Anxiety Disorder and Perception of Inspiratory Resistive Loads*

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Sensations of breathlessness in the absence of respiratory disease are common in anxiety disorders. Perceptions of breathlessness in eight patients with anxiety disorder were compared with eight normal control subjects, matched for age and sex, by the application of Steven's law to the magnitude of resistive load test. All subjects estimated the magnitudes of resistive loads to inspiration while peak inspiratory mouth pressures were monitored. Anxious patient's perceptions of the added loads were significantly less sensitive than normal, even though the effort, determined by peak inspiratory mouth pressure, in overcoming each load was normal. Correlations between estimates of resistive loads and peak inspiratory mouth pressure were significantly less for the anxious patients than for normal subjects. Thus, perception of breathlessness in anxiety disorders may be affected by factors not normally associated with breathlessness and may help account for the greater than normal variability in resistive load perception in respiratory disease.

Dyspnea or a feeling of breathlessness is common in the anxiety disorders.1 With any emotional excitement, breathing rate increases as metabolism increases,2,3 but is not normally associated with dyspnea. In contrast, many individuals suffering from anxiety disorders have the sensation of inability to get enough air, even to the point of panic. This anxiety-related dyspnea may be a relatively constant feature of an individual's complaints. Unlike the dyspnea of airways disease, there is no increased respiratory impedance to account for the perception of breathlessness. It is possible that in anxiety, misperception of normal breathing activity contributes to the sensation of dyspnea. In respiratory disease, patients with similar levels of mechanical resistance display varying levels of distress, apparently due to different interpretations of the proprioceptive sensations associated with breathlessness.4 It is not known if anxiety factors contribute to the variation.

Normal perception of respiratory resistive loads appears to depend upon three major components: (1) the effort required to overcome the resistance,5 (2) increased pulmonary volume,6 and (3) increased drive,7 the first being the most influential.5 The effort expended on breathing can be assessed by the force generated by the contraction of muscles associated with respiration.8 Mouth pressure is an accurate estimate of the muscular force applied during inspiration.9 The magnitude of resistive load test, in which subjects assess the magnitudes of randomly presented physical resistances to inspiration, tests the relationship of respiratory perception and mouth pressure by Steven's law.3,9 The relationship has been found to obey Steven's law for both resistive and elastic loads in chronic obstruction of airflow, asthma, and normal control subjects.10 The application of Steven's law to respiration has not been investigated in anxiety disorders, and little is known about factors influencing respiratory perception in anxiety in the absence of respiratory disease.

With both exteroception and interoception, anxious patients may have a heightened awareness of any stimulus that they find distressing.11 It is also possible that anxious patients' perceptions of physiologic sensations are not accurate but represent distortions of the stimuli. The magnitude of resistive load test offers a suitable method for testing these two hypotheses for respiratory perception. The first would suggest that the Steven's law exponent (a measure of sensitivity) should be greater in anxiety than normal. The second would be supported by a breakdown of the normal relationship between subjective and objective assessments and a less than normal correlation between the two. This could indicate that for anxious patients, variables other than inspiratory effort are more influential than normal in the perception of dyspnea.

**Material and Methods**

**Subjects and Procedure**

Eight physically healthy patients (three male patients) suffering from agoraphobia with panic (N = 4), panic disorder (N = 3), and generalized anxiety disorder1 (N = 1) were compared with normal control subjects matched for age and sex. All subjects gave informed consent to participate in the study after verbal and written explana-
tions, according to the guidelines of the National Health and Medical Research Council.13

All subjects were free of medication for at least 24 hours, and did not consume caffeine or alcohol for at least 12 hours before testing. It was not feasible to control for the effects of tobacco smoking, but subjects did not smoke for at least 1.5 hours before testing. Each subject was tested between 10:30 A.M. and 11 A.M. after a light breakfast.

All subjects demonstrated normal pulmonary function with conventional spirometry using the predicted normal values of Goldman and Becklake.14 Baseline respiratory frequency and end-tidal carbon dioxide tension (PcO2) were recorded. Psychologic assessment was conducted on the same morning as testing and included the observer-rated Diagnostic Interview Schedule8 and the Hamilton Anxiety Inventory (HAI).10 Self-assessment measures included the State-Trait Anxiety Inventory (STAI-XI, STAI-X2).17

The subjects had been familiarized with the procedure for the magnitude of resistive load testing a week before testing, and further questions were answered on the morning of the test. It was explained again before proceeding, and subjects were assured that they could stop at any time before completion. Each subject was told that on at least 15 signalled occasions, an added load or resistance would make it harder to breathe in and that the size of the load would vary. An auditory signal would indicate the presence of a load during the next breath in. It was not a signal to breathe in immediately but to note the load's magnitude during the normal breathing rhythm and then to record it on the chart provided. To prevent cueing or distraction, each subject was shielded from observing the manipulation of resistance by the experimenter. After the detailed explanation, it was confirmed that each subject understood what was involved in the procedure, and any questions were answered. Then each subject had a preliminary random-order trial to choose a suitable personal range for the unrestricted numerical representation of the five resistances.

