# Heightened ventilatory response during stair climbing in individuals with dysfunctional breathing



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*To the Editor*:

Dysfunctional breathing, defined as an alteration in the normal pattern of breathing [1, 2], is recognised to be an important differential diagnosis for individuals with "unexplained" dyspnoea. It is estimated that dysfunctional breathing is present in up to 10% of the general population [3] and is a prevalent comorbid finding in individuals with airways disease, acting to amplify symptom burden and to confound accurate assessment of disease control [1, 3, 4].

Individuals with dysfunctional breathing often report disproportionate symptoms [5], such as breathlessness at the onset of everyday activities. Tasks that typically cause breathlessness include a change in posture, such as when bending forward or starting to climb stairs [5]. Although there is currently no gold-standard means for the assessment of exertion-related aspects of dysfunctional breathing, when studies have employed standard laboratory-based exercise assessments (*e.g.* using an incremental exercise protocol with cardiopulmonary exercise testing (CPET)), overall exercise capacity appears to be preserved in those with dysfunctional breathing [6].

To evaluate the apparent discrepancy between subjective and objective findings in individuals with dysfunctional breathing, we evaluated cardiopulmonary and ventilatory response during a pragmatic or "real-life" exercise challenge, *i.e.* during a stair climb. We hypothesised that the ventilatory response to exercise would be disordered in individuals with dysfunctional breathing, when comparing with an age-matched control group.

Patients prospectively attending the unexplained breathlessness service at the Royal Brompton Hospital, London, UK, between May and September 2019 were invited to undertake a stair-climb CPET assessment, as described below. Participants were recruited if they were diagnosed with dysfunctional breathing, based on the positive identification (by a senior respiratory physiotherapist) of a series of typical characteristics of dysfunctional breathing [4, 5] and having had other relevant pathologies excluded (*e.g.* with pulmonary function tests, imaging and cardiac investigations, as indicated). In addition, a laboratory-based CPET revealed no significant cardiorespiratory abnormality. Age- and sex-matched individuals with no history of cardiorespiratory illness were recruited as a control group. All participants provided written consent for this ethically approved study (Local REC Project reference: 18/WM/0268).

Participants initially completed dyspnoea-related questionnaires (Dyspnoea-12 [7] and Nijmegen [8]), spirometry and a stair-climb exercise test with a portable CPET device (Oxycon Mobile, CareFusion) and heart rate belt (Polar T31 transmitter). Baseline data were collected with subjects in the seated position for 2 min. Resting respiratory rate was reported as the mean of a 30-s period after 1 min rest. Participants were then instructed to climb four flights of stairs consisting of 11 steps (rise 160 mm; total elevation gain 7.04 m), at their own pace. Recovery data was collected for 2 min in a seated position. Ratings of breathlessness and muscular exertion were obtained at rest and upon the end of the exercise bout, using the modified Borg Dyspnoea Scale and Rating of Perceived Exertion (RPE) Scales (0–10) [9]. Independent t-tests and the Mann–Whitney U-test were used, as appropriate, to test for differences between groups. A Chi-squared test or Fisher's exact test were used for binary variables. All analyses were performed using IBM SPSS statistics version 26.0. A p-value of $<0.05$ was considered significant.

Shareable abstract (@ERSpublications)
**This prospective cohort study confirms that patients with dysfunctional breathing experience dyspnoea and an abnormal breathing pattern when faced with undertaking everyday exercise challenges, such as climbing stairs** https://bit.ly/3OEWwPM

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A total of 24 subjects completed assessment. Patients (n=11) and controls (n=13) were well matched for age and sex, although patients had a slightly greater body mass index (BMI) (table 1). Patients reported higher baseline dyspnoea scores on questionnaires than controls: Dyspnoea-12, p<0.01; Nijmegen, p<0.01) (table 1). Patients also had a slightly higher breathing frequency than controls at rest (p=0.01) but a similar minute ventilation (p=0.36) (table 1). Resting spirometric indices were normal in both groups (table 1). Patients with dysfunctional breathing had a mean peak oxygen consumption ($V'_{O_2}$) of 97% predicted (n=3, peak $V'_{O_2}$ <80%), from their laboratory-based CPET.

