Research Report

Cardiovascular and Metabolic Responses to Upper- and Lower-Extremity Exercise in Men With Idiopathic Parkinson's Disease

Background and Purpose. The aerobic capacity of individuals with Parkinson's disease (PD) has not been characterized. This study (1) compared maximal exercise performance in individuals with and without PD, (2) compared exercise performance during upper- and lower-extremity exercise, and (3) described submaximal exercise responses. **Subjects.** Eight men with PD (PD group) and 7 men without PD (control group) participated. **Methods.** Subjects performed a lower-extremity ergometer test (LE test) and an arm-cranking ergometer test (AC test). Peak oxygen consumption, heart rate, respiratory exchange ratio, and power, as well as submaximal values of oxygen consumption and heart rate for each power level, were recorded. **Results.** No differences were found between the groups for either test. Peak power was less for the PD group than for the control group for both tests. Submaximal heart rate and oxygen consumption were higher for the PD group than for the control group. **Conclusion and Discussion.** We conclude that individuals with mild to moderate PD can be tested with both exercise protocols to a peak exercise capacity and that there are differences in upper- and lower-extremity peak power and submaximal responses between persons with and without PD. [Protas EJ, Stanley RK, Jankovic J, MacNeill B. Cardiovascular and metabolic responses to upper- and lower-extremity exercise in men with idiopathic Parkinson's disease. *Phys Ther.* 1996;76:34–40.]

Key Words: *Cardiac, tests and measurements; Cardiovascular system; Exercise, general; Parkinson's disease.*

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The disability and immobility that occur with idiopathic parkinsonism or Parkinson's disease (PD) can contribute to cardiovascular deconditioning. Deconditioning and decreased endurance in the individual with PD have been discussed, but not documented.[1,2] In a series of 10 patients with PD in whom fitness level was classified, 4 patients were considered to have low fitness, 5 patients had fair fitness, and only 1 patient had average fitness.[3] In addition, both heart rate and blood pressure responses during light isometric exercise have been shown to vary in individuals with PD compared with responses in individuals without PD.[3]

Standardized exercise tests to maximum capacity with treadmills or ergometers are used to measure cardiovascular conditioning or fitness.[4–6] These tests involve progressive increases in exercise until the individual can no longer maintain the exercise.[7] The peak oxygen consumption (peak$\dot{V}O_2$) and the peak heart rate (peakHR) reached during exercise are used to define the level of cardiovascular conditioning and to prescribe exercise. The peak values achieved may vary with the type of exercise performed and the amount of muscle mass engaged in the activity.[8]

Although PD influences extremity and spine musculature, not all areas are affected equally. Muscular rigidity affects the proximal musculature first, especially around the shoulders and neck, and may progress to the facial muscles and the extremities.[9] Body regions that have displayed symptoms longer tend to be more severely involved. Symptoms may vary unilaterally, between extremities, and between the upper and lower extremities.[9] Oxygen consumption ($\dot{V}O_2$) and heart rate responses to submaximal exercise are increased in individuals with PD when the more affected extremities are being used.[10] Thus, multiple testing strategies using both upper- and lower-extremity tasks should be examined.

There is a need to objectively document the physiologic responses of individuals with PD during standardized exercise testing procedures in order to prescribe aerobic exercise. The purposes of this study, therefore, were (1) to compare maximal exercise performance in individuals with and without PD; (2) to compare exercise performance within and between these groups during two different exercise testing protocols, one using bicycle ergometry and the other using arm-cranking ergometry; and (3) to describe submaximal exercise responses. We hypothesized that the neuromuscular involvement seen in individuals with PD will influence (1) exercise responses when compared with individuals without PD and (2) responses to upper-extremity exercise compared with those to lower-extremity exercise. We also hypothesize that early involvement of the shoulders,

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Table 1.
Characteristics of Subjects With Parkinson's Disease

Subject No.	Age (y)	No. of Years Since Diagnosis	Hoehn and Yahr Stage
1	59	6.0	2.0
2	63	3.0	2.0
3	58	12.0	2.5
4	51	2.5	2.0
5	64	6.0	2.0
6	67	15.0	2.0
7	73	14.0	3.0
8	56	10.0	2.5
$\bar{X}$	61.4	8.56	2.25
SD	6.9	4.87	

Table 2.
Modified Hoehn and Yahr Scale[11]

Stage	Description
0.0	No signs of disease
1.0	Unilateral disease
1.5	Unilateral and axial involvement
2.0	Bilateral disease, without impairment of balance
2.5	Mild bilateral disease, with recovery on pull test
3.0	Mild to moderate bilateral disease; some postural instability; physically independent
4.0	Severe disability; still able to walk or stand unassisted
5.0	Wheelchair bound or bedridden unless aided

neck, and axial musculature can decrease upper-extremity peak values and increase submaximal efforts.

