Cardiovascular Responses during Isokinetic Muscle Assessment in Claudicant Patients

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Abstract

Background: **Isokinetic dynamometry is becoming increasingly important for the assessment of muscle function in individuals with intermittent claudication. However, there is still little information available about the cardiovascular responses of these patients during this type of assessment.**

Objective: **To assess and compare the cardiovascular responses recorded during the assessment of muscle strength and endurance for two exercises commonly used in patients with IC (plantar flexion/dorsiflexion and knee flexion/extension).**

Methods: **The sample consisted of 17 claudicant patients with stable disease for at least 6 months. During the isokinetic dynamometer testing, non-invasive measurements of heart rate, blood pressure and double product at rest and at peak exertion were obtained according to specific protocols established for muscle strength and endurance assessment.**

Results: **Except for diastolic blood pressure, heart rate, systolic blood pressure and double product values rose during the exercise compared to the resting stage ($p < 0.05$). Elevations in heart rate and double product values were higher during knee extension/flexion than during plantar flexion/dorsiflexion ($p < 0.05$). Increases in heart rate were also higher during the endurance assessment protocol than during muscle strength assessment.**

Conclusion: **Isokinetic strength and endurance testing in patients with IC results in elevation of heart rate, systolic blood pressure and double product values during the exercises. These increases are higher during the muscle endurance exercises and in those involving greater muscle mass, suggesting that strength testing of small muscle groups causes less cardiovascular overload in these patients. (Arq Bras Cardiol 2010; 95(5): 571-576)**

Keywords: **Intermittent claudication; muscle strength dynamometer; muscle strength; exercise test.**

Introduction

Lower limb pain while exercising that subsides with rest, known as intermittent claudication (IC), is the most common symptom of peripheral arterial occlusive disease[1]. Patients with this symptom have diminished walking capacity, muscle strength and endurance[2,3]. For this reason, besides monitoring functionality by means of questionnaires[4], physical capacity testing has been frequently used to assess the impact of the disease on functional ability[5,6].

Treadmill stress test is the most frequently used method, since it provides important information about the effects of the disease on the individual's capacity to ambulate[6]. On the other hand, this test has limited application for some patients, as is the case for the very old with orthopedic dysfunctions that prevent them from undergoing the cycle ergometer test, as well as for amputated patients. Furthermore, in patients with the disease in both lower extremities, the treadmill stress test assesses mainly the limb in which the disease is more severe, and doesn't provide data about the less affected limb.

Due to these limitations, in recent years other types of functional testing have been proposed[7-10], and among these, assessment of muscle function has grown in importance. Actually, studies have indicated a significant correlation between muscle strength tests[8] and endurance tests[11], with the limitation of ambulation and disease severity, respectively, being the basis for the use of these tests for functional assessment of individuals with IC.

However, a potential disadvantage of the muscle function tests is the pronounced hemodynamic responses they elicit. As individuals with IC have a high prevalence of associated cardiovascular diseases, as well as high mortality due to cardiac causes, the selection of low cardiovascular stress protocols should be considered. However, to the present no previous study has described cardiovascular responses to isokinetic exercises in individuals with intermittent claudication[12,13].

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Therefore, the objective of this study was to compare the cardiovascular responses to two exercises commonly used for assessing muscle strength and endurance in patients with IC: plantar flexion/dorsiflexion and knee flexion/extension.

Methods

Patients

This study was approved by the Research Ethics Committee of the *Hospital das Clínicas de São Paulo* (no. 0758/08). Before data collection, all patients were informed about the risks and benefits of their participation in the study and were required to sign an informed consent form.

The sample of the present study consisted of seventeen patients (n= 17), who were being followed at a vascular disease outpatient unit of a tertiary hospital (outpatient ward of intermittent claudication). The patients had to meet the following inclusion criteria: stable IC symptoms for over 6 months, ankle/brachial index < 0.90 in both lower limbs, and the ability to walk for at least 2 minutes at 3.2 km/h.

