Comparison of Continuous and Discrete Measurements of Dyspnea During Exercise in Patients With COPD and Normal Subjects*

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Study objectives: The objectives of this study were as follows: (1) to compare results of the discrete and the continuous methods for measuring breathlessness; (2) to examine test-retest reliability; (3) and to test the hypothesis that patients with COPD have higher slopes and lower x-intercepts and absolute thresholds for power production, oxygen consumption (V\textsubscript{O\textsubscript{2}}), and minute ventilation as independent variables and breathlessness ratings as the dependent variable, as compared with healthy subjects.

Design: Visit 1 (familiarization) and visit 2 and visit 3 (2 days apart) with randomized assignment of the discrete and continuous methods for subjects rating breathlessness during cycle ergometry.

Setting: Cardiopulmonary exercise laboratory in a university medical center.

Participants: Twenty-four patients with COPD (mean age, 66 ± 8 years [± SD]) and 24 healthy subjects (mean age, 66 ± 10 years).

Interventions: None.

Measurements and results: Ratings of breathlessness on the Borg scale on cue with subjects moving and pressing the computer mouse button to indicate a rating (discrete method) or by moving the position of the mouse to adjust a vertical bar to indicate a change in breathlessness (continuous method). There were no significant differences in results between visit 2 and visit 3. Although peak exercise variables were similar with the discrete and continuous methods, both groups provided significantly more ratings of breathlessness with the continuous method. Patients with COPD exhibited higher slopes, lower x-intercepts, and lower absolute thresholds (breathlessness rating ≥ 0.5 [“just noticeable”] on the Borg scale) for power production and V\textsubscript{O\textsubscript{2}}-breathlessness compared with healthy subjects (p < 0.05).

Conclusions: Elderly patients with COPD and healthy subjects are able to use the continuous method successfully. Reliability is excellent for both methods. The continuous method provides a greater number of breathlessness ratings over the course of exercise, and allows the clinician to calculate an absolute threshold and just-noticeable differences. Regression parameters and absolute thresholds discriminate between patients with COPD and healthy subjects.

Key words: computer administration; continuous method for rating breathlessness; exercise testing

Abbreviations: JND = just-noticeable difference; V\textsubscript{E} = minute ventilation; V\textsubscript{O\textsubscript{2}} = oxygen consumption

Exercise testing provides a direct approach to examine an individual’s perception of breathlessness based on the principles of psychophysics. The traditional approach has been to ask the patient at specific time intervals (eg, each minute of an incremental or ramp exercise test) to select a rating on the Borg scale or on a visual analog scale that matches severity of breathlessness. However, there are at least two major limitations of this methodology. First, if the patient can only exercise for 3 to 4 min...

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because of severe respiratory disease, only a few ratings of dyspnea are obtained. Second, the subject is asked “on cue” each minute to provide a rating. Although this discrete method for measuring breathlessness is convenient from the physician’s perspective, it is completely arbitrary for the patient because the experience of breathlessness can change continuously during the exercise test. Due to these limitations, valuable information may be lost about the progressive nature of dyspnea throughout exercise.

In 1993, Harty et al. reported that six healthy individuals were able to continuously report ratings of breathlessness using a potentiometer to indicate a score on a visual analog scale during cycle ergometry. In 2001, we described the validity, reliability, and responsiveness of a continuous method for recording changes in dyspnea. With this method, subjects moved a computer mouse forward or backward during cycle ergometry in order to adjust a vertical bar on a monitor that was positioned adjacent to the Borg scale to indicate changes in the severity of breathlessness. Our initial testing included 28 healthy, college-aged subjects (14 women and 14 men) along with preliminary evaluation of 6 patients with COPD.

The present study had three objectives. First, we sought to establish that elderly individuals could successfully use the computer system and provide comparable results (slope and intercept) with the continuous method, as obtained with the standard discrete approach. Second, we examined test-retest reliability of the continuous method in patients with COPD and in healthy individuals of similar age and gender. Third, we wanted to determine whether the parameters obtained from the continuous method (slope, intercept, and absolute threshold) differentiated symptomatic patients with COPD from healthy control subjects of comparable age.

