Use of Auditory Distraction to Alter Exertional Dyspnea in Young, Obese Females: A Case Study

by

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Abstract

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Introduction: It is well understood that exercise is an important component in the prevention and treatment of obesity. Many obese adults, however, are unable or unwilling to exercise due to dyspnea on exertion (DOE). Previous research has demonstrated that auditory distraction can reduce exertional dyspnea in patients with respiratory disease (von Leupoldt, A., et al., 2007). The purpose of this study was to examine the exercise cardiorespiratory and perceptual responses with and without distractive auditory stimuli in obese females with DOE. **Methods:** Obese females with and without DOE were recruited for participation in this study. Subjects completed standardized tests of body composition, pulmonary function, and peak aerobic capacity ($\dot{V}O_{2peak}$) during the initial visit. Subsequently, intensities of breathlessness and unpleasantness of breathlessness were assessed during 6 minutes of constant-load cycling at 60 watts on two separate occasions. Distractive auditory stimuli via headphones was presented during the exercise test on one occasion (AD), while no distractive auditory stimuli were presented during exercise on the other occasion (NAD). Negative affect dimensions experienced by the subjects were recorded immediately after the constant load exercise test using visual analog scales. **Results:** The subject (age: 19 y, height: 154.5 cm, body mass: 79.4 kg, %body fat: 39.2%, body mass index: 33.3 kg·m^{-2}) exhibited normal pulmonary function and cardiovascular conditioning (2.15 L·min^{-1};110% predicted) but reduced physical fitness (26.9 mL·kg^{-1}·min^{-1}; 79% predicted). During constant load cycling, ratings of perceived breathlessness were similar between the NAD and AD trials (2 vs. 2 Borg units). Additionally, ratings of perceived unpleasantness were similar during the NAD and AD trials (2 vs. 2 Borg units). Further, scores for depression, anxiety, frustration, anger, and fear were similar between the two conditions. **Conclusion:** It appears from the current data that auditory distraction does not alter perceptual responses related to dyspnea in young, obese females. However, additional subjects are needed to complete the investigation.

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INTRODUCTION

Obesity has become an epidemic within the United States' population. Over 35% of American adults are considered obese (body mass index (BMI) > 30kg/m^2) (Ogden et al, 2012). Over a 10-year period beginning in 1998, the overall medical costs associated with obesity tripled, reaching nearly $209 billion (Cawley, J. and C. Meyerhoefer, 2012; Finklenstein, E.A. et al., 2009). A number of health concerns are associated with the onset of obesity, such as increased risk of type 2 diabetes, cardiovascular disease (hypertension, myocardial infarction, stroke, etc.), and several forms of cancer (Grundy, S.M., 2004). Additionally, many obese adults experience dyspnea on exertion (DOE), or commonly known as breathlessness during exercise, causing them to be unable or reluctant to engage in physical activity or exercise (Sin et al., 2002). However, regular exercise is a key element for treating and preventing obesity (NIH, 2011). Therefore, understanding the link between DOE and exercise tolerance, as well as developing potential methods to abate DOE during exercise, are critical to addressing the national obesity epidemic and improving treatment strategies.

Dyspnea is "a subjective experience of breathing discomfort that consists of qualitatively distinct sensations that vary in intensity" (Mahler, D.A., O'Donnell, D.E., 2014). In a large survey, including subjects aged 37-57 years old, 80% reported shortness of breath after climbing two flights of stairs while only 16% of same aged non-obese individuals experienced shortness of breath during the same activity (Sjostrom, 1992). Additionally, 36% of obese adults with a BMI greater than 31 kg·m^{-2} and 28% of obese adults with BMI of 27 to 31 kg·m^{-2} reported symptoms of dyspnea while walking up hill (Sin, 2002). Within a laboratory setting, DOE has been found to be present within approximately one third of obese adults (Babb, T.G. et al., 1989, 2002, 2008 & 2011; DeLorey, D.S. et al., 2005; Bernhardt, V. et al., 2013). These obese adults did not suffer from other health issues (e.g., cardiovascular, respiratory, and/or metabolic diseases) and were not classified as being physically deconditioned. Therefore, among obese adults with DOE, the cause of DOE does not appear to be due to underlying disease or the inability of the individual to breath in, transport, and utilize oxygen in the body. Despite not knowing the cause, weight loss and improved physical fitness have been demonstrated to attenuate ratings of breathlessness during exercise in obese women. Yet, because DOE is not fully abated following weight loss and exercise training, other factors besides the load placed on the chest (i.e., fat) and overall levels of cardiorespiratory function must affect the intensity of DOE experienced (Bernhardt, 2014).

