Dysfunctional Breathing – View of Pulmonologist

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Abstract
Dysfunctional breathing (DB) is a respiratory disorder defined by non-regular breathing patterns. It is a breathing condition where long term changes in breathing pattern result in symptoms (main is dyspnoea) but also non-respiratory symptoms, with no prominent cardio-respiratory or neuro-psychiatric disease (sometimes secondary to them). It has been identified in different age groups and also among asthma patients. Although DB has been investigated for long time, it is poorly understood because of lack in clinical trials and validated outcome measures specific to this population. DB irregularity is often missed, because of the similarity of its associated symptoms (dyspnoea, tachycardia, and dizziness) to those of other common cardiorespiratory diseases such as heart failure, asthma and chronic obstructive pulmonary disease (COPD). The high rates of misdiagnosis of DB suggest that health care professionals do not fully understand this condition and may therefore fail to provide patients with an appropriate treatment. A holistic assessment is the most appropriate way to improve understanding and diagnostic accuracy.

Keywords: dysfunctional breathing, hyperventilation, pulmonary function tests

Abbreviations
ACQ - Asthma Control Questionnaire
AQLQ - Asthma Quality of Life Questionnaire
BMI - Body Mass Index
BHT - Breath Holding Time
BPAT - Brompton Breathing Pattern Assessment Tool
CART - capnography-assisted respiratory therapy
COPD - Chronic Obstructive Pulmonary Disease
CPET - Cardiopulmonary Exercise Testing
DB - Dysfunctional breathing
ET-CO2 - end-tidal carbon dioxide measurement
HVPT - Hyperventilation Provocation Test
HVS - Hyperventilation syndrome
MARM - Manual Assessment of Respiratory Motion
NQ - Nijmegen Questionnaire
SEBQ - Self-Evaluation of Breathing Questionnaire

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Introduction

Dysfunctional breathing (DB) is a chronic or recurrent alteration of normal breathing pattern, recognized as an important differential diagnosis for individuals with "unexplained" dyspnoea.[1] Hidden in the complex management of many respiratory diseases, such as asthma, COPD and "long-COVID", DB may exacerbate these diseases/disorders, reduce symptom control and increase medication and healthcare service use.[2–6] Recently, more evidence-based classification, diagnostic criteria and treatment modalities of DB have been developed.[2]

Dysfunctional breathing in the modern era?

Eighty-five years ago a group of authors remarked: "Patients presenting well known pattern of symptoms haunt the offices of physicians and specialists in every field of medical practice. They are often shunted from one physician to another, and the sins of commission inflicted upon them fill many black pages in our book of achievement."[7]

In 1975, in the respiratory physiology department of Papworth Hospital, Cambridge, England, the specialists dubbed this phenomenon simply as the "multiple doctor" or the "fat folder syndrome".[8] In the late 1960's, one of the newly reported major side effects of recently introduced oral contraceptives was venous thromboembolism. Since then, as many physicians encountered young ladies taking birth-control pills that reported syncopal attacks and other possible manifestations of pulmonary embolism, dysfunctional breathing (most known as "hyperventilation syndrome" (HVS) has become more and more recognized in different clinical settings.

Definition

There is no formal definition of DB. Barker and Everard reviewed the literature and suggested a new definition of DB: "an alteration in the normal biomechanical patterns of breathing that results in intermittent or chronic symptoms which may be respiratory and/or non-respiratory".[9] Various terms have been used: earlier it was mainly described as a hyperventilation syndrome, while nowadays it is more often called dysfunctional breathing, functional breathing disorder, breathing pattern disorder and behavioural or psychogenic breathlessness, etc. The later terminology results from better understanding of pathophysiological processes underlying the abnormal pattern of breathing which itself does not necessarily include hyperventilation. In this narrative review we will prefer the term "dysfunctional breathing".

Aetiology and pathophysiology

Efficient breathing results from balanced motion between the upper rib cage and the lower rib cage and the abdomen. It requires synchronized movement of diaphragm, abdominal and rib cage muscles.[10] Discoordination of muscle contractions results in sensations of dyspnoea and is often present in DB, especially in apical, thoracic dominant breathing.[11]

