CHEST

Original Research

SIGNS AND SYMPTOMS OF CHEST DISEASE

Respiratory Symptom Perception Differs in Obese Women With Strong or Mild Breathlessness During Constant-Load Exercise

Vipa Bernhardt, PhD; and Tony G. Babb, PhD

Background: **During constant-load exercise, some otherwise healthy obese women report substantially more dyspnea on exertion (DOE) than do others. The objective of this study was to investigate whether qualitative differences exist between the sensations of dyspnea felt by these women.**
Methods: **Seventy-eight women were categorized based on their ratings of perceived breathlessness (RPBs) (Borg 0-10 scale) after 6 min of 60-W cycling. Thirty-four women rated RPB ≥ 4 (+DOE) (34 ± 7 years, 36 ± 5 kg/m² BMI), and 22 women rated RPB ≤ 2 (−DOE) (32 ± 7 years, 37 ± 4 kg/m² BMI). Twenty-two women rated RPB as 3 (RPB = 3) (34 ± 7 years, 34 ± 4 kg/m² BMI) and were grouped separately to allow for a better delineation of the +DOE and the −DOE groups. After the exercise test, subjects were asked to pick three of 15 statements that best described their respiratory sensations.**
Results: **The +DOE and the −DOE groups were characterized differentially ($P < .05$) by the respiratory clusters "Breathing more" (82% of −DOE vs 41% of +DOE), "Shallow" (36% vs 6%), and "Heavy" (14% vs 53%). All four descriptors in the cluster "Work/Effort" were chosen more frequently by women in the +DOE group than by women in the −DOE group. Although relative exercise intensity was higher in the +DOE women (75% ± 13% vs 67% ± 10% of oxygen uptake at peak exercise, 41 ± 10 L/min vs 31 ± 8 L/min as % maximal voluntary ventilation, 83% ± 7% vs 76% ± 7% of peak heart rate), none of these variables was significantly associated with RPB.**
Conclusions: **Not only is the intensity of dyspnea significantly different between the +DOE and the −DOE groups, but so are the self-reported qualitative aspects of their dyspnea. Women in the +DOE group reported an increased sensation of the work of breathing relative to women in the −DOE group, which may be associated with the elevated RPB.** ***CHEST 2014; 145(2):361–369***

Abbreviations: DOE = dyspnea on exertion; HR = heart rate; MVV = maximal voluntary ventilation; RPB = rating of perceived breathlessness; $\dot{V}CO_2$ = CO_2 output; $\dot{V}E$ = minute ventilation; $\dot{V}O_2$ = oxygen uptake; $\dot{V}O_2$peak = oxygen uptake at peak exercise; VT = tidal volume

Dyspnea is defined as a subjective experience of breathing discomfort that consists of qualitatively distinct sensations that vary in intensity; these sensations originate from interactions among multiple physiologic, psychologic, social, and environmental factors and may induce secondary physiologic and behavioral responses.[1,2] Dyspnea on exertion (DOE) is a very common symptom in obesity.[3] In one large epidemiologic survey, 80% of obese adults reported breathlessness after climbing two flights of stairs compared with 16% of nonobese control subjects.[4] Another survey (N = 16,692) found that 36% of obese adults experienced dyspnea when walking up a hill.[5] Our laboratory

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Affiliations: From the Institute for Exercise and Environmental Medicine, Texas Health Presbyterian Hospital Dallas; and University of Texas Southwestern Medical Center, Dallas, TX.
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Correspondence to: Tony G. Babb, PhD, Institute for Exercise and Environmental Medicine, 7232 Greenville Ave, Ste 435, Dallas, TX 75231; e-mail: TonyBabb@TexasHealth.org

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has reported previously that 37% of otherwise healthy obese women had an elevated intensity of dyspnea during constant-load cycling exercise.[6]

In addition to intensity, dyspnea also encompasses qualitatively distinct sensations, and this symptom perception is the end result of a series of processes including neural activation, integration, and interpretation.[7] As such, it has been shown that healthy adults and patients with breathlessness can be distinguished based on their qualitative descriptors of dyspnea.[8-11] However, as we reported previously, the quality of respiratory sensation during exercise in otherwise healthy obese men was not different in those with or without DOE.[12] It is unknown whether respiratory sensations during exertion are similar or different in obese women, who differ from obese men in fat distribution[13] and have greater respiratory limitations than do men, especially during exercise.[14,15] These sex differences, such as differences in chest wall fat (ie, visceral vs subcutaneous), work of breathing, respiratory pressures, pulmonary function, respiratory muscle strength, and ventilatory capacity could make the relative demand for breathing more strenuous in obese women, especially obese women with DOE, who have a greater oxygen cost of breathing.[6,12-14,16,17] Based on these potential sex differences, it is important to investigate whether there are differential responses in respiratory sensations during exertion in obese women unlike in obese men, especially in work/effort.