Our specific hypotheses were as follows: (1) the continuous method provides high test-retest reliability that is at least comparable to the discrete method, (2) the slopes of the linear regressions for power production, oxygen consumption (\( \dot{V}O_2 \)), and minute ventilation (\( \dot{V}E \)) as independent variables and breathlessness as the dependent variable are higher in patients with COPD than in healthy subjects, and (3) the x-intercepts and absolute thresholds are lower for patients with COPD compared with healthy subjects.

**Materials and Methods**

**Subjects**

Inclusion criteria for all participants were as follows: age \( \geq 45 \) years, ability to exercise on the cycle ergometer, and no history of clinically important comorbid disease. Patients with COPD were recruited from the outpatient clinics of our institution. The diagnosis of COPD was based on American Thoracic Society criteria, and each patient complained of exertional breathlessness. All healthy subjects were recruited from family members or friends of the patients; they denied any cardiorespiratory complaints, and they had normal spirometry results. Institutional review board approval was obtained, and all participants gave written informed consent.

**Experimental Protocol**

Each subject participated in three visits over a 5-day time period. At visit 1, spirometry and 12-lead ECG (to exclude any major rhythm abnormality) were performed to ensure that the subject met the inclusion criteria. Next, the participant was familiarized with the equipment and protocol by pedaling on the cycle ergometer for 5 min and practiced using the computer system to provide ratings of breathlessness.

At visit 2 (2 days after visit 1) and visit 3 (2 days after visit 2), spirometry was performed using a standard system (Collins model CPL; Warren E. Collins; Braintree, MA) to ensure that lung function was stable. The highest values for FVC and FEV\(_1\) were selected from a minimum of three FVC maneuvers. Predicted values for spirometry were taken from Crapo et al. Next, subjects performed two incremental exercise tests separated by a 60-min rest. The method for measuring breathlessness (discrete or continuous) was assigned by an alternating schedule. At visit 2, 12 patients and 12 healthy subjects used the discrete method first and the continuous method second; the other subjects rated breathlessness in the opposite order. At visit 3, the method for measuring breathlessness was reversed for each participant.

Cardiopulmonary exercise testing was conducted while the subject was seated on the electronically braked cycle ergometer (Ergo-Metrics 800S; SensorMedics; Yorba Linda, CA) and breathing ambient air through a mouthpiece. Expired gas was analyzed for \( \dot{V}E \) and \( \dot{V}O_2 \) with every breath, using a metabolic measurement system (Medgraphics Cardiorespiratory Diagnostic Systems; St. Paul, MN). After a 1-min equilibration period, the subject pedaled at a speed of 50 revolutions per minute at zero resistance for 1 min. Then the resistance of the cycle ergometer was electronically increased in 15 W/min increments using a ramp protocol until the subject stopped because of symptom limitation.

The system used to rate breathlessness consisted of a computer, a monitor, and a mouse (Fig. 1). The computer system presented numbers from 0 (top of the screen) to 10 (bottom of the screen) listed on the left side of the screen, and descriptors of the severity of breathlessness were displayed on the right side of the screen. The nature and spacing of the numbers and descriptor categories were identical to the scale developed by Borg. The total length of the scale was 15.25 cm; the Geneva font size of the letters for the category descriptors was No. 12. The numbers and descriptors on the screen (positioned approximately 70 cm from the subjects’ eyes) were easy for all subjects to read when seated on the cycle ergometer. The mouse rested on a small horizontal platform attached to the handlebar of the cycle ergometer. At the onset of exercise, the black bar (continuous method) or crosshairs (discrete method) appeared at zero on the scale.

For the discrete method, the subject provided a rating each minute during exercise on cue by an investigator by adjusting crosshairs (0.5 cm by 0.5 cm) to a position on the scale and then pressing the mouse button. The subjects read the following written instructions before performing the exercise test:

>This is a scale for rating breathlessness. The No. 0 represents no breathlessness. The No. 10 represents the strongest or greatest breathlessness that you have ever
experienced. Each minute during the exercise test you will be asked to select a number that represents your perceived level of breathlessness by positioning the crosshairs of the cursor on your selection and pressing the mouse button. Use the written descriptors to the right of the numbers to help guide your selection.

The subjects were told that they could use the entire scale including values between integers.