A simplified physiological process encountered in hyperventilation may help partly understand relationships between causes of DB and its consequences (Figure 1). Hyperventilation is an increase in ventilation that is greater than that required by metabolic needs or arterial blood gas tensions. It may be acute, episodic, and chronic. Furthermore, it has been well-described that stressful events, especially emotional upset, can elicit a habitual change in breathing pattern.[12] Indeed, changes in breathing depend on a variety of external and internal factors (i.e. cold, heat, hypoxia, pain and panic).[13] DB can be described as a habit in breathing and in some cases includes over-breathing (increase in both tidal volume and respiratory rate). Thus, it may result in decrease in carbon dioxide. Consequently, hypocapnia directly induces cerebral vasoconstriction and cerebral hypoxia, while kidneys excrete the excess bicarbonate ion. Hydrogen ion deficiency suppresses hydrochloric acid formation by the stomach as well. Further on, in the state of alkalosis, smooth muscles of the digestive tract also constrict, while haemoglobin slowly delivers smaller amount of oxygen (Bohr effect). Hypocalcaemia, secondary to calciuria induced by alkalemia, results in poor muscle and nerve function, e.g. hyperexcitability of skeletal and visceral muscles. As in the *vicious circle*, all potential resultant symptoms (Table 1) exaggerate previously existing anxiety, which in its turn, aggravate disordered pattern of breathing. The regulation of breathing involves both voluntary (cortex) and involuntary (neural, emotional, endocrine, and metabolic) control mechanisms. Numbers of hormones participate in ventilatory regulation. For example, hyperventilation with resultant hypocapnia may be present during the luteal phase of the menstrual cycle as well as in pregnancy.[14] However, respiratory complaints appear to have a stronger relationship to breathing pattern.[15] Thus, pathophysiological mechanisms underlying DB require further research on the levels of neural ventilatory control and skeletal muscle metabolic function, which would include processes in the normocapnic settings as well.[16]

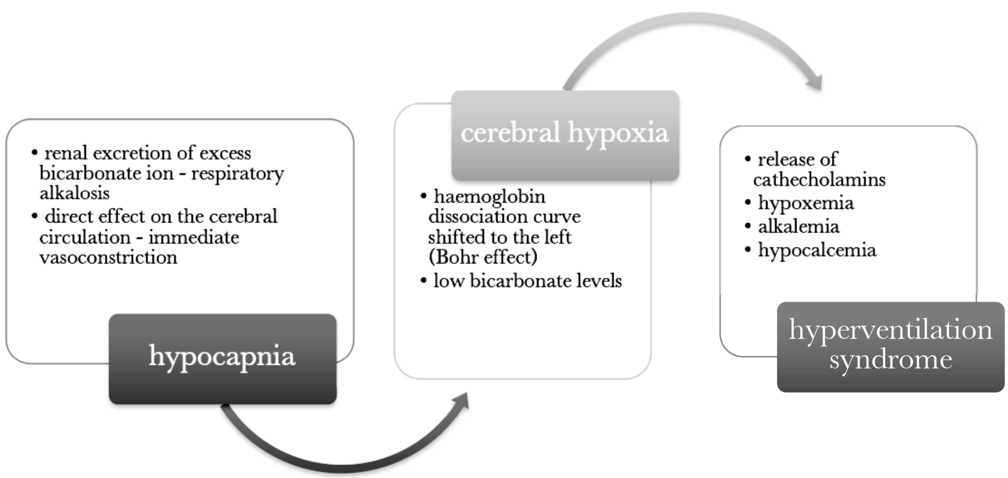

Figure 1.Pathophysiologic process in hyperventilation

Epidemiology

The prevalence of DB in general population is estimated to be approximately 8%.[8] As the disordered is ill-defined without standardized diagnostic tools, it is hard to estimate its true prevalence. Dysfunctional breathing may affect individuals across all age groups and is more often found in asthmatics who are female, with poor asthma control, frequent exacerbations and comorbid anxiety states.[17–19]

Presentation

The key respiratory symptom in dysfunctional breathing is breathlessness ("air hunger"). Non-respiratory associated symptoms may be attributable to hyperventilation (increased minute ventilation) and respiratory alkalosis such as paraesthesia (i.e. tingling), numbness, dizziness, palpitations and, rarely, tetany. Also, frequently reported are chest tightness, chest pain, deep sighing, exercise-induced dyspnoea and frequent yawning. However, none of the symptoms are specific to dysfunctional breathing.[20]

Table 1. Symptoms and signs of disfunctional breathing

System	Most probably caused by hypocapnia in hyperventilation
Cardiovascular	Palpitations, tachycardia, precordial pain, cold hands or feet
Respiratory	Shortness of breath, chest pain, chest tightness
Gastrointestinal	Globus, dysphagia, epigastric pain, aerophagy, bloated feeling in the stomach
Neurological	Central: dizziness, disturbance of consciousness, blurred vision, Peripheral: paresthesia (tingling fingers), tetany (rarely)
Musculoskeletal	Muscle pains, tremors, tetany
Psychic	Feeling tense, anxiety
General	Fatigability, weakness, exhaustion, sleep disturbance, nightmares

In order to better illustrate respiratory complains that may be evaluated, we quote in *Table 2* the questions included in a preliminary version of Self Evaluation of Breathing Questionnaire, revised by Courtney R and Greenwood KM.[21]

Table 2. The Self-Evaluation of Breathing Questionnaire (SEBQ), revised version (21).