The end-stair climb $V'_{O_2}$ and heart rate at the end of the challenge were similar between patients and controls (table 1) (all p>0.05). At end-exercise, patients reported a higher Borg dyspnoea rating (p<0.01), with 91% reporting the challenge as Borg ⩾3 (rating as moderate to severe); in contrast, only 8% of controls reported the same severity rating. At the end of the stair climb, breathing frequency was ~10 breaths per min higher (p<0.01) in patients but with a similar tidal volume (p=0.87), when compared with controls.

The ventilatory response to a simple, everyday physical activity challenge appears to be amplified in individuals with dysfunctional breathing when compared with a matched control group, despite a similar cardiac and metabolic demand. Specifically, in individuals with dysfunctional breathing, stair-climbing was associated with a heightened end-stair-climb exercise ventilation, arising from seemingly excessive exertional hyperpnoea. These findings align with patients' subjective reports of breathlessness in response to this type of activity and a sensation of "faster breathing" during simple activities.

**TABLE 1** Baseline data and cardiopulmonary response to stair climbing

| | Controls[#] | Patients[¶] | p-value |
|---|---|---|---|
| **Males/females** | 3/10 | 5/6 | 0.25 |
| **Age, years** | 49±8.0 | 54±9.9 | 0.19 |
| **BMI, kg·m$^{-2}$** | 26±5.2 | 29±3.0 | 0.047* |
| **Nijmegen questionnaire[+]** | 3.5±4.7 | 23±9.8 | <0.01** |
| **Dyspnoea-12 questionnaire[§]** | 0.0±0 | 15.7±8.6 | <0.01** |
| **$FEV_1$, % predicted** | 99.4±16 | 109±10 | 0.23 |
| **FVC, % predicted** | 101±18 | 115±12 | 0.04* |
| **Rest measurements** | | | |
| $V_E$, L·min$^{-1}$ | 11±4.1 | 12±4.9 | 0.36 |
| BF, breaths per min | 17±3.3 | 22±5.0 | 0.01* |
| $V'_{O_2}$, mL·min$^{-1}$·kg$^{-1}$ | 4.5±1.2 | 3.8±0.7 | 0.91 |
| $V_T$, L·min$^{-1}$ | 0.69±0.2 | 0.59±0.1 | 0.09 |
| HR, beats per min | 78±14 | 78±9.5 | 0.73 |
| $P_{ETCO_2}$, kPa | 4.4±0.3 | 4.0±0.4 | <0.01** |
| RER | 0.92±0.1 | 0.88±0.2 | 0.15 |
| Dyspnoea[f] | 0.0 (0.0) | 0.5 (1.0) | 0.02* |
| RPE[f] | 0.0 (0.0) | 1.0 (1.0) | 0.02* |
| **End-stair climb measurements** | | | |
| $V_E$, L·min$^{-1}$ | 24±8.6 | 36±9.0 | <0.01** |
| $V_E$, % maximum | 22±5.9 | 31±9.7 | 0.02* |
| BF, per min | 21±4.1 | 31±11 | <0.01** |
| $V'_{O_2}$, mL·min$^{-1}$·kg$^{-1}$ | 13±2.6 | 14±3.0 | 0.57 |
| BF change, breaths per min | 4±4.2 | 10±8.6 | 0.21 |
| $V_T$, L·min$^{-1}$ | 1.3±0.4 | 1.3±0.4 | 0.87 |
| HR, beats per min | 121±19 | 116±17 | 0.65 |
| Dyspnoea[f] | 0.5 (0.5) | 4.0 (2.0) | 0.00** |
| RPE[f] | 1.0 (1.5) | 3.0 (4.0) | 0.00** |
| Stair-climb time, s | 35.6±9.0 | 48.3±21 | 0.04* |