Furthermore, the inability to perceive, or a tendency to overperceive, respiratory sensations could be detrimental. In patients with asthma, underperception of bronchoconstriction leads to a delay in seeking help, inadequate use of effective medications, and possibly death, whereas overperception of symptoms results in overuse of medical services and potential iatrogenic side effects.[7,18,19] In obesity, overperception of dyspnea during exertion could be an important factor contributing to exercise avoidance, the inability to lose weight, and/or reduced adherence to an exercise program, thus, resulting in more weight gain. However, it is not just the intensity of dyspnea, but also the quality of the sensation that affects the person's willingness to exercise. For example, it has been shown that between air hunger and the work/effort of breathing, air hunger is significantly more unpleasant than maximal respiratory work.[20] It is unclear which quality/qualities of breathlessness occur in obese women, but any of them could contribute to exercise avoidance in obese individuals. Therefore, it is important to understand the origins of this increased sensation of dyspnea and why some individuals are more prone to experience this "detrimental" perception.

We hypothesized that the work/effort of breathing would be a significant complaint in women with DOE. The objective of this study was to investigate whether self-reported qualitative differences exist between the sensations of dyspnea experienced during constant-load exercise by otherwise healthy obese women with strong vs mild DOE.

Materials and Methods

Participants were part of a larger, interventional study. Obese women were screened based on BMI (ie, >30 kg/m^2). Exclusion criteria included a history of smoking, asthma, cardiovascular disease, sleep disorders, or musculoskeletal abnormalities that would preclude maximal exercise. Volunteers participating in regular vigorous exercise (exercise more than two times a week with a specific athletic goal) during the preceding 6 months were also excluded. In accordance with the University of Texas Southwestern Institutional Review Board (STU122010-108), written informed consent was obtained before participation.

For the current study, participants visited the laboratory on two separate occasions. On visit 1, they performed hydrostatic weighing and pulmonary function testing. On visit 2, they performed constant-load and incremental exercise testing.

Subject Characteristics, Body Composition, and Pulmonary Function

Standard measures of height and weight were taken. Hydrostatic weighing was performed as described previously to determine percent body fat, lean body mass, and total body fat mass.[6,13] Standard pulmonary function testing, including spirometry, lung volume, and diffusing capacity, was performed according to American Thoracic Society guidelines.[21]

Intensity and Quality of Respiratory Sensations During Constant-Load 60-W Exercise

Before the exercise test, participants were given the following written instructions for rating the intensity of perceived breathlessness:

> The number 0 represents no breathlessness. The number 10 represents the strongest or greatest breathlessness that you have ever experienced. Each minute during the exercise test you will be asked to point to a number, [...], which represents your perceived level of breathlessness at the time. [...]

Exercise testing began with subjects seated on an electronically braked cycle ergometer with 3 min of resting baseline measurements, after which a 6-min constant-load exercise cycling test at 60 W was initiated. This exercise work rate was chosen based on a prior study in obese women who obtained ventilatory threshold at approximately 60 W.[17] The rating of perceived breathlessness (RPB) was collected every 2 min of the test using the modified Borg scale,[22] and the last value recorded was used for analysis. Following the exercise test, subjects completed a dyspnea questionnaire to examine the quality of their respiratory sensations if their RPB >0. The questionnaire consisted of 15 descriptors relating to dyspnea adapted from Mahler et al.[10] (Fig 1, left panel). Subjects were instructed to select the "top 3 descriptors that best describe the respiratory sensations [they] felt during the exercise." Cardiorespiratory responses, including heart rate (HR), BP, minute ventilation ($\dot{V}E$), and gas exchange (oxygen uptake [$\dot{V}O_2$] and CO_2 output [$\dot{V}CO_2$]), were measured at rest and throughout exercise. Blood lactate concentration ([lactate]) was determined within 1 min after exercise while subjects continued cycling.