A medical interview was conducted to determine comorbidities and use of medication. The comorbidities considered were: presence of diseases previously diagnosed and registered in the patients' medical record, and regular use of medications prescribed by a physician to treat diseases. The presence of heart disease was confirmed by a history of acute myocardial infarction, coronary ischemia, angina or coronary revascularization.

Patients who met the inclusion criteria underwent the maximal stress test in an ergometric treadmill (Inbrasport - model ATL - Brazil). A staggered protocol specific for individuals with IC was used at a constant speed of 3.2 Km/h, and with two-degree increments every two minutes until exhaustion. The test was supervised by a physician who measured blood pressure every two minutes with a mercury sphygmomanometer (Unitec Hospitalar, Brazil) and a stethoscope (Littman Stethoscope Cardiologic II, USA). Moreover, during the test heart rate was continuously monitored by electrocardiogram (CardioPerfect, USA). The patient was advised to inform the moment when he/she started to feel pain in the lower limb, that is, the initial claudication distance. The total distance walked, i.e. the maximum distance that the individual was able to walk, was also recorded. Patients who had cardiovascular abnormalities which restricted the practice of physical activity, such as myocardial ischemia or complex arrhythmias, were not included in the study.

Experimental protocol

Isokinetic muscle assessment

Muscle strength and endurance of ankles and knees were assessed with an isokinetic dynamometer, *Cybex™* brand, *Norm™* 6000 model (CSMI, USA). The instructions of the Standardization, Test and Rehabilitation System manual provided by the manufacturer were followed to position the patients in the isokinetic dynamometer, as well as for setting up and calibrating the equipment. The isokinetic parameters (peak torque and total work) were obtained from a computerized program (*HUMAC/CYBEX™ NORM™*, *USA*). The angular velocity and the number of repetitions in each protocol were chosen based on previous studies[14,15].

In order to become acquainted with the requirements of the test, patients were asked to perform three movements in test position (non weight-bearing). However, no warm-up procedures were conducted before the isokinetic assessment, since the disease reduces the ability to sustain exertion, and performing physical exercises prior to the assessment could impair or invalidate it.

For the assessment of muscle strength and endurance of the ankle joint (concentric evaluation of plantar flexion and dorsiflexion movements), angular velocities of 30º/sec and 90º/sec, respectively, were used. Five repetitions were used for the assessment of muscle strength, whereas sets of eight repetitions were used for muscle endurance assessment, with 5-second rest intervals between the sets of exercises.

For the assessment of muscle strength and endurance of the knee joint (concentric evaluation of knee flexion and extension movements), angular velocities of 60º/sec and 180º/sec were used, respectively. Five repetitions were used for the assessment of muscle strength, whereas sets of 15 repetitions were used to assess muscle endurance, with 5-second rest intervals between the sets of exercises.

During the test, patients were continuously encouraged verbally. In addition, they received visual feedback about the activity of the muscular group being tested by the monitor connected to the isokinetic dynamometer.

Cardiovascular measurements before, during and after isokinetic assessment

The isokinetic dynamometer test protocol was supervised by a physician, who measured blood pressure and collected heart rate data. Before the start of the isokinetic assessment, resting blood pressure and heart rate were measured. For this, individuals were asked to lie down in supine position for 10 minutes. Blood pressure measurement was taken with a stethoscope (Littman Stethocospe Cardiologic II, USA) and a properly calibrated aneroid sphygmomanometer (Wech Allyn/Tycos, USA). Blood pressure was measured three times in both arms and the mean value was considered for the analyses. Heart rate was continuously monitored with a heart rate monitor (Polar FS1, Finland), and the value recorded right after the measurement of blood pressure was used for the analyses.

