

CLINICAL SCIENCE

ECCENTRIC STRENGTH AND ENDURANCE IN PATIENTS WITH UNILATERAL INTERMITTENT CLAUDICATION

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OBJECTIVE: To analyze concentric and eccentric strength and endurance in patients with unilateral intermittent claudication.

INTRODUCTION: Basic motor tasks are composed of concentric, isometric, and eccentric actions, which are related and contribute to physical performance. In previous studies of patients with intermittent claudication, the disease-related reduction in concentric and isometric muscular strength and endurance resulted in poorer walking performance. To date, no study has evaluated eccentric muscle action in patients with intermittent claudication.

METHODS: Eleven patients with unilateral intermittent claudication performed isokinetic concentric and eccentric actions at the ankle joints to assess peak torque and total work in both symptomatic and asymptomatic legs.

RESULTS: Concentric peak torque and total work were lower in the symptomatic than in the asymptomatic leg (80 ± 32 vs. 95 ± 41 N/m, $P = 0.01$; 1479 ± 667 vs. 1709 ± 879 J, $P = 0.03$, respectively). There were no differences in eccentric peak torque and total work between symptomatic and asymptomatic legs (96 ± 30 vs. 108 ± 48 N/m; 1852 ± 879 vs. 1891 ± 755 J, respectively).

CONCLUSION: Strength and endurance in the symptomatic leg were lower during concentric compared to eccentric action. Future studies are recommended to investigate the mechanisms underlying these responses and to analyze the effects of interventions to improve concentric strength and endurance on functional limitations in patients with intermittent claudication.

KEYWORDS: Peripheral arterial disease; Atherosclerosis; Muscle contraction; Isokinetics; Resistance training.

INTRODUCTION

Intermittent claudication (IC) is the most common symptom of peripheral arterial disease. It results in exercise intolerance during common daily activities such as walking, leading to a reduction in daily physical activity levels and a decrease in health-related quality of life.¹⁻⁴

Patients with IC also present reduced strength, endurance, and muscle mass in the lower legs. The reductions in leg

strength have been observed during concentric and isometric actions. Moreover, positive correlations between lower leg strength and walking tolerance have been identified, suggesting that interventions to improve leg strength might increase exercise tolerance in these patients.⁵

However, basic locomotor tasks involve not only concentric and isometric, but also eccentric action,⁶ which is defined as the force exerted by muscles while lengthening. Lower eccentric strength and endurance might also be related to exercise intolerance in patients with IC. Therefore, interventions to improve eccentric strength and endurance might also be useful in improving exercise tolerance in these patients. Nevertheless, this is the first study to analyze the effect of peripheral arterial disease in eccentric strength. We hypothesized that reduced muscle strength and endurance would be observed during both concentric and eccentric actions.

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MATERIALS AND METHODS

Patients

Eleven male patients with unilateral peripheral arterial disease (11 symptomatic and 11 asymptomatic legs) and stable symptoms of IC were recruited from a tertiary center specializing in vascular disease. Patients were included if they had Fontaine stage II peripheral arterial disease,⁷ ankle/brachial index (ABI) at rest ≤ 0.90 in one leg, ABI > 1.0 in the other leg, and symptoms of calf claudication. Moreover, since the assessment of strength and endurance was performed on the gastrocnemius and soleus muscles, the arterial obstruction had to be present in femoral-popliteal and/or iliac-femoral sites as determined by arterial palpation.

Patients were excluded under the following conditions: ABI measurement could not be obtained, presence of chronic lung disease, exercise tolerance limited by factors other than claudication (e.g., dyspnea or poorly controlled blood pressure), presence of electrocardiogram response suggestive of myocardial ischemia during the exercise test, or history of revascularization in the previous year.

This study was approved by the ethics committee for research involving human trials, in compliance with Helsinki Declaration of 1975, as revised in 1989. All participants gave written informed consent.

Ankle Brachial Index

Arm and leg blood pressures were measured using a mercury column (Unitec) and Doppler ultrasound (Martec DV600). The ABI was obtained by dividing the highest value of systolic blood pressure recorded in the legs (in the dorsalis pedis artery or in the posterior tibial artery) by the highest brachial systolic blood pressure (right or left arm).