DOE “derives from the interaction among multiple physiological, social, and environmental factors… (Parshall, M.B. et al., 2012)” with sensory (intensity and quality), affective (unpleasantness, distress, etc.), and impact (activities of daily living, etc.) being the three core dimensions (Mahler, D.A., O’Donnell, D.E., 2014). Of the three dimensions the sensory aspect consists of many properties and biological indicators that can possibly increase the symptoms of dyspnea. With respect to the affective dimension, “Air hunger”, “unsatisfied inspiration”, “sense of effort”, and “chest tightness” are examples of distinct qualitative sensations used to describe DOE. It is hypothesized that each sensation is caused by a unique neurophysiological mechanism (von Leupoldt, A., et al., 2013). This mechanism alerts the brain of an experience that is different than expected, amplifying the physiological focus towards that specific sensation. For example, when you are wearing clothing and it is in contact of your skin, the brain has essentially ignored the sensations until an aspect changes (becomes tighter, wet, etc.). The brain will then amplify its focus to the specific change, making the body more alert of the sensation. Therefore, qualifying the sensation(s) associated with the perception of DOE may assist in the identification of the underlying mechanism.

Dyspnea occurs because of neuro-mechanical “uncoupling”, caused by improperly matched respiratory efferent and afferent feedback. In a healthy individual who does not experience DOE, the sensory cortex detects an increase in respiratory muscle activity, initiating an appropriate physiological response to increase mechanical output and ventilation. However, in an individual with abnormal breathing mechanics, the afferent feedback that signals a proper ventilatory response is disrupted and requires an increased central motor command to properly sustain ventilation at the given exercise intensity (Sheel, W.A., G.E. Foster, and L.M. Romer, 2011). Obese adults suffering with DOE may have increased afferent feedback, increased ascending corollary discharge from the respiratory control center, and/or a change in the “respiratory gate” (Chan, P.Y. and P.W. Davenport, 2010; von Leupoldt, A. et al., 2013). It is hypothesized that the respiratory gate is located at the subcortical level. It determines if the intensity of the stimulus being sent to the brain is great enough to cause cortical awareness. The level at which a person reaches this threshold to cause awareness can be modified, heightened or distracted through additional attentional focus. The way this state of awareness is modified controls whether consciousness is obtained, inhibited, or habituated

Among these includes auditory stimulus of ventilation (Hampson et al, 2001). Obese adults become aware of their own breathing levels by listening to the sound and speed of their breathing, which may increase their perception of dyspnea and cause early cessation of exercise. Since dyspnea is a subjective experience, auditory stimulation of afferent receptors (Type III and IV mechano- and metabosensitive) causes transmission of information to the sensory areas of the cerebral cortex which are responsible for the recognition of feelings of uncomfortableness and unpleasantness (Parshall et al, 2012). Blocking this transmission to the sensory areas through the use of an auditory distraction may possibly decrease or eliminate dyspnea in subjects (von Leupoldt et al, 2007).

Blockade or disruption to stimuli to the somatosensory cortex can change the overall emotional state and DOE of an individual (von Leupoldt, A., et al., 2013). The ventilatory auditory stimulus can be removed by adding an auditory distraction while exercising, causing a “down regulation” of attentional focus, which ultimately causes the altered perceived experience. This occurs due to the fact that the affective dimension of perceived dyspnea is especially susceptible to psychological influences such as an auditory distraction (von Leupoldt et al, 2007).