After the resting measurements had been taken, patients were sent to the evaluation room and positioned in the isokinetic dynamometer. During the tests, blood pressure and heart rate measurements were taken at rest before the exercise and at maximal exertion. Blood pressure was measured according to the procedures previously described by Polito and Farinatti[16]. The cuff began to be quickly inflated when the patient started to show signs of fatigue (unstable motion and tendency to perform Valsalva maneuver), so that it could begin to be deflated right afterwards, and systolic blood pressure could be measured during the last repetition performed. After the measurement of blood pressure, the cuff was totally deflated. Similarly, the heart rate recorded at maximal exertion, that is, at the end of the muscle strength and endurance assessment, was used for the analyses.

In order to standardize the measurements, the patient's right side was always assessed first, and the order of the assessment was muscle strength first, followed by muscle endurance (figure 1). The time interval between the segments evaluated was roughly three minutes, the time necessary for assembling and calibrating the next segment to be assessed. Therefore, the total assessment time in the isokinetic equipment was roughly 35 to 40 minutes.

Statistical analysis

The Statistica™ 6.0™ (Statsoft Inc, USA) statistical software was used to analyze the results. To compare changes in heart rate, systolic blood pressure, diastolic blood pressure and double product throughout the experimental protocol, the one-way ANOVA was used for repeated measures, and the Newman-Keuls post *hoc* test was used whenever a statistical significance was observed. A p value of < 0.05 was considered statistically significant and data are presented as means and standard deviations.

Results

The sample's general characteristics are shown in Table 1. Most participants were elderly, physically inactive and hypertensive individuals who were on antihypertensive and antiplatelet medications. During the maximal exertion tests, all patients experienced intermittent claudication, and the tests had to be interrupted due to pain in the lower limb. The cardiovascular responses observed in these tests were consistent with the findings from literature about this population.

Table 2 shows data on the changes occurred in heart rates recorded during the plantar flexion/dorsiflexion and flexion/extension exercises in the muscular strength and endurance assessment protocols.

With both exercises and both assessment protocols, a significant increase in heart rate was recorded in comparison with pre-test values (pre-test values: 72.1 ± 8.2 bpm; plantar flexion/dorsiflexion maximal strength: 78.4 ± 12.8 bpm; plantar flexion/dorsiflexion muscle endurance: 84.6 ± 16.9 bpm; knee flexion/extension maximal strength: 85.6 ± 13.6 bpm; knee flexion/extension muscle endurance: 94.1 ± 14.2 bpm; $P < 0.05$). In both exercises there was a higher elevation in heart rate during the muscle endurance assessment protocol than in the muscle strength assessment

Table 1 - **General characteristics of the sample**

Variables	Values
Anthropometric and demographic characteristics	
Age (years)	65,1 ± 9,7
Physically inactive (%)	52,9
BMI (Kg.$^{m-2}$)	28,9 ± 4,8
Comorbidities and cardiovascular risk factors	
Smokers (%)	17,6
Hypertensive (%)	94,1
Diabetic (%)	41,2
Obese (%)	47,1
History of heart disease (%)	23,5
Medications	
Beta-bloker agents (%)	23,5%
Antihypertensive agents (%)	76,5%
Antiplatelet agents (%)	76,5%
Limb Hemodynamics	
More severe ankle/brachial/leg index	0,45 ± 0,18
Less severe ankle/brachial/leg index	0,59 ± 0,18
Responses to the treadmill stress test	
Initial claudication distance (m)	405,6 ± 301,6
Distance walked (m)	752,0 ± 314,2
Maximal systolic blood pressure (mmHg)	185,9± 34,1
Maximal diastolic blood pressure (mmHg)	84,2 ± 11,4
Maximal heart rate (bpm)	113,5 ± 14,3

