Variability of Breathlessness Measurement in Patients with Chronic Obstructive Pulmonary Disease

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The purpose of our study was to evaluate the reproducibility of a Borg rating of dyspnea in patients with COPD. We examined nine patients with COPD who performed a SST on four separate days within a ten-day period. The patients walked on a treadmill for 6 min. At the end of each minute, patients matched a Borg rating to the intensity of their breathlessness. We measured the HR, VE, VO2, VT and f at the end of each minute. While the mean VO2, VE, HR, VT and f stabilized after one or two attempts, the Borg ratings decreased with successive tests. We conclude that the Borg scale for measuring breathlessness shows progressive decreases with repetition whereas VO2, VE, HR, VT and f stabilize after one or two practice attempts. This suggests that desensitization to dyspnea may play a role in the improvement of patients after exercise.

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There is considerable controversy regarding the best way to assess exercise capacity in patients with COPD.1 The VO2max which is a reliable guide to aerobic capacity in normal subjects is of questionable value in patients with COPD as peak exercise in the latter reaches a ventilatory limitation at levels below that of the VO2max. The VO2 fails to reach a plateau, and thus no objective endpoint is reached.2 Similarly, the anaerobic threshold as determined by standard gas exchange criteria (VE/VO2 and VE/VCO2), is of limited value because many patients with COPD fail to increase their ventilation appropriately in response to metabolic acidosis.3-5 The modified V-slope method6 which is reputedly more sensitive than the standard method detected the AT in less than half of a sample of 22 COPD patients. Timed maximal walk tests suffer from motivational factors as well as the fact that significant improvement may follow repetition of the test.6-6

Clinical scales and psychophysical methods have been used in an effort to improve measurement of exercise capacity. Scales like the Dyspnea Index described by Mahler and co-workers7 grade dyspnea on a clinical scale which accounts for magnitude of the task, as well as magnitude of effort during exercise performance. This assessment is performed via an interview of the patient and is dependent upon accurate patient recall. Other scales like the visual analogue or category scales such as the Borg Ratings of Perceived Exertion Scale (Borg RPE Scale),8-10 can be used by the subjects to match their degree of effort with a ranking during actual performance of the exercise.

The Borg RPE Scale has evolved from a type of ratio scaling known as “magnitude estimation” in which patients assign numbers to different stimuli depending on the intensity with which the stimuli are perceived.9 Ratio scales only allow for relative comparisons between stimuli and give no basis for interindividual comparisons. To overcome this, Borg added descriptive categories referring to “perceived exertion” to give the ratios an anchor and allow patients to respond in a more “absolute” way to the stimuli, and thus allow for direct interindividual comparisons.10

The purpose of our study was to evaluate the reproducibility of the Borg Scale as an assessment of breathlessness during exercise in patients with COPD. If indeed there is a small intraindividual variation in this scale with repeated exercise attempts, then it would be invaluable in assessing exercise capacity as well as the response to therapeutic interventions, such as bronchodilator medications or exercise training programs.

Methods

Eleven patients with moderate to severe COPD were entered into the study which was approved by the Human Subjects Committee at our institution. Patients were excluded if they demonstrated (1) an increase of greater than 200 ml and 15 percent in the post-bronchodilator FEV1; (2) hypoxemia (PaO2 of 55 mm Hg or less or SaO2 of 88 percent or less) at rest or with exercise; or (3) greater than 10 percent variation in the FEV1 on any of the study days. All were clinically stable outpatients who did not know the purpose of the study.

Pulmonary function tests were performed using standard techniques.11 Forced vital capacity, FEV1, FEF25-70% and MVV were
performed using a dry rolling seal spirometer (Cardio-Pulmonary Instruments, Dayton, OH). Functional residual capacity and RV were measured using the helium dilution technique.\textsuperscript{14} Arterial blood gas levels were obtained while patients breathed room air at rest and were measured on a pH/blood gas analyzer (model 178; Corning Medical and Scientific, Medfield, MA).

