Effect of Experimental Modulation of Mood on Perception of Exertional Dyspnea in Healthy Subjects

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Running Head: Effect of Mood on Exertional Dyspnea

Key Words: Dyspnea, mood, treadmill exercise, cardiopulmonary disease
ABSTRACT

Background: In many diseases across a range of pathologies (e.g. cardiopulmonary, neuromuscular, cancer), chronic dyspnea, particularly on exertion, is a major debilitating symptom often associated with clinical anxiety/depression. This study aims to explore the interaction between mood state and exertional dyspnea in a healthy population. Methodology: Following familiarization, 20 healthy subjects (27-54 years) performed six 5-min treadmill tests on 3 separate days. On each day subjects viewed randomly-assigned images designed to induce positive, negative or neutral mood states (International Affective Picture System-IAPS). For each condition, at minute intervals, subjects rated dyspnea (sensory and affective domains) in the first test and mood (valence and arousal domains), in the second test. Oxygen uptake (\(\dot{V}O_2\), L/min), carbon dioxide production (\(\dot{V}CO_2\), L/min), ventilation (\(\dot{V}E\), L/min), respiratory frequency (\(f_R\), beats/min) and heart rate (HR, bpm), were measured throughout the exercise. Results: \(\dot{V}O_2\), \(\dot{V}CO_2\), \(\dot{V}E\), HR and \(f_R\) were not statistically significantly different among the three mood states (p>0.05). Mood valence was significantly higher with parallel viewing of positive (last 2-min mean ± SEM = 6.9±0.2) compared to negative pictures (2.4±0.2; p<0.001). Both sensory and affective domains of dyspnea were significantly higher during negative (sensory: 5.6±0.3; affective: 3.3±0.5) compared to positive mood (sensory: 4.4±0.4, p<0.001); affective: 2.1±0.4, p=0.002). Conclusion: These findings suggest that positive mood alleviates both the sensory and affective domains of exertional dyspnea in healthy subjects. Thus the treatment of anxiety/depression in dyspnic populations could be a worthwhile therapeutic strategy in increasing symptom-limited exercise tolerance thereby contributing to improved quality of life.

Key Words: Dyspnea, mood, IAPS, treadmill exercise, cardiopulmonary disease
INTRODUCTION

Dyspnea is a significant clinical symptom defined as a “subjective experience of breathing discomfort which varies in its qualitative components, their unpleasantness and their emotional/behavioral significance” (19). Although dyspnea probably shares neural correlates with the shortness of breath reported by healthy individuals during exercise, its manifestation in cardiorespiratory and related conditions is both debilitating (37) and generally associated with poor prognosis (27). To better understand the genesis of dyspnea, many researchers have pointed to the analogy of pain. This concept has further led to a categorization of this symptom in terms of its sensory (intensity) and affective (bother/unpleasantness) domains (6, 38).

The purpose of present study was to examine the impact of induced changes in mood state on exertional dyspnea in healthy subjects. Like previous investigators (32, 34) we have used the viewing of images from the “International Affective Picture System”-IAPS (11) to modulate mood while assessing both the sensory and affective domains of experimentally-induced dyspnea. We chose to use an exercise challenge modelled on stair climbing (14, 24, 25) and to measure the effects of both positive and negative changes in mood on dyspnea throughout the exercise while accounting for any related changes in breathing. We hypothesized that for the same degree of cardiopulmonary stress “positive” and “negative” mood states would be associated with respectively decreased and increased rating of both sensory and affective domains of dyspnea compared with experimentally induced “neutral” mood state.