Data are presented as mean±SD or median (interquartile range), unless otherwise stated. BMI: body mass index; $FEV_1$: forced expiratory volume in 1 s; FVC: forced vital capacity; $V_E$: exhaled volume per breath; BF: breathing frequency; $V'_{O_2}$: oxygen consumption; $V_T$: tidal volume; HR: heart rate; $P_{ETCO_2}$: end-tidal carbon dioxide tension; RER: respiratory exchange ratio; RPE: Rate of Perceived Exertion. [#]: N=13; [¶]: N=11; [+]: out of 64; [§]: out of 24; [f]: Borg Dyspnoea Scale. *: p<0.05; **: p<0.01.

Stair-climbing is an important daily activity for most people but represents a "composite" physiological challenge, with a requirement for synchronous changes in not only respiratory patterns, but also muscular tone and vascular and cardiac responses [10]. The mechanisms relating to metabolic and respiratory control during exercise remain debated and feed-forward, anticipatory responses are likely to be relevant [11]. The disordered ventilatory response we observed during exercise in patients with dysfunctional breathing aligns with our previous work [6], which indicated that individuals with this condition appear to have a chaotic and amplified ventilatory response during CPET. Further mechanistic work is needed to determine if this amplified response pattern is centrally controlled and/or potentially arises from alterations in chemosensitivity, oxygen extraction, central control or aberrant autonomic control mechanisms [12, 13]. These are important mechanistic considerations that need to be explored in future studies to help provide targeted treatments.

Previous studies have quantified dysfunctional breathing using different techniques, including the Self-Evaluation of Breathing Questionnaire, Manual Assessment of Respiratory Motion, end-tidal carbon dioxide measurement and the Breathing Pattern Assessment Tool measurement [4]. These assessment tools fail to adequately evaluate breathing patterns on exertion, a relevant consideration in dysfunctional breathing. This study therefore potentially establishes a protocol that could now be used to assess dysfunctional breathing and responsiveness to intervention, for example with physiotherapy. Our findings also highlight the need for targeted intervention to help alleviate the breathlessness arising from this type of challenge. In this context, an energy-conserving, pacing strategy has been successfully employed to help patients with COPD [14] during stair-climbing and a similar approach may prove beneficial in dysfunctional breathing. Future work should also explore relationships between stair-climbing breathing response and the different phenotypes of dysfunctional breathing [5].

We acknowledge several methodological limitations. Firstly, the sample size is small, subjects were recruited from a single specialist centre and we do not have CPET data in a standard laboratory test from the control group. Our ability to recruit more subjects was unfortunately curtailed by the COVID-19 pandemic. Future studies should increase subject numbers and ideally aim to provide a comparator with standard laboratory CPET in both groups. It is also possible that some of the findings are explained by minor differences in BMI between the groups and ability to regulate their self-determined pace on stair-climbing, *i.e.* the control group had a lower total stair climb time. The use of nonstandardised exercise test protocols warrants a need for caution in the interpretation of some aspects of the results; however, self-paced protocols are commonly used to assess exertional performance (*e.g.* the 6-min walking test). The choice of the protocol described in the current work was determined by our desire to deliver a pragmatic design but future work could explore differences in breathing control with a regulated pace; indeed, this approach likely underpins some approaches to pacing that are used to help manage dyspnoea.

A second important consideration relates to the methodology used to diagnose dysfunctional breathing. As outlined earlier, there is currently no gold-standard means for establishing this diagnosis and accordingly, we utilised the type of approach used to identify individuals with dysfunctional breathing that would be undertaken in standard clinical practise.

In conclusion, this study of individuals with dysfunctional breathing provides physiological insight to support the subjective report of an abnormal or heightened ventilatory response to exercise and demonstrates commensurate, objective alterations in ventilatory response. This pragmatic approach to assessing ventilatory response in dysfunctional breathing now needs to be validated and standardised in larger, multiple-centre studies. There may also be value in evaluating the recovery profile in respiratory rate on exercise cessation to provide insight regarding resumption of "normal" breathing control following exercise.

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