Paediatric Respiratory Reviews 24 (2017) 29–31

Contents lists available at ScienceDirect

Paediatric Respiratory Reviews

Clinical usefulness

Dyspnea in Children: What is driving it and how to approach it

Larry C. Lands

Pediatric Respiratory medicine, Montreal Children's Hospital-McGill University, Health Centre

EDUCATIONAL AIMS

The reader will:

- Recognize the principal qualities of dyspnea
- Quantitate the degree of dyspnea
- Employ a diagnostic approach with appropriate utilization of laboratory tests

ARTICLE INFO

Keywords:
Breathing discomfort
neurocognition
asthma
exercise

ABSTRACT

Dyspnea in children has important physical and psychosocial impact. It is useful to define the quality of the dyspnea and quantify its magnitude in a child-friendly manner. Through careful history taking and physical examination, a targeted investigation can lead to identification of the cause and potential treatment. This article provides a framework for the clinical approach to dyspnea in children, including important information to gather during the history, physical assessment, how to quantify dyspnea, and choice and use of laboratory measurements.

© 2017 Published by Elsevier Ltd.

INTRODUCTION

Dyspnea is a subjective sensation, akin to pain [1]. A combination of breathing qualities produces the sensation of breathing discomfort. Breathing qualities include a sense of work or breathing effort, chest tightness, air hunger or a sense of insufficiency of inspiration, and occasionally others, such as those related to cardiovascular disease. The relative importance and significance of these qualities varies with the situation for an individual and between individuals, very much like the sensation of pain. In fact, much of the modelling of our understanding of dyspnea comes from pain research.

An interaction between physiological and psychological factors, along with social and environmental inputs, result in dyspnea, which in turn, leads to physiological and behavioural changes [1]. Interplay between afferent signals and higher cerebral functions leads to the sensation and impact of dyspnea [2]. Afferent signals can be grouped into those coming from the central nervous system and peripheral chemoreceptors, pulmonary receptors such as stretch and irritant receptors, peripheral skeletal muscle, and chest wall and skin receptors.

To illustrate this interaction between higher cerebral functions such as context, mood, and cognition, and the sense of dyspnea, patients with chronic obstructive pulmonary disease had a marked rise in the sensation of dyspnea when given word clues such as "climbing stairs", compared to healthy individuals [3]. Functional brain imaging shows that acute experimental dyspnea activates the insular cortex, and the anterior cingulate cortex and amygdala

E-mail address: larry.lands@mcgill.ca.

http://dx.doi.org/10.1016/j.prrv.2017.03.013
1526-0542/© 2017 Published by Elsevier Ltd.

[2]. The right insular cortex, responsible for recognizing physiological condition and initiation of homeostatic compensation, is activated in elite athletes when given a resistive load [4]. It is interesting to note that the elite athletes demonstrated an increase in activation in anticipation of the load, and a reduced activation during, and following the load, compared to untrained individuals. This was similar to what was observe in Navy SEALs during a test of emotion face-processing [5]. Elite athletes were also able to maintain accuracy on the task, compared to the untrained control subjects. It is unclear whether elite athletes respond in this manner due to training or to innate ability, enabling them to become elite athletes.

The degree of dyspnea can be quantified using a variety of scoring methods [6]. The standard method used for adults is the 10-point Borg Category-Ratio Perceived Exertion Scale [7], also known as the modified Borg scale. Children may have difficulties with such a scoring system or using a visual analog scale. The difficulty with these analog scales is their linearity that does not reflect the marked increase in breathlessness that occurs at maximal exercise. Pictorial representations, such as the Dalhousie Dyspnea and Exertion Scale, may be much more comprehensible for children, do not rely on translation, and show good reproducibility [8]. Typically subjects reach a moderate level of dyspnea (7/10 on modified Borg scale, 5/7 on Dalhousie scale).

A common situation where dyspnea can occur is asthma. In adults presenting for emergency care, dyspnea scores improved after the first treatment with bronchodilators, as did lung function (FEV_1, Forced Expiratory Volume in 1-second) [9]. With subsequent treatment with bronchodilators, dyspnea continued to improve, but lung function did not. When exploring the qualities of dyspnea, chest tightness decreased from presentation through the course of bronchodilator treatment. However, the sense of work or breathing effort persisted, and indicated persistent reduction in lung function. Thus, simply recording dyspnea, and not the qualities of dyspnea, can lead to an overestimation of the degree of lung function improvement with bronchodilatation. In a study of adults with asthma, dyspnea qualities were assessed following bronchoconstriction with methacholine to provoke either a 15% or 25% fall in FEV1 [10]. Chest tightness and difficulty of inspiration increased more than unrewarded inspiration or difficulty with expiration. Symptom perception was partially related to mechanical factors, as assessed by forced oscillation.

It has also been suggested that patients with more severe asthma may poorly perceive their degree of respiratory difficulty. A study in children asked them to rate their dyspnea using the modified Borg scale during a methacholine challenge to determine their score at which there was 20% decrease in FEV1 [11]. This score positively correlated with baseline lung function and the methacholine dose provoking a 20% fall in FEV1. In other words, those with higher initial lung function and less bronchoreactivity had higher dyspnea ratings when their lung function decreased by 20%, so that those with better controlled asthma were more perceptive of the loss of lung function.

