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Breathing in classical singing: Linking science and teaching

Sally Collyer

Melbourne, Australia

This article addresses three issues. Firstly, breathing studies of trained classical singers have found high inter-singer variability, which raises many questions about the nature and role of breathing in singing; these study findings and their implications are discussed from a pedagogical perspective. Secondly, the article examines the resulting limitations inherent in a segmented model that divides voice into respiration, phonation, and articulation and that excludes key components from a narrow concept of a "breathing system." Finally, the article examines how this wider paradigm of singing-breathing inevitably positions breathing at the confluence of technique, emotion, and musical line.

Keywords: singing; breathing; pedagogy; lung volumes; kinematics

When classical singers and singing teachers are asked "what do you need to sing well?" the list almost always starts with "good breathing." Yet, despite hard work on all sides there remains a large gulf between research into breathing for singing and its influence in the teaching studio. There are three main reasons for the lack of interaction. First, singing teachers often find the concepts, techniques, and equipment used in breathing studies to be difficult to access. This lack of familiarity makes it difficult for teachers to interpret and apply research findings in the studio. Second, the scope of what is considered to be "the breathing system" is often too narrow, neglecting the respiratory contribution of elements not immediately associated with respiration. Last, conceptualizing breathing as simply air supply for phonation negates its role as the link between phonation, emotion, and musical line, a role that is crucial to singing and in teaching singing. This has led some pedagogical approaches to reject studies as unrealistic or irrelevant.

The article introduces, from a pedagogical perspective, some of the concepts and methods used in the study of breathing. The first section explains

certain assumptions, terminology, and techniques employed in the measurement of breathing generally and with respect to singing. The second section discusses problems that arise when paradigms of breathing employ a narrow definition of what constitutes the "breathing system." The third section explores how a wider paradigm supports a view of breathing more relevant to the role of breathing in singing and more consistent with historical vocal pedagogy. The paper is not intended to be exhaustive or prescriptive but to assist the teacher in accessing findings and exploring paradigms in other disciplines which have implications for the discipline of vocal pedagogy. The paper outlines the major points to be presented in the second and third sections, but particularly takes the opportunity to describe the measurement of lung volumes and chest-wall kinematics to assist the teacher in understanding implications for pedagogy.

MAIN CONTRIBUTION

Breathing studies

This section briefly describes the techniques used in breathing measurement. Interpreting any research requires an understanding of the background concepts and the methods used. Teachers who happily discourse on partials, the singer's formant, and the relationship between the thyroarytenoid and cricothyroid go silent at the mention of recoil, rib-cage volume contribution, or resting expiratory level. There is nothing inherently more complex about respiratory analysis than acoustical analysis, or about the physiology of one part of the human body versus another. The difference is familiarity. Powerful personal computers and cheap (and more recently free) software offer singing teachers the chance to experience firsthand how these relate to their teaching and to the singer standing before them. By contrast, equipment for measuring breathing is currently specialized, cumbersome, and expensive, and few teachers have the opportunity to play, one of the most powerful aids to learning. However, advances in sensor tracking technology, fuelled by the enormous entertainment and virtual reality industries, make it increasingly probable that breathing measurement will become as accessible in the future as acoustic measurement is today. The chance to play with respiratory recording will provide an impressive learning tool but will require that teachers acquire an appreciation of the discipline of respiratory research, just as many have acquired an appreciation of acoustics. Fortunately, a basic understanding of breathing analysis is not difficult to acquire and offers singing teachers access to studies that speak directly to their questions.

Lung volumes

The most common assessment of breathing is lung volume (LV). Key measurements are LV at the start and end of each phrase, with the difference between these being the amount of air used (to normalize comparisons, LV measures are expressed as a percentage of the individual's vital capacity [%VC], measured by having the singer breathe in to full capacity and then exhale as far as possible). On average, singers generally start phrases at 70-80%VC and end phrases at 30-50%VC (Hixon 1991). The individual singer is highly consistent in LV measurements (Thomasson and Sundberg 1999), but singers are very different (Collyer *et al.* 2008, Collyer *et al.* in press). Intra-singer consistency versus inter-singer variability can be seen in Figure 1. The question immediately arises whether a particular LV behavior is associated with better singing, but no study has yet been able to find such a link. The next question, then, is how is LV measured?

Chest-wall kinematics

It is possible to measure LV directly with a spirometer or indirectly by measuring airflow over time. However, these require a mouthpiece (and nose clip) or a mask, which tend to inhibit singing. Konno and Mead (1967) developed an alternative approach which estimated LV change from changes in the surface dimensions of the ribcage and abdomen (known together as the chest wall, and "kinematics" is simply the study of motion). Generally, ribcage (RC) and abdomen (AB) dimensions have been measured by encircling the RC and AB (strain gauges, inductance bands) or by applying sensors which measure the anteroposterior (front-to-back) distance. In brief, changes in RC and AB dimension are recorded while the singer performs various respiratory maneuvers on a spirometer (with mouthpiece and nose clip). Known changes in RC and AB dimension are therefore matched with known changes in LV, so changes in RC and AB can be used to estimate LV when the singer is no longer encumbered by the spirometer. The left panel in Figure 2 shows how LV is the weighted sum of RC and AB, weighted because it takes less change in RC than in AB dimension to move a given LV. The right panel shows a CWK (or volume contribution) plot. The key to understanding these plots is to remember that, since LV change is the *sum* of RC and AB change, changes in LV are at 45° angles, as indicated by the dotted arrows. So, the line A-B moves toward 100%VC and thus is inhalatory; the line also tells us that the inhalation was due almost entirely to an AB increase (see Figure 2, left panel). Line B-C shows that an RC increase and an AB decrease cancelled each other out, so there was no net change in LV; we know this because line B-C is par-