Regarding the treatment of DOE, it has been shown that interventions that reduce central ventilatory drive, improve dynamic ventilatory mechanics, or improve respiratory function can relieve symptoms. Symptom relief is thought to be accomplished by decreasing the respiratory effort required and/or diminishing the inappropriately matched relationship between increasing central respiratory effort and respiratory mechanical/afferent responses as exercise intensity increases. For individuals with COPD, management of DOE should include a combination of pharmacological and non-pharmacological interventions (i.e. pulmonary rehabilitation). Pulmonary rehabilitation allows an individual to develop a higher exercise capacity and reduce DOE. Another strategy for individuals with COPD is respiratory muscle training. With a correctly controlled training load, DOE sensations can be diminished through respiratory muscle training alone or through a combination of whole-body exercises (Sheel, W.A., G.E. Foster, and L.M. Romer, 2011).

Some studies have shown differences in intensity and underlying mechanism between males and females suffering from dyspnea. These studies show dyspnea ratings in females with chronic obstructive pulmonary disease (COPD) to be higher than males with COPD. DOE in males may be related to gas exchange impairments. In females, DOE may be related to factors including partial pressure of arterial oxygen and pulmonary diffusion capacity. Women typically have greater airway resistance and more turbulent airflow than men of the same lung capacity (Sheel, W.A., G.E. Foster, and L.M. Romer, 2011). Pulmonary rehabilitation and other treatments have become promising means of alleviating DOE in patients, however, research regarding sex differences is limited. Sex differences are recognized, but a “normal” has yet to be established for DOE gender comparisons (Sheel, W.A., G.E. Foster, and L.M. Romer, 2011). The mechanisms behind DOE sex differences have yet to be experimentally determined

The mechanistic complexities and multi-dimensional aspects that have been revealed through recent studies have facilitated the formation of a general model for DOE. Much related to dyspnea remains unknown, but the importance of the insular cortex in perception of DOE under specific conditions has been established. The purpose of this study is to investigate sensory and affective components of exertional dyspnea in obese females while exercising with a distractive auditory stimulus. I will measure cardiorespiratory and perceptual responses related dyspnea during exercise with and without auditory distraction in an obese female. For this case study, I hypothesize that, while the planned investigation will not delineate the detailed pathways explained, introduction of an auditory stimulus will distract the "respiratory gate" and alter the affective dimensions related to dyspnea. Through this distraction, consciousness and ratings of DOE will decrease.

METHODS

All experimental procedures were approved by the Appalachian State University Institutional Review Board (#16-0308) prior to subject testing. Written and verbal informed consent were obtained voluntarily from the subject before participation.

Subject

The subject was a young female classified as being mild-to-moderately obese. The subject was a non-smoker, had no history of asthma, cardiovascular disease, or musculoskeletal abnormalities, and had no active physical activity routine (had a specific training goal and exercised more than two times a week) over the previous 6 months.

Study Protocol

The subject visited the laboratory on four occasions. On the first visit, measurements of body composition and pulmonary function were collected. The second visit consisted of the subject receiving a dyspnea grouping classification based on the level of breathlessness experienced during mild cycling exercise before completing a peak aerobic exercise capacity test to measure cardiovascular fitness. The subject was classified as either having (+DOE) or not having (-DOE) dyspnea on exertion. During the last two visits (visits three and four), the subject repeated the mild cycling exercise test. During one of the visits, auditory distraction through the use of headphones was used during the exercise tests. During the other remaining visit, the subject wore headphones during the exercise tests, but no auditory stimuli were administered. The control and auditory distraction trials were randomly assigned.

Body Composition

Measurements of mass and percent body fat were obtained through air plethysmography (Ginde et al., 2005; McCrory et al., 1995). Body density was estimated using the BOD POD (Life Measurement Inc., Concord, CA) and the appropriate equation was used in the calculation of body fat.