"I get easily breathless out of proportion to my fitness"
"I notice myself breathing shallowly"
"I get short of breath reading and talking"
"I notice myself sighing"
"I notice myself yawning"
"I feel I cannot get a deep or satisfying breath"
"I notice that I am breathing irregularly"
"My breathing feels stuck or restricted"
"My rib cage feels tight and can't expand"
"I notice that I am breathing quickly"
"I get breathless when I am anxious"
"I find myself holding my breath"
"I feel breathless in association with other physical symptoms"
"I have trouble coordinating my breathing when I am speaking"
"I can't catch my breath"
"I feel that the air is stuffy, as if not enough air in the room"
"I get breathless even when I am resting"
"My breath feels like it does not go in all the way"
"My breath feels like it does not go out all the way"
"My breathing is heavy"
"I feel that I am breathing more"
"My breathing requires work"
"My breathing requires effort"
"I find myself breathing through my mouth during the day"
"I breathe through my mouth at night while I sleep"

Classification

More than 45 years ago Lum and colleagues[8] proposed classification related to dominant pattern in breathing:

1. Rapid breathing.
2. Irregular amplitude of breaths.
3. Irregular rhythm.
4. Frequent sighs and yawns.
5. Habitual sniffing and coughing.
6. Fast breathless talking.
7. General tension in the whole body

Researchers have suggested a few alternative classifications for other patterns of DB.

Boulding and colleagues found that "tracking of respiratory flow, frequency and volumes during quiet tidal breathing, often performed before and after exercise, can give useful information to the clinician and be used for providing feedback to the patient." Further, they used those data to guide them in defining and classifying various dysfunctional breathing patterns.[2]

Classification of DB, by Boulding and colleagues:

1. *Hyperventilation syndrome* is associated with symptoms both related to respiratory alkalosis and independent of hypocapnia.
2. *Periodic deep sighing* represents frequent sighing with an irregular breathing pattern.
3. *Thoracic dominant breathing* is characterized by an absence of costal expansion and an increased reliance on upper thoracic muscles during inspiration. As a consequence, this type of breathing

results in high operating lung volumes and reduced inspiratory capacity, as in HVS. Also, it can frequently manifest in organic disease, but in the absence of disease it may be considered dysfunctional and results in dyspnoea.

4. *Forced abdominal expiration*: these patients utilize inappropriate and excessive abdominal muscle contraction to aid expiration. This type of DB results in very low lung volumes, and therefore a reduced functional residual capacity.

5. *Thoraco-abdominal asynchrony* is seen when there is delay between rib cage and abdominal contraction resulting in ineffective breathing mechanics.[2]

The most recognized model of DB is HVS, characterized by acute or chronic hyperventilation (increased minute ventilation) at rest or during exercise/stress. HVS may be part of somatic/physiological conditions, still it commonly develops secondary to psychological/behavioural factors (particularly anxiety, depression, perfectionism, and feelings of inferiority).[22–24]

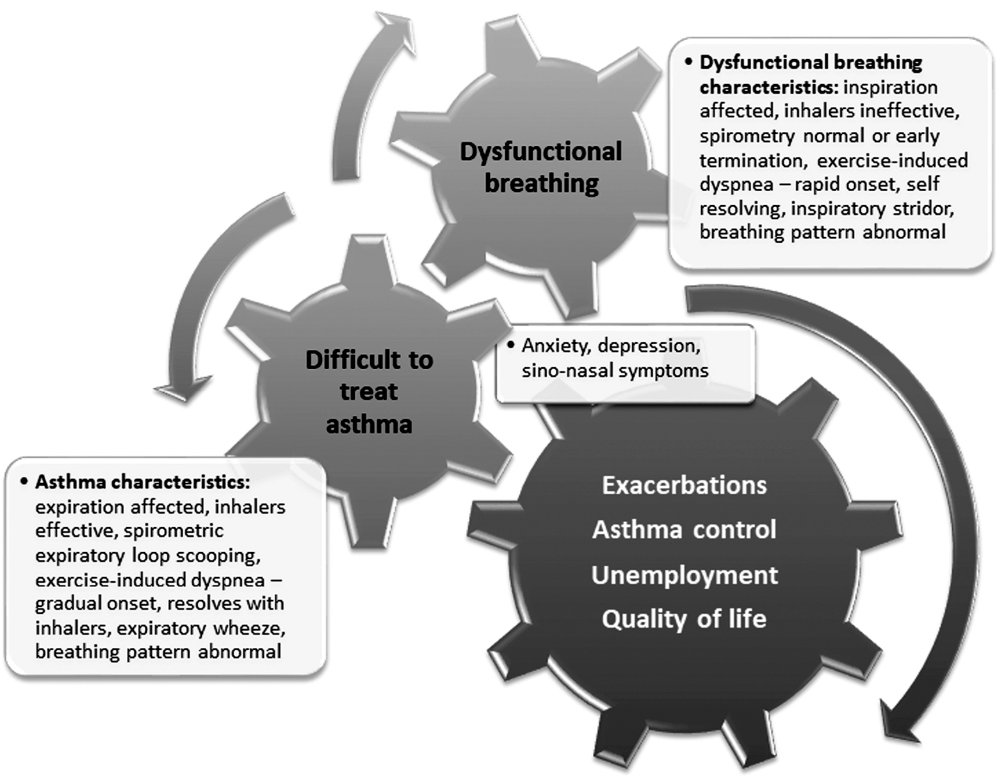

Figure 2. Differential diagnosis between DB and difficult-to-treat asthma and the detrimental effect of DB on asthma and asthma-related outcomes.[30,31]