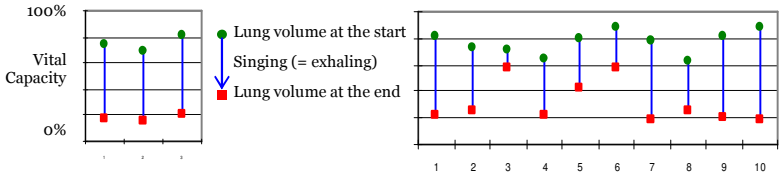

Figure 1. Lung volumes (LV) used in the *messa di voce* on B4. At left: consistency of one singer performing three *messe di voce*. At right: variability amongst 10 female singers. Data are taken from studies published in Collyer *et al.* (2008) and Collyer *et al.* (in press). (See full color version at www.performancescience.org.)

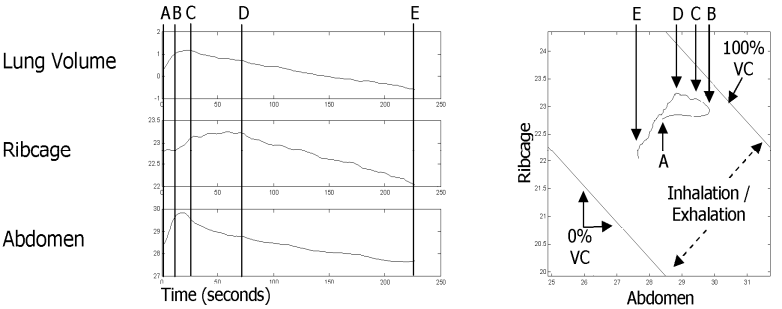

Figure 2. Relationship between LV estimation and chest-wall kinematics (CWK). See main text for description.

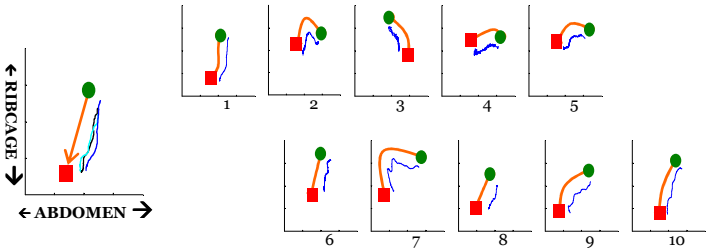

Figure 3. CWK plots for the LV changes shown in Figure 1. (See full color version at www.performancescience.org.)

allel to the 100%VC line. Line C-D-E follows the singer performing a *messa di voce*. Note that at first (C-D) this singer expands the RC (paradoxical behavior), but greater AB decrease gives *net* exhalation and then RC also decreases (D-E).

CWK plots have provided a great deal of information about singers' behavior. The prephonatory adjustment (B-C) is very common (Thorpe *et al.* 2001). So too are paradoxical movements (where RC or AB dimension decreases during inhalation or increases during singing). But the most striking feature is that, while a trained singer shows a highly consistent CWK pattern on the same task, singers are very different from each other. Figure 3 shows the CWK plots underlying the LV changes in Figure 1.

What is the "breathing system"?

The second section of the paper addresses the definition of a "breathing system." Voice is often conceptualized as consisting of three isolated stages: respiration, phonation, and articulation. This segmented model is inconsistent with human anatomy and physiology because it models the larynx as an independently functioning entity rather than as an intrinsic and inseparable part of the respiratory system at all stages of development. For example, the role of the larynx in modulating airflow for singing derives from its role in modulating airflow for respiratory needs, which in turn originates with modulation of lung fluid efflux by the larynx, which is essential for lung development in the womb (Harding *et al.* 1986). Even when protecting the airway during swallowing, a role often considered to be the larynx's primary function, the larynx also assumes an expiratory modulation role to assist aspiration (Cedborg *et al.* 2009). The conference presentation considers the limitations of the segmented model, which requires that laryngeal adjustments can occur independently of respiratory adjustments.

Breathing, emotion, and musical line

The final section of the paper extends this wider "breathing system" model to incorporate emotional influences of and on breathing and then to relate these to the nature of musical line. This pivotal role of breathing as the intermediary between phonation, emotion, and music—which is at the heart of historical pedagogy's reverence for breathing—cannot be sustained under a segmented or larynx-driven paradigm. The conference presentation discusses how a wider concept of the nature of breathing is consistent with the nature of singing at all levels: the technical, the interpretative, and the human.

IMPLICATIONS

LV and CWK data raise many questions for the teacher. What determines a singer's breathing pattern? How susceptible to training is breathing? What represents an improvement for a singer? How does the teacher match training with singer? In the conference presentation, findings of the studies are presented from a pedagogical perspective, including the implications of study limitations such as technical constraints.

Address for correspondence

Sally Collyer, PO Box 156, Box Hill, Victoria 3128, Australia; *Email:* sallycollyer@yahoo.com.au

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