This present study was designed to investigate the impact on exertional dyspnea and leg fatigue of both positive and negative changes in mood to clarify the unresolved issue of the extent to which experimental changes in mood impact on the sensory and affective domains of dyspnea. Finally monitoring ventilation has enabled us to control for the potential confound of mood impacting on exertional dyspnea via an effect on breathing pattern.
METHODS

Subjects

The study was carried out on 20 healthy individuals (38.8 ± 10.7 years; 9 females) recruited from Griffith University staff following approval by Griffith University Human Research Ethics Committee. Each subject provided written informed consent. The sample size was determined based on previous data obtained in a similar study (14) to detect a 1.0 unit difference in dyspnea rating (0 - 10 scale) at a power of 90% with p < 0.05 of a Type I error. Subjects were screened using the AHS/ACSM Health/Fitness Preparticipation Screening Questionnaire (1) to meet the standard criteria for undertaking a submaximal exercise test without medical supervision. In addition, subjects performed forced spirometry (13); all subjects had lung function values within their predicted normal range.

This study required participants to visit the Exercise Physiology Research Laboratory on four different occasions, comprising an initial familiarization visit and 3 further experimental sessions. No two visits occurred on consecutive days nor were separated by more than one week. The baseline characteristics of subjects are detailed in Table 1.

<< Insert Table 1 here>>
Experimental modulation of mood during exercise

For each of the experimental sessions (visits 2 - 4), subjects performed two identical 5 min bouts of treadmill exercise, separated by an interval of at least 30 min, while viewing a series of images from the International Affective Picture System (IAPS) displayed on a computer monitor in front of the treadmill. IAPS comprises more than 1000 pictures, each with a population based rating of its effect on mood (valence, arousal and dominance) (11). For this study, we selected 3 sets of 24 images associated with high, low and median scores for valence (pleasant, unpleasant and neutral). Each set was modified (i.e. substitution of 5 - 7 images) to ensure population rating equivalence for male and female subjects. On any single visit, the same set of images was viewed during both exercise bouts with the 3 sets randomly allocated over the 3 visits in a balanced design. Using custom built software, each image in a set was displayed for 6 s (11) followed by a 4 s interval before the next image appeared. At minute intervals throughout exercise, the viewing of IAPS images was interrupted for 14 s to allow subjective ratings of either dyspnea or mood using a clicker attached to the handrail of the treadmill (see below).

Assessment of dyspnea

During the first of the two daily exercise bouts, subjects were asked to report their prevailing level of exertional dyspnea at minute intervals in both the sensory (intensity) and affective (unpleasant/bother) domains (11, 34, 38). To achieve this, a numeric scale (14) was displayed on a monitor in front of the treadmill and subjects used a clicker mounted on the handrail to select a number between 0 and 10 which represented the intensity of their dyspnea. A rating of “0” meant they had no shortness of breath (SOB) while “10” meant extreme SOB, a level that would cause them to stop or lower their exercise intensity to gain relief. After 7 s, this scale was replaced by a second 0-10 scale which was used to obtain a rating of the unpleasantness of
their dyspnea. A rating of “0” meant their SOB was not bothering them at all while “10” meant that their SOB was extremely bothersome. To underscore the difference between intensity and bother, subjects were earlier given illustrative examples; for instance, a marathon runner might have a high intensity of SOB with minimal bother, whereas a healthy person could be extremely bothered by unexpected SOB even of low intensity.

**Assessment of mood**

During the second of the two daily exercise tests, subjects rated their prevailing mood using a 9 point pictorial (faces) rating scale (Self-Assessment Manikin - SAM) specifically developed for this purpose (11). As for dyspnea, two subsets of SAM were displayed consecutively for 7 s each, enabling the subject to rate their prevailing mood in terms of valence (extremely unhappy to extremely happy) and arousal (extremely calm to extremely excited). Each SAM scale appeared with the neutral (point 5) image highlighted. Subjects used the clicker/display (described for dyspnea) to select the image that best represented how viewing the pictures made them feel. Ratings were recorded as the numerical equivalent of the selected image (i.e. 1 = extremely unhappy for valence and extremely calm for arousal; 9 = extremely happy for valence and extremely excited for arousal).