Modified from:
Denton E, Bondarenko J, Tay T, et al. Factors Associated with Dysfunctional Breathing in Patients with DifficulttoTreat Asthma. J Allergy Clin Immunol Pract. 2019;7(5):1471-1476.
Connett GJ, Thomas M. Dysfunctional Breathing in Children and Adults With Asthma. Front Pediatr. 2018;6:406.

Associated conditions

DB can occur either in the absence of organic diseases (i.e., due to psychogenic causes such as anxiety) or it may be coexisting with respiratory diseases (asthma, COPD, interstitial lung diseases), cardiovascular disease, thoracic wall abnormalities, hyperventilation in anxiety related disorders and panic disorder. Symptoms of DB can mimic asthma, which may influence the level of disease control and potentially lead to overtreatment, especially in difficult-to-treat and severe asthma phenotype, as illustrated in *Figure 2*.[17,25,26] The expected treatment success with bronchodilators and anti-inflammatory medicines may be substantially reduced due to the presence of disorder in breathing pattern. Among individuals with asthma, a positive diagnosis of DB is found in a third of women and a fifth of men.[27] Also, DB may exacerbate myofascial pain syndromes, such as temporomandibular joint disease [28], and other common conditions such as headaches and migraines.[29] DB is present in the so-called 'long COVID' syndrome as part of a long-lasting dyspnoea associated with previous SARS-CoV-2 infection persisting for months after acute infection.

Diagnostic methods

Diagnosis of DB may be established only after assessment, exclusion or adequate treatment of other possible conditions. A gold standard diagnostic method is yet to be established. Several questionnaires and functional tests have been used with less or more success. Tools should help multidimensional evaluation of breathing as it comprises three main functions: gas exchange (lung function), change in posture and movement of the trunk (biomechanical function)[9] and a "sense of self" (mental function).[32,33] We offer a brief algorithm in assessment of DB (*Figure 3*).

The Nijmegen Questionnaire (NQ) was introduced and validated in individuals with exercise induced hyperventilation syndrome, where it shows sensitivity of 91% and specificity of 95%. The questionnaire consists of 16 items of which seven are linked with respiratory symptoms, four assess excessive ventilation and five relate to central nervous system symptoms. Questions are answered in a few minutes on a five-point scale ranging from 'never' (0 points) to 'very often' (4 points).[34] The score ranges from 0 to 64, with cut-off value of 23 and more points that best indicates HVS. However, elevated score is not diagnostic of a specific syndrome. The questionnaire has been increasingly used as an outcome measure in various clinical and research settings for physiotherapists and other specialists. The cut-off value to detect DB and distinguish it from other abnormalities depends on the context in which the NQ is used, i.e. in poorly managed asthma, COPD, panic disorder and anxiety, where its specificity may be lower.[6] Actually, the score measures "functional respiratory complaints" meaning that it refers to ventilation, dyspnoea and breathing movement in relationship with stress and anxiety. Van Dixhoon and group of authors[34] that developed the questionnaire comment that "it detects transdiagnostic and probably nonmedical abnormality", "reflects a subjective aspect of DB" and that "early detection of these tension related complaints would prevent unnecessary visits to medical specialists and treatment". The NQ is not copyrighted (free to use) but depends heavily on patients' understanding of questions and adequate self-assessment.

The Self-Evaluation of Breathing Questionnaire (SEBQ) includes 25 questions of which 23 refer to breathing or forms of breath. Thus, it is complementary to NQ as it evaluates more respiratory symptoms related to the manual assessment measure.[35] In a study by Courtney R and Greenwood KM, SEBQ demonstrated both very high test–retest reliability and internal consistency in a group of adults from the general population.[21] However, as they concluded, "whilst SEBQ may bring a greater sensitivity than alterna-

