Original

Effects of Trait Anxiety on Breathlessness and Respiratory Patterns during Repeated Breath-holds

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Abstract: Breathlessness is an unpleasant sensation related to respiration and is induced by hypercapnia or hypoxia. However, breathlessness is affected by psychological changes, especially anxiety. In this study we investigated how trait anxiety affected breathlessness induced by repetitive breath-holds. Breathlessness increased linearly with breath-hold trials. The subjects in the group of high trait anxiety (group H), whose scores were more than 43.2, had higher breathlessness as compared to the group of low trait anxiety (group L). Tidal volume (V_T) and V_T/T_I also increased linearly with breath-hold trials, but there was no difference between group H and group L. This study suggests that respiratory effort increases while repetitive breath-holds augment breathlessness. This research also suggests that breathlessness may increase in a subject who has high trait anxiety.

Key words: breathlessness, breath-hold, trait anxiety

Introduction

Breathlessness or dyspnea is a subjective feeling of discomfort and is a common symptom in patients with cardiopulmonary disease¹⁾. There are many studies showing the cause of breathlessness. Chemoreceptors or mechanoreceptors activated in the respiratory control system are capable of causing breathlessness. It is still unknown whether hypoxia induces breathlessness. Breathlessness decreased and exercise tolerance improved when oxygen was applied to patients with chronic obstructive pulmonary disease²⁾. Contrary to hypoxia, hypercapnia has been proven to induce breathlessness³⁾. The sense of effort is also one of the possible causes of breathlessness. Breathlessness increased parallel to the sense of effort with an increase of respiratory resistive load⁴⁾.

Breathlessness may also be related to individual arousal, attention and anxiety levels and these can be additional factors for an increase of breathlessness and ventilatory responses to sensory stimulations. It is well known that a central pattern generator for respiration exists

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in the brainstem, but the respiratory pattern is also influenced by activation of the limbic structure⁵⁾. In an awakened state, CO₂ inhalation alters respiratory patterns primarily by the stimulation of chemoreceptors, but final respiratory output is generated by the interaction between metabolism requirements and inputs from the limbic structure. It has been reported that subjective air hunger sensitivity is common in high trait anxious subjects⁶⁾. Also, there is a positive correlation between breathlessness and anxiety levels both in normal controls and in patients with hyperventilation syndrome⁷⁾. In addition, repeated experiments of breathlessness induced by CO₂ inhalation influence the subjective feeling and ventilator responses⁶⁾.

In this study, we investigated whether breathlessness was related to individual anxiety levels and whether the repeated experiences of breathlessness increased breathlessness induced by the combined effects of CO₂ inhalation and breath-hold.

Materials and Methods

Seven normal subjects (all males; mean age, 31.6 years) participated in this study. All subjects gave informed consent and the study was approved by the Ethics Committee of Showa University School of Medicine. All subjects completed Spielberger's State-Trait Anxiety Inventory (STAI)⁸⁾ before the experiment. The trait anxiety scale in the STAI was used to assess their anxiety personality.

After the STAI assessment, the subjects were seated to rest for the next experiment. A face mask with a transducer for measuring respiratory flow and volume with a flow meter was attached to each subject (AE280, Minato Medical Science, Osaka, Japan). The end tidal CO₂ concentration was measured with a CO₂ analyzer (IH31, Sanei, Japan). The subjects inhaled the gas mixture of 5% carbon dioxide + 95% oxygen through a one-way valve connected to the mask. Fig. 1 shows the experimental setup of the study. The subjects were instructed to breath-hold at the end of expiration for 10 seconds after spontaneous breathing for 20 seconds. They repeated this trial 10 times. We asked the subjects about their breathlessness by use of a visual analogue scale (VAS) after each breath-hold. Respiratory flow and volume together with the CO₂ concentration were continuously measured and stored in a computer. Tidal volume (V_T), inspiratory time (T_I) and end tidal CO₂ concentration (ETCO₂) of the first breath after each breath-hold was fed into an analyzer.

As the trait anxiety score of each subject had an effect on respiration⁹⁾, we divided the subjects into two groups. The mean score after the STAI assessment for all subjects was 43.2. The subjects with a score of more than 43.2 were placed in a high trait anxiety group (group H; $N=4$), and a score of less than 43.2 were in a low trait anxiety group (group L; $N=3$). There was a significant difference in trait anxiety scores between group H and group L ($P=0.03$).

For statistical analysis, a software package (SPSS, SPSS Japan) was employed. Two-way repeated measures analysis of variance (ANOVA) was used to test for the effect of CO₂

Fig. 1 End tidal CO₂ concentration (ETCO₂) of 9 trials.
Data indicates the mean ± SD of all subjects

and the effect of trait anxiety. Greenhouse-Geisser adjustment of the degree of freedom was applied to ANOVA to correct for violation of the assumption of sphericity.

Results

There was no significant difference in the ETCO₂ concentration of the first breath after each 10 second breath-hold (Fig. 1).