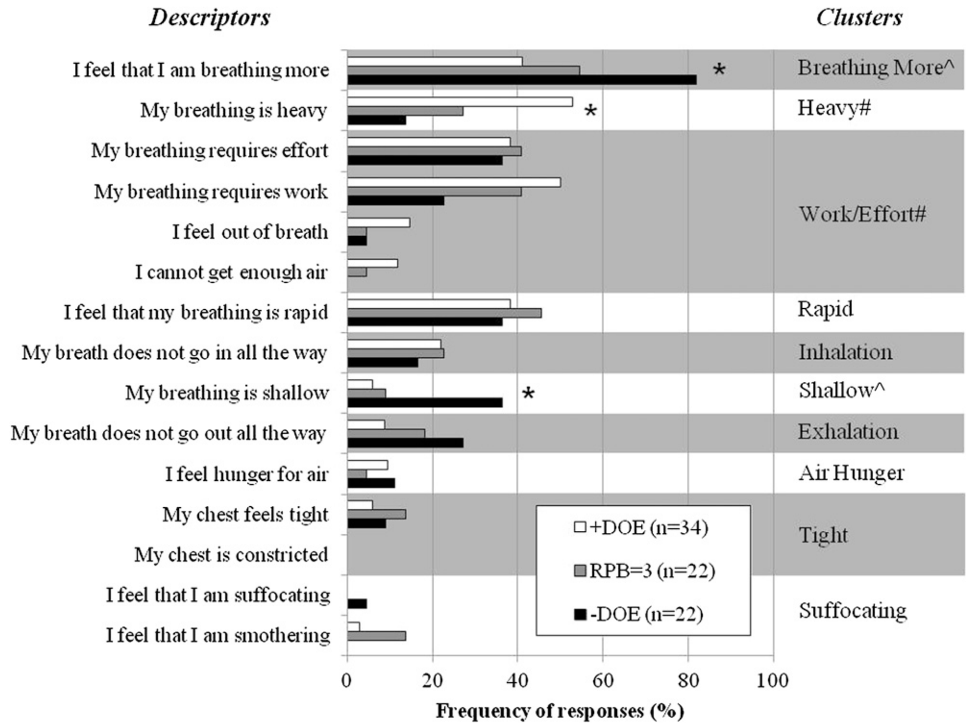

FIGURE 1. Percentage of subjects who selected the descriptors (left) as one of the "best three" that applied to their shortness of breath during the constant-load cycling exercise at 60 W. Clusters (right) were adapted from Mahler et al.[10] *$P < .05$ differences in descriptors chosen between +DOE (RPB ≥ 4) and the −DOE (RPB ≤ 2) groups. ^Clusters that include more women in the −DOE group. #Clusters that include more women in the +DOE group. DOE = dyspnea on exertion; RPB = rating of perceived breathlessness.

Peak Cardiovascular Exercise Capacity

Peak exercise capacity was determined by graded cycle ergometry to volitional exhaustion or pedal rate ≤50 rpm. After resting baseline measurements, subjects started pedaling at 60 to 65 rpm with an initial work rate of 20 W. The work rate was increased by 20 W each minute until termination of the test; maximal effort was evidenced by approaching predicted peak HR, peak work rate, oxygen uptake at peak exercise ($\dot{V}O_2$peak), and/or respiratory exchange rate > 1.1.

Data Analysis

The obese women were assigned to one of three groups according to their RPB (0-10 Borg scale) during minute 6 of the constant-load 60-W exercise test. Those with an RPB ≤ 2 were designated as obese women with mild DOE (−DOE group), and those with an RPB ≥ 4 were designated as obese women with DOE (+DOE group). Those women with an RPB = 3 were excluded from the larger interventional study to better delineate differences between the +DOE and the −DOE groups (ie, maximal incremental exercise test was not performed); however, available data for this group were included in the current analyses. The grouping was based on our previous finding that obese women have an average RPB of 2 ± 1 at ventilatory threshold during incremental exercise.[17]

Anthropometric and physiologic differences between the +DOE and the −DOE groups were determined by independent Student *t* test. Relationships among variables were determined with Pearson's product-moment correlation coefficients. Questionnaire responses were analyzed as frequency statistics and were compared using the Fisher exact test. A *P* value of < .05 was considered significant.

RESULTS

Subject Characteristics, Body Composition, and Pulmonary Function

Subject characteristics and body fat measurements were not significantly different among groups (Table 1[23-26]). Pulmonary function measurements in all subjects were within normal limits, and there were no significant differences between the +DOE and the −DOE groups, with the exception of maximal voluntary ventilation (MVV) and maximal expiratory pressure, which were higher in the −DOE group ($P < .05$). There were no differences between the women in the +DOE and RPB = 3 groups, and only few differences between the women in the RPB = 3 and the −DOE groups in pulmonary function variables (Table 1).

Intensity and Quality of Respiratory Sensations During Constant-Load 60-W Exercise

All women rated RPB > 0 during the constant-load cycling at 60 W. Thirty-four of the 78 subjects (44%) had an RPB ≥ 4 (+DOE; RPB range, 4-8) compared with 22 women with RPB ≤ 2 (−DOE; 28%; RPB range, 0.5-2) and 22 women with RPB = 3 (28%). Overall, RPB during exercise was more than twofold higher in the women in the +DOE group than in