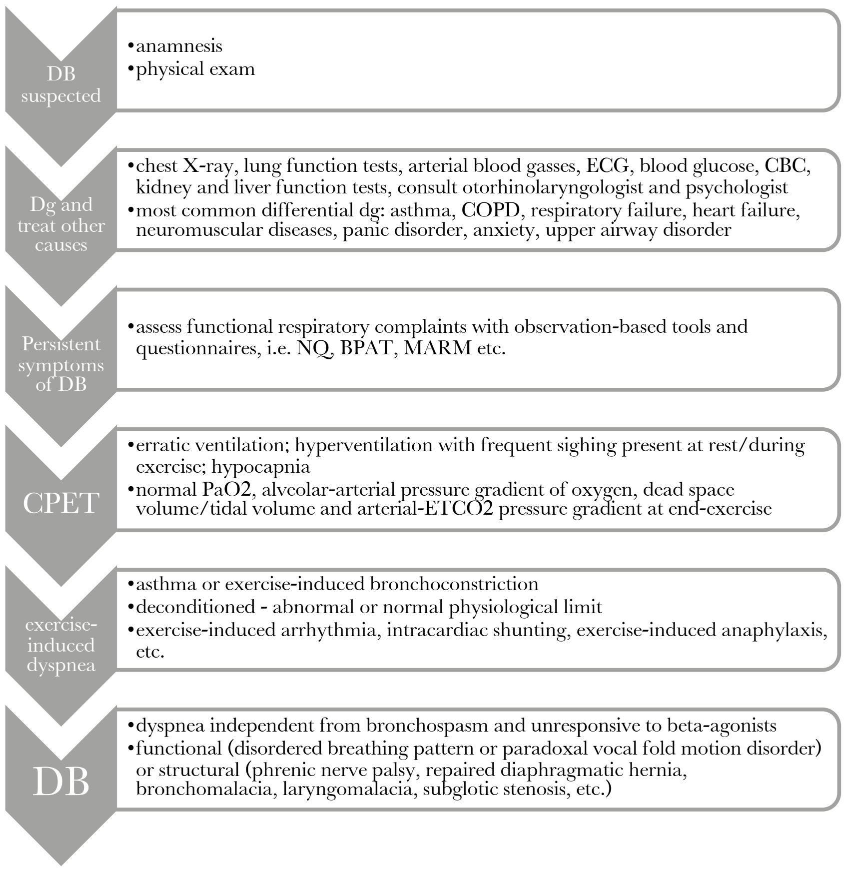

Figure 3. An example of diagnostic algorithm for DB

tives to the assessment of DB-related symptoms because it is not oriented around the direct effects of hyperventilation, the trade-off may be reduced specificity, particularly for people with respiratory medical conditions such as asthma, for whom similar symptoms might arise from pathological changes in airways rather than from disturbed biomechanical breathing patterns".

The Manual Assessment of Respiratory Motion (MARM) is a palpation technique based on the examiner's interpretation and estimate of motion identified by hands at the posterior and lateral lower rib cage. The MARM enables examiner to measure different aspects of breathing (i.e. rate, regularity). The most important part is to assess breathing pattern and the relative distribution of breathing motion between upper rib cage and lower rib cage and abdomen. The MARM is a practical and reliable tool for the breathing pattern assessment with good agreement between examiners. Moreover, one study comparing MARM with respiratory induction pletizmography found that it can better distinguish thoracic from abdominal breathing.[36]

The Brompton Breathing Pattern Assessment Tool (BPAT) is, like MARM, a tool used by the observer (i.e. physiotherapist).

The BPAT includes assessment of abdominal or apical breathing, inspiratory and expiratory flow, inspiration and expiration through mouth or nose, air hunger, breathing rate and rhythm.[17] Recently, it appeared to be a useful screening tool for identifying DB in patients with difficult-to-treat and severe asthma (with score ≥4 as a cut-off for diagnosing DB was confirmed with sensitivity 95% and specificity 78%).[37] Similarly, it is useful in evaluating DB in long COVID (12 weeks after confirmed or presumed pneumonia caused by SARS-CoV2 virus). Using the established cut-off, it showed a sensitivity of 89.5% and specificity of 78.3%.[3]

The Hyperventilation Provocation Test (HVPT) requires voluntary hyperventilation for several minutes and is considered positive if symptoms of HVS are recognized by the examinee. Earlier, the test was a gold standard for diagnosing HVS and the symptoms of HVS were largely attributable to hypocapnia (low end-tidal carbon dioxide). However, a high percentage of false-positive results during the HVPT has been found in studies with a control condition of stressful mental load.[38,39] What is more, when limiting symptoms to hypocapnia, a study in the Lancet found a high rate of false positives (66%) in patients where end-tidal pCO2 was maintained at baseline value by manual titration of carbon dioxide from the cylinder into the inspired air.[40]

The end-tidal carbon dioxide measurement (ET-CO2) is measured using capnography with an expected low ET-CO2 in hyperventilation.[41]

The Breath Hold Test or *Breath Holding Time (BHT)* is an indicator of a person's ventilatory response to biochemical (sensitivity to hypoxia and hypercapnia), biomechanical (lung volumes), non-chemical factors, and psychologic factors, as well as training, exercise and altitude, etc. For example, divers may accommodate to the absence of respiratory movements (non-chemical factors for ventilatory response) and prolong BHT to 40 or 50s.[42] A short BHT (<30s) after normal expiration at functional residual capacity is considered to be related to DB. A physician Konstantin Buteyko, M.D., Ph.D., that developed breathing technics to reduce HVS claimed that BHT can detect chronic hyperventilation and that BHT predicts alveolar CO2 (PaCO2) according to his patented mathematical formula.[41,43]