Method

Subjects

Eight men with a diagnosis of PD for at least 1 year were recruited from local neurology clinics and support groups for persons with PD. The characteristics of the subjects with PD are shown in Table 1. The subjects and their physicians did not report a history of other chronic neuromuscular, musculoskeletal, or cardiopulmonary disease. All subjects except one were regularly taking at least three antiparkinsonian medications, including carbidopa/levodopa, deprenyl, and one other dopaminergic medication (eg, amantadine, pergolide). One subject was taking only carbidopa/levodopa and deprenyl. Only two of the subjects (subjects 4 and 8) were employed full- or part-time. All subjects were in stage 2.0 or 3.0 of the Hoehn and Yahr disability scale as described in Table 2.[11] Two subjects (subjects 4 and 8) engaged in regular aerobic exercise. The rest were relatively sedentary except for participation in once-weekly flexibility exercise groups. Seven men who were similar in age to the PD group, had no history of chronic neuromuscular, musculoskeletal, or cardiopulmonary disease, and had self-reported activity and exercise levels comparable to the PD group were recruited in the community to act as a comparison group. The subjects' physicians were called to verify their medical history. The nature, purpose, and risks of the study were explained verbally and in writing to the subjects before obtaining written consent to participate.

Instrumentation

An electronically braked bicycle ergometer* was used for a progressive, incremental, cycling test (LE test). An electronically braked arm ergometer† was used for an arm-cranking test (AC test). A computerized gas analysis system was used to collect and analyze expired gases during exercise.‡ The system consists of a mouthpiece, a two-way breathing valve, a rolling seal spirometer, an oxygen analyzer, and a carbon dioxide analyzer. The system was calibrated with known gas concentrations and volumes prior to each test. Heart rates and rhythms were recorded on a chart recorder.§ A standard CM5 chest lead was used.

In separate studies, the test-retest reliability of the peak$\dot{V}O_2$ and peakHR measures was assessed. The first study examined the reliability of the AC test in three individuals without PD over a 4-week period. The second study examined the reliability of the LE test in four individuals with PD over a 4-week period. A two-way analysis of variance yielded values from which the intraclass correlation coefficients (ICC[3,1]) were calculated.[12,13] The ICCs were .92 for peak$\dot{V}O_2$ and .94 for peakHR for the AC test and .97 for both peak$\dot{V}O_2$ and peakHR during the LE test.

Procedure

Subjects were instructed to refrain from eating for at least 3 hours prior to testing and to refrain from drinking liquids for 1 hour prior to testing. Subjects with PD were instructed to take their medications upon arriving at the laboratory. While the subjects waited for the medications to take effect, the testing procedures were explained and they read and signed consent forms. The exercise tests were performed between 45 and 90 minutes after the medications were taken. This should be an optimal range for reaching a peak plasma levodopa level.[3,14] This procedure minimized motor fluctuations in response to medications during testing.

After giving informed consent, each subject was allowed a short time for practice and to become familiar with the LE and AC tasks. The subject was given instructions on how to signal the investigators when he reached fatigue. The subject's skin was cleansed with alcohol, and electrodes were

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†Uppercycle, Engineering Dynamic Corp, 120 Stedman St, Lowell, MA 01851.
‡Gould 9000 IV, Sensormedics, 2676 Indian Ripple Rd, Dayton, OH 45440.
§Model DMP-48, Narco Biosystems, PO Box 12511, 7651 Airport Blvd, Houston, TX 77336.

applied to the clavicle, manubrium, and fifth rib. The subject was randomly assigned to either LE or AC as the first test. After placing the mouthpiece of the breathing apparatus between the lips and teeth, the subject was instructed to maintain a tight seal around the mouthpiece. The subject was observed during testing to ensure that the seal was maintained. A noseclip was placed so that no air could be breathed through the nostrils.