**Assessment of leg fatigue**

During the first of the two daily exercise tests, we obtained a single measure of the level of perceived leg fatigue/discomfort using a 0 - 10 numeric scale similar to that used for rating exertional dyspnea. This assessment of leg fatigue was given verbally immediately at the end of exercise. The rationale for rating this second exercise-related symptom was to explore whether mood impacted specifically on exertional dyspnea or more generally on exercise-related discomfort.
Experimental protocol

Visit 1 (Familiarization visit):

During this visit, informed written consent was sought and height, weight and resting blood pressure were measured to facilitate risk stratification. Subjects then practiced walking on a steep slope treadmill (~25%) at a moderate speed (~4kph); these conditions have previously been found to induce moderate dyspnea without exhaustion in healthy subjects (14). Subjects exercised connected to an ECG/Pulse oximeter monitor (Prizm 5 patient monitor, Charmcare Co. Ltd, S. Korea) and wearing a face mask connected to a metabolic system (Quark, Cosmed srl, Italy). In addition, whilst exercising, subjects practiced (a) viewing neutral IAPS images (b) rating their perceived dyspnea and (c) rating their mood (see above). In training subjects to attend to IAPS images and report associated mood changes, we used a standard script modified from that described in the IAPS technical manual (11). During this visit, we established an individualized speed (~4 kph) and grade (~25%) combination based on the subject’s height and fitness level, to produce a peak of 80 - 85% age-predicted maximum heart rate in all tests.

Visits 2 - 4 (experimental visits):

At each visit, subjects performed two treadmill exercise tests, at the speed and grade established on the first visit. Throughout each test, subjects attended to the IAPS images/rating procedures as described above. On any single visit, subjects viewed only a single set of images (i.e. positive, negative or neutral) and the ordering of sets was randomized between subjects. Prior to undertaking exercise on each of these visits, subjects completed a 24- point Brunel Mood Scale questionnaire (BRUMS) (30, 31) to enable the assessment of any significant differences in baseline mood between the three visits. In making this experimental intervention, we wanted to ensure that during for each condition, the ratings of mood and dyspnea were
made during the same experimental day but not within the same exercise bout so as to increase
the likelihood of independent assessment of these different perceptions. As noted above,
subjects always rated dyspnea in the first of the two exercise bouts since this was our primary
outcome measure and we wished to avoid the potential confound on dyspnea ratings of
habituation to viewing images for a second time on the same day. A further concern was that in
viewing images that were clearly either pleasant or disturbing, our subjects might modulate
their dyspnea ratings as a result of an “expectation” that they would feel better or worse. We
addressed this issue by falsely advising our subjects that the speed or slope of the treadmill
could change from test to test and that they should focus on purely reporting their dyspnea.

Physiological Measurements

During each test, ventilation ($\dot{V}_E$), oxygen uptake ($\dot{V}_{O_2}$) carbon dioxide output ($\dot{V}_{CO_2}$), tidal
volume ($V_T$) and respiratory frequency ($f_R$) were measured by the metabolic system. Heart rate
(HR) was measured using a Polar monitor linked to the metabolic system. All cardiorespiratory
variables were recorded breath by breath.

Data analysis

Physiological data were averaged over 1 min intervals and, together with minute by minute
ratings of mood or dyspnea, were analyzed using two way repeated measures ANOVA (with
experimental condition and time as factors). Data for the 24-point Brunel Mood Score
questionnaire were first grouped into six category domains; Tension, Depression, Anger, Vigor,
Fatigue, Confusion (30, 31) and analyzed using one way ANOVA. Ratings of leg fatigue were
also analyzed using one way ANOVA. Linear correlation analysis (Pearson correlation
coefficient) of paired individual responses of dyspnea intensity and dyspnea bother was
undertaken to explore the association between these two domains of dyspnea. All statistical
analyses were carried out using a standard statistical package (IBM SPSS statistics 21.0); a p
value of 0.05 was used to establish statistical significance.