Finally, to objectively evaluate breathing patterns in various clinical and outpatient settings, an ideal system should tend to fulfill the following characteristics: (1) Accurate calculation of volume changes without using a mouthpiece that may alter the normal breathing pattern; (2) Need of a simple, stable and repeatable calibration; (3) Possibility of use in non-collaborating subjects (during sleep, or in unconscious patients); (4) Permitting the analysis in different postures; (5) Permitting the analysis under dynamic conditions such as walking or cycling; (6) Allowing high frequency response in order to accurately describe rapid phenomena (i.e. electric or magnetic stimulation of phrenic nerves); (6) Allowing the analysis of movements and volume changing of the upper thorax, lower thorax, and abdomen; (7) Allowing the analysis of movements and volume changing of the hemi thoraces; (8) Being non-invasive and safe for the patient.[44] Different techniques with various limitations are available for measuring natural breathing at rest - tidal breathing patterns, as well as exercise-induced changes in breathing. A less frequently used techniques include pneumotachography, respiratory induction plethysmography optoelectronic plethysmography and structured light plethysmography. These vary in the source of the signal and the type of parameters that are generated, such as thoraco-abdominal asynchrony.[45–47] Only structured light plethysmography does not necessitate direct contact with patient's body and is less dependent on patient's cooperation.[47] How-

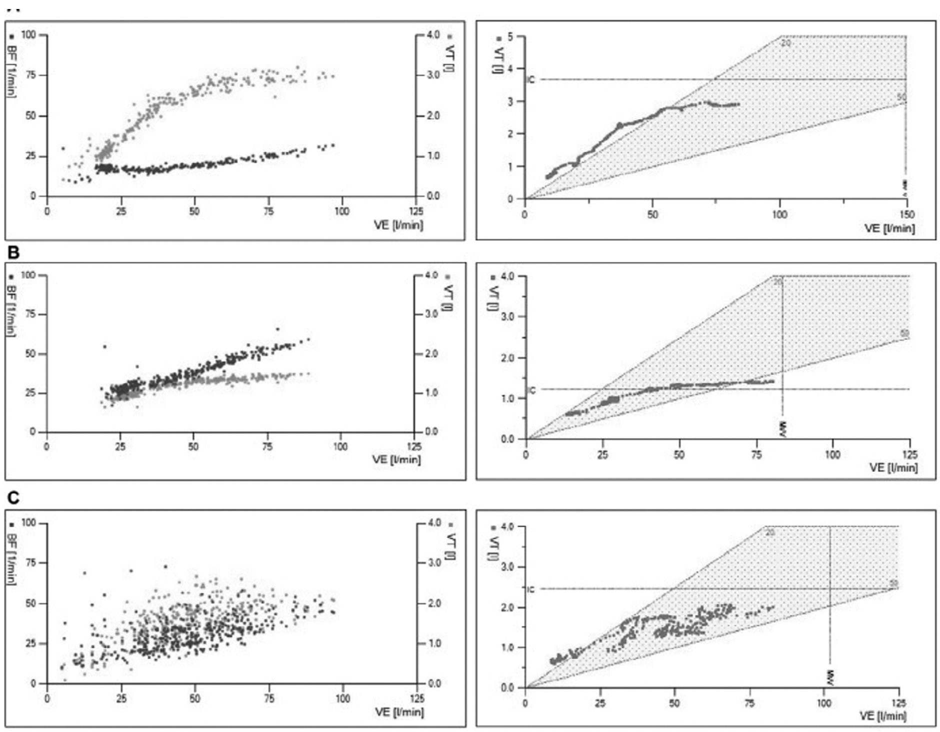

Figure 4. Ventilation slopes and Wasserman panel (VT/V'E). (A) Normal subject. (B) Respiratory limitation showing a regular, but limited increase of tidal volume with high breathing frequency. (C) Dysfunctional breathing with an erratic pattern. Plots of tidal volume (VT on the right y-axis) and breathing frequency (BF on the left y-axis) against minute ventilation (V'E on the x-axis) during incremental exercise testing. Data are not filtered in the ventilation slopes. Geratherm Respiratory combined filter is used in the Wasserman panel (VT/V'E). BF, breathing frequency; VT, tidal volume; V'E, minute ventilation.[51]

ever, these techniques are resource- and evidence-limited and need further clinical and experimental research.[48]