For the LE test, each subject was given a 1-minute warm-up pedaling at a 20-W power level to become accustomed to the test situation. The resistance on the bike was increased every 2 minutes by 20-W increments, beginning at 40 W, until the subject met our established criteria for peak exercise. The subject was encouraged to complete the last full 2-minute stage. Following the test, the subject continued cycling without resistance as a cool-down.

For the AC test, each subject was given a 1-minute warm-up with no resistance, followed by increases in resistance at 10-W increments every 2 minutes until the subject met our criteria for peak exercise. We encouraged the subject to complete the last 2-minute stage. The subject continued to arm crank without resistance as a cool-down for another 2 to 3 minutes.

After completing the first test, each subject was allowed to rest prior to attempting the second test. When the heart rate returned to preexercise values and at least 20 minutes had elapsed, the subject was set up for the second test.

A standard open-circuit method was used to collect expired gases.[15] Expired gases were analyzed every 20 seconds during exercise. Oxygen consumption, carbon dioxide exhaled ($\dot{V}CO_2$), and the respiratory exchange ratio (RER, where $RER=\dot{V}CO_2/\dot{V}O_2$) were recorded during the last 20 seconds of each 2-minute stage as the values representing the metabolic responses to that power level. Heart rates were observed continuously on the chart recorder during the last 20 seconds of each exercise stage. These values were extrapolated to the minute values in beats per minute.

The effort was considered to reach a peak value during the last stage if the subject reached two out of three of the following criteria: (1) volitional fatigue, (2) ±10 beats of age-predicted maximum heart rate for cycling or arm cranking, and (3) an RER value of >1.0. These have been suggested as criteria for maximal exercise for older subjects.[16] The age-predicted maximal heart rate for cycling was estimated as 220 − age.[4] The age-predicted maximal heart rate for the AC test was estimated as 90% of the age-predicted heart rate for cycle ergometry.[6] Peak$\dot{V}O_2$, peakHR, peak respiratory exchange ratio (peakRER), and peak power (peakP) were the highest values achieved during the last stage of exercise. All subjects reached at least two out of three of these criteria during testing for both tests.

Data Analysis

Medians and ranges were calculated for peak$\dot{V}O_2$, peakHR, peakRER, and peakP for both the PD and comparison groups during LE and AC tests. Nonparametric analysis was used because the data for the PD group was skewed and did not meet the assumptions for parametric analysis.[17] A Mann-Whitney *U*-Wilcoxon rank-sum test was used to compare age, peak$\dot{V}O_2$, peakHR, peakRER, and peakP between the groups for both the LE and AC tests.[18] A Wilcoxon matched-pairs signed-rank test was used to compare the LE and AC tests. An alpha level of .05 was selected as the level of significance. Submaximal exercise data were plotted and presented descriptively for both the LE and AC tests.

Results

The median values and ranges are presented in Table 3. There were no differences between the groups on age, peak$\dot{V}O_2$, peakHR, or peakRER for either the LE test or the AC test. When comparisons were made between the LE and AC tests, only peak$\dot{V}O_2$ was different, with the peak$\dot{V}O_2$ value lower for the AC test than for the LE test for both groups (P=.01 for the PD group and P=.02 for the control group). The subjects' peak$\dot{V}O_2$ during the AC test was 61.2% of the value observed for the PD group during the LE test and 67.1% of the value observed for the control group during the LE test. The peakP achieved by the PD group during both the LE and AC tests was less (P=.02 for the LE test and P=.001 for the AC test) than the peakP achieved by the control group.

In order to examine the submaximal exercise responses, the heart rates and $\dot{V}O_2$ during four submaximal power levels for both the AC and LE tests were plotted (Figs. 1 and 2). Although no statistical analysis was conducted, the submaximal heart rate and $\dot{V}O_2$ values for the PD group appeared to be higher for both the AC and LE tests compared with the control group.

