# The Role of the Pelvic Floor in Respiration: A Multidisciplinary Literature Review

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**Summary: Objective.** To conduct an interdisciplinary literature review on the function of the pelvic floor musculature during respiration and its role in phonation, particularly singing.

**Study Design.** This is a literature review.

**Methods.** A literature review was conducted using three electronic databases: PubMed, Scopus, and Google Scholar. An index search was also performed for the NATS Journal/Journal of Singing utilizing the keywords from the original search, as these articles did not appear in the original search. Peer-reviewed articles from 1985 to 2017 were gathered on the respiratory musculature and/or support mechanisms for phonation (anatomy and physiology). Articles that pertained to the muscular function of the respiratory system in breathing and/or phonation were utilized in the review. Eighty-five articles were included in this review.

**Results.** Breathing and support strategies were variable and nonspecific in much of the singing voice literature. The voice science literature was a rich source of articles written about breathing and support for singing. Multiple studies looked at musculature utilized in respiration and breath support and subglottal pressure generation for muscular support. However, little or no mention was made specifically of the pelvic floor. The physical medicine literature includes the pelvic floor musculature as having an important role in respiration, as a key player in the generation of intra-abdominal pressure, and as a primary expiratory muscle.

**Conclusions.** The information gleaned from this literature review suggests that a cross-pollination between areas of science is needed, because quite obviously, the pelvic floor is a topic in physical medicine, but it is not (so much) in the voice literature. Reaching a consensus on how we describe the function of the respiratory musculature and specifically including the role of the pelvic floor in respiration and phonation deserves future attention. Further research looking specifically at the role of the pelvic floor in phonation is also warranted.

**Key Words:** Pelvic floor−Thoracic diaphragm−Breath support−Intra-abdominal pressure−Sub-glottal pressure−Forced expiration.

## INTRODUCTION

The physical act of respiration is dynamic and involves a simultaneous, coordinated synergy of muscular events. In the video by Roger Fiammetti titled “La Respiration Totale,”[1] undulation of the entire body during respiration is displayed in animation. During the video, Fiammetti narrates how each of the four diaphragms of the body plays a role in respiration. These four diaphragms are commonly taught primarily in osteopathic medicine and include the cranial diaphragm, the cervical diaphragm, the thoracic diaphragm, and the pelvic diaphragm (pelvic floor).

The cranial diaphragm moves during respiration and regulates movement of cerebral spinal fluid. The cervical diaphragm consists of the tongue, floor of mouth, and hyoid complex of musculature and its movement is affected by tracheal pull during respiration. The thoracic diaphragm is the primary inspiratory muscle and descends caudally when contracted to inhale. The pelvic floor musculature (PFM) forms the bottom of the abdominal cavity opposite the thoracic diaphragm and moves caudally when the diaphragm contracts during inspiration. All four diaphragms move symbiotically with one another and are responsible for the movement of fluid throughout the body during respiration. The movement of the thoracic diaphragm is (the primary diaphragm) affects the behavior of the three other diaphragms.[2]

Singing relies on our ability to breathe even more dynamically, more actively, like that of an athlete. It involves special training to become an accomplished vocal athlete.[3−11] That training involves development of optimal posture, efficient breathing, and measured control of airflow and voicing during phonation (breath support). It relies on teachers of singing to have a comprehensive understanding of the biomechanical processes involved in phonation.[12−17] Unfortunately, the physiological mechanisms behind muscular support have been described inconsistently in the singing/pedagogical literature, leaving room for interpretation and misunderstanding. Efforts are being made to eliminate incorrect terminology and replace ambiguous definitions of muscular support with biomechanical descriptions in the singing voice literature.[18,19] With these efforts in mind, a review of the literature was performed across disciplines of singing voice, voice science and physical medicine to identify commonalities, inconsistencies, and discrepancies across the disciplines of physical medicine, voice science and the singing voice literature regarding the muscles of respiration and support.

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## METHODS

A literature review was conducted using three electronic databases: PubMed, Scopus, and Google Scholar. An index search was also performed for the NATS Journal/Journal of Singing utilizing the keywords from the original search, as these articles did not appear in the original search. To meet inclusion criteria, articles must have been in English, from peer-reviewed journals, and written between 1985 and 2017. Articles that pertained to the muscular function of the respiratory system, breath support for phonation, generation of intra-abdominal pressure, or subglottal pressure were utilized in the review. Eighty-five articles were included in this review. Animal studies were excluded because the literature review was specific to the role of the pelvic floor in breathing and phonation (in singing).