Table 1—*Subject Characteristics and Pulmonary Function*

Characteristic	+DOE	RPB = 3	−DOE
No.	34	22	22
Age, y	34 ± 7	34 ± 7	32 ± 7
Height, cm	162.6 ± 6.1	165.2 ± 6.3	163.8 ± 7.1
Weight, kg	95.3 ± 13.3	93.7 ± 12.1	98.5 ± 13.6
Waist to hip ratio	0.87 ± 0.08	0.86 ± 0.07	0.90 ± 0.09
BMI, kg/m^2	36.1 ± 4.8	34.3 ± 3.9	36.7 ± 4.4
Body fat, %	46.4 ± 4.3	43.9 ± 4.8	45.1 ± 4.9
Fat weight, kg	45 ± 9	42 ± 9	45 ± 10
Lean body mass, kg	48 ± 5	52 ± 6	54 ± 6
FVC, % predicted	103.0 ± 12.5	105.1 ± 12.4	108.2 ± 11.9
FEV_1, % predicted	99.4 ± 13.0	102.6 ± 13.0	103.3 ± 10.4
FEV_1/FVC	81.0 ± 4.5	82.1 ± 15.9	80.8 ± 6.5
PEF, % predicted	108.2 ± 14.5	104.8 ± 13.4	111.3 ± 14.9
MVV, % predicted	103.0 ± 15.4	103.9 ± 111.5[a]	111.5 ± 13.5[b]
TLC, % predicted	91.7 ± 11.8	91.3 ± 19.8	93.1 ± 13.1
FRC, % predicted	83.5 ± 10.9	85.7 ± 14.3	81.5 ± 11.9
RV, % predicted	66.2 ± 13.1	65.7 ± 14.8	68.4 ± 19.0
DLCO, % predicted	77.0 ± 11.6	79.6 ± 11.0	76.9 ± 9.8

Data are presented as mean ± SD. Predicted values for spirometry, lung volumes, and diffusing capacity were based on the norms of Knudson et al,[23,24] Goldman and Becklake,[25] and Burrows et al,[26] respectively. DLCO = diffusing capacity of the lung for carbon monoxide; DOE = dyspnea on exertion; FRC = functional residual capacity (note: reported as % TLC); −DOE = mild dyspnea on exertion (rating of perceived breathlessness ≤ 2); MVV = maximal voluntary ventilation; PEF = peak expiratory flow; +DOE = with dyspnea on exertion (rating of perceived breathlessness ≥ 4); RPB = rating of perceived breathlessness; RV = residual volume; TLC = total lung capacity.
[a]$P < .05$ between RPB = 3 and −DOE groups.
[b]$P < .05$ between +DOE and −DOE groups.

the −DOE group (4.7 ± 1.2 vs 1.6 ± 0.6, $P < .001$). RPB was not strongly correlated with any measurements of subject characteristics or body composition. RPB was significantly, but weakly, correlated with FEV_1 ($P < .05$, $r^2 = 0.070$) and FVC ($P < .05$, $r^2 = 0.089$).

Figure 1 shows the frequency distribution with which subjects chose a particular statement when asked to describe the respiratory sensations they felt during minute 6 of the constant-load cycling exercise. Seventeen of the 22 women in the −DOE group (81%) picked the dyspnea descriptor "I feel that I am breathing more," whereas only 14 of the 36 women in the +DOE group (39%) chose this statement ($P < .05$) (Fig 1). The descriptor "My breathing is shallow" was also preferentially selected by the −DOE group, whereas "My breathing is heavy" was favored by the +DOE group ($P < .05$). For most descriptors, the frequency responses of the RPB = 3 group fell between the responses of the +DOE and the −DOE groups. The 15 descriptors were then compared using the cluster analysis published previously by Mahler et al.[10] The +DOE and the −DOE groups were characterized differentially ($P < .05$) by the clusters "Breathing more" (82% of −DOE vs 41% of +DOE), "Shallow" (36% vs 6%), and "Heavy" (14% vs 53%). All four descriptors in the cluster "Work/Effort" were chosen more frequently by women in the +DOE group than by women in the −DOE group.

Table 2 shows the cardiorespiratory responses during constant-load cycling exercise at 60 W. Based on the significant differences among groups in $\dot{V}O_2$ (% $\dot{V}O_2$peak), HR (% HR peak), $\dot{V}E$ (% MVV), $\dot{V}E/\dot{V}CO_2$, and blood [lactate], the relative intensity of exercise and ventilatory demand at 60 W were significantly greater for the +DOE compared with the −DOE group. However, Figure 2 shows that RPB was only mild to moderately correlated with $\dot{V}O_2$ (% $\dot{V}O_2$peak, $r^2 = 0.25$, $P < .0001$), blood [lactate] ($r^2 = 0.20$, $P < .0001$), and $\dot{V}E$ (% MVV) ($r^2 = 0.35$, $P < .0001$). Furthermore, the range of $\dot{V}O_2$ (% $\dot{V}O_2$peak) during 60-W cycling was similar between these groups (+DOE: 52%-100%; −DOE: 48%-92%).

Breathing pattern during the constant-load exercise test is shown in Figure 3. Tidal volume (VT) was similar ($P > .05$) among groups. Breath duration was longer in the women in the −DOE group than in the women in the +DOE group, mainly because of a longer expiratory duration. Mean inspiratory flow rate and mean expiratory flow rate were significantly greater in the +DOE group compared with the other groups.