Discussion

The peak cardiovascular (peakHR) and metabolic (peak$\dot{V}O_2$ and peakRER) responses to graded exercise were similar for the PD and control groups. The peakHR and peakRER achieved by both groups indicate that the subjects achieved the exercise endpoints required as our criteria for peak exercise. The peak$\dot{V}O_2$ values for both groups are comparable to maximal values appearing in the literature for older men performing cycle ergometer tests.[19] We have also demonstrated that these values can be reliably reproduced on retesting. The criteria we used as exercise endpoints and the peak$\dot{V}O_2$ reflect maximal exercise performance in these subjects.[7] This finding suggests that individuals with mild disability (Hoehn and Yahr stage 2.0 of PD) can be tested to selected exercise endpoints using standard exercise testing protocols and that the responses are similar to those in an asymptomatic comparison group. Only one of our subjects was classified as being in stage 3.0, in which there is greater

Table 3.
Median Values and Ranges for Peak Exercise Responses in Individuals With and Without Parkinson's Disease

	Parkinson's Disease Group (n=8)		Control Group (n=7)	
Variable[a]	**Median**	**Range**	**Median**	**Range**
Age (y)	61.0	51–73	65.0	53–71
Peak$\dot{V}O_2$ (mL/kg/min)				
LE	23.7	18.2–37.62	25.0	20.3–34.9
AC	15.1	9.9–18.8[b]	16.0	14.8–21.3[c]
PeakHR (bpm)				
LE	147.0	120–174	153.5	138–168
AC	132.0	126–168	138.0	120–156
PeakRER				
LE	1.12	1.01–1.30	1.13	1.01–1.23
AC	1.05	0.96–1.35	1.07	1.0–1.18
PeakP (W)				
LE	115.0	100–140[d]	142.9	100–180
AC	53.8	40–70[e]	81.4	70–90

[a]Peak$\dot{V}O_2$=peak oxygen consumption, LE=bicycle ergometry, AC=arm cranking, peakHR=peak heart rate, peakRER=peak respiratory exchange ratio, peakP=peak power.
[b]Significantly different from LE (P=.01).
[c]Significantly different from LE (P=.02).
[d]Significantly different from control group (P=.02).
[e]Significantly different from control group (P=.001).

bilateral involvement and postural instability. Perhaps a sample with a greater level of disability (ie, predominantly stage 3.0 and 4.0) would respond differently to these tests than nondisabled counterparts would respond.

An individual's maximal oxygen consumption ($\dot{V}O_2$max) is used to describe fitness level and to prescribe exercise.[4] This group of individuals with PD had at least fair to average levels of fitness when compared with men of the same age with comparable activity levels. This finding does not support the notion that PD will contribute to cardiovascular deconditioning at a stage 2.0 disability level. The time since the onset of PD symptoms varied from 2.5 to 15 years in this sample. This range may suggest that the length of time in which symptoms are apparent does not affect the fitness level in individuals with PD similar to those in our sample. In addition, all members of the PD group participated in at least weekly flexibility exercise groups or regular exercise. Perhaps this activity is sufficient to maintain fitness levels in persons with PD in relation to elderly persons with similar ages and activity levels, especially sedentary older men. Further exploration of the influence of sustained exercise on the level of fitness in people with PD is needed.

Standard exercise testing protocols use running uphill[20] or cycling.[21] A progressive cycling protocol was selected for this study because of concern about balance problems in individuals with PD. Running uphill produces higher $\dot{V}O_2$max and HR values than cycling.[8,22,23] Consequently, the peak$\dot{V}O_2$ values in our study were somewhat lower than would be expected during running uphill for 60-year-old men. Although the estimate of maximum exercise capacity offered by cycling is lower, this test may be more practical for the PD population and closer to the type of seated exercise frequently utilized in PD exercise programs.[24]

Arm exercise produces lower $\dot{V}O_2$max values than cycling. In younger populations, the $\dot{V}O_2$max during arm cranking is between 67% and 73% of the values obtained with cycling.[8,22,23] Although the control group achieved 67.1% of the cycling value during the AC test, the PD group reached only 61.2%. Although we did not compare these values statistically, this finding suggests that the PD group was not able to achieve $\dot{V}O_2$ levels during upper-extremity exercise that were as high as those achieved during lower-extremity exercise. The amount of $\dot{V}O_2$ achieved during exercise depends on the muscle mass involved in the activity and the subject's level of fitness for arm work.[23] The individuals with PD did not seem to be as fit for upper-extremity exercise. This finding could be related to slower reaction times, longer movement times, slower velocities, and poor coordination of upper-extremity movement in individuals with PD compared with individuals without PD.[25,26] Because many exercise programs recommended for people with PD include both upper- and lower-extremity activities, the difference in response to upper-extremity exercise should be kept in mind. Clinicians may wish to use a separate AC test and prescribe arm cranking as an aerobic conditioning program for individuals with PD.

