittent claudication. Intermittent claudication occurs most commonly in the calf muscles and is associated with a severe limitation in walking ability, which may adversely affect leisure and work activities in many patients (9). The few treatments currently available for claudication include a program of exercise rehabilitation or invasive procedures, such as angioplasty. The primary treatment goals are the relief of claudication pain and an improvement in ease and duration of walking. In this article, we outline a resistance-training program that has been used successfully in our laboratory with these patients and offers an alternative to the more traditional walking programs that are currently recommended. Also, we believe that this program can be modified for other elderly populations who experience difficulty with walking and everyday activities.

Exercise Rehabilitation for PAD

It has been well documented that supervised walking programs are a safe and effective method of improving walking ability in patients with PAD (13). Exercise offers the advantage over other methods of treatment by being noninvasive and relatively inexpensive. Numerous trials of exercise rehabilitation in this population have been per-
formed with most using walking or some form of dynamic leg exercise. The majority of studies assessing the effects of exercise rehabilitation have shown improvements in walking distances and reduced severity of claudication pain during exercise (7, 13). Differences in the components of the exercise programs, such as intensity, duration, and frequency, may account for the large variation in improvements. In addition, there has been a wide range in the severity of the disease among the patient populations.

Resistance-training programs have not been evaluated to the extent of aerobic-training programs, so it is still unclear which is more effective. Research has shown that the reduction in strength that occurs with advancing age has negative consequences on walking and other aspects of physical performance (1, 2, 16, 23). It is clear that an increase in strength in deconditioned older adults is associated with improvements in physical function (2, 6, 18). Elderly subjects seem to respond to weight training in a similar manner as young subjects, with large increases in maximum loads lifted and accompanying enlargement of whole muscle and muscle fiber areas (2, 18). Resistance training has also been used effectively in the rehabilitation of patients with coronary artery disease (11, 20).

The observation that patients with PAD have muscle weakness suggests that strength training muscle groups of the lower extremity will help to improve walking ability (8, 14). Also, decreased muscular strength in both the upper and lower extremities has been associated with increased prevalence of PAD in elderly women (21). Resistance training offers the advantage of individualizing the exercise by allowing the patient to train those muscles that suffer the worst hypoxia in isolation.

### Resistance-training Program

The program we use is designed to target the lower extremities, but 2–3 exercises are also performed for the upper body in each session (Table 1). Patients normally complete 3 sessions per week for 24 weeks. Training sessions are separated by a minimum of 48 hours (e.g., Monday, Wednesday, and Friday), with patients completing 2 sets of each exercise with a 1-minute rest between exercises. The number of repetitions is periodized throughout the program (Table 2). In our laboratory, if the number of repetitions exceeds the designated repetition range by 2 or more, the resistance is increased for the next training session. Researchers have suggested that in order for the exercise training to be effective in improving symptomatic PAD, it must elicit claudication pain to stimulate adaptation (5, 7, 10). Therefore, a brief rest period of 1 minute between sets is used to increase the demand on blood flow to the working muscles, thus promoting muscle ischaemia and claudication pain. We also chose to use a higher range of repetitions at the beginning of each 12-week cycle to further promote the onset of claudication pain during the exercises. The patients are encouraged to complete the designated number of repetitions without resting. The patients often experience the claudication pain after only a few repetitions when performing the specific calf exercises.

At the beginning of each training session, subjects warm up with 3 minutes of cycling followed

### Table 1

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<thead>
<tr>
<th>Day 1</th>
<th>Day 2</th>
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<tr>
<td>Dumbbell squats</td>
<td>Seated leg press</td>
<td>Step-ups</td>
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<tr>
<td>Standing calf raises</td>
<td>Dumbbell squat and calf raise</td>
<td>Leg extensions</td>
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<tr>
<td>Toe raises</td>
<td>Toe raises</td>
<td>Leg curls</td>
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<tr>
<td>Calf raise on leg press machine</td>
<td>1-legged calf raise</td>
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<tr>
<td>Leg extensions</td>
<td>Leg curls</td>
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### Table 2

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<tr>
<th>Weeks</th>
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<th>RM (10–12)</th>
<th>RM (8–10)</th>
<th>RM (12–15)</th>
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<td>22–25</td>
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RM = repetition maximum (the maximum load that can be lifted for a prescribed number of repetitions).
by stretching of the major muscle groups. Two familiarization sessions are performed at the beginning of the training program. Correct lifting techniques are explained and demonstrated to the subjects prior to starting each exercise. All subjects are supervised by qualified instructors throughout the course of the training program. In addition, continuous electrocardiogram (ECG) and blood pressure responses are monitored during the course of the training sessions. Stretching of the major muscle groups is completed at the end of each training session followed by 3 minutes of cycling to cool down, and training logs are kept for all training sessions.

