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RAPID COMMUNICATION

Walking economy and aerobic power in Parkinson's disease after endurance exercise training: A pilot study

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OBJECTIVE: To verify the effect of an endurance exercise program in middle stages of Parkinson's disease.
METHODS: The patients were two women and seven men with Parkinson's disease, aged 56 to 74 years, classified at Hoehn and Yahr stages 2 to 2.5. The study was designed as an open long-term pilot trial over three months of supervised treadmill exercise training. Cardiopulmonary exercise test evaluations were performed before the start of the study (test 1) and after three months (test 2). The main outcome measure was walking economy (i.e., the rate of oxygen consumption during gait) measured between VT_1 and VT_2 speeds and Oxygen consumption (VO_2).
RESULTS: No changes ($p=0.551$) were observed for maximal oxygen uptake (VO_2max, 24.6 vs 23.6 $mL.kg^{-1}.min^{-1}$) between tests. The walking economy was 20% better ($p<0.001$) after three months of aerobic endurance training (266.7 vs 212.6 $mL.kg^{-1}.km^{-1}$, pre- vs. post-training); the Cohen's "d" effect size (ES) was 0.99, a very large effect.
CONCLUSION: Evidence from this pilot study in individuals with Parkinson's disease suggests that gains in walking economy occurs with a treadmill-training program without gain in aerobic power, but which may positively reduce the energy expenditure of activities of daily living in these patients.

KEYWORDS: physical functioning, ventilatory threshold, maximal oxygen uptake.

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INTRODUCTION

Parkinson's disease (PD) is a progressive, neurodegenerative movement disorder that is often accompanied by impaired balance and walking, as well as a reduced quality of life (QoL). Walking economy (WE), defined as the steady-state aerobic demand for a given submaximal speed of walking,[1] is abnormal in some vascular, neurological and orthopedic disorders.[2] Increased energy expenditure during walking (i.e, poor economy) has been linked to such conditions as peripheral arterial disease,[3] stroke,[4] spinal cord injury,[5] amputation,[6] and cerebral palsy.[7] In men with Parkinson's disease (PD), there was a trend for energy to be increased relative to healthy age and sex-matched controls.[8] In PD, although neuromuscular, metabolic and cardiopulmonary limitations with low aerobic power can compromise functional capacity, little is known about the WE in this population. The finding that energy expenditure was increased during the displacement of the body led us to the hypothesis that WE may also be impaired for patients with PD. If true, interventions targeted to improve economy would be indicated to limit patient fatigue during daily activity. However, few studies have paid attention to this particular aspect, namely whether the energy cost of walking is increased in patients with PD. The findings observed in the literature suggest that the physiologic stress of daily physical activities is increased in patients with early to mid-stage PD, and this may contribute to the elevated level of fatigue that is characteristic of PD.[9] Therefore, the aim of this study was to assess WE in patients with PD before and after endurance aerobic training on the treadmill.

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METHODS

Study design and participants

This was a longitudinal study. In the present pilot study, seven patients (2 women and 7 men; mean age ± SD, 66.3 ± 6.4 years [range: 56-74yrs]) with PD participated in our study. Volunteers underwent screening through a neurological examination, blood testing, and a submaximal graded cardiopulmonary exercise stress test. Diagnosis of PD was verified by a neurologist using the UK Brain Bank criteria.[10] Volunteers in stages 1.5 to 3 using the modified Hoehn and Yahr scale[11] were enrolled. Patients were excluded if they had uncontrolled hypertension, or limited exercise capacity based on musculoskeletal, neuromuscular (other than PD), or cardiovascular disorders. This protocol was approved (under the number cappesq 11623/15) by the institutional review board at the University of São Paulo, School of Medicine, Hospital das Clinicas. Informed consent was obtained from each participant.

Procedures

Cardiopulmonary exercise testing, to assess cardiovascular capacity and indirect calorimetry to assess metabolic responses, were carried out at the Laboratory of Movement Studies of the HC-FMUSP Institute of Orthopedics and Traumatology utilizing a metabolic cart (CPX/Ultima, MedGraphic™, St. Paul, MN, USA). The Heart rate was monitored continuously using a 12-lead electrocardiogram (HeartWare™, Belo Horizonte, MG, Brasil). The usual ECG parameters (heart rate, PR interval, QRS duration, QT and QTc intervals, and P, QRS and T axes) were analyzed in rest, during exercise, and cooldown period.