The PD group was unable to perform to the same level of exercise as rated by maximum power when compared with the control group for either the LE or AC test, even though the peak$\dot{V}O_2$ and peakHR were similar. This finding suggests poorer exercise efficiency in the PD group than in the control group. Exercise efficiency can be described as lower heart rate responses to specified rates of work.[27] Figures 1 and 2 show that the control group had lower submaximal heart rates than the PD group for each of four power levels during both the LE and AC tests. These differences ranged between 10 and 16.5 bpm during the LE test to between 19

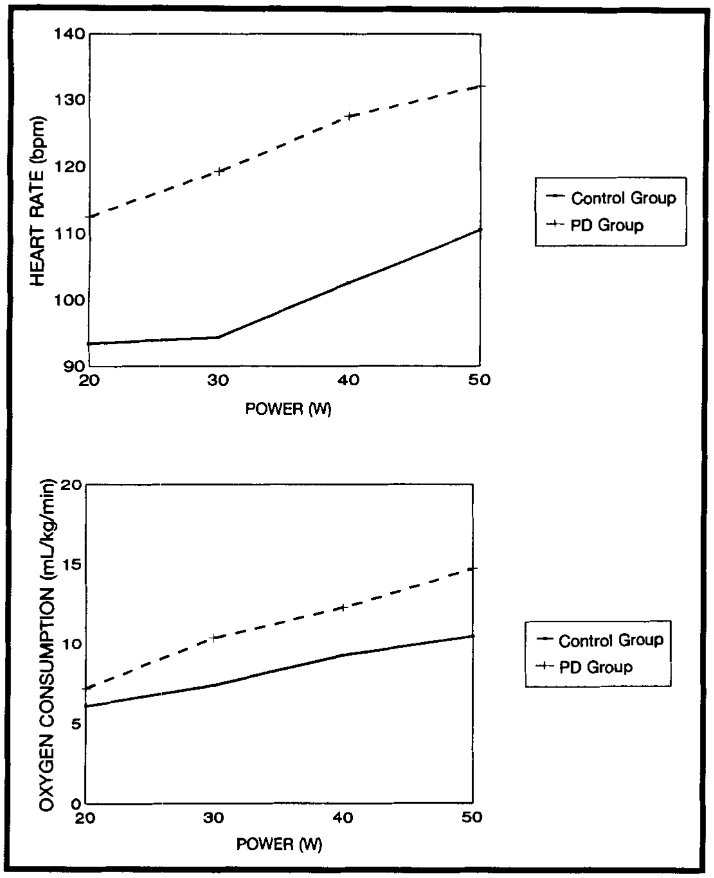

Figure 1.
Submaximal heart rates and oxygen consumption in response to four submaximal power levels for arm cranking in subjects with Parkinson's disease (PD group) and in subjects without Parkinson's disease (control group).