<< Insert Table 2 here>>
RESULTS

Subjects

All subjects studied were normotensive and had normal lung function (Table 1). We did not observe arterial desaturation, cardiac arrhythmias or any contraindicative signs or symptoms associated with exercise testing.

Baseline mood profile

Statistical analysis revealed no significant difference in the mean group values for any of the six category domains of baseline mood state (BRUMS) preceding the viewing of neutral, positive or negative images.

Modulation of mood

The ratings of mood, associated with the viewing of IAPS images during standard exercise are shown in Figure 1 (panels A and B) and Figure 2 (Panels A1, A2, B1 and B2). Analysis of variance revealed a highly statistically significant effect of experimental condition (IAPS-related mood modulation) on rating of mood valence ($p < 0.001$). Post-hoc analysis (repeated measures ANOVA) showed significant differences between positive (last 2 min mean ± SEM = 6.9 ± 0.2) and neutral (4.9 ± 0.2) conditions ($p < 0.001$) and between neutral and negative (2.4 ± 0.2) conditions ($p < 0.001$). Inspection of the interaction statistic indicated that there was a statistically significant difference between conditions in the changes in mood valence over the 5 min period of exercise ($p = 0.005$). Post-hoc analysis showed that when viewing negative images, mood was becoming progressively more negative with continuing exercise compared to viewing neutral images ($p = 0.001$), whereas trends over the exercise period were not significantly different between viewing positive and neutral images ($p = 0.172$).
Mood arousal ratings during the three exercise conditions showed a statistically significant effect of experimental condition ($p = 0.002$). Post-hoc analysis revealed statistically significantly higher arousal ratings with viewing of negative images (last 2 min mean = 5.2 ± 0.4) compared to neutral images (3.2 ± 0.3; $p = 0.001$). However, arousal ratings when viewing positive images (4.1 ± 0.3) were not significantly different from those for neutral images ($p = 0.115$) (Figure 1). There was no significant interaction between condition and time indicating that changes in the arousal ratings across the 5 min period of exercise was similar between conditions ($p = 0.201$).

**Physiological data**

Statistical analysis revealed that there was no significant effect of viewing the different categories of images during a standard exercise bout on any of the cardiorespiratory variables ($\overline{V_O}_2$, $\overline{V}_C0_2$, $V_T$, $f_R$, $\overline{V}_E$ and HR) (Table 2).

**Exertional dyspnea**

The ratings of exertional dyspnea in both sensory and affective domains are shown in Figure 1 (Panels C and D) and Figure 2 (Panels C1, C2, D1 and D2). The viewing of the different categories of IAPS images had a highly statistically significant effect on the intensity of dyspnea (sensory) during a standard exercise bout ($p < 0.001$). Post-hoc analysis revealed a statistically significantly higher level of dyspnea intensity with viewing of negative images (last 2 min mean = 5.6 ± 0.3) compared to viewing neutral images (4.7 ± 0.3; $p = 0.011$). Similarly, dyspnea intensity when viewing positive images (4.0 ± 0.3) was significantly lower than when viewing neutral images ($p = 0.013$). The interaction statistic indicated that there was a statistically significant effect of image category on the rate at which dyspnea intensity increased over the 5 min exercise bout ($p < 0.001$). Post-hoc analysis revealed that compared to
viewing neutral images, viewing positive images significantly slowed the rate rise of dyspnea intensity over the 5 min exercise period \( p = 0.004 \). By contrast, viewing negative images increased the rate of rise of dyspnea intensity as exercise progressed \( p = 0.003 \).

Dyspnea bother (unpleasantness) ratings showed a statistically significant effect of experimental condition \( p = 0.006 \). Post-hoc analysis revealed that there was no significant difference when viewing neutral images (last 2 min mean = 2.4 ± 0.3) compared with either positive images (1.8 ± 0.3) or negative images (3.3 ± 0.5). However, viewing negative images was associated with significantly greater dyspnea bother compared to viewing positive images \( p = 0.002 \). The interaction statistic indicated that no difference in the rate of increase of dyspnea bother over the exercise bout during the three conditions.