The stress test was conducted on a medical-grade treadmill (h/p/cosmos™, pulsar, Nussdorf-Traunstein, Germany) with variable speed ($km \cdot h^{-1}$) and slope (%). A modified version of the Heck stress test protocol was used with fixed speed and increasing slope increments at the rate of 2% per minute.[12] The speed was selected from those available (2.4, 3.6, 4.8, 6.0, and 6.5 $km \cdot h^{-1}$) based on the limit of individual conditions after two pilot tests with different speeds.[13] Once a speed had been selected, individuals remained for a one-minute period at rest and shortly thereafter began the protocol at the previously chosen and tested speed. Perceived exertion was evaluated by the patient at each stage of the exercise test on a 15-point linear scale (6-20) as described by Borg.[14] The test was discontinued at the request of the participant or when signs of tiredness were perceived. During the 3-minute recovery phase, beginning immediately after the end of the test proper, speed was decreased and maintained for one minute at every step of decrement. The entire test lasted on average for 10 minutes.

Walking economy determination

Walking economy (WE) was determined by measuring rate of oxygen consumption (VO_2) by indirect calorimetry. The oxygen uptake (VO_2) and walking speed at the ventilatory thresholds 1 and 2 (VT_1 and VT_2) were determined. Based on these walking speeds, VO_2 at VT_1 and VT_2 were averaged between these two intensities. For the determination of WE, VO_2 and walking speeds were expressed as a function of ventilatory thresholds 1 and 2 (VT_1 and VT_2).

Training sessions

Figure 1 displays the non-weight-bearing harness used in this project: it is projected to eliminate the risk of falls. PD patients received a 12-week aerobic training program. Each session lasted 50 minutes, with a frequency of twice a week. All patients underwent treadmill training. The initial speed was 0.5 $km \cdot h^{-1}$, which corresponds to ventilatory threshold 1; workload was by increased by 0.5 $km \cdot h^{-1}$ as tolerated. Vital signs were measured before, during, and after the assigned exercise. The PD patients had an attendance rate of 100% at the end of the program. All sessions were performed at the Laboratory of Movement Studies under direct supervision of exercise physiotherapist with study physicians available.

Figure 1. Non-weight-bearing harness used for treadmill exercise training with patients with Parkinson's disease

Statistics

The Gaussian distribution (normality) for the data was verified by the Kolmogorov–Smirnov goodness-of-fit test (Z value < 1.0). Descriptive statistics are expressed as mean ± standard deviation (SD). A paired Student t-test was used for pre- and post-training comparison. Cohen's "*d*" effect size (*ES*) descriptors (trivial 0.0–0.1, small 0.1–0.3, moderate 0.3–0.5, large 0.5–0.7, very large 0.7–0.9, nearly perfect 0.9–1, and perfect > 1) were used to compare the variables after intervention.[15] The level of significance was established as p<0.05 for all the statistical analyzes. Analyses were performed using Sigma Stat (version 3.5, Systat Software, Inc, Point Richmond, CA).

RESULTS

The main outcome measure was WE (rate of oxygen consumption during gait at the speed in $mL \cdot kg^{-1} \cdot Km^{-1}$) measured at treadmill. Nine subjects (7 men and 2 woman) completed this pilot study. The subjects had a range of disease severity from mild to moderately severe PD. The level of medical comorbidity in the sample was low, and only one was a current user of beta-blocker therapy to attenuate other forms of tremor (atenolol, 50mg/day).

Table 1 displays the walking economy, which was 20% better (p <0.001) after three months of aerobic endurance training, with a very large Cohen's "*d*" effect size *ES*=0.99. No changes were observed for maximal oxygen uptake, oxygen pulse, age-predicted maximal heart rate, percentage of age-predicted maximal heart rate, respiratory exchange ratio, and time test. Effect Size ES for all other measured parameters were small to moderate after training.

DISCUSSION

This small pilot study showed that aerobic exercise provides an important contribution to Parkinson's disease patients. Improving oxygen delivery by reducing energy expenditure in this population is a giant step towards improving quality of life. Studies have shown that aerobic exercise increases factors that potentially have a protective effect on the brain, which can slow the progression of the disease.[16] Aerobic exercise liberates trophic factors - small proteins in the brain that behave as fertilizers. Exercise helps maintain brain connections and counters brain shrinkage from PD as well as from aging. The current study shows that a training program conducted on a low-volume, low-intensity treadmill protocol induces significant improvement in the WE of PD patients. In the present study, the results showed a 20% lower energy expenditure after the training period. The patients were more economical when moving on the treadmill. Therefore, the improvement in submaximal aerobic capacity suggests that PD patients may benefit from exercise just as much as a normal population. In addition, the treadmill allows a more rigorous control of the metabolic and cardiorespiratory demand. These findings are of clinical importance when prescribing exercise in PD patients, in order to reduce the fatigue of these patients. However, the VO_{2max} and all other parameters related to cardiovascular performance as O_2 pulse, HRmax, and percentage of HRmax did not change significantly after 12 weeks of aerobic training. It is probable that bradykinesia of the respiratory movement associated with degeneration of the cardiac sympathetic nerve that begins in the early phases of PD was a limiting factor to increase the cardiac output in these patients and consequently culminating with a low level of aerobic power.[17]