During the preliminary trial, it was established that the subject understood the procedure, knew when to expect an added resistance, and knew how to score their responses. The five resistances were then presented three times in random order, one resistance after every two to four breaths. The order was the same for each subject. It was confirmed that subjects wrote their response after the presentation of each resistance and at no other time.

**Resistive Load Apparatus**

The resistive loads were devised by fitting a series of filter papers (Whatman No. 1) across a rigid tube 5 cm in diameter. A resistance of known magnitude could be added to the baseline resistance of the connector circuitry and the subject's airway by closing the side ports ahead of a filter. The resistances were 4, 8, 12, 25, and 51 cm H2O/L/sec. A one-way valve (Hans Rudolph, Inc) confined the load to inspiration only. Mouth pressure and time of inspiration were monitored with a differential transducer (Hewlett-Packard 270).

**Analysis**

Sensitivity to magnitude of resistive loads was calculated using the Steven's power law,4,18 represented by the following equation:

$$\psi = k \phi^b$$

where $\psi$ is the magnitude of the perceived resistance, $\phi$ is the peak inspiratory mouth pressure, $k$ is a constant, and $b$ is an exponent expressing the rate at which $\psi$ changes with change in $\phi$ and is the measure of sensitivity. The correction factor for inspiratory time was also used in the following form:

$$\psi = k \phi^b t^c$$

where $t$ is the inspiratory time, and $c$ is a constant found to have the value 0.56.11

To enable each subject to contribute equally to results, despite the choosing of personal scales, individual correction factors based on the grand geometric mean for all estimates were calculated.16 Individual and group estimates of $b$ were calculated using the least-squares method of linear regression analysis of the log-transformed data:

$$\log \psi = k + b \log \phi$$

The equivalent time-corrected equation was:

$$\log (\psi/t^{c\phi}) = k + b \log \phi$$

Calculations were performed corrected and uncorrected for inspiratory time. The regression coefficients for the independent variable, mouth pressure, and the dependent variable, perceived resistance, were calculated individually and for groups. Relationships between mouth pressure, perceived resistance, respiratory frequency, end-tidal $\text{PCO}_2$, and psychologic variables were also examined. Descriptive statistics were calculated for each variable.

All analyses were performed on a Melbourne University digital computer (VAX4) using SPSS parametric or nonparametric tests were used where appropriate. Although subjects were matched for age and sex, because it was not known whether other uncontrolled variables might have been influential, independent comparisons were performed throughout with a significance level of $p<0.05$. The correlation significance level was set at $p<0.01$. Because numbers in the group were small, it was recognized that the power of the tests to pick up significant differences was weak.

**RESULTS**

Descriptive and experimental data are given in Table 1. The psychiatric and psychologic assessments confirmed that the anxious patients had anxiety disorders.

**Table 1—Comparison of Normal Control Subjects and Patients with Anxiety Disorder for Magnitude of Resistive Load Test**

<table>
<thead>
<tr>
<th>Data*</th>
<th>Normal Control (N = 8)$\dagger$</th>
<th>Anxiety Disorder (N = 8)$\dagger$</th>
<th>2-tailed $t$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, yr</td>
<td>34 ± 11</td>
<td>34 ± 10</td>
<td>0.02</td>
<td>0.981</td>
</tr>
<tr>
<td>VC, percent of normal</td>
<td>93.4 ± 10.0</td>
<td>90.6 ± 9.4</td>
<td>0.57</td>
<td>0.579</td>
</tr>
<tr>
<td>FEV1, percent of VC</td>
<td>83.8 ± 10.6</td>
<td>88.4 ± 6.3</td>
<td>1.05</td>
<td>0.310</td>
</tr>
<tr>
<td>f (per minute)</td>
<td>12.4 ± 4.0</td>
<td>17.4 ± 5.4</td>
<td>2.11</td>
<td>0.027$\ddagger$</td>
</tr>
<tr>
<td>End-tidal $\text{PCO}_2$, mm Hg</td>
<td>37.4 ± 6.6</td>
<td>38.7 ± 11.7</td>
<td>0.28</td>
<td>0.893$\ddagger$</td>
</tr>
<tr>
<td>HAI</td>
<td>0.8 ± 0.1</td>
<td>17.1 ± 10.8</td>
<td>$&gt;3.42$$\ast$</td>
<td>0.001$\ast$</td>
</tr>
<tr>
<td>STAI-X1</td>
<td>27.3 ± 5.6</td>
<td>43.5 ± 13.6</td>
<td>3.12</td>
<td>0.004$\dagger$</td>
</tr>
<tr>
<td>STAI-X2</td>
<td>27.8 ± 5.3</td>
<td>48.6 ± 9.9</td>
<td>5.27</td>
<td>0.000$\dagger$</td>
</tr>
<tr>
<td>b</td>
<td>0.82 ± 0.53$\ddagger$</td>
<td>0.13 ± 0.54</td>
<td>$&gt;2.35$$\ast$</td>
<td>0.022</td>
</tr>
<tr>
<td>b,</td>
<td>0.61 ± 0.43$\ddagger$</td>
<td>0.09 ± 0.47</td>
<td>$&gt;2.70$$\ast$</td>
<td>0.017</td>
</tr>
<tr>
<td>r</td>
<td>0.88 ± 0.10</td>
<td>0.18 ± 0.77</td>
<td>$&gt;1.73$$\ast$</td>
<td>0.041</td>
</tr>
</tbody>
</table>