For the continuous method, the subject adjusted the vertical length of a black bar (0.7 cm wide) on the screen by changing the location of the mouse (in a direction toward or away from the body) to express the perceived level of breathlessness. No verbal cues were given as to when ratings were to be made. The subjects read the following written instructions before performing the exercise test:

This is a scale for rating breathlessness. The No. 0 represents no breathlessness. The No. 10 represents the strongest or greatest breathlessness that you have ever experienced. You should adjust the length of the solid black bar to represent your perceived level of breathlessness by moving the position of the mouse. Use the written descriptions to the right of the numbers to help guide your selection. You should adjust the length of the bar (up or down) at any time during the exercise when you experience a change in your breathlessness.

**Statistical Analysis**

Both linear regression and power function models were applied to relate breathlessness ratings (B) as a function of three X variables: power production (watts), $\dot{V}_\text{O}_2$ (milligrams per kilogram per minute), and $V_e$ (liters per minute).

linear function: $B = Ax + b$,

where $a =$ slope and $b =$ intercept

power function: $B = kX^\beta$,

where $k =$ constant and $\beta =$ exponent

Linear function and power function values were obtained for each participant at each session at visit 2 and visit 3. Pearson correlation coefficients were calculated to determine the best-fitting linear and power relationships between breathlessness ratings and each of the three X variables. Slopes and x-intercepts of the linear regression equation were compared for the discrete and continuous methods for rating breathlessness at visit 2 and visit 3 using paired $t$ tests.

The absolute threshold for breathlessness was taken as the X variables accompanying the first time the black bar on the screen matched or surpassed the No. 0.5 (“just noticeable”) on the Borg scale. Starting with values beyond the absolute threshold, we computed a series of “change” thresholds considered as just-
noticeable differences (JNDs) in breathlessness with the continuous method. A change in breathlessness was indicated whenever the bar was moved to a higher position on the scale and was stationary for at least 1 s. The scale value present after such change was treated as a single rating obtained by the continuous method. This definition of a rating was more conservative than the one used in our previous study, and resulted in a much smaller number of total ratings over the duration of exercise. An Ekman fraction was calculated as the ratio of the breathlessness JND on the Borg scale to the previous breathlessness rating. When multiplied by 100, this measure indicates the percentage of change in breathlessness associated with each physiologic or work JND starting from the absolute threshold to the rating just prior to peak breathlessness.

The peak values for breathlessness and the physiologic variables were selected when exercise stopped because of exhaustion or symptom limitation. All data are reported as mean ± SD; p < 0.05 was considered statistically significant.

RESULTS

A total of 49 subjects were enrolled in the study. One patient was withdrawn from the study after visit 2 because she was unable to use the computer system consistently. Table 1 gives the characteristics of the 24 patients with COPD and 24 age-matched healthy subjects who completed the study. The age and gender distribution of the two groups were similar.

Figure 2 represents exercise data for an individual patient with COPD to illustrate the relationships between the physiologic variables and breathlessness ratings. The different graphs show the relation between the independent variables of power production (Fig 2, top), \( V_{\text{O}_2} \) (center), and \( V_{\text{E}} \) (bottom) and the corresponding ratings of breathlessness. The best-fitting linear equation is shown for each relationship. For each group, there were high Pearson correlation coefficients for power production \( (r = 0.96 \text{ to } 0.98) \), \( V_{\text{O}_2} \) \( (r = 0.95 \text{ to } 0.96) \), and \( V_{\text{E}} \) \( (r = 0.95 \text{ to } 0.97) \) and breathlessness ratings. There were no differences in the magnitude of the correlations between the discrete and continuous meth-

Table 1—Selected Characteristics for Patients With COPD and Healthy Subjects at Visit 2

<table>
<thead>
<tr>
<th>Variables</th>
<th>COPD</th>
<th>Healthy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjects, No.</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>Age, yr</td>
<td>66 ± 10</td>
<td>66 ± 8</td>
</tr>
<tr>
<td>Female/male gender, No.</td>
<td>11/13</td>
<td>11/13</td>
</tr>
<tr>
<td>FEV1, % predicted</td>
<td>51 ± 14</td>
<td>112 ± 24</td>
</tr>
<tr>
<td>At peak exercise</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power production, W</td>
<td>84.2 ± 21.7</td>
<td>142.2 ± 38.2</td>
</tr>
<tr>
<td>( V_{\text{O}_2} ), mL/kg/min</td>
<td>16.5 ± 3.7</td>
<td>26.8 ± 6.0</td>
</tr>
<tr>
<td>( V_{\text{E}} ), L/min</td>
<td>44.3 ± 12.2</td>
<td>72.0 ± 21.3</td>
</tr>
</tbody>
</table>