Previous studies have observed that cardiac uptake of metaiodobenzylguanidine (MIBG) is frequently decreased even in the early stages of PD (Hoehn-Yahr stage 1 or 2), which suggests an early involvement of the cardiac sympathetic nerve in these patients.[18] Although the maximal respiratory exchange rate (RER_{max}) of the Parkinson's diseased patients amounted to a large ventilatory effort (RER = 1.15) at the exercise peak, it was not enough to improve aerobic power or exercise tolerance at maximal effort performed in treadmill exercise test.

In conclusion, we suggest that in PD the gain in WE may occur with a treadmill-training program, which may actually reduce the energy expenditure of activities of daily living. Low exercise intensity has the merit for improving WE motor manifestations of PD without increased in aerobic power.

Table 1. Outcomes of 9 participants with Parkinson's Disease following aerobic exercise (mean ± SD).

Variables	Pre training (baseline)	Post training (12-weeks)	Change (%)	p-value	Cohen´s d effect size
VO_2max ($mL.kg^{-1}.min^{-1}$)	24.6±6.6	23.6±7.3	-4	0.551	0.14
WE ($mL.kg^{-1}.km^{-1}$)	266.7±61.3	212.6±47.2	-20	< 0.001	0.99
O_2 Pulse ($mL.HR^{-1}$)	13.1±3.1	12.7±3.1	-3	0.614	0.12
HRmax ($beats.min^{-1}$)	131.2±24.3	133.6±27.4	+ 1.8	0.429	0.09
HRmax (%)	81.1±13.7	83±15.7	+ 2.3	0.359	0.12
RERmax (VCO_2/VO_2)	1.11±0.10	1.15±0.07	+ 3.6	0.177	0.46
Time test (min)	10.2±2.7	11.4±2.2	+ 12	0.216	0.48

VO_2max: maximal oxygen uptake; WE: walking economy; O_2 Pulse: oxygen pulse; HRmax: age-predicted maximal heart rate; HRmax%: percentage of maximal heart rate; RERmax: maximal respiratory exchange ratio. The significant parameter is stressed in bold characters.

CONFLICT OF INTEREST

Authors report no conflict of interest regarding this paper

AUTHOR PARTICIPATION

JMDAG, PRSS and DSS: Lead author, wrote the manuscript, analyzed the data; Corrected the manuscript; Corrected the manuscript, analyzed the data, supervisor.

ECONOMIA DE CAMINHADA E POTÊNCIA AERÓBIA NA DOENÇA DE PARKINSON APÓS PROGRAMA DE TREINAMENTO DE ENDURANCE: UM ESTUDO PILOTO

OBJETIVO: Verificar o efeito de um programa de treinamento físico aeróbio em estágios intermediários da doença de Parkinson (PD).

MÉTODOS: Os pacientes eram duas mulheres e sete homens com PD, com idade entre 56 e 74 anos, classificados como estágios Hoehn e Yahr 2 a 2,5. O estudo foi concebido como um ensaio piloto aberto de longo prazo durante três meses de treinamento supervisionado e realizado em esteira ergométrica. As avaliações da troca gasosa pelo teste de exercício cardiopulmonar foram realizadas antes do início do estudo (teste 1) e após três meses (teste 2). A determinação da economia de caminhada (taxa de consumo de oxigênio durante a marcha) foi medida entre as velocidades do primeiro e do segundo limiar (LV_1 e LV_2) e do consumo de oxigênio (VO_2) entre as duas velocidades por interpolação.

RESULTADOS: Não foram observadas alterações (P = 0,153) para o consumo máximo de oxigênio (VO_2max: 26,7 vs. 24,2 $mL \cdot kg^{-1} \cdot min^{-1}$) após o período de intervenção. A economia de caminhada foi 23% maior (P <0,001) após três meses de treinamento físico aeróbio (273,4 vs. 209,4 $mL \cdot kg^{-1} \cdot km^{-1}$, ES = 0.99, muito alto).

CONCLUSÃO: Evidências deste estudo piloto em indivíduos com DP sugerem que os ganhos na economia de caminhada podem ocorrer com um programa de treinamento de "endurance" aeróbica na esteira sem ganho na potência aeróbia, mas que positivamente pode reduzir o gasto de energia das atividades da vida diária nesses pacientes.

PALAVRAS-CHAVE: Condicionamento físico, limiar ventilatório, Consumo máximo de oxigênio

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