Exercise Descriptions

Following is a description of the lower-body exercises performed in the program.

1. Standing calf raises. Subjects begin in a standing position on the calf-raise machine, then plantar flex the ankle and then return to the starting position (Figure 1).

2. One-legged calf raise. Subjects begin in a standing position on the calf-raise machine with 1 leg on the plate and the other leg slightly flexed and unsupported (Figure 2). Subjects then plantar flex the ankle to full plantar flexion and then return to the starting position. Some subjects perform this exercise off a 20-cm high box as they find the exercise too difficult with the calf-raise machine.

3. Dumbbell squat and calf raise. This exercise combines the squat and calf-raise exercises. Subjects begin in a standing position and squat until the knees were flexed to approximately 90° (Figure 3) and then return to the starting position. Subjects then plantar flex the ankles to full plantar flexion (Figure 4) before returning to the initial position. Dumbbell squats are used, rather than barbell squats, to avoid the discomfort of a barbell resting on the shoulders. Further, many elderly subjects do not have the necessary shoulder flexibility to hold the barbell on the back of the shoulders comfortably.

4. Toe raises. Subjects sit on a bench with both feet placed underneath the elastic band
attached to a board (Figure 5). Subjects then dorsiflex the ankle as high as possible before returning to the starting position. This exercise is designed to isolate the ankle dorsiflexors, and the elastic band allows the resistance to be altered as required.

5. Calf raise on the leg press machine. Subjects sit with both feet resting on the footplate directly in front of them. Subjects then plantar flex their ankles as far as possible and then return to the starting position (Figure 6).

6. Leg extensions. Subjects are seated upright with both ankles resting behind the pads. Subjects then extend their knees to full extension and then return to the starting position (Figure 7).

7. Seated leg press. Subjects sit with both feet resting on the footplate directly in front of them. Subjects then extend their knees and hips until their knees are carefully extended, and then they return to the starting position (Figure 8).

8. Leg curls. Subjects begin lying prone on the leg-curl machine with the ankles resting under the pads. Subjects then flex the knees to approximately 90° and then return to the starting position (Figure 9).

9. Step-ups. Subjects complete this exercise while holding dumbbells. Subjects step up and down onto a 20-cm high box using alternate legs to lead.

**Evaluation of the Program**

A 12-week pilot study with 10 patients was conducted in our laboratory in 1997 to evaluate the program. Large improvements in lower-limb strength and pain-free maximal walking following the resistance-training program were found (19). More recently, a controlled, 24-week study was completed to assess the program. There were large improvements in both pain-free and maximal walking distances. Strength measures on an isokinetic dynamometer improved, as did 10 repetition maximum (10RM) leg press and calf press.
Most subjects have reported feeling stronger and having less difficulty with daily tasks of living, such as climbing stairs and gardening.

No musculoskeletal injuries or cardiac events were reported during the training program. Also, there were no reports of elevated blood pressure responses that prevented or stopped patients' training during the training sessions. As there is an increased incidence of coronary artery disease, the patients were closely monitored during the training sessions with continuous ECG and periodic blood pressure measurements made. The patients attended a high number of sessions throughout the 24 weeks of training (average compliance 90±6%). High levels of compliance may have been
attributable to the transportation service that was provided to and from the training and evaluation sessions. Claudication pain was reported on most exercises throughout the program, especially for those exercises that involved plantar flexion. Patients reported some delayed-onset muscle soreness, particularly early in the program. However, we had no patients withdraw from the training whose ability to tolerate the training improved after the first few weeks of the program.

Typically, there were only minor improvements in blood flow (measured using Doppler ultrasound) to the lower extremities following the resistance-training program. This is similar to findings of previous researchers who have found little or no improvement in peripheral blood flow following exercise rehabilitation (13). This suggests that adaptations within the working muscles contribute to the improvements in walking. However, the mechanisms responsible for these improvements are not fully understood.

Conclusions and Recommendations

The main findings of our research have been that progressive resistance training improved pain-free walking distances along with increasing strength of the plantar flexors. The resistance-training program has proven to be safe and effective, and it does appear that patients with PAD can tolerate a progressive resistance-training program. It is important that the patients be carefully screened and closely supervised at all times. The training program we use is structured and uses specialized equipment. However, a modified program with similar exercises should provide benefits for patients with PAD.

References

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