*pData are presented as mean ± SD unless otherwise indicated. †p < 0.05 for patients with COPD vs healthy subjects.
ods. A power function was also fit to the same data sets, but in all but one case there was no significant difference between the correlation coefficients (as an indicator of goodness of fit) obtained from the two models. The only exception was that linear function for $\dot{V}E$-breathlessness fit the data significantly better ($p < 0.05$) than did the power function. Based on the above results, and because various authors have previously reported linear regression analyses to describe similar data, we present our current results as linear functions. Moreover, the differences between the continuous and discrete methods, and the differences between patients with COPD and healthy control subjects, were the same whether the data were fit by a linear or power function.

**Test-Retest Reliability**

There were no significant differences for pulmonary function test data and exercise data (linear regression parameters, peak values, absolute thresholds, as well as Ekman fractions) between visit 2 and visit 3 in patients with COPD, in healthy subjects, or when the groups were combined. Based on the observed consistency, data from visit 2 and visit 3 were combined for all subsequent analyses.

**Comparison Between Discrete and Continuous Methods**

Table 2 presents the measures for breathlessness ratings for discrete and continuous methods. There were no significant differences for peak ratings of breathlessness between the two methods in either group. However, subjects in each group provided a significantly greater number of breathlessness ratings between the two methods in either group and the healthy control subjects for power production and $\dot{V}O_2$, but were similar for $\dot{V}E$ with healthy subjects (Table 3).

Table 3 presents summary data for the parameters of the linear regression analyses and absolute thresholds for the independent variables of power production, $\dot{V}O_2$, and $\dot{V}E$, respectively. There were no significant differences for the slopes and intercepts for the three independent variables and breathlessness ratings between the methods. Absolute thresholds could only be calculated with the continuous method.

**Comparison Between Patients With COPD and Healthy Subjects**

As expected, the peak exercise values for all three independent variables attained by the patients with COPD were significantly lower than that attained by the healthy subjects (Table 1). However, both the patient group and the healthy control subjects reported similar peak breathlessness ratings (approximately 6 on the Borg scale) [Table 2].

Patients with COPD exhibited significantly higher slopes compared to the healthy subjects for all three independent variables (Table 3). The x-intercepts were lower for patients with COPD for the independent variables of power production and $\dot{V}O_2$, but were higher for $\dot{V}E$ compared with the healthy subjects (Table 3).

The onset (absolute threshold) of breathlessness occurred significantly sooner (3.6 ± 0.9 min) for patients than for healthy subjects (5.5 ± 1.8 min). The absolute thresholds were lower in patients than in control subjects for power production and $\dot{V}O_2$, but were similar for $\dot{V}E$ (Table 3). The Ekman fractions were similar between the two groups (Table 2).

**Table 2—Selected Measures of Breathlessness Ratings During Exercise*  

<table>
<thead>
<tr>
<th>Variables</th>
<th>COPD</th>
<th>Healthy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Discrete Method</td>
<td>Continuous Method</td>
</tr>
<tr>
<td>Ratings, No.</td>
<td>4.8 ± 1.4†</td>
<td>11 ± 3.3†</td>
</tr>
<tr>
<td>Time to reach threshold, min</td>
<td>3.6 ± 0.9†</td>
<td>6.3 ± 1.7</td>
</tr>
<tr>
<td>Peak breathlessness</td>
<td>6.8 ± 2.2</td>
<td>0.33 ± 0.14</td>
</tr>
</tbody>
</table>

*Data are presented as mean ± SD.
†p < 0.05 for patients with COPD vs healthy subjects.
‡Significant difference between discrete and continuous methods.
Vo2 compared with healthy subjects; and (5) the Ekman fraction was similar between the two groups of subjects.

Statistical Analysis Considerations

Both linear3–7,11–14 and power2,15 function equations have been used to summarize the relationships between physiologic variables during exercise and the perceptual response of dyspnea. In simple terms, both approaches involve the matching of one continuum to another continuum. In 1992, Killian and colleagues2 published results of perceived magnitude of dyspnea and leg effort during cycle ergometry in 460 normal subjects using power function equations. However, the data shown in Figure 2 of an individual patient with COPD clearly illustrate that linear relationships can also be used to describe such results. Based on correlation coefficients as an indicator of goodness of fit, the physiologic/perceptual relationships in our subjects were similar for linear and power function analyses, except that linear regression for Ve-breathlessness fit the data significantly better than did the power function. Moreover, numerous investigators3–7,11–14 have used linear regression to report their data. For these reasons, we used linear function analyses to summarize the findings in this report.