On the initial study day, patients were familiarized with the study protocol and the Borg Scale. Patients performed a progressive, incremental exercise test to a symptom-limited maximum on a motorized treadmill (Quinton Instrument Co., Seattle, WA) while breathing room air. Prior to each test, the patients rested while standing upright on the treadmill for 4 min with a standard rubber mouthpiece in place for gas collection. Using a Ventilation Measurement Module (VMM Sensorsmedics, Anaheim, CA) and a mass spectrometer (MGA 1000; Perkin-Elmer Medical Instruments, Pomona, CA), \( V_{E}, V_{O_2}, V_{CO_2}, Vr \) and \( f \) were calculated on line with a PDP-11/64 computer (Digital Equipment Corporation, Maynard, MA). Results of these variables were averaged over the last 30 s of each minute. The \( S_aO_2 \) was measured by a pulse oximeter (Biox 3700; Ohmeda, Boulder, CO) and HR was recorded continuously on a three-lead ECG (Tram Series 7000 monitor; Marquette Instruments, Inc., Milwaukee, WI). Treadmill speed was increased by 0.75 mph for each minute of exercise up to a maximum speed of 2.25 mph. Once this speed was achieved, treadmill grade was increased by 2 percent each minute. All tests were stopped by the patients when dyspnea limited continuation of exercise. During the treadmill walking, the patients were instructed not to hold onto the treadmill bars.

Patients returned on four subsequent days within a ten-day period. Spirometry was performed on each day to ensure that lung function was stable. On each day, following 2 min of rest equilibration, a SST was repeated on a treadmill for 6 min at a speed selected to produce 95 percent of the \( V_{O_2,max} \) as determined from the baseline incremental exercise test. Data were collected in a manner similar to the baseline test. Patients were asked to rate the intensity of breathlessness using the modified Borg Scale.\textsuperscript{15} A sheet of paper on which the Borg Scale was printed was shown to patients during the last 10 s of each minute of exercise, and patients pointed to the rating which best described their intensity of breathlessness at that moment. The top end of the scale was anchored by having the patient recall the most severe dyspnea experienced in the past. Patients were reminded of the intensity of the dyspnea at the completion of their incremental exercise test as a guide to comprehending a rating of 10 on the modified Borg scale. The lower end was described as the respiratory sensation while completely at rest. Standard instructions for the Borg Scale were read to the patient by the same individual prior to each exercise study. These instructions follow here:

The Borg score is an indicator of the severity of your breathlessness. The scale ranges from 0 to 10 where a value of 0 represents nothing at all or no discomfort with your breathing and a score of 10 means that the intensity of the breathlessness is maximal. Imagine a situation or past experience which has caused the worst breathlessness for you—an equivalent sensation should represent a "10" on this scale. You will be asked every minute of the exercise test to point with your finger to a Borg rating between "0" and "10" which should represent your perceived level of breathlessness at that moment.

Patients were instructed to maintain their regular diets and all medications were maintained at a constant schedule and dosage. Exercise testing was performed at approximately the same time of day to avoid diurnal variation in the symptomatology.

Statistical Methods and Analysis

The day-to-day differences in the mean absolute values for each index during the SST were compared by using repeated measures analysis of variance with Tukey's Studentized Range Test (experimentwise error rate was set at 0.05). Because Borg ratings are not characterized by normal distributions, analysis of this variable was performed after applying rank transformation.\textsuperscript{15}

RESULTS

Patient Characteristics

Two patients were excluded from the analysis because of excessive fluctuations (>10 percent) of the FEV\(_1\), Salient anthropomorphic data, pulmonary function test results and gas exchange data for the remaining nine patients are shown in Table 1. The mean age was 65.4 ± 3.1 (SE) years. Baseline resting pulmonary function studies revealed the mean FEV\(_1/\)FVC to be 46.3 ± 3.3 percent, and serial spirometry revealed changes of less than 5 percent over the study period. The mean \( V_{O_2,max} \) achieved on the initial symptom-limited incremental exercise test was 1.07 ± 0.08 L/min. No patient developed \( O_2 \) desaturation (<90 percent) during exercise. Three of the nine patients did not complete the sixth minute of the SST on day 1 because of dyspnea.