Correlation analysis of individual paired responses for dyspnea intensity and dyspnea bother were statistically significantly associated between the two domains of dyspnea for each of the three mood states (positive, \( r = 0.69 \), \( p = 0.001 \); neutral, \( r = 0.57 \), \( p = 0.009 \); negative, \( r = 0.62 \), \( p = 0.003 \)).

**Leg fatigue**

Statistical analysis revealed that there was no significant effect of viewing the mood changing images on the ratings of leg fatigue at the end of exercise (Table 2).

<< Insert Figures here>>
DISCUSSION

The main finding of this study is that in healthy subjects who are exercising, experimentally induced positive mood states are associated with lower dyspnea ratings (intensity and unpleasantness) than negative mood states. Such an association was not found between mood state and leg fatigue. This suggests that dyspnea perception results from more complex central neural processing, embracing cognitive/emotional events, than is the case for the more peripherally dependent perception of fatigue. Thus a greater focus on strategies aimed at improving mood in individuals with chronic dyspnea could alleviate the morbidity associated with this symptom.

Our findings are in general agreement with previous studies reporting an inverse relationship between perceived dyspnea and image viewing induced alterations in mood. In healthy subjects, von Leupold et al. (32, 33) used resistive-loaded breathing to induce dyspnea and reported positive and negative effects (compared to neutral) on the affective (unpleasantness) component of dyspnea but not on its sensory (intensity) domain. Allen and Friedman (3) employed paced slow deep breathing in healthy subjects to induce dyspnea and reported alleviation of the symptom when viewing positive images. Neither of these perceptual experiences would be equivalent to the exertional, and clinically more relevant, dyspnea induced in our study. With respect to exertion, Rietveld and Prins (23) noted greater dyspnea in asthmatic children after viewing a film inducing negative emotions and von Leupoldt et al. (34) reported greater dyspnea intensity (but not unpleasantness), while viewing negative compared to positive IAPS images, in individuals with COPD. The present study extends previous observations in a number of respects. Firstly, we have shown in healthy subjects that exertional dyspnea can be both alleviated and exacerbated by viewing positive and negative images respectively (compared to a neutral mood). Secondly, the impact of mood is predominantly on
Effect of Mood on Exertional Dyspnea

the intensity rather than unpleasantness of exertional dyspnea, as found in exercising COPD
patients (34) but different from resistive loading dyspnea in healthy subjects (32, 33). Thirdly,
both of our positive and negative mood conditions were associated with heightened arousal
indicating that it is the valence of mood rather than the corresponding arousal that impacts on
dyspnea perception.

In designing this study, we were concerned that the need to complete the exercise bouts over a
number of days could mean that any day-to-day variations in general mood could impact on
exertional dyspnea over and above the effect of viewing different mood altering images.
However, our assessment of baseline (i.e. before exercise) mood state (BRUMS) revealed no
differences in any aspect of mood preceding the viewing of the different image sets. In
addition, it was important that all exercise bouts were performed at the same intensity and this
was confirmed by no difference in mean values for oxygen uptake and heart rate across the
three experimental conditions. The lack of any difference in respiratory frequency or tidal
volume further confirms that differences in dyspnea were not associated with any mood-related
effects on breathing.

In examining the effect of experimental changes in mood on perceived intensity of leg fatigue,
we noted that the difference between the positive and negative conditions (4.2 vs 4.8) was
considerably less than the corresponding (final) dyspnea intensity (4.1 vs 5.8) scores. Post-hoc
analysis of these data pairs confirmed a difference in statistical outcomes (fatigue: p = 0.066;
dyspnea p = 0.014). This may be reflective of differences in the neural substrates of these two
types of exercise-related discomfort such that mood has a greater impact on the more centrally
generated sensation of dyspnea compared to the more peripherally induced sensation of leg
fatigue. The fact that the two concurrent symptoms were differently affected by the altered
mood state gives us confidence that our subjects’ ratings during these studies were not unduly influenced by expectation bias.