Pulmonary Function

The subject performed spirometry (Miller, 2005) and lung volume (Wanger, 2005) determinations in a body plethysmograph (V62J Auto Box, Carefusion, Yorba Linda, CA) according to American Thoracic Society and European Respiratory Society guidelines. The subject performed the procedures seated while breathing room air and wearing a nose clip. The procedure for completing spirometry was 1) three-to-five normal tidal volume breaths, 2) maximal inhalation, 3) forced maximal exhalation, and 4) maximal inhalation. The spirometry procedure required the participant to perform three acceptable spirograms. The values measured included: forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), forced mid expiratory flow rate ($FEF_{25-75\%}$), and peak expiratory flow rate (PEFR). During the measurement of lung volumes, the subject 1) breathed normally, 2) panted against an occluded airway, 3) inhaled maximally, and 4) exhaled maximally. The values measured were FRC, TLC, IC, and RV. The maximum amount of air the subject could exhale in twelve seconds (reported as a minute value) was reported as maximal voluntary ventilation (MVV). The largest measurements for pulmonary function volumes and flow were corrected to BTPS conditions.

Peak Aerobic Capacity ($\dot{V}O_{2peak}$)

The participant completed a $\dot{V}O_{2peak}$ test on one occasion. After a rest period while seated on the cycle ergometer, the participant pedaled at 60-65 rpm at 20W, which was increased by 20W each minute thereafter until volitional exhaustion. During the exercise test, the participant was verbally encouraged to exercise as long as possible. Expired air was collected continuously throughout the test and analyzed using a metabolic system (Parvo Medics, Sandy, UT) for oxygen consumption ($\dot{V}O_2$), carbon dioxide production ($\dot{V}CO_2$), respiratory exchange ratio (RER), and minute ventilation ($\dot{V}_E$). $\dot{V}O_{2peak}$ was determined as the largest value recorded. Maximal effort was assessed using the following criteria: 1) a heart rate ≥ 90% of the age-predicted maximal heart rate (220-age), 2) a respiratory exchange ratio ≥ 1.10, and 3) identification of a plateau (≤ 150 mL) in $\dot{V}O_2$ with an increase in exercise intensity. In order to be considered a valid test, the subject must have met two or more of the criteria. Ratings of perceived breathlessness (RPB), unpleasantness of breathlessness (RPU), and exertion (RPE) were assessed each minute of $\dot{V}O_{2peak}$ test.

Mild Cycling Exercise

Upon arrival to the laboratory on each of days 2-4, the subject completed a Positive and Negative Affect Schedule (PANAS) questionnaire. Subsequent to the PANAS questionnaire, the subject performed mild cycling exercise. Following a period of seated rest on the cycle ergometer (Lode Corival CPET, The Netherlands), the subject began cycling at 60 W for 6 min. The subjects was asked to maintain a pedal cadence of 60-70 rpm. Every two minutes the participant was asked to provide her RPB, PRU, and RPE. The participant was classified as +DOE (RPB ≥ 4) or -DOE (RPB ≤ 2) based off of her RPB during the 6th min of the cycle test completed on day 2 of the study. All procedures were repeated during the tests completed on days 3 and 4. The ratings provided during the 6th min of the cycle tests completed on these days was used to examine the potential effect of auditory distraction (Vivaldi's *Four Seasons*) on DOE.

Following completion of the cycle test, the subject completed a Visual Analog Scale (VAS), which quantified negative affect dimensions associated with breathlessness on a 0-10 scale.

RESULTS

Subject

The subject was a young, obese female (age: 19 yr, height: 154.5 cm, body mass: 79.4 kg, BMI: 33.3 kg·m^{-2}). She appeared to be an out-going student interested in Exercise Science research. She was excited to be present in a lab setting and to experience various physiological testing procedures. She appeared to be happy and in good spirts throughout all of her visits.

Body Composition

The subject was 21.8 kg above her ideal body weight (Wasserman, K. et al., 1999). The subject had 31.4 kg of fat mass and 48.6 kg of fat-free mass, resulting in 39.2% body fat.

Pulmonary Function

The subject displayed normal values for spirometry and lung volumes (Table 1).