*VC, Vital capacity; FEV1, forced expiratory volume in one second; f, respiratory frequency; HAI, Hamilton anxiety inventory; STAI-X1, state scale of state-trait anxiety inventory; STAI-X2, trait scale of state-trait anxiety inventory; b, Steven's law exponent (sensitivity to inspiratory resistance); b, time-corrected exponent; and r, regression coefficient for perceived inspiratory resistance with peak inspiratory mouth pressure. $\dagger$ Data are means ± SD. $\ddagger$ One-tailed probability. $\ddagger$ Nonparametric Mann-Whitney.

For difference between b and b, $t = 5.75$, and $p = 0.001$.

For difference between b and b, $t = 2.7$, and $p = 0.03$.

Perception of Inspiratory Resistive Loads (Tilt, Pain, Biddle)
NORMAL ANXIOUS

Figure 1. Magnitude of resistive load exponents (b), either uncorrected (UTC) or corrected (TC), for inspiratory times for normal control subjects and patients with anxiety disorder (see Table 1 for significances).

and no other psychiatric disorders. For the anxious group, all psychologic measures were significantly greater than normal, and the resting respiratory frequency was significantly higher. End-tidal PCO₂ was similar for normal and anxious groups.

The exponent, b, and the regression coefficient, r, for the anxious group were significantly less than for the controls (Table 1). While b for some anxious patients was within the normal range, others demonstrated inverse relationships (Fig 1). The regression of log transformed perceived resistance with mouth pres-

![Graph showing comparison between normal and anxious groups for resistive load exponents.](image)

Figure 2. Comparison of normal controls (open circles; N = 8) and patients with anxiety disorder (solid circles; N = 8) for magnitude of resistive load test. Equations for normal (N) and anxious (A) subjects are as follows: log r = 0.31 + 0.74 log P (p = 0.0006; SE = 0.056); and log r = 1.04 + 0.10 log P (p = 0.077; SE = 0.022), where r is resistance, and P is mouth pressure.

![Graph showing relationship between perceived magnitude of resistive load and mouth pressure.](image)

Figure 3. Perceived magnitudes (mean and SE) for normal controls (open circles; N = 8) and patients with anxiety disorder (solid circles; N = 8) at five inspiratory loads of magnitude of resistive load test (A = 4, B = 8, C = 12, D = 25, and E = 51 cm H₂O/L/sec).

sure for the anxious group did not display the significant linear trend of the normal group (Fig 2). The significant linear increase in perceived resistance with increasing resistance found for the normal group (F = 7.82; p = 0.008; df = 1,35) was not present for the anxious group, and perceived resistance was significantly less than normal at the greatest resistance (t = 2.01; p = 0.034; df = 14; one-tailed; Fig 3). Mean mouth pressure at each resistance was similar for the normal and anxious groups (p > 0.1 throughout; Fig 4). Time-corrected exponents (bₜ) were significantly lower than the uncorrected (Table 1).

The exponent for the normal group was significantly inversely related to HAI scores (r = -0.831; p = 0.005).

![Graph showing comparison between normal and anxious groups for mouth pressure.](image)

Figure 4. Mouth pressure (mean and SE) for normal controls (open circles; N = 8) and patients with anxiety disorder (solid circles; N = 8) at five inspiratory loads of magnitude of resistive load test (A = 4, B = 8, C = 12, D = 25, and E = 51 cm H₂O/L/sec).
There was no evidence of a similar correlation for the anxious group ($r = 0.065; p = 0.439$). Correlations were reduced if the time-corrected exponent was used; for example, for the normal group the correlation with HAl decreased from $r = -0.831$ to $r = -0.793$.