In speculating what our findings might tell us about the neural basis of the mood modulation of exertional dyspnea we might first consider what is known about the patterns of neural activation accompanying the viewing of IAPS images. Using fMRI in healthy subjects, Aldhafeeri and coworkers found activations selectively in the hippocampus, amygdala and visual cortex when viewing negative compared to neutral images and in the superior and middle frontal gyrus, prefrontal cortex and posterior cingulate gyrus with positive images (2). Similarly with fMRI, Hariri and colleagues found activation of the amygdala during viewing of unpleasant IAPS images compared to geometric shapes (9). Neural imaging of experimental (albeit not exertional) dyspnea has also shown to activate the amygdala (7, 33) alongside associated limbic structures particularly the anterior insula (4, 12, 20). Thus the central processing of neural activity within these brain regions, known to be concerned with emotionally driven behaviors, offers a possible neurophysiological basis for the impact of mood state on dyspnea perception. Support for this idea comes from studies demonstrating that tolerance of pain, which also has a strong amygdalic/limbic representation (39), is increased or decreased when viewing positive and negative IAPS images respectively (29).

There is now widespread clinical evidence that there is an increased prevalence of anxiety and depression in individuals across a range of chronic conditions including COPD (26), heart failure (28), pulmonary hypertension (10, 22), myasthenia gravis (21) and late stage cancer (5, 8, 36). The presence of these psychological comorbidities is associated with poorer health outcomes (35, 38). Whether these associations are causative and if so in which direction is not established, although there is suggestive evidence that onset of anxiety and depression results in a worsening of dyspnea (15).
reported to improve depression and negative emotion (16) and treating psychopathology as a
means of alleviating dyspnea is not a new idea. For example, a number of studies have shown
cognitive behavioral therapy to be promising for reducing dyspnea in patients with COPD
(18). Current recommendations for Pulmonary Rehabilitation articulate the need for the
teaching of relaxation and stress reduction techniques to help with the management of dyspnea
in COPD and other chronic conditions (17), although evidence supporting the additional benefit
gained over and above other components of pulmonary rehabilitation, particularly exercise, is
lacking.

The results of the current study clearly show that in healthy subjects, perception of exertional
dyspnea can be modulated by experimental alteration in emotional state. This supports the view
that strategies aimed at improving an individual’s mood are worthwhile pursuing in an attempt
to alleviate the morbidly associated with chronic exertional dyspnea. Our findings do not
indicate any specific approach that might be effective in a chronic disease population but they
do suggest that there is a sound psychophysiological basis for conducting further research in
this area.

ACKNOWLEDGEMENTS

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Emotion and Attention for providing us the mood modulating IAPS images, and Dr. David
Neumann and Mr. John Zhong from the Griffith University School of Psychology for their
assistance in the use of IAPS to modulate mood states during exercise.
AUTHOR'S CONTRIBUTION

LA made the primary contributions to the conception of this work with all authors contributing substantially to its design. PS was primarily responsible for data acquisition and was assisted with analysis and interpretation by LA and NM. Initial drafting the work was by PS with LA and NM revising it critically for important intellectual content. Final approval of the version to be published was made by LA and NM. All authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

DISCLOSURES

We declare no conflict of interest
REFERENCES


Table 1 General characteristics of participants (n = 20)