Table 1. Pulmonary function testing values

	Measured	***%Predicted*** ***(Hankinson, 1999)***
FVC (L)	4.00	119
FEV_1 (L)	3.43	119
FEV_1/FVC (%)	86	95
PEF (L·s^{-1})	7.82	124
$FEF_{25-75\%}$ (L·s^{-1})	3.83	107
MVV (L·min^{-1})	123	102
TLC (L)	5.07	111
FRC (L)	2.43	100
RV (L)	1.06	87

FVC, forced vital capacity; FEV_1, forced expiratory volume in 1 s; PEF, peak expiratory flow; $FEF_{25-75\%}$, forced expiratory flow at 25-75% FVC; MVV, maximal voluntary ventilation; TLC, total lung capacity; FRC, functional residual capacity; RV, residual volume.

Cardiovascular Fitness

The subject's cardiovascular fitness (i.e., absolute $\dot{V}O_{2peak}$) was measured at 2.15 $L \cdot min^{-1}$ (110% of predicted). Her physical fitness (i.e., relative $\dot{V}O_{2peak}$) was 26.9 $mL \cdot kg^{-1} \cdot m^{-1}$ (79% of predicted).

PANAS Questionnaire

Prior to completing the AD exercise test, the subject rated greater levels of excitement, alertness, and nervousness compared with the NAD exercise test. Additionally, the subject rated a lower level of determination prior to the AD test as compared with the NAD test. However, the subject had a similar affective state when comparing the two visits. She did appear to be slightly more excited, alert and nervous during the AD visit as compared with the NAD visit. Regardless, the minor differences in her responses to the PANAS questionnaire did not appear to have an influence over the perceptual responses during exercise.

DOE Classification

During the 6-min constant work rate test to classify dyspnea grouping, her final RPB was 4 (+DOE). The subject also responded with a RPU of 3 and a RPE of 14.

Effect of Auditory Distraction of Perceptual Responses

RPB responses during the NAD (day 3) and AD (day 4) exercise tests were similar (Figure 1). During the NAD 6-minute test the subject responded that her RPU was 2 and RPE was 9. During the AD 6-minute test the subject responded that her RPU was 2 and RPE was 11. Following completion of the AD test, the subject described the music as being "intense".

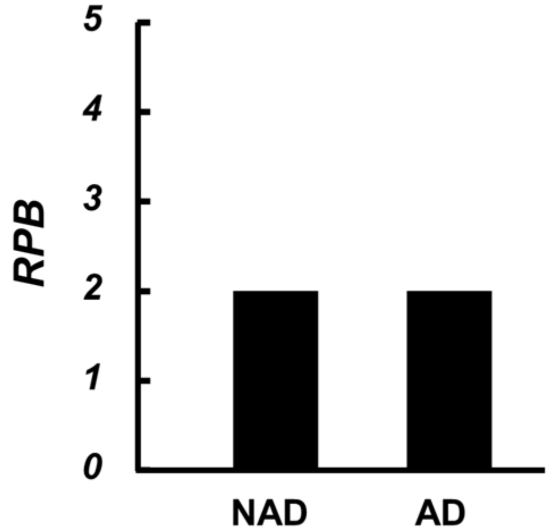

Figure 1. The subject reported the same perceived breathlessness of 2 for both the NAD and AD 6-minute tests.

Negative affect dimensions associated with breathlessness are shown in Table 2.