Assessment of muscular strength and endurance

Each patient underwent tests to measure isokinetic strength and endurance during plantar flexion. The tests were carried out using a Cybex 6000 isokinetic dynamometer (Cybex, division of Lumex, Ronkonkoma, New York) in both concentric and eccentric modes.

Both action modes were tested in the supine position with the knee flexed at 90° and with the thigh supported by a custom apparatus. The thigh, pelvis, and trunk were stabilized with straps. The axis of rotation of the dynamometer arm was aligned with the ankle joint, and the foot was stabilized in a specific support apparatus using Velcro® straps.⁸

Patients were tested unilaterally. The order of leg testing (symptomatic or asymptomatic) and action types (concentric or eccentric) were randomly determined. All adjustments were made by the same investigator. Patients were allowed to practice three submaximal and two maximal trials before each test. During all procedures, the inactive leg was immobilized using a specific support as recommended by manufacturer.

Concentric and eccentric peak torque (PT) and total work (TW) during plantar flexion was measured during maximal voluntary contractions at a speed of 120°/s. The highest PT assessed over five consecutive repetitions was considered for analysis, while TW was obtained during 60 consecutive repetitions. We employed a rest period of 30 s between warm up and testing, and 1 min between testing PT and TW. The rest period between legs and action types was 10 min.

To analyze the quality of PT and TW data, the reliability was assessed in all patients during two different test sessions separated by at least three days. The obtained intraclass correlation coefficient ranged from 0.94 to 0.98 without any differences in the means between sessions for both PT and TW, confirming the reliability of the data.

Statistical analysis

The statistically required sample size was calculated using data from a previous study.¹ For a desired power of 80% and an alpha error of 5%, a total of 20 legs were needed to detect differences between symptomatic and asymptomatic limbs.

Shapiro-Wilks and Levene tests confirmed the normal distribution and the homogeneity of variance of the data, respectively. The comparisons between symptomatic and asymptomatic legs in concentric and eccentric PT and TW were performed using the two-tailed *t* test for dependent samples. Significance was established at an alpha level of $P \leq 0.05$, and data are expressed as means \pm standard deviation.

RESULTS

The clinical characteristics of the patients are presented in Table 1.

Patients were mostly elderly and overweight. As expected, the ABIs of the symptomatic legs were lower than those of the asymptomatic legs ($P < 0.05$).

The concentric and eccentric PT and TW of symptomatic and asymptomatic legs are presented in Table 2.

Concentric PT and TW in symptomatic legs were lower than in asymptomatic legs ($P < 0.05$). There were no differences in eccentric PT or TW between symptomatic and asymptomatic legs.

Table 1 - Clinical characteristics of samples (n = 11)

	Mean \pm SD
Age (years)	63.6 \pm 8.1
Weight (kg)	75.0 \pm 13.2
Height (cm)	168.1 \pm 6.6
Body mass index (kg/m ²)	26.4 \pm 3.3
ABI symptomatic leg	0.7 \pm 0.1
ABI asymptomatic leg	1.1 \pm 0.1*

* Difference between symptomatic and asymptomatic legs ($P < 0.05$)**Table 2** - Concentric and eccentric peak torque and total work in symptomatic and asymptomatic legs in patients with unilateral intermittent claudication

	Symptomatic leg (n = 11)	Asymptomatic leg (n = 11)	P
Concentric			
Peak torque (N/m)	80.4 \pm 31.6	95.3 \pm 40.5	0.01*
Total work (J)	1479.0 \pm 666.9	1708.6 \pm 878.5	0.03*
Eccentric			
Peak torque (N/m)	96.4 \pm 29.8	108.4 \pm 48.4	0.21
Total work (J)	1852.1 \pm 879.0	1890.8 \pm 754.5	0.72

* Difference between symptomatic and asymptomatic legs ($P \leq 0.05$).

DISCUSSION

This study is one of the few to analyze strength and endurance during concentric action, and it is the first to evaluate eccentric action in patients with IC. The main findings of this study were (i) patients with unilateral IC exhibited significantly lower concentric PT and TW in the symptomatic compared with the asymptomatic leg; and (ii) there were no differences in eccentric PT or TW between symptomatic and asymptomatic legs.