Mean Absolute Values

The mean absolute value of each objective index was examined across the four study days at minutes 2 and 5 for the SST. During the SST there was a significant decrease between days 1 and 2 for HR at minutes 2 and 5, but no significant decreases over

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<th>Patient</th>
<th>Age (yr)</th>
<th>Sex</th>
<th>FVC (L)</th>
<th>FEV(_1) (L)</th>
<th>FEV(_1/)FVC (%)</th>
<th>( V_{O_2,max} ) (L/min)</th>
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Variability of Breathlessness in COPD (Belman et al)

**DISCUSSION**

We found that untrained patients with moderately severe COPD acclimated to the treadmill walking and achieved stable baseline values in VO$_2$, VE, HR, VT and f by the second day of testing. Conversely, the Borg ratings decreased progressively, especially at

**Table 2—Mean VE/VO$_2$ During SST for Days 1 through 4**

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more strenuous levels of exercise, and failed to reach a stable level even after four days of testing. We found that the proportionately greater fall in the Borg ratings with repetitive testing was independent of a true physiologic training effect.

A recent study by Silverman et al.\textsuperscript{14} concluded that the perception of effort in breathing in patients with COPD is highly reproducible. In this study, patients underwent repeated symptom-limited incremental exercise tests on a cycle ergometer. Variability of the sensory scores at the second and the final minute of exercise were no more variable than the physiologic indices at these times. The authors concluded that both the sense of effort in breathing and the rate of growth of the sensation over time were highly reproducible.

Differences in findings between the two studies probably result from difference in designs. It previously has been shown that the $\dot{V}O_2$max is highly reproducible in patients with chronic airflow obstruction.\textsuperscript{15} In the previous study by Silverman and co-workers\textsuperscript{14} the patients performed an incremental exercise study and stopped exercising at or close to their peak $\dot{V}O_2$max and maximal dyspnea.\textsuperscript{14} Achieving maximal or near maximal values of the Borg Score with each test would tend to minimize the variability between tests. In contrast, in our study, the $\dot{V}O_2$max during the SST was never achieved, although it was approached during the latter minutes of exercise. Had exercise continued beyond 6 min allowing a $\dot{V}O_2$max to be reached, the variability of the Borg ratings at these higher levels might have been similar to the objective measures and similar to the results of Silverman et al.\textsuperscript{14}

The conscious perception of breathlessness is interpreted in light of experience and learning.\textsuperscript{16} Silverman et al\textsuperscript{14} performed two trials on the same day. Although memory of previous perceptions may have affected both studies, it would be more likely to influence trials separated by one hour than those separated by a day or more. This finding is supported by the work of Wilson and Jones\textsuperscript{17} who showed a decrease in the Borg score when the two trials were repeated two weeks apart but not when repeated on the same day. In addition, the different Borg scales utilized would affect the results. The mean Borg rating at minute 2 in the previous study was approximately 13 on a scale of 6 to 20.\textsuperscript{17} In the present study, we used the modified Borg scale in which the mean Borg rating at minute 2 was approximately 4 on a scale of 0 to 10.\textsuperscript{10} The percentage of change between a rating of 13 to 14 is much smaller than the change between a rating of 4 or 5, and the variation using the former Borg scale would be expected to be smaller at comparable levels of work.