Test-Retest Reliability

Both the continuous and discrete methods were highly reliable over time in these populations of elderly subjects. Previous investigators have demonstrated satisfactory to excellent reliability of the slope of a physiologic variable and dyspnea (measured by the discrete method) in patients with asthma4 or COPD3,11 on repeat testing. Harty et al9 reported good "reproducible measurements in repeated tests" in six normal subjects who used the continuous method. In a previous study,7 we observed excellent test-retest reliability in healthy, college-aged subjects with both the discrete and the continuous methods at 2- to 3-day intervals. One major difference between the two methods for measuring breathlessness during exercise is that the continuous method resulted in significantly more ratings than the discrete method. The high number of ratings with the continuous method can be an important advantage because patients with reduced exercise capacity may only be able to give a small number of ratings with the discrete method. Consequently, the slopes of the linear function may become difficult to calculate with any confidence or certainty, especially if the data points are nonmonotonic (do not always increase) with progressive exercise. In our previous report,7 we also found that the slopes of work-dyspnea were similar between the two methods in separate studies of 14 healthy women and in 14 healthy, college-aged subjects.

The continuous method also permits calculation of an absolute threshold corresponding to the onset of breathlessness in a manner similar to standard procedures followed throughout other areas of sensory psychophysics.1 In other words, there are no statistical assumptions required in determining the threshold for a single subject because the value is inherent in the rating method. We have defined the threshold as the physiologic value corresponding to

<table>
<thead>
<tr>
<th>Variables</th>
<th>COPD</th>
<th>Healthy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power production</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slope</td>
<td>0.11 ± 0.06</td>
<td>0.10 ± 0.04</td>
</tr>
<tr>
<td>Intercept</td>
<td>9.7 ± 40.8</td>
<td>19.5 ± 13.5</td>
</tr>
<tr>
<td>Absolute threshold</td>
<td>21.4 ± 13.0</td>
<td>50.04 ± 26.9</td>
</tr>
<tr>
<td>Vo2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slope</td>
<td>0.70 ± 0.48</td>
<td>0.74 ± 0.36</td>
</tr>
<tr>
<td>Intercept</td>
<td>5.5 ± 6.3</td>
<td>7.7 ± 2.3</td>
</tr>
<tr>
<td>Absolute threshold</td>
<td>8.2 ± 2.3</td>
<td>11.7 ± 4.8</td>
</tr>
<tr>
<td>Ve</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slope</td>
<td>0.29 ± 0.17</td>
<td>0.28 ± 0.14</td>
</tr>
<tr>
<td>Intercept</td>
<td>13.8 ± 15.0</td>
<td>19.3 ± 5.8</td>
</tr>
<tr>
<td>Absolute threshold</td>
<td>21.1 ± 5.9</td>
<td>23.7 ± 8.8</td>
</tr>
</tbody>
</table>

*Data are presented as mean ± SD. Slope refers to linear regression between the physiologic variable and breathlessness ratings. Intercept refers to value on the x-axis when breathlessness = 0. \( p < 0.05 \) for patients with COPD vs healthy subjects.
the “first dyspnea rating that surpasses the No. 0.5 (just noticeable)" on the Borg scale. As with all such measures of threshold obtained by classical psycho-physical methods, this particular criterion is arbitrary in that other cutoff values could have been selected. What is important here is that the same statistical criterion be applied for all comparisons among conditions.\textsuperscript{1}

Comparison Between Patients With COPD and Healthy Subjects

Although peak exercise physiologic values were all lower in the COPD population than in the healthy control subjects, the peak ratings of breathlessness were comparable. Similar results have been observed previously, and the lower physiologic values are likely due to the impaired exercise capacity in patients with respiratory disease.\textsuperscript{12,15,16} The slopes of the linear function were significantly higher for patients with COPD compared to healthy, age-matched subjects for both the discrete and continuous methods. These results are consistent with previous studies\textsuperscript{12,15} that also showed a higher slope for work (or $V\dot{O}_2$) and dyspnea in patients with respiratory disease compared to healthy individuals. These collective findings indicate that the linear regression slope relating breathlessness to a physiologic exercise variable has discriminative properties.