<table>
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<tr>
<th>Characteristics</th>
<th>Male</th>
<th>Female</th>
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<tbody>
<tr>
<td>Age range (years)</td>
<td>27 - 56 (36.2 ± 10.0)</td>
<td>29 - 54 (38.2 ± 8.7)</td>
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<tr>
<td>Number of participants</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td>123 ± 6</td>
<td>112 ± 11</td>
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<tr>
<td>Diastolic blood pressure (mmHg)</td>
<td>82 ± 5</td>
<td>75 ± 8</td>
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<tr>
<td>Height (cm)</td>
<td>181.5 ± 5.3</td>
<td>167.2 ± 7.0</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>25.2 ± 2.0</td>
<td>23.9 ± 4.3</td>
</tr>
<tr>
<td>FEV₁ (% predicted)</td>
<td>90 ± 9</td>
<td>102 ± 17</td>
</tr>
<tr>
<td>FVC (% predicted)</td>
<td>100 ± 14</td>
<td>102 ± 16</td>
</tr>
</tbody>
</table>

Values are represented as mean ± SD

BMI = Body Mass Index, FEV₁ = Forced Expiratory Volume in 1 s, FVC = Forced Vital Capacity.
Table 2: Last 2 min mean ± SEM of measured cardiorespiratory variables and perceived leg fatigue during exercise while viewing sets of images designed to induce a positive, neutral or negative mood (n=20). There was no statistically significant effect of image type on any of these variables.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Positive</th>
<th>Neutral</th>
<th>Negative</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \dot{V}O_2 ) (L/min)</td>
<td>2.63 ± 0.15</td>
<td>2.70 ± 0.14</td>
<td>2.67 ± 0.13</td>
</tr>
<tr>
<td>( \dot{V}CO_2 ) (L/min)</td>
<td>2.69 ± 0.15</td>
<td>2.76 ± 0.14</td>
<td>2.71 ± 0.12</td>
</tr>
<tr>
<td>( V_T ) (L)</td>
<td>2.30 ± 0.18</td>
<td>2.30 ± 0.18</td>
<td>2.37 ± 0.14</td>
</tr>
<tr>
<td>( f_R ) (breaths/min)</td>
<td>31.5 ± 1.4</td>
<td>31.3 ± 1.3</td>
<td>31.9 ± 1.5</td>
</tr>
<tr>
<td>( \dot{V}_E ) (L/min)</td>
<td>73.0 ± 3.8</td>
<td>73.9 ± 4.2</td>
<td>73.4 ± 4.4</td>
</tr>
<tr>
<td>HR (beats/min)</td>
<td>154 ± 3</td>
<td>155 ± 3</td>
<td>153 ± 3</td>
</tr>
<tr>
<td>Leg fatigue</td>
<td>4.2 ± 0.5</td>
<td>4.9 ± 0.5</td>
<td>4.8 ± 0.4</td>
</tr>
</tbody>
</table>

\( \dot{V}O_2 \) = oxygen uptake; \( \dot{V}CO_2 \) = carbon dioxide output; \( V_T \) = tidal volume; \( f_R \) = respiratory frequency; \( \dot{V}_E \) = ventilation; HR = heart rate.
Figure 1. Mean (SEM; n=20) levels of Mood Valence (Panel A), Mood Arousal (Panel B), Dyspnea Intensity (Panel C) and Dyspnea Bother (Panel D) during 6 identical exercise bouts performed on three separate days. During each exercise bout, subjects viewed either positive (●), neutral (○) or negative (▼) IAPS images and rated either the two domains of mood (valence: 1 = very unpleasant, 9 = very pleasant; arousal: 1 = very calm, 9 = very excited) or the two domains of dyspnea (intensity: 0 = no dyspnea, 10 = extreme dyspnea; unpleasantness: 0 = not at all unpleasant, 10 = extremely unpleasant).

Symbols represent statistically significant difference between: * positive and neutral, † negative and neutral, ‡ positive and negative.

Figure 2. Mean (SEM; n= 20) levels of Mood Valence (A), Mood Arousal (B), Dyspnea Intensity (C), and Dyspnea Bother (D). Each plotted against mean $\dot{V}_E$ (Panel 1) and mean $\dot{V}O_2$ (Panel 2) during positive (●), neutral (○) and negative (▼) mood modulation.