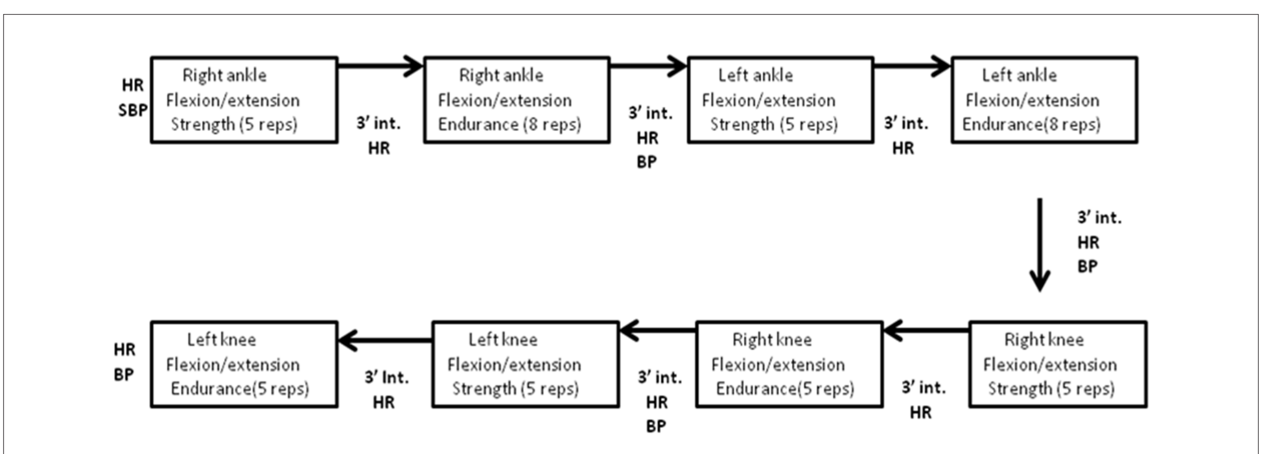

Figure 1 - Design of the experimental protocol. HR - measurement of Heart Rate; BP - measurement of blood pressure; int - interval.

Table 2 - **Changes in heart rate during the peak torque assessment (strength assessment) and total work (endurance assessment) in knee plantar flexion/extension exercises**

Variables	Plantar flexion/dorsifelxion			Knee flexion/extension		
	At rest	Peak	Change (%)	At rest	Peak	Change (%)
HR torque peak	72.1 (8.2)	78.4 (12.8)	+8.8*	72.1 (8.2)	84.6 (16.9)	+17.8*‡
HR total work	72.1 (8.2)	85.6 (13.6)	+19.2*†	72.1 (8.2)	94.1 (14.2)	+31.3*†‡

Significant difference at rest; † Significant difference of peak torque assessment; ‡ Significant difference of plantar flexion/dorsiflexion exercise.

protocol ($P < 0.05$). In both assessments (muscle strength and endurance), the changes observed in heart rate were higher for the knee flexion/extension exercises than for the plantar flexion/dorsiflexion exercises ($P < 0.05$).

The relative changes in systolic blood pressure, diastolic blood pressure and double product during the endurance portion of plantar flexion/dorsiflexion and knee flexion/extension exercises are shown in Figure 2.

In both exercises, systolic blood pressure values rose significantly and in a similar fashion compared to the resting values (pre: 131.4 ± 18.1 mmHg; plantar flexion/dorsiflexion: 159.8 ± 26.3 mmHg; knee flexion/extension: 158.8 ± 32.1 mmHg; $P < 0.05$). In both exercises, the double product values rose significantly compared to the resting stage (pre: 9,465 ± 1,691 bpm*mmHg; plantar flexion/dorsiflexion: 13,444 ± 3,103 bpm*mmHg; knee flexion/extension: 14,903 ± 3,660; $P < 0.05$). However, changes in the double product values during the knee extension/flexion exercises were significantly higher than the changes observed in the plantar flexion/dorsiflexion exercises ($P < 0.05$). No significant changes in diastolic blood pressure values were observed.