The sensation and impact of dyspnea in children with asthma was eloquently explored by Woodgate [12]. Dyspnea included both physical and emotional sensations. The children recognized provoking factors, and how asthma led to self-limitation of activities and feelings of isolation. The remembrance of remote severe episodes had long term negative impact on the children's feelings about asthma.

Both dyspnea and leg effort can be assessed during exercise, as discussed previously [6,8]. Typically there is a lag before the sense of respiratory effort increases; in children this occurs at about 40% of maximal ventilation, while it occurs between 20-40% of maximal ventilation in adults. In a retrospective review of children evaluated for dyspnea in the exercise lab, the majority had simple normal physiological limitation [13]. Other important causes were previously unrecognized restrictive disorders, exercise-induced hyperventilation, and exercise-induced bronchospasm.

MAKING THE DIAGNOSIS

The basis for making a correct diagnosis of the cause of dyspnea is history and physical examination. It is important to first ascertain that it is dyspnea and then tease out the qualitative elements of the dyspnea (sense of effort, chest tightness, and air hunger). The timing of dyspnea is important, including whether the dyspnea is recent or long standing, whether it is consistent and reproducible, and whether it is provoked by exercise or other situations [14,15]. In this regard, it is important to recall that there are a variety of non-pulmonary causes of dyspnea, including musculoskeletal causes, cardiac and cardiovascular causes, upper airway sources, systemic or metabolic causes, and other situations such as the competitive athlete (Table 1). Other factors that figure prominently in children in the peri-adolescent period include anxiety and rapid limb growth in the adolescent leading to physical (and potentially social) awkwardness.

History

A variety of questions will assist in determining the need for further investigation and the use of laboratory tests (Table 2) [14,15]. These include whether there are associated respiratory signs, such as noisy breathing and cough, previous history of asthma, the environmental context of the dyspnea events, symptoms related to activity and the context of the activity (eg competing in a sports event), and symptoms suggesting hyperventilation. Questions to ask that would suggest the need for a cardiac evaluation include whether there is chest discomfort or palpitations, whether there is light headedness or has the person lost consciousness during exercise, and whether there is a family history of serious cardiac disease or sudden death. The timing of onset of dyspnea can also suggest its cause. Dyspnea at peak

Table 1
Extra-Pulmonary Causes of Exertional Dyspnea.

Musculoskeletal
Trauma, thoracic and spinal column malformations (eg., kyphoscoliosis), costochondritis
Cardiovascular
Arrhythmias, myocarditis and pericarditis, pulmonary embolism, rarely ischemia
Upper airway
Vocal cord dysfunction, laryngospasm, malformations (eg., tracheal web)
Systemic or Metabolic
Anxiety, highly competitive athlete, dysproportional limb growth, anemia, metabolic acidosis

Table 2
Questions to Ask about Dyspnea.

Qualities of dyspnea-sense of effort, chest tightness, air hunger
For how long have symptoms been present?
Is there worsening of dyspnea or development of associated symptoms?
Situations that dyspnea occurs?
Has there been a recent change in the environment where dyspnea is occurring?
Is there a history suggestive of asthma?
Are the symptoms recurrent and reproducible?
Is there excess fatigue during exercise or other situations?
Is there associated noisy breathing? If so, is it on inspiration, expiration, both?
Is there coughing? If so, is it dry or productive?
Is dyspnea related to athletic competition, and if so, what is happening with performance during competition?
Is there numbness or tingling in fingers or toes associated with the dyspnea?

Table 3
Laboratory Testing for Dyspnea.

Pulmonary Function: spirometry pre- and post-bronchodilators, lung volumes, diffusing capacity, respiratory muscle strength
Oxygen saturation by pulse oximeter Chest radiograph Complete Blood Count and differential Capillary blood gas Electrolytes, urea nitrogen, creatinine, Thyroid Stimulating Hormone Formal exercise testing Provocation testing (Cardiology: ECG and echo)

exertion that improves with reduction of effort suggests cardiac arrhythmia or vocal cord dysfunction or laryngospasm. In contrast, exercised-induced bronchospasm comes on with sustained effort of relatively high intensity and wains more slowly after exercise.

Examination

The following respiratory signs should be evaluated on physical exam: observation during quiet breathing including respiratory rate and depth of breathing, notation of voice and phonation, use of accessory muscles or retractions and splinting, chest wall deformities including kyphoscoliosis, digital clubbing, and auscultation of both the neck and chest during both quiet and deep breathing. Heart rate and blood pressure should be noted and cardiac auscultation performed with the patient in both in the sitting and lying positions. A brief evaluation of muscular strength includes assessing the ability to raise the arms above the head (which also reflects thoracic cage strength) and being able to climb on and off the examination table.

Investigations

Laboratory testing should include complete pulmonary function testing (spirometry pre- and post-bronchodilators, lung volumes, diffusing capacity, and respiratory muscle strength). Resting oxygen saturation should be recorded and a chest radiograph performed (Table 3). Based upon the history and physical examination, blood tests to consider are a capillary blood gas, electrolytes, kidney function (blood urea nitrogen and creatinine), and Thyroid Stimulating Hormone (TSH).