Breathlessness expressed as VAS progressively increased with trials. VAS was divided by the ETCO₂ of the first breath after breath-hold to avoid the effect of CO₂ on the sensation. The subjects were divided into two groups. One group (group H) had a higher trait anxiety score of more than 43 (mean ± SD: 48.75 ± 4.4), and the other group (group L) had a lower score of less than 43 (mean ± SD: 36.0 ± 5.6). VAS/ETCO₂ after the first breath-hold was 3.75 ± 2.21 (mean ± SD) in group H and 3.22 ± 1.27 (mean ± SD) in group L. Those after the 10th breath-hold were 12.35 ± 1.14 (mean ± SD) in group H and 8.42 ± 1.39 (mean ± SD) in group L. VAS/ETCO₂ after the 10th trial was significantly higher than that after the 1st trial in both groups. VAS/ETCO₂ in the H group was significantly higher than that in the L group after both the 1st trial and the 10th trial. VAS/ETCO₂ was gradually increased by the reiterate trials except for the 1st trial. The increased value from the 1st trial and the 2nd trial was larger compared with the values between the other trials. Regression lines of VAS/ETCO₂ from the 2nd to the 10th trials were $Y = 0.61X + 7.5$ ($R^2: 0.946$) in group H and $Y = 0.46X + 4.7$ ($R^2: 0.9$) in group L. Both lines have significant correlations. The slope of the H group is steeper than that of the L group (Fig. 2).

The breathing patterns also changed with the trials. V_T progressively increased in the reiterate trials of both groups. V_T after the 1st trial was 1.09 ± 0.14 (mean ± SD) in group H and 0.73 ± 0.21 (mean ± SD) in group L. V_T after the 10th trial was 1.96 ± 0.69 (mean ± SD)

Fig. 2 Regression lines of visual analogue scale/end tidal CO₂ concentration (VAS/ETCO₂) from the 2nd to 10th trials. Group H (closed diamonds) ; group L (closed squares)

Fig. 3 Tidal volume (V_T) of 9 trials for group H and group L. Group H (closed diamonds) ; group L (closed squares)

in group H and 1.27 ± 0.46 (mean $\pm$ SD) in group L. V_T after the 10th trial was significantly higher than that of the 1st trial in both groups. V_T in group H was significantly higher than that of group L both after the 1st and the 10th trials. The regression line of V_T from the 2nd to the 10th trial was $Y = 0.05X + 1.61$ (R^2 : 0.85) in group H and $Y = 0.04X + 0.93$ (R^2 : 0.84) in group L. Both lines had significant correlations (Fig. 3).

V_T/T_I is generally used to express the value of respiratory central output. V_T/T_I after the 1st trial was 0.63 ± 0.08 (mean $\pm$ SD) in group H and 0.46 ± 0.07 in group L. V_T/T_I after the 10th trial was 1.23 ± 0.18 (mean $\pm$ SD) in group H and 0.87 ± 0.16 (mean $\pm$ SD) in

Fig. 4 Tidal volume / inspiratory time (V_T/T_I) of 9 trials for group H and group L. Group H (closed diamonds) ; group L (closed squares)

group L. V_T/T_I after the 10th trial was significantly larger than that after the 1st trial both in group H and group L. V_T/T_I in group H was significantly larger than that in group L both after the 1st and the 10th trials. The increased value from the 1st to the 2nd trial was larger compared with values of other trials. The regression line of V_T/T_I from the 2nd to the 10th trial was $Y = 0.04X + 0.9$ ($R^2: 0.95$) in group H and $Y = 0.04X + 0.5$ ($R^2: 0.912$) in group L. Both lines had significant correlations, but the slopes of these 2 lines showed no significant differences (Fig. 4).

Discussion

The purpose of this study was to identify the factors that increase breathlessness and those that cause breathlessness with repetitive stimulation. Breathlessness, which is a more general term used mostly in clinics, is a major symptom of cardiopulmonary disease but can occur in normal subjects during exercise. It is known that breath-holding causes breathlessness and the longer the breath-hold time the higher the level of breathlessness¹⁰⁾. Most studies of breathlessness during breath-hold measured breathlessness tolerance^{11, 12)}. However, we investigated whether repetitive breath-holds affected breathlessness.

In this study, we have clearly demonstrated that breathlessness is accumulated by repetitive breath-holds. Breathlessness during a 10 second breath-hold was linearly increased by repetitive breath-holds at intervals of 20 seconds. There are several factors involved in increasing breathlessness. For example, breathlessness is increased by the stimulation of chemoreceptors by CO_2 or hypoxia^{10, 13, 14)}, or by the stimulation of mechanoreceptors by inflation or deflation of the lungs¹⁵⁾. In the present study, the $ETCO_2$ at the first breath after the breath-hold did not increase with the trials. Therefore, CO_2 , which is the most

effective factor in breathlessness, did not contribute to the progressive increase of breathlessness. There may be no change in mechanoreceptors with repetitive trials. Also, there may be other factors causing an increase in breathlessness with repetitive trials, such as a sense of effort, for example⁴⁾.

Breathlessness is the sense induced by the corollary discharges from respiratory motor cortexes. Therefore, breathlessness may be reflected in respiratory motor output, such as V_T or V_T/T_I , which also increased with trials. However, there was no significant difference in increased V_T or V_T/T_I between groups H and L. Contrary to V_T and V_T/T_I , the increase of $VAS/ETCO_2$ in the trials was different in groups H and L. The increased value of breathlessness in group H was higher than the value in group L. Respiratory sensation is reported to be dependent on the subject's emotional state^{5,16)} and we found that anxiety changes respiratory patterns and sensation. Also, the progressive increase of breathlessness induced by the repetitive trials of breath-hold may be induced by the increase of inspiratory effort. Although this study used a limited number of subjects, we have demonstrated that trait anxiety may enhance breathlessness.

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