Cardiopulmonary Exercise Testing (CPET) is the most detailed diagnostic tool to objectify breathing patterns during exercise and it represents "an ideal candidate" for gold standard among proposed diagnostic methods for DB.[12] A major benefit of CPET is that, in contrast to the questionnaires and observation-based approaches, it offers objective measurements and plots data which can be directly analysed. Erratic ventilation, hyperventilation with frequent sighing present at rest or during exercise and recorded in the respiratory panels of CPET can bring up to a diagnosis of DB. Furthermore, CPET may unravel the mechanisms of breathlessness by simultaneously evaluating cardiovascular adaptation, ventilation, and gas exchange through exercise. CPET permits recognition of any pathophysiological cause of exertional dyspnoea which would not manifest during tests performed at rest.[49–51] Precisely, patients with DB usually present with high frequency of breathing at rest which rises swiftly at the begging of exercise, while tidal volume may remain stable. This can increase dead space ventilation and change the kinetics of multiple CPET variables. Also, decreasing $PaCO_2$ set point in rapid shallow breathing, as seen in hyperventilation type of DB, typically induces ventilatory inefficiency characterized by high minute ventilation/CO2 output (VE/VCO2 slope), with generally a normal dead volume/tidal volume ratio. Important to notice is that increase in end-inspiratory and end-expiratory lung volumes, as seen in hyperinflation, therefore reduces inspiratory capacity and possibly contributes to the troublesome dyspnoea sensation regardless of the existence of true hypocapnia.[2] However, other types of DB with normal PaCO2 and VE/VCO2 have been described, in particular, erratic ventilation with wide and irregular variations of tidal volumes and breathing frequency over the progression of effort during CPET.[52] Boulding and colleagues suggested a classification of DB patterns according to incremental CPET data, as well as change in breathing frequency, tidal volumes, and respiratory muscle mechanics before and after exercise.[2] Analysis of ventilation patterns on CPET may contribute in differentiating types of breathing dysregulation in people with dyspnoea present in the absence of deconditioning as a post–acute-phase sequelae of mild infection with SARS-CoV2 virus. Nonetheless, one should consider its highly demanding resources and setups in the context of the high prevalence of post-COVID-19, as well as the fact that "exercising at physiological limits may exacerbate symptoms in these patients, also referred to as postexercise malaise".[12,53] An example of CPET in a normal subject compared with a person with limited tidal volume and high breathing frequency and a person with dysfunctional breathing is showed in *Figure 4*.[51]

Differential diagnosis should always and firstly include all diseases that can be the cause of dyspnoea in the first place, and also, may be associated with DB. The finding of erratic breathing on CPET cannot exclude accompanying disease, nor can it precisely confirm DB diagnosis. Most frequently patients with DB present with resting hypocapnia and normal PaO2, alveolar-arterial pressure gradient of oxygen, dead space volume/tidal volume and arterial-ETCO2 pressure gradient at end-exercise. These findings can help differentiate from other conditions in which chronic hyperventilation occurs, as in patients with increased dead space ventilation, such as those with heart failure or pulmonary hypertension. Similarly, an identified marker of disease severity in patients with heart failure due to left ventricular systolic dysfunction is periodic breathing. As happens in DB, it may develop at rest or during exercise and last throughout the entire period of incremental workload or disappear facing the end of exercise. However, the characteristic periodicity of waxing and waning of tidal volumes (minute ventilation, as well) present in periodic breathing is in sharp contrast to the unpredictable and irregular breathing pattern of DB. Further, thoracic-dominant patterns may be present in morbidly obese patients in response to their low abdominal compliance. At last, one must consider asthma and COPD, where patients may develop thoracic-dominant and forced expiratory breathing patterns as a physiological adaptive response to pulmonary hyperinflation, in which case they should not be regarded as dysfunctional.[12] Ionescu and colleagues proposed a diagnostic and therapeutic algorithm for patients with unexplained dyspnoea. Starting with high clinical suspicion of DB, electrocardiography, chest radiography and spirometry test should be one of the first tools to exclude or prove possible cardiopulmonary etiologies of dyspnoea. If symptoms persist after adequate management, the next step is CPET. If there is good fitness on CPET with no evidence of DB, reassure the patient and discharge. If there are abnormalities present in terms of cardiac, ventilatory, gas exchange or metabolic parameters on CPET, proceed to targeted management. If there are, in addition or alone, one or more features of DB identified on CPET, refer the patient to a chest physiotherapist, with targeted therapeutic intervention.[12]