A progressive exercise test, typically using a cycle ergometer [16], may be required to make a diagnosis. This tests consists of 1-minute step-wise increments in workloads until the subject can no longer continue the effort. The step increments in workload are selected based on predicted maximal exercise equations and baseline lung function, such that the test is completed within 8–12 minutes. From this test, maximal exercise capacity and oxygen consumption can be assessed, along with whether there is any significant oxygen desaturation. The heart rate response, and the ventilatory response in terms of both the increase in respiratory rate and tidal volume are also assessed. Many centers will also measure the ventilatory threshold, the work capacity at which the slope of ventilation to work increases. Bloodless estimation of the dead space to tidal volume ratio can also be assessed.

To detect exercise-induced bronchospasm, an exercise provocation test may be required. This consists of having the subject exercise at 80-90% of their predicted maximum for 4–6 minutes, with repeated pulmonary function testing for up to 30 minutes [17]. Bronchoconstriction is more likely to be elicited if the subject breathes in cool dry air. Some centers will be set up to assess vocal cord dysfunction at the time of peak exertion with simultaneous nasal endoscopy.

Conclusion

Dyspnea is a sensation that is a personal experience. It has both physical and emotional significance for the individual. Children experience and recognize dyspnea, and this can be quantified using ready available numeric and pictorial scores. A carful history and physical examination are key to making the diagnosis and selecting the appropriate laboratory tests.

DIRECTIONS FOR FUTURE RESEARCH

- Central neural responses to increased respiratory effort in children
- Refinement and validation of dyspnea rating systems for children

References

[1] Parshall MB, et al. An official American Thoracic Society statement: update on the mechanisms, assessment, and management of dyspnea. *American journal of respiratory and critical care medicine* 2012;**185**(4):435–52.
[2] Herigstad M, Hayen A, Wiech K, Pattinson KT. Dyspnoea and the brain. *Respiratory medicine* 2011;**105**(6):809–17.
[3] Herigstad M, et al. Dyspnea-related cues engage the prefrontal cortex: evidence from functional brain imaging in COPD. *Chest* 2015;**148**(4):953–61.
[4] Paulus MP, et al. Subjecting elite athletes to inspiratory breathing load reveals behavioral and neural signatures of optimal performers in extreme environments. *PloS one* 2012;**7**(1):e29394.
[5] Paulus MP, et al. Differential Brain Activation to Angry Faces by Elite Warfighters: Neural Processing Evidence for Enhanced Threat Detection. *PloS one* 2010;**5**(4):e10096.
[6] Schweitzer C, Marchal F. Dyspnoea in children. Does development alter the perception of breathlessness? *Respiratory physiology & neurobiology* 2009;**167**(1):144–53.
[7] Borg G. Simple rating methods for estimation of perceived exertion. In: Physical work and effort. 1976;39–46.
[8] Pianosi PT, Huebner M, Zhang Z, Turchetta A, McGrath PJ. Dalhousie Pictorial Scales Measuring Dyspnea and Perceived Exertion during Exercise for Children and Adolescents. *Annals of the American Thoracic Society* 2015;**12**(5):718–26.
[9] Moy ML, Lantin ML, Harver A, Schwartzstein RM. Language of dyspnea in assessment of patients with acute asthma treated with nebulized albuterol. *American journal of respiratory and critical care medicine* 1998;**158**(3):5.
[10] Antonelli A, et al. Mechanical correlates of dyspnea in bronchial asthma. *Physiological Reports* 2013;**1**(7):e00166.
[11] Nuijsink M, et al. Perception of bronchoconstriction: a complementary disease marker in children with asthma. *Journal of Asthma* 2013;**50**(6):5.
[12] Woodgate R. The experience of dyspnea in school-age children with asthma. *MCN The American journal of maternal child nursing* 2009;**34**(3):9.
[13] Weinberger M, Abu-Hasan M. Pseudo-asthma: when cough, wheezing, and dyspnea are not asthma. *Pediatrics* 2007;**120**(4):855–64.
[14] Haddad F, Finocchiaro G, Myers J. 3A. Personal History: Have You Ever Had Excessive Shortness of Breath or Fatigue with Exercise beyond What Is Expected for Your Level of Fitness? *Current sports medicine reports* 2015;**14**(3):257–9.
[15] Kenny J-ES, Ruoss S. 3B. Personal History: Have You Ever Had Excessive Shortness of Breath or Fatigue with Exercise beyond What Is Expected for Your Level of Fitness? *Current sports medicine reports* 2015;**14**(3):259–60.
[16] Hebestreit H, et al. Statement on Exercise Testing in Cystic Fibrosis. *Respiration; international review of thoracic diseases* 2015;**90**(4):332–51.
[17] Parsons JP, et al. An Official American Thoracic Society Clinical Practice Guideline: Exercise-induced Bronchoconstriction. *American journal of respiratory and critical care medicine* 2013;**187**(9):1016–27.