Respiratory frequency for the anxious group was correlated with HAl ($r = 0.826; p = 0.006$), STAI-X1 ($r = 0.776; p = 0.012$), and STAI-X2 ($r = 0.743; p = 0.017$). These correlations were not evident for the normal group.

**Discussion**

Contrary to the hypothesis that there may be a heightened sensitivity to respiratory stimuli in patients with anxiety disorder, sensitivity seems to be blunted, and there appears to be a dissociation between muscular effort and the perception of dyspnea. The perception of dyspnea for the normal group depended directly upon the muscular effort of breathing, while no such relationship existed for the anxious patients taken as a group. It is important to note that the physiologic responses (mouth pressure) of the anxious patients to the added resistances were similar to those of the normal control subjects, so that it was concluded that anxious patients depend on other stimuli for their perceptions of breathlessness. The regression coefficient for the group with anxiety disorder was close to zero, suggesting that their perception of dyspnea is not determined by the same stimuli as for the normal control subjects and is not related to the most influential normal cue for breathlessness, respiratory muscular effort.

It is unlikely that the differences in exponents resulted from difficulties that anxious patients may have had in understanding instructions. Each subject proceeded with the test only after thorough briefing and confirmation that the testing procedure was understood, nor was there evidence to suggest that the anxious subjects perceived added resistances normally but, because of gross memory deficits, were unable to remember them and so kept changing the frame of reference for estimations of magnitude.

There was a correlation between respiratory frequency and observer (HAl) and subjective (STAI-X1, STAI-X2) assessments of anxiety for the anxious group. If high respiratory frequency is a constant feature of anxiety in some individuals, it may lead to perceptual changes. When an individual is exposed to a stimulus for a prolonged period, perception declines, particularly at low stimulus intensities, which may elevate the threshold for the perception of an added load. Increased threshold to added loads would not explain the inverse relationship between perceived load and mouth pressure found for some anxious patients. It is not known when temporal adaptation to resistive loads noticeably affects results, but it is thought that it should not be relevant during a brief trial, as in this study; however, in anxiety disorders, where rapid breathing may be a relatively constant feature, it is possible that sensitivity to added loads may be reduced. There were too few subjects in this study to partial out these potentially influential variables when examining the exponent.

Hyperventilation in anxious patients could also contribute to the sensation of breathlessness by providing other cues. Excessive ventilation up to about twice the normal tidal volume is a very weak stimulus in normal individuals, and awareness of increases at these levels is low but may be different in anxiety, where up to five times the normal tidal volume has been observed. In the study sample, values for end-tidal $\text{PCO}_2$ did not suggest that all anxious patients were hyperventilating. Whether increased pulmonary volumes or increased drive is significantly more influential than normal is unknown.

Anxious people have been shown to have impaired perceptions, especially in areas about which they worry. Their automatic selective processing of "danger cues" impairs other perceptions and could explain the reported impaired perception of resistive loads. Furthermore, if sensory information is insufficient for perceptual resolution, perceptual instability can be generated with no relationship between the objective stimulus and its perception. Apart from the stimulus properties, a number of intervening factors can influence perceptual resolution. Cognitive factors influence emotional states, and development of the three-factor model of fear and emotions with cognitive, physiologic, and motoric components provides a framework to understand these subjects' responses.

We suggest that anxious patients do not perceive changes in respiratory proprioceptive stimuli in a normal fashion, as shown in this study, but only after substantial deviations from homeostasis. The abrupt change in their perceptions following substantial deviations may then be perceived as increased anxiety "out of the blue" and responded to as such, as there is no basis to appropriately ascribe the altered perceptions. This contrasts with the situation for normal subjects, who readily perceive proprioceptive changes and adapt and respond to them gradually as they occur.

Time correction of the exponent has been proposed as providing a more appropriate measure of sensitivity than uncorrected $b$. While the time-corrected exponent for the anxious group remained significantly lower than for the normal control subjects, correlations with other variables were weaker. A more appropriate alternative to time-corrected peak mouth pressure could be mouth pressure integrated over the inspiratory time. The relevance of inspiratory time as an independent variable requires more investigation.

In respiratory disease, while groups of patients have
the same exponents as normal control subjects, inter-individual variability is greater. The greater-than-normal variance may be partially explained by the differences between normal and anxious subjects in the perception and sensation of breathlessness, noted in this study. Anxiety has been found to account for a proportion of the variability of threshold detection of resistive load in asthmatic and control subjects. The study of the effects of anxiety upon respiratory variables is important to respiratory disease, as anxiety interacts with its management and outcome.

The results from this study suggest that patients with anxiety disorder can be distinguished from normal controls by their blunted subjective responses to a specific perceptual test of inspiratory loads. They also pose a number of questions about relationships between respiration and anxiety and suggest areas for further study.

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REFERENCES