Discussion

The main findings of the present study were: (i) the responses in heart rate were higher in the exercises of localized muscle endurance compared to the strength exercises in individuals with IC; (ii) heart rate and double product values were higher in the knee flexion/extension exercises than the values recorded in plantar flexion/dorsiflexion exercises in individuals with IC; and (iii) the responses in systolic blood pressure were similar between knee flexion/extension exercises and plantar flexion/dorsiflexion exercises in individuals with IC.

The findings of the current study indicated that the muscle strength and endurance exercises promoted significant increases in heart rate values up to roughly 60% of the maximal heart rate expected for the age or 77% of the

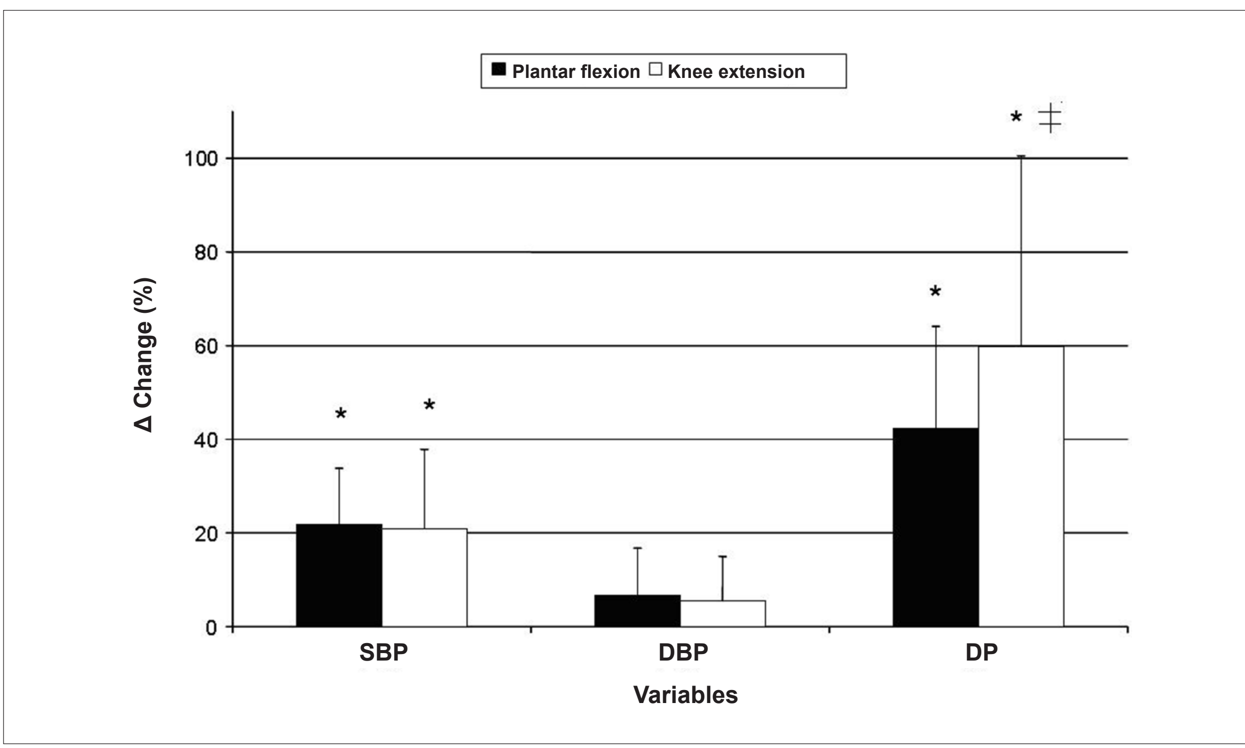

*Figure 2 - Changes in systolic blood pressure (SBP), diastolic blood pressure (DBP) and double product (DP) during the assessment of the total work (endurance assessment) in plantar flexion/dorsiflexion and knee flexion/extension exercises. The black horizontal bars represent the plantar flexion/dorsiflexion exercises, whereas the white horizontal bars represent the knee flexion/extension exercises. *A significant elevation with the exercise. ‡ Significant difference of the plantar flexion/dorsiflexion exercise.*

maximal heart rate recorded during the maximal ergometric test[17]. These results were similar to those of Demonty et al[3] who observed similar increases in heart rate (on average 66% of the maximum expected for the age) during isokinetic assessment in claudicant patients. Moreover, the current study showed clearly that the increases in heart rate values were more pronounced in muscle endurance exercises than in muscle strength exercises[18]. As increases in heart rate are proportional to the duration of the strength exercise, major increments were expected to occur in the muscle endurance segment, since the latter took longer to be performed due to the greater number of repetitions[17,18].