Peak Cardiovascular Exercise Capacity

Exercise capacity was within normal limits in both DOE groups (Table 3). The +DOE group stopped

Table 2—*Cardiopulmonary Variables After 6 Min of Constant-Load Cycling at 60 W*

Variable	+DOE	RPB = 3	−DOE
$\dot{V}E$, L/min	46.0 ± 10.0	40.1 ± 7.1[a]	38.6 ± 6.0[b]
$\dot{V}E$ (% MVV)	41 ± 10	34.8 ± 8.1[a]	31 ± 8[b]
$\dot{V}O_2$, L/min	1.24 ± 0.13	1.22 ± 0.14	1.23 ± 0.12
$\dot{V}O_2$ (% peak)	75 ± 13	…[c]	67 ± 10[b]
$\dot{V}E/\dot{V}CO_2$	34.6 ± 4.6	32.4 ± 3.0[a]	31.4 ± 2.9[b]
VT (% FVC)	42.9 ± 8.2	38.7 ± 6.3[a]	41.8 ± 6.4
Breathing frequency	33.1 ± 10.4	29.5 ± 9.2	25.8 ± 6.4[b]
HR, bpm	151 ± 14	141 ± 11[a]	141 ± 13[b]
HR (% peak)	83 ± 7	…[c]	76 ± 7[b]
RER	1.08 ± 0.09	1.01 ± 0.07[a]	0.99 ± 0.06[b]
RPB	4.7 ± 1.2[d]	3.0 ± 0.0	1.6 ± 0.6[b,e]
Blood [lactate], mmol/L	4.9 ± 1.6	3.9 ± 1.5[a]	3.4 ± 1.4[b]
Systolic BP, mm Hg	168 ± 22	164 ± 29	162 ± 22
Diastolic BP, mm Hg	74 ± 15	70 ± 16	73 ± 12

Data are presented as mean ± SD. bpm = beats per min; HR = heart rate; RER = respiratory exchange rate; $\dot{V}E$ = minute ventilation; $\dot{V}E/\dot{V}CO_2$ = ventilatory equivalent ratio for CO_2; $\dot{V}O_2$ = oxygen uptake; VT = tidal volume. See Table 1 legend for expansion of other abbreviations.
[a]$P < .05$ between +DOE and RPB = 3 groups.
[b]$P < .05$ between +DOE and −DOE groups.
[c]Group did not perform maximal exercise test, and, thus, does not have % peak values.
[d]Range, 4-8.
[e]Range, 0.5-2.

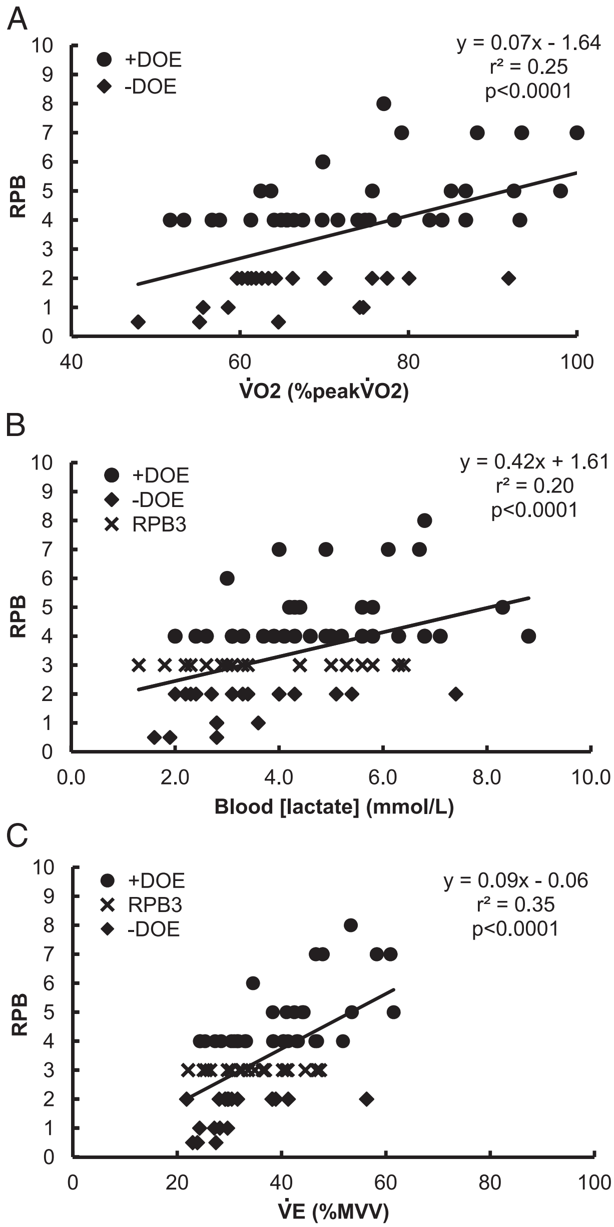

FIGURE 2. Mild to moderate correlations between RPBs and various exercise intensity measures during minute 6 of constant-load cycling exercise at 60 W in obese women in the +DOE (n = 36) and −DOE (n = 22) groups. A, Correlation with V̇O2 (%V̇O2 peak). B, Correlation with blood [lactate]. C, Correlation with V̇E (% MVV). V̇O2 (%peakV̇O2) = oxygen uptake (as percent of V̇O2 peak); V̇E (%MVV) = minute ventilation (as percent of maximal voluntary ventilation). See Figure 1 legend for expansion of other abbreviations.