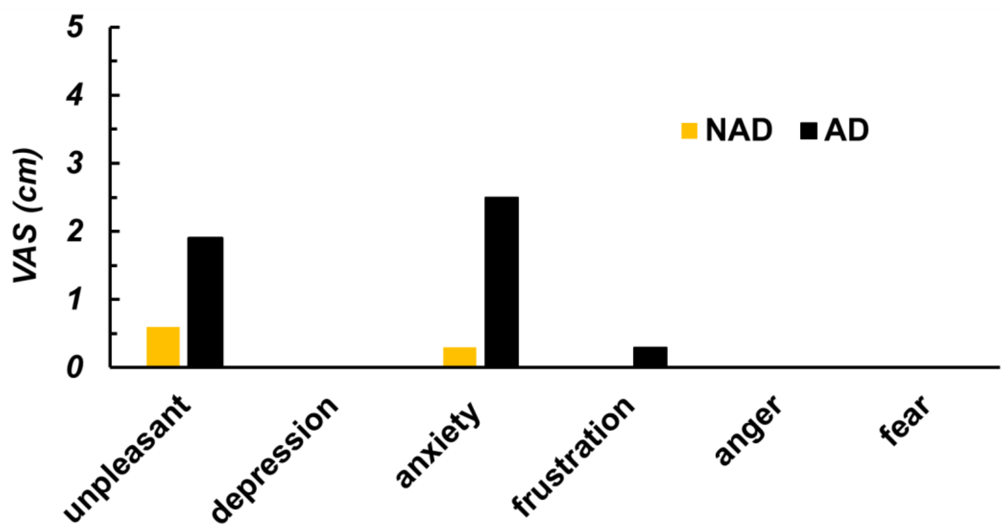

Figure 2. Visual analog scale (0-10) versus negative affect dimensions associated with breathlessness.

Metabolic and Ventilatory Responses

The metabolic and ventilatory responses during the NAD and AD exercise tests were similar (Table 2).

Table 2. Metabolic and ventilatory responses during the 6-minute constant work rate test

	NAD	**AD**
$\dot{V}O_2$ (mL·kg^{-1}·m^{-1})	13.5	12.8
$\dot{V}O_2$ (L·min^{-1})	1.07	1.03
$\dot{V}CO_2$ (L·min-^{1})	0.95	0.95
RER	0.89	0.93
V_E (L·min^{-1})	32	33
f_B (bpm)	30.4	29.6
V_t (L)	1.05	1.12
HR (bpm)	126	120
O_2 pulse (mL ·beat^{-1})	8.52	8.58

$\dot{V}O_2$, oxygen consumption; $\dot{V}CO_2$, carbon dioxide production; RER, respiratory exchange ratio; V_E, minute ventilation; f_B, respiratory rate; V_t, tidal volume; HR, heart rate; O_2 pulse, volume of oxygen consumed by the body per heartbeat.

DISCUSSION

We sought to examine the effect that incorporating an AD during exercise has on the perception of DOE. I observed that the introduction of AD in an obese female during constant work rate exercise had no impact on her perception responses surrounding her breathlessness. However, the current investigation is not without its limitations (e.g., N=1), and more research into the use of AD to alter DOE is warranted.

The subject included in the current investigation was considered obese according to her BMI (33.3 $kg \cdot m^2$) (ACSM, 2008). Additionally, the subject was 22.6 kg (49.8 lb) greater than her ideal body weight according to her age and height (Wasserman, K. et al., 1999). Her body composition was 39.2% body fat. It is recommended that young females have a BMI of 18.5-24.9 $kg \cdot m^{-2}$ and have 20.6-23.6% body fat (ACSM, 2008). The subject did have greater fat-free mass than predicted (48.6 kg vs. 44.9 kg), and this likely is a result of a larger body mass in general. A previous study examining the physiological effects of obesity have involved females with an average BMI of 32.9 ± 4.3 $kg \cdot m^{-2}$ and a mean weight of 89.2 kg (Anderson, R.E., 1999). Thus, the current subject exhibited characteristics common in obesity and was similar to subjects utilized in previous investigations.

The subject's pulmonary function was normal, indicating that the subject had a healthy respiratory system (ATS, 1991). Mild-to-moderate obese females usually do not exhibit impaired pulmonary function; however, they have decreased FRC due to fat accumulation on the chest and abdominal wall (Koenig, S.M., 2001). Compared to subjects in other studies where FRC is typically reduced by approximately 20% (Douglas, F.G., and P.Y. Chong, 1972), the subject's FRC appeared greater than we would predict for mild-to-moderate obese females. Yet, this difference may be attributed to administrator and/or technique differences.