Stark and co-workers examined\textsuperscript{18} the reproducibility of a VAS in patients with COPD. Although these authors stated that their data showed acceptable reproducibility, statistical analysis was not performed and examination of the individual plots of the VAS against ventilation shows obvious variability. Studies in young normal subjects who performed incremental exercise tests showed good reproducibility between breathlessness as assessed by a VAS at increasing levels of ventilation.\textsuperscript{19,20} Conversely, in the normal elderly, Belman and Gaesser\textsuperscript{21} showed that during three repetitions over three months measurements of breathlessness and perceived leg effort decreased significantly during both an incremental and SST. In a study of ten normal subjects a 16 percent decrease in the Borg score was found when the exercise study was repeated two to six weeks later.\textsuperscript{17} These studies demonstrate that breathlessness scores are not universally reproducible.

It is doubtful that the improvement in Borg ratings resulted from a true physiologic training effect. It would be highly unlikely that a total of four 6-min walks at submaximal levels performed over ten days would result in improved cardiopulmonary performance. Lack of true physiologic training is supported by the fact that no decrease in exercise HR or $\dot{V}E$/$\dot{V}O_2$ at comparable exercise levels was found.\textsuperscript{22,23} Indeed the HR response of the patients stabilized by day 2.

In the current study, the mean values for $\dot{V}O_2$, $\dot{V}E$, HR, $\dot{V}r$ and $f$ were not significantly different on study days 2 through 4, $\dot{V}r$, a baseline was reached by the second day of testing for these objective indices. Improvement in these measures with test repetition on a treadmill previously has been noted.\textsuperscript{24,27} The improvement with repetition alone is believed to result from habituation to the testing environment and to the task of treadmill walking. Reduced energy expenditure during treadmill walking has been related to improved neuromuscular coordination, including a decrease in vertical lift work, $\dot{V}r$, the elevation of the body per step.\textsuperscript{25} These changes are usually complete by the second or third test as shown in our study.

In contrast to the physiologic indices, the mean Borg ratings showed a progressive improvement at comparable work loads with test repetition. These ratings did not reach a baseline by the second test day and continued to decrease significantly even from day 3 to 4. This change was not associated with differences in breathing strategy as shown by the relatively stable $\dot{V}r$ and $f$ from days 2 through 4. We believe that the serial improvement in perception of dyspnea after repetitive exercise trials may have resulted from "desensitization" to dyspnea. The concept of desensitization was well described by Agle et al.\textsuperscript{28} In their study, the patients underwent an intensive four-week inpatient program of graduated exercise, group therapy and vocational and social counseling. The data obtained from psychiatric interviewing and psycho-
logic testing correlated positively with success in rehabilitation. Positive change was noted following the completion of the four-week program and at the one-year followup. The authors concluded that desensitization to the fear of dyspnea and increased patient autonomy in the control of symptoms was of particular importance in affecting positive change. Patients in a control group of a study of ventilatory muscle training also ascribed their improvement to a reduction in anxiety. This group also showed improvement in psychological testing compatible with a process of phobic desensitization.

Fear of dyspnea during strenuous activity has been suggested as an aggravating factor in the physical deconditioning that occurs in patients with COPD. Thus, the symptom of dyspnea can lead to reduced effort and increased anxiety. The anxiety, or “respiratory panic,” exacerbates the dyspnea. In the present study, the subjective sensation of reduced dyspnea at comparable work levels occurred without the benefit of graded exercise or any formal therapy or counseling. Dudley and co-workers have referred to a form of therapy for psychologically based symptoms wherein a patient is exposed to doses of the feared activity while simultaneously receiving reassurance and support. It is possible that repetition of the exercise in the presence of medical personnel served as a desensitizing form of behavior modification. Thus, desensitization may be an important mechanism of improvement after rehabilitation programs and warrants further systematic investigation.

The continued improvement in Borg score with test repetition indicates that considerable caution is necessary when using this test to assess responses to treatment. In the absence of a control group or placebo treatment, a decrement in dyspnea measured by a Borg score should not be ascribed to a therapeutic intervention alone.

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