the incremental exercise test sooner than did the −DOE group, and the $\dot{V}O_2$ peak in the +DOE group was statistically significantly lower (approximately 11% difference in $\dot{V}O_2$ peak). The most common reason for stopping the maximal exercise test was leg fatigue (+DOE: 62%; −DOE: 73%). Breathing limitation was reported by 20% of the women in the +DOE group but in only 5% of the women in the −DOE group, and both muscle fatigue and breathing limitation were

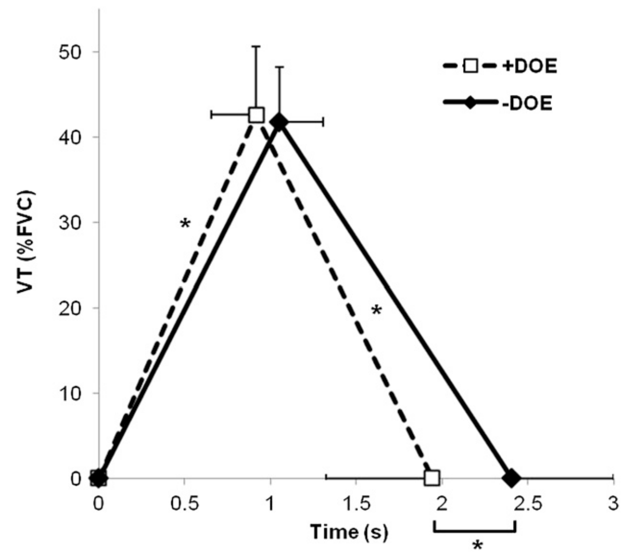

FIGURE 3. Breath timing and VT (as a percent of FVC) during constant-load cycling exercise at 60 W. $^*P < .05$ between the +DOE and the −DOE groups. VT = tidal volume. See Figure 1 legend for expansion of other abbreviations.

reported by 6% +DOE and 14% −DOE groups. There were no other important significant differences between these groups at peak exercise, nor strong correlations with RPB (data not shown).

Discussion

We found that nearly one-half of the obese women recruited had a significantly elevated intensity of breathlessness during exertion. Self-reported qualitative descriptions and clusters of the respiratory sensations differed between the obese women in the +DOE and −DOE groups, indicating that not only was the intensity of dyspnea significantly different between these groups, but so were the qualitative aspects of their dyspnea. The relative intensity of exercise differed between the groups; however, RPB was

Table 3—*End-Exercise Cardiopulmonary Variables From Maximal Incremental Cycling Exercise*

Variable	+DOE	−DOE
Work rate, W	129 ± 20	147 ± 21[a]
Exercise time, min	6.3 ± 1.0	7.2 ± 1.0[a]
$\dot{V}E$, L/min	80.06 ± 16.33	88.66 ± 12.17
$\dot{V}O_2$, L/min	1.70 ± 0.27	1.91 ± 0.27[a]
$\dot{V}E/\dot{V}CO_2$	38.65 ± 5.15	36.98 ± 3.62
HR, bpm	182 ± 10	185 ± 9
RER	1.23 ± 0.07	1.26 ± 0.07
RPB	8.0 ± 1.7	8.5 ± 1.7
Blood [lactate], mmol/L	8.2 ± 1.7	8.5 ± 1.9
Systolic BP, mm Hg	172 ± 28	179 ± 23
Diastolic BP, mm Hg	76 ± 11	76 ± 18

Data are presented as mean ± SD. See Table 1 and 2 legends for expansion of abbreviations.
[a]$P < .05$ between +DOE and −DOE groups.

only mild to moderately correlated with measures of relative intensity, suggesting that other and/or multiple factors may have been involved. In addition, we observed that breathing frequency was significantly higher in the women in the +DOE group, mainly because of a shorter expiratory time. Mean inspiratory and mean expiratory flow were significantly faster in the women in the +DOE group. No significant differences in subject characteristics or body composition were observed.