The subject's cardiovascular conditioning (i.e., absolute $\dot{V}O_{2peak}$) was greater than predicted (110% of predicted using ideal body weight), which is indicative of a healthy cardiovascular system. A healthy cardiopulmonary system is defined by how well the lungs, heart, and blood vessels function together. Based off of the subject's ideal body weight, the predicted absolute $VO_{2\ peak}$ would be 1.96 $L \cdot min^{-1}$, and the predicted relative $VO_{2\ peak}$ would 34.1 $mL \cdot kg^{-1} \cdot m^{-1}$ (Wasserman, K. et al., 1999). The subject's cardiovascular conditioning was very similar to that of obese females, regardless of DOE classification, studied in previous research (Babb, T.G., 2008; Bernhardt, V., 2013). Additionally, the subject's physical fitness (i.e., relative $\dot{V}O_{2peak}$) was reduced due to her increased body mass (i.e., additional fat mass). These physiological responses at peak exercise were expected and are indicative of otherwise healthy obese females (Torchio, R., et al., 2009).

Emotional state is believed potentially to play a part in the level of DOE experienced (Banzett, R.B., et al., 2015). While I did not set out to investigate the effect of emotions on RPB, I did ask the subject to complete the PANAS questionnaire before each mild exercise bout. The purpose was to potentially highlight any large discrepancies in emotional state in conjunction with any observed difference in RPB between the NAD and AD tests.

The subject originally rated her RPB as 4 during the DOE classification visit (day 2), which categorized her as +DOE. Approximately 30% of all obese women are classified as +DOE (Babb, T.G, et. al., 2008; Bernhardt, V. and T.G. Babb, 2013). Based off of the subject’s RPB classification, it was expected that she would be a good candidate to monitor the potential for change in perception of DOE through an incorporated stimulus; there was no possibility of her exhibiting a floor effect. However, during her NAD test, her RPB was 2. The difference in RPB from the DOE classification to NAD trials may be attributed to the exposure therapy phenomenon (Richard, D.C., and D. Lauterbach, 2007). During the classification visit, the subject rated heightened proudness and jitteriness on the PANAS questionnaire compared to visits 2 and 3. These feelings may have been caused by lack of experience with the equipment, exercise tests, and the lab in general. Thus, the unfamiliarity and the introduced physiological stress may have artificially elevated the level of DOE experienced during the classification visit as compared to her subsequent visit (NAD). At the NAD visit, the subject was no longer unacquainted with the routine, and therefore her perceptual responses to the mild exercise were more representative of her DOE than measured during the classification visit. The lack of difference in RPB between the NAD and AD trial may indicate that there is no effect on perception of DOE when incorporating an auditory stimulus during exercise.

It seems plausible that the use of AD may decrease the perception of breathlessness in young, obese females. However, the chosen AD may have increased the breathlessness experienced by the subject. She noted that the AD was “intense.” The term intense for her subjective experience is hard to interpret, as additional questioning was not undertaken, but is seems reasonable that the “intensity” of the type of auditory distraction chosen may have counteracted the potential of any auditory distraction to decrease breathlessness and yielded no net difference.

I am unable to make any conclusions at present due to the small sample size, but according to our current data, auditory distraction does not reduce exertional dyspnea in young, obese females. In the future, we would need to include more subjects (N=32; 16 +DOE and 16 -DOE) within the study in order to test our hypotheses and identify a possible underlying mechanism. Based on previous data (Babb, 2011; von Leupoldt, 2007), to detect a reduction in RPB within the positive DOE group at an effect size of 0.60 (one-tailed test, $\alpha = 0.05$, $\beta = 0.80$), it was estimated that 19 participants would be necessary. The Shapiro-Wilk test would be used to check the normality of the data collected. Paired t-tests would be used to evaluate the differences in variables between the NAD) and AD trials. Pearson correlation coefficients would be used to determine the relationships among the variables studied. Data at $P < 0.05$ would therefore be considered statistically significant and all data collected would be expressed as means ± SD.

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