As expected, the x-intercepts for power production and $V\dot{O}_2$ were lower in the patients with COPD compared to the elderly healthy subjects. These findings are generally similar to the x-intercepts reported by Killian.\textsuperscript{13} Moreover, the reduced x-intercepts are consistent with the lower absolute threshold, and indicate that patients with COPD experience the onset of breathlessness at lower levels of exercise intensity compared with healthy individuals. However, the x-intercept for the $V\dot{E}$-dyspnea relationship was significantly higher in patients with COPD compared with healthy subjects. These findings are consistent with previous observations that $V\dot{E}$ is higher at similar exercise intensities in patients with COPD compared to normal subjects, due, at least in part, to an increase in dead space ventilation.\textsuperscript{15}

The absolute threshold may be an important parameter to consider in evaluating breathlessness during exercise testing. For example, Killian and colleagues\textsuperscript{2} estimated that the thresholds for leg effort and dyspnea occurred “between 20% and 40% of maximal power output” based on discrete perceptual ratings. Although Teramoto et al\textsuperscript{14} termed the $V\dot{O}_2$ on the x-intercept as the “threshold load of dyspnea,” it is not possible to calculate an absolute threshold based on the discrete method for rating breathlessness.\textsuperscript{1,7} Rather, the continuous method enables the direct measurement of a threshold that we identify as “just noticeable” breathlessness on the Borg scale.\textsuperscript{7} The absolute threshold may prove to be a useful new metric because many patients describe slowing down or even stopping an activity when they first experience the onset of breathlessness. One possible explanation for this strategy is that patients typically try to minimize intense distress associated with breathing, and therefore avoid further physical activity. In an earlier report,\textsuperscript{17} we found that healthy elderly subjects had lower physiologic values for the absolute threshold during cycle ergometry compared with healthy, college-aged subjects. It remains to be determined whether the corresponding physiologic values for the absolute threshold of breathlessness are useful in evaluating the efficacy of various interventions or treatments.

Ekman Fraction

For all sensory modalities, Weber’s law states that the physical change in the size of a JND must be increased by a constant fraction of its original or background value to produce a perceived change in sensory experience.\textsuperscript{1} Whereas the Weber fraction relates to a physical or physiologic variable, the Ekman fraction refers to a sensory sensation such as breathlessness.\textsuperscript{1} With the continuous, but not the discrete, method for measuring breathlessness, the change in breathlessness can be determined over the course of exercise (ie, Ekman fraction). Our results showed similar mean Ekman fractions between patients with COPD (33%) and healthy, age-matched subjects (29%). Of interest, these values are higher than the 23% that we observed in 14 healthy, female college subjects, and the 18% observed in 14 healthy, male college students.\textsuperscript{7} Whether the observed differences in the Ekman fractions are real and, if so, are related to the age of the subjects will require future testing in a larger population.

Conclusions

The current study extends our previous report\textsuperscript{7} that elderly individuals, both healthy subjects as well as patients with COPD, can successfully use a computer system to provide spontaneous and continuous ratings of breathlessness during exercise. Furthermore, these results highlight several advantages of the continuous method. The continuous method illustrates clearly how the perception of breathlessness changes throughout the entire course of an exercise test rather than only at arbitrary 1-min time intervals. Thus, the standard discrete approach of obtaining ratings each minute may not accurately reflect the individual’s perceptual changes in dyspnea.
A major advantage of the continuous method is that substantially greater numbers of breathlessness ratings can be obtained compared with the discrete method. This can be important because many patients with severe cardiopulmonary disease are only able to exercise for a few minutes. Consequently, only four or five data points for dyspnea ratings may be obtained using the discrete method. This outcome occurred in many of the patients with COPD in our study. From a statistical standpoint, it can be problematic fitting a reliable quantitative function using a small number of data points.

Additional benefits of the continuous method are that an absolute threshold and an Ekman fraction can be determined directly as part of the measurement process. It is possible, though unproven, that these metrics may have clinical utility in examining the efficacy of various treatments being evaluated during the stimulus of exercise.

REFERENCES

13 Killian KJ. The objective measurement of breathlessness. Chest 1985; 88:84S–90S

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