Intensity of Breathlessness During Constant-Load 60 W Exercise

As in our previous study in obese men,[12] we found that 44% of the obese women recruited reported breathlessness during the constant-load exercise. Although we cannot address the true prevalence of DOE in obese women from this study, it is reasonable to infer that a large proportion of obese women experience significant DOE, which is consistent with the findings of prior studies in obese women.[6]

Although the groups differed in their relative intensity of exercise, RPB was only moderately correlated with $\dot{V}O_2$ at 60-W cycling (% $\dot{V}O_2$peak), and the range of $\dot{V}O_2$ was similar among the groups (Fig 2A), indicating that exercise intensity was not the only factor influencing the level of dyspnea. Similarly, RPB and blood [lactate] were not strongly correlated (Fig 2B). RPB was moderately correlated with $\dot{V}E$ (as % of MVV); however, only 35% of the variability in RPB can be explained by the level of ventilation. In addition, in our previous studies in obese women and men, we found similar marked differences in RPB between the +DOE and the −DOE groups, whereas the relative as well as absolute exercise intensities were not different between the groups.[6,12] Thus, the occurrence of DOE cannot be explained simply by deconditioning or by an increased ventilatory demand, although it is likely that these and/or other factors contribute, at least in part, to DOE.

Quality of Respiratory Sensations During Constant-Load 60-W Exercise

In contrast to our previous study in obese men,[12] in which there were no differences in the quality of respiratory sensations between men with and without DOE, the women in the current study identified several significantly different sensations depending on their RPB. The descriptor "My breathing is shallow" was chosen more frequently by the women in the −DOE group, and the cluster "Shallow" was one of the top three clusters in this group. "Rapid" breathing was not significantly different between the +DOE and the −DOE groups but it was one of the top three clusters for both groups. Shallow breathing is characterized by low V_T, and rapid breathing by a high breathing frequency. Simon et al[8] induced feelings of "shallow breathing" in normal subjects when they imposed a breathing pattern that was limited to 50% of the subjects' normal V_T. In the current study, V_T (as a percentage of FVC) was not different among the groups. However, the women in the +DOE group had a significantly shorter cycle duration (increased breathing frequency), as well as both faster mean inspiratory and expiratory flow, than did the women in the −DOE group (Fig 3). Feelings of "shallow" and "rapid" breathing are consistent with the finding that obese individuals have decreased V_T and a shorter respiratory cycle compared with nonobese individuals during quiet breathing.[27] Chest-wall strapping or chest loading of lean individuals also resulted in decreased V_T and increased breathing frequency during exercise.[28-30] Although breathing frequency was significantly faster in the +DOE than in the −DOE group, both groups rated "My breathing is rapid" with the same frequency. Breathing pattern changes (V_T and breath timing) seemed to be more noticeable to the women in the −DOE group, whereas the women in the +DOE group were more concerned with the heaviness of their breathing and the work and effort it required. This increased sense of work of breathing is likely more disconcerting than a change in breathing pattern, which may be associated with the elevated intensity of dyspnea in the women in the +DOE group. The perception of the effort of breathing and changes in breathing pattern are believed to evolve from different neural mechanisms; effort perception arises from corollary discharges to the sensory cortex at the same time as the muscles are activated, whereas breathing pattern is dependent on afferent feedback information from pulmonary vagal receptors.[1,31,32] Women in the +DOE group may be more "sensitive" to an increase in the work of breathing than are women in the −DOE group, which ultimately may contribute to exercise avoidance.

Mean inspiratory flow rate is an indicator of central inspiratory drive[33] and was greater in the women in the +DOE group (Fig 3). This increased drive may have been sensed as an increased work to breathe and could account for the higher frequency of the descriptors "heavy," "work," and "effort" in this group. In contrast, the women in the −DOE group did not choose "heavy" as frequently when describing their breathlessness, suggesting that the central inspiratory drive was not playing as major a role in their breathlessness as in the women in the +DOE group.

The clusters "Suffocating," "Tight," and "Air Hunger" were chosen with the least frequency. "Suffocating" has been associated with patients with congestive heart failure, "Tight" with asthma and cystic fibrosis, and "Air Hunger" with COPD, congestive heart failure, asthma, and neuromuscular weakness.[9] Chest tightness is believed to be sensed by receptors in airway smooth muscle and mediated through vagal and autonomic pathways.[32,34,35] Air hunger is hypothesized to arise from corollary discharge from the medullary respiratory center as the afferent stimulus.[36,37] All subjects in the current study were free of cardiovascular or respiratory disease; thus, the low frequency of these dyspnea clusters is in agreement with previous findings in these patient populations[9,10] and increases our confidence in the validity of the questionnaire. In addition, the RPB = 3 group responses for most clusters fell between the +DOE and the −DOE group responses, which also indicates that the questionnaire can be used reliably to assess respiratory sensations.