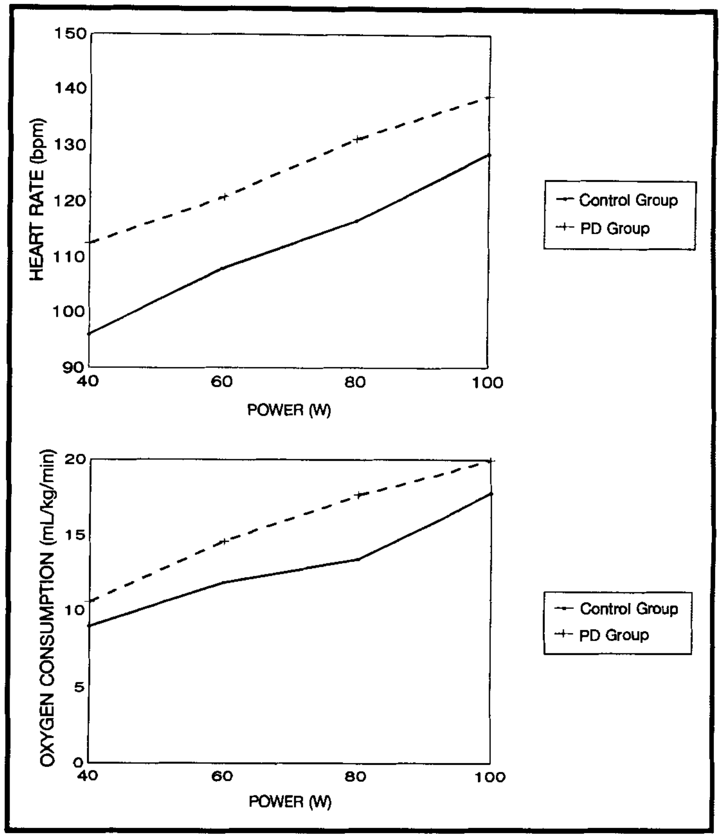

Figure 2.
Submaximal heart rates and oxygen consumption in response to four submaximal power levels for lower-extremity ergometry in subjects with Parkinson's disease (PD group) and in subjects without Parkinson's disease (control group).

and 25 bpm during the AC test. The submaximal $\dot{V}O_2$ values for both exercises and all power levels were also lower for the control group. Wilmore and Costill[27] suggested that aerobic conditioning lowers submaximal heart rates at specified work rates. The differences in submaximal values and peakP were the only indicators of differences in exercise responses between these two groups. The PD-associated movement disorders of rigidity and bradykinesia can increase cardiovascular and metabolic responses to submaximal exercise by interfering with the exercise movement. All PD group subjects tested in this study had bilateral involvement of all extremities with axial involvement. Although symptoms can vary from extremity to extremity, this finding suggests that stage-2.0 PD will lessen the efficiency of both upper- and lower-extremity exercise compared with exercise efficiency in persons without PD.

Another way to look at submaximal responses is to plot heart rates against the same level of $\dot{V}O_2$ rather than against power. Although both groups had similar heart rates at the same level of $\dot{V}O_2$ during the LE test, the PD group consistently had higher heart rates with each level of submaximal $\dot{V}O_2$ during the AC test. At submaximal $\dot{V}O_2$ levels of 8.5 and 11.5 mL/kg/min, for example, the PD group had heart rates of 116 and 127 bpm compared with 101 and 112 bpm for the control group. The PD group had heart rates 15 bpm higher for the same level of metabolic demand. Because the upper extremities are frequently the first extremities to display symptoms, the higher heart rates may be related to a longer length of time that these muscle groups have had symptoms.[10] Saltin and Landin[10] observed that the most affected extremities in individuals with PD create higher heart rate and blood lactate values during exercise.

An exercise prescription for enhancing cardiovascular fitness should be based on an individual's exercise capacity.[4] An appropriate intensity is generally a heart rate that corresponds to between 60% and 85% of $\dot{V}O_2max$.[4] For the people with PD in our study, this would mean exercise-training heart rates of between 120 and 140 bpm maintained for 15 to 60 minutes while riding the cycle ergometer. For AC exercise, corresponding heart rates would be between 116 and 128 bpm. The different exercise responses to the upper- and lower-extremity activities add support to the notion that exercise interventions should include both upper- and lower-extremity exercises. Different training heart rates and intensities for upper- versus lower-extremity exercise should be included in the exercise prescription. In addition, the AC exercise used during our study required considerable involvement of the neck and trunk musculature in order to stabilize for the activity. Muscle involvement around the thorax and neck have been implicated in relation to airflow limitations in people with PD.[28] Aerobic exercise training programs in asymptomatic elderly persons improves the effectiveness of ventilation during moderate exercise and enhances their maximal ventilatory capability.[29–31] Perhaps exercise programs aimed at improving ventilation could affect some of the respiratory limitations seen in individuals with PD.

Conclusions

We have demonstrated that individuals with PD can reach peak exercise using standard exercise testing protocols. The peak cardiovascular and metabolic responses of the PD group subjects were comparable to those of the control group subjects, except for peakP in which the PD group reached lower levels for both the LE and AC tests. Peak$\dot{V}O_2$ values during the AC test were lower than peak$\dot{V}O_2$ values during the LE test for both groups. Differences in submaximal responses suggest that the PD group had lower efficiency during exercise and support the need for exercise conditioning in all extremities.

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