The results of the current study showed higher elevations in heart rate and double product values, which are the main indicators of cardiovascular overload during physical exertion, in the knee flexion/extension exercises than in plantar flexion/dorsiflexion exercises. These results can be attributed to the greater muscle mass involved in knee flexion/extension exercises, which has been associated with greater elevations of heart rate[19,20].

In absolute terms, the mean systolic blood pressure recorded at the peak of exercise was roughly 160 mmHg, a value lower than that recorded at maximal exertion during the ergometric test. Although these values have a relatively small magnitude, it is important that these data be carefully analyzed, because blood pressure measured during the strength exercise can be underestimated by up to 30 mmHg when this measurement is taken by the auscultatory method[16]. On the other hand, although the auscultatory method does not provide an accurate measure of blood pressure, it seems to have reproducible values in the protocols; thus, it can be useful to compare the hemodynamic responses among the different exercises[21]. In light of these considerations, the results of the current study showed similar increments in systolic blood pressure values between knee flexion/extension exercises and plantar flexion/dorsiflexion exercises, suggesting that regardless of the blood pressure value reached, it was similar between the two protocols. These findings differ from those in literature that demonstrate higher elevations of blood pressure in exercises involving greater muscle mass[19,20]. The reasons for this controversy are still not clear; however, it is possible that by recruiting those muscles that are more affected by arterial obstruction, the plantar flexion/dorsiflexion exercises may have caused the ischemia. This ischemia, in turn, may have exacerbated blood pressure elevation during the exercise. Nevertheless, this hypothesis needs to be further researched.

In practical terms, the results of the present study indicated that the cardiovascular overload is greater in both the muscle endurance protocol and in the exercises that recruit more muscle mass.

Considering that individuals with IC are at an increased risk of experiencing cardiovascular events while performing physical exercises[13], the use of strength testing with plantar flexion/dorsiflexion movements seems to be the safest option from a cardiovascular point of view. However, it is noteworthy that no symptoms (such as tachycardia, angina, dizziness, malaise, breathlessness), abnormal hemodynamic responses (exacerbated or prolonged elevation of systolic blood pressure and heart rate after the end of the assessment), or more severe events were observed during the assessments, confirming the safety of the protocol used. Nevertheless, as the patients had been previously screened for cardiovascular disorders and untreated clinical diseases, probably this has minimized the incidence of events.

This study has several limitations. The exercise protocol was carried out in one single sequence; however the interval between the exercises (3 minutes) has shown to be enough to reestablish the heart rate and blood pressure after the strength exercise[19,20]. Blood pressure was not measured in the strength exercises due to the protocol's own characteristic which was finalized within less than 20 seconds, hindering an accurate measurement of blood pressure. Finally, the inclusion of the control group without the disease should provide indications about the possible abnormalities in the hemodynamic responses caused specifically by the disease. Nevertheless, the analysis of the impact of the disease on cardiovascular responses is beyond the scope of this study and should be further analyzed in future studies.

Conclusion

Isokinetic testing of muscle strength and endurance in patients with IC causes elevation of heart rate, systolic blood pressure and double product during the performance of the exercises. These elevations are higher in muscle endurance tests and in those that recruit more muscle mass, suggesting that strength testing of smaller muscular groups causes less cardiovascular overload in these patients.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Sources of Funding

There were no external funding sources for this study.

Study Association

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