The intensity dimension of dyspnea and the affective dimension are thought to be mediated and processed via two different pathways.[38,39] The intensity pathway originates mainly in the respiratory muscles and is relayed via the thalamus to the somatosensory cortex, where dyspnea is perceived quantitatively (ie, RPB). The affective pathway originates primarily from vagal afferents in the lungs and airways, from where they are relayed via the thalamus and amygdala to the insula and cingulated cortex; this limbic pathway is most likely responsible for the qualitative aspect of dyspnea (ie, dyspnea descriptors).[40-42]

The respiratory sensory gating system model proposed by Davenport and Reep[39] suggests that the awareness of respiratory stimuli is a threshold-gated mechanism; it is a way to control what and how much of the information will be received by higher brain centers. For example, eupneic breathing is usually not perceived consciously, meaning that respiratory afferents during normal breathing are gated out and do not reach higher brain centers. However, if ventilation changes sufficiently or breathing is attended to, the sensation is gated in and the person becomes aware of his or her breathing.[43] This awareness is usually an aversive sensation (feeling of dyspnea) and is associated with distressing emotions.[40,44] To avoid feeling breathless, people will modify their behavior, such as terminating exercise as soon as the sensation becomes overwhelmingly uncomfortable.

As mentioned before, various afferents from muscles, airways, and lung mechanoreceptors or chemoreceptors carry respiratory sensory information to the thalamic gate.[45] It is not known whether the different sensory modalities have different threshold requirements to be gated into higher brain centers or if they are processed differently. It may be speculated that the results from our study suggest that information on the work/effort of breathing and breathing pattern are differentially gated and/or processed in the women who experience DOE compared with those who do not. The neural gate is also thought to be shaped by thoughts and experience[45]; as such, prior experience and the memory of physical activity could play a role in how the different dyspnea symptoms are perceived by a person.

Underperception of dyspnea during exertion is most likely not problematic in otherwise healthy overweight/obese individuals during moderate exercise. On the other hand, overperception of dyspnea during exertion could play an important role, especially in overweight/obese individuals, contributing to exercise avoidance, reduced adherence to an exercise program, or both and, thus, resulting in more weight gain. It is not clear which qualities of dyspnea can lead to overperception. Banzett et al[20] have demonstrated that moderately intense air hunger is more unpleasant than the work/effort of maximal eucapnic voluntary hyperpnea. Another study showed that, in healthy individuals, descriptors grouped under “Compensation of dyspnea” were perceived to be less uncomfortable than those grouped under “Breathing deficiencies”; however, most of the subjects had never experienced the latter qualities of dyspnea.[46] Interestingly, only one dyspnea descriptor was found to be perceived as pleasant (“Breathing more”).[46] The findings of our study are similar in that the subjects were healthy, young women, and the majority picked descriptors in the “Compensation of dyspnea” category. The women in the −DOE group chose “Breathing more” significantly more frequently than did the women in the +DOE group; it may be speculated that the women in the −DOE group perceived the exercise as more pleasant/less unpleasant.

It is unknown how emotionally taxing the other dyspnea clusters (ie, rapid, shallow, heavy breathing) are compared with each other. In the current study, only 9% of women in the +DOE and the −DOE groups chose air hunger as one of the descriptors characterizing their breathlessness during submaximal exercise, indicating that the feeling of air hunger does not play a major role in obese individuals who exercise. Heavy breathing and the work/effort of breathing were the primary descriptors chosen significantly more frequently in the +DOE compared with the −DOE group, suggesting that these descriptors were contributing to the higher RPB ratings in the women in the +DOE group. It follows that the work/effort of breathing could be the most unpleasant feelings in otherwise healthy obese women with DOE. It may be speculated that individuals in the +DOE group with the perception of a high work/effort of breathing avoid exercise primarily because of labored breathing, whereas individuals in the −DOE group do so because of other factors. Women in the +DOE group could potentially benefit from a breathing program that would help them overcome their discomfort.

Those individuals who experience shortness of breath during exercise are more likely to stop exercising altogether, thereby lowering cardiovascular fitness and making dyspnea even worse. The women in the −DOE group in our study demonstrated a higher peak $\dot{V}O_2$ and exercise capacity than did the women in the +DOE group. From our study, we are unable to distinguish whether breathlessness or a lower cardiovascular fitness level was the initiator that led to even more dyspnea and less fitness.

Limitations

The affective dimension of dyspnea was not one of the outcome measures examined in this study; thus, we can only speculate as to whether higher ratings of breathlessness are related to higher perceived unpleasantness of exercise and ultimately exercise avoidance. However, increases in externally applied breathing loads resulted in increases in both intensity and unpleasantness ratings in healthy subjects; indeed, perceived unpleasantness increased more than perceived intensity.[47] Future studies are needed to determine if the affective dimension of breathlessness influences DOE.

Conclusions

In conclusion, the qualitative aspects of the respiratory sensations during exercise were significantly different between obese women with strong or weak DOE. Women with an elevated intensity of dyspnea reported an increased sensation of the work of breathing compared with women without dyspnea. The lack of significant physiologic differences and the lack of association of dyspnea with ventilatory demand and exercise intensity are suggestive of the importance of the individual's symptom perception. This differential symptom perception may occur at any point, from neural activation to interpretation of the respiratory stimulus,[7] which our study does not address. Future studies on the underlying mechanism of DOE are warranted, which may lead to better treatment avenues alleviating the individual's dyspnea symptoms.

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