Combining different tools possibly could be the best choice as it may increase diagnostic accuracy. For example, in the recent studies the NQ was used to evaluate symptoms related to DB, and supplemented with the BPAT to objectively assess breathing pattern in patients with difficult-to-treat asthma.[17,25] Identifying DB as a co-morbidity in difficult-to-treat asthma is of a special interest, to avoid potentially harmful or costly overtreatments such as oral steroids, or biological treatments. One group of researchers found that almost quarter of patients referred to severe asthma clinic had only DB.[17] In comparison, Sedeh and colleagues[25] firstly comprehensively and systematically verified asthma diagnosis in all participants, then assessed disease severity according to international recommendations[26] and, at last, applied the NQ, BPAT, as well as Asthma Control Questionnaire (ACQ) and Asthma Quality of Life Questionnaire (AQLQ). The researchers found that patients with uncontrolled asthma and DB were mostly female (74%), had higher body mass index (BMI), had significantly poorer asthma control and lower quality of life compared to patients without DB. After adjusting for BMI the relationship between DB and poor asthma control, did not change, meaning that symptoms of DB were not induced by obesity. Also, DB alone, the NQ score as well as the BPAT were an independent determinants of ACQ-score meaning that the adverse impact of DB on asthma control could not be explained by other factors such as more bronchial hyper-responsiveness or lower lung function in patients with DB. Moreover, patients with a low NQ, but high BPAT (objective signs of DB), had a significantly poorer asthma control, compared to patients with both low NQ and low BPAT. Similar results were found in one study on asthma patients using the NQ and ACQ-score.[54] Difficult-to-treat asthma is asthma that is uncontrolled despite medium/high dose inhaled corticosteroids with a second controller, or on maintenance oral corticosteroids or that requires such treatment to maintain good symptom control and reduce the risk of exacerbations.[26] The aforementioned findings reinforce the idea to routinely search for DB in the patients referred for specialist management of asthma.[25,54] Further investigations are necessary to determine a possible benefit of physiotherapeutic treatment in reduction of inhaled corticosteroids use in patients with concomitant asthma and DB.

Treatment

Patient education about the condition, reassurance
Abdominal breathing retraining
Breathing rate and depth control
Breathing retraining in progressively taxing postures such as walking
Recognition of triggers
Control of symptoms during an episode of DB and manual therapy

Various modes of breathing retraining programs guided by a qualified professional (e.g. physiotherapist) are recommended, such as breathing control, diaphragmatic breathing, yoga breathing, Buteyko breathing, biofeedback-guided breathing modification, and yawn/sigh suppression.[55,56]

Educating patients about DB is the key and the first step in the program. Helping patients differentiate symptoms of DB from the associated conditions, such as asthma, is an important goal. For instance, DB would not respond to targeted treatments for asthma.

One randomized controlled trial by Lindeboom and colleagues compared relaxation therapy versus relaxation therapy and breathing exercises.[57] According to a Cochrane review[58], the results of this study "describe a significant reduction in frequency and severity of hyperventilation attacks in the breathing exercise group compared with the control group, which demonstrated an increase in the frequency and severity of attacks. In addition, a significant difference in frequency and severity of hyperventilation attacks between the breathing and relaxation group was reported."

Diaphragmatic (abdominal) breathing represents breathing in slowly and deeply through the nose using the diaphragm with the least possible movement of the chest in a supine position with one hand laid on the chest and the other on the umbilical region. Lately, a systematic review has reported that mind–body exercises, such as yoga or tai chi, which incorporate diaphragmatic breathing can lower effect of intense stress or unfavourable emotions by balancing the sympathetic and vagal tone.[59] Even through many trials have found that breathing exercises are helpful in treating COPD, asthma, and postoperative pulmonary function, the efficacy of diaphragmatic breathing in managing other diseases/disorders, i.e. cancer, heart failure, and anxiety, still needs to be studied further. To stress out, diaphragmatic breathing may worsen dyspnoea in severe COPD patients.[55]

A novel mind-body breathing therapy intervention adjunct is a capnography-assisted respiratory therapy (CART) has found application in COPD-related DB management. CART consists of patient-centered biofeedback, tailored breathing exercises, a home exercise program and motivational interviewing counselling.[60]

Primary therapeutic outcome should be improvement in quality of life. Secondary outcomes mainly include the Nijmegen questionnaire score, minute volume, tidal volume, respiratory frequency, ET-CO2 or transcutaneous CO2 measurement, and functional exercise capacity. However, over the course of the therapy, evolution from the first assessment to consecutive follow-ups is frequently recorded using NQ, SEBQ, or BPAT scores. As aforementioned, these tools subjectively differentiate symptoms and breathing pattern. What is more, there is risk of bias in process monitoring. After initiating therapy, a patient filling out a questionnaire may, either intuitively or intentionally, answer the questions as they perceive the practitioner wishes them to, lowering the scores given to describe the presence of their symptoms in order to demonstrate the treatment is working. Similarly, the practitioner knows that the patient has received therapy and so will be searching for proof that therapy has been successful. In reality, it has been noticed that patient symptoms and quality of life improve, as assessed in one study with Asthma Quality of Life Questionnaire, even though the NQ/SEBQ/BPAT scores do not substantially increase from the baseline.[61] CPET may be effective in the objective guidance of the breathing retraining process and in the monitoring of therapeutic effect.[12]

Conclusion

Taking into account the heterogeneity, psychological and physiological aspects of DB, a multidimensional, holistic assessment would appear the most correct approach to improve understanding and diagnostic efficiency. The current narrative review was composed in a manner of brief summary of the available data considering DB, in order to promote understanding of the disorder by health care professionals. Upgrading knowledge of the etiologic and pathophysiologic factors, diagnostic tools and treatment options in DB management enables practitioners to improve health-related quality of life in people experiencing breathing pattern abnormalities.

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