Peak torque is considered the most important indicator of muscle strength that can be obtained using an isokinetic dynamometer.⁹ It can be used to identify any early impairment in muscular performance as well as to assess maximal strength levels. Total work represents the work performed by the muscular group during the whole test, indicating the muscle endurance capacity of muscle groups.⁹ It is considered the most sensitive parameter for evaluating muscle fatigue.¹⁰

Reduced concentric strength in patients with IC has been observed in previous studies. Impaired concentric strength in the gastrocnemius and tibial muscles was observed in 26 men with IC compared with six age-matched controls.⁴ The effects of the disease in terms of muscle strength and endurance were confirmed by other studies using isometric^{11,12} and concentric¹⁰ actions. Moreover, a significant

relationship was observed between lower extremity strength, ABI, and walking tolerance, suggesting that strength levels are associated with disease severity.⁵ The mechanisms underlying the strength impairments in patients with peripheral arterial disease are not completely understood and remain controversial. It has been hypothesized that type I and II fiber atrophy and denervation of muscle fibers are the main causes of decreased muscle function in such patients.^{4,13}

The lower TW in the symptomatic leg compared with the asymptomatic leg during concentric action in patients with IC was previously observed in studies analyzing lower¹⁰ and upper leg regions.¹ These results may be due to the aerobic nature of the endurance test protocol (60 actions), which results in maximum flow demands to the leg. Therefore, once the symptomatic leg has an arterial obstruction, a lower level of performance is expected in symptomatic as compared with asymptomatic legs.

There were no differences in eccentric PT and TW between symptomatic and asymptomatic legs. No previous study has evaluated eccentric strength in IC patients, despite the importance of this contraction in the daily activities of elderly people.⁶ Several factors inherent to eccentric action might explain the lack of influence of the disease in terms of the strength and endurance of this action mode. The reduction in eccentric strength with aging seems to be less pronounced than that in concentric strength,¹⁴⁻¹⁶ suggesting that strength and endurance are better preserved during disease process in eccentric than in concentric action. The similar TW between symptomatic and asymptomatic legs during eccentric action may be partly caused by the lower caloric cost of this mode of contraction.¹⁷⁻¹⁹ Some authors have reported a 14% to 20% lower energy cost in eccentric compared with concentric action.¹⁷ Thus, the limited blood flow observed in patients with IC has fewer muscle endurance effects in eccentric as compared with concentric action. However, this hypothesis must be analyzed carefully, because no prior study has investigated the net caloric cost of eccentric isokinetic contractions in this population.

The reduced muscle strength and endurance have been associated with impaired walking tolerance in IC patients.⁵ Therefore, interventions to improve muscle strength and endurance, such as strength training, might be useful to minimize the effects of the disease on strength and to improve exercise tolerance in patients with unilateral IC. Previous studies analyzing the effects of strength training in IC patients that used both concentric and eccentric action during training showed improvements in walking tolerance²⁰ and in quality of life.²¹ The results of the present study suggest that a strength training program that focuses on concentric strength would probably be most effective for patients with IC. However, the effects of different strength

training programs for patients with IC remain unknown. This study highlights the need for future studies to analyze the effects of different strength training programs on concentric muscle strength and endurance, as well as on functional limitations of these patients.

Since the design of this study did not include a control group, it was not possible to compare muscle strength and endurance of subjects with and without peripheral arterial disease. However, it is well known that strength and endurance are influenced by several factors, including both physical activity levels^{22,23} and associated diseases.^{24,25} Therefore, the inclusion of a control group with different physical activity levels and diseases would not have allowed us to determine the specific effects of IC on strength and endurance. Therefore, the use of the asymptomatic leg as the

control permitted us to determine the specific effects of the disease in terms of strength and endurance while controlling other possible variables.

CONCLUSION

The present study showed that strength and endurance in the symptomatic leg of patients with intermittent claudication is reduced in concentric, but not in eccentric action as compared to the asymptomatic leg. Future studies are recommended to investigate the mechanisms underlying these responses and to analyze the effects of interventions to improve concentric strength and endurance in the context of functional limitations in patients with intermittent claudication.

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