## OVERVIEW OF SINGING VOICE LITERATURE

There is a universal agreement in the singing voice literature that the diaphragm is the primary muscle of inspiration, but there were variable, contradictory and/or inaccurate (anatomical and/or physiological) descriptions of the muscles of expiration and breath support for singing.[20] Pedagogical directives such as "Sing from your diaphragm" most likely developed because of misconceptions of vocal technique or the biomechanics of the singing mechanism[21,22] and singers conceptions and use of support were not equivalent.[23]

### Breath support

Muscles of expiration were described globally as approaches of breath support rather than in anatomical or physiological terms. "Appoggio," which literally means "to lean," is a technique that establishes "a dynamic balance between the inspiratory, phonatory, and resonatory systems in singing".[24,25] Two other popular concepts of support that dominated vocal pedagogy for decades were also discussed: "down and out" and "up and in." The "down and out" concept assumes that the diaphragm must move down and out during phonation. The "up and in" technique assumes that the diaphragm moves up and in during singing, moving a column of air from the abdomen to the larynx. Both concepts were considered "perilous" because both techniques are based on false assumptions of respiratory function.[26]

In 1994, a literature review was conducted regarding the past pedagogical terms for breath support.[27] The summary of this research included three different subglottal pressure control mechanisms:

1) the abdomen and the diaphragm-the diaphragm descends and the abdomen extends during inhalation and the abdomen contracts as the diaphragm ascends during exhalation;
2) the diaphragm, costal and back musculature- the ribcage area remains expanded during singing;
3) the ribs, diaphragm and abdominal wall-the ribcage expands during inhalation and the abdomen is contracted inward tightly while singing.

Body type may influence the type of muscular support one utilizes. In a study looking at 30 singers with various body types, endomorphs had more movement in the umbilicus which is consistent with an appoggio style of support, mesomorphs preferred a more costal approach (more movement in the ribcage), and ectomorphs demonstrated more pancostal patterns (lateral ribcage movement).[28] Other descriptions of muscles of expiration in the singing literature were in more global terms (eg, abdominal musculature was responsible for providing a steady air pressure to the vocal cords [folds] during singing).[29–33]

### Posture

There was no mention of pelvic floor musculature or pelvic diaphragm in the singing voice literature search. The pelvis was acknowledged as important for postural alignment and pelvic floor exercises were recommended to strengthen the deep muscles of the pelvis and the transversus abdominis.[34]

## OVERVIEW OF VOICE SCIENCE LITERATURE

The voice science literature is a rich source of research on muscles of respiration, breath support, phonatory breathing patterns, and subglottal pressure in singing. The physical act of breathing is an essential part of respiration, phonation, generation of intra-abdominal, thoracic, and subglottal pressure, and impacts fluid dynamics and posture.[1,35] The breath is considered the main power source for voice production in the three subsystem model of phonation[36–39] although there is not always a clear agreement of the anatomy or physiology of the respiratory musculature involved. It is accepted that there are no sex-related differences in respiratory function and the suggestion for training breathing and support should be the same for men and women.[40]

### Breath support

Breath support is defined as the ability to control breath pressure, subglottal resistance, and airflow for a desired sound and is essential for excellent singing.[41] There is a clear consensus that this muscular support involves an active synergy of abdominal, thoracic, and phonatory muscles to control intra-abdominal and, subsequently, subglottal pressure.[42] Subglottal pressure is the driving force behind the control of phonatory loudness (sound pressure level) and will increase with higher lung volumes[43] an increase in fundamental frequency and an increase in sound pressure level.[44–46] Changes in vocal register or phonation type will also increase subglottal pressure,[47] as will changes in manner of phonation (eg, emphatic speech, pronounced diction).[45,48] The expiratory muscles are activated whenever forced expiration is required, such as breathing in heavy exercise or dance, coughing, sneezing, or blowing.[49]

The musculature thought responsible for generating subglottal pressure was initially described as the rib cage, with the abdominal wall serving as a postural stabilizer.[50] It is now widely accepted that the abdominal muscles are responsible for the generation and regulation of subglottal pressure necessary during phonation.[51–53] There is some evidence that the transversus abdominis (TA) and obliqus internis (OI) play a primary role in pressure generation[54–56] while accessory respiratory muscles (sternocleidomastoid, latissimus dorsi) provide pressure modulation preventing subglottal pressure from getting too high.[57,58] There is also evidence that there are prephonatory abdominal wall movements which contribute to an increase in intra-abdominal pressure (IAP).[59–61] There was no mention of the pelvic floor as part of the abdominal musculature involved in breathing or contributing to muscular support.

Breathing strategies are variable in singers depending on the style of music sung. Classical singers use more abdominal musculature for increasing lung volumes than rib cage[62,63] and use greater ribcage and abdominal movement and higher subglottal pressures than their country singer cohorts.[64,65] They also demonstrate consistent lung volumes, rib cage movement, and abdominal wall movement in their breathing patterns, and high lung volume was associated with a lower position of the larynx.[66] Musical theatre performers demonstrated more variety in their breathing strategies, primarily because they are often dancing and moving while they sing. They call on the diaphragm and periabdominal musculature to simultaneously contribute to postural support and singing. Musical theatre singers show more variability in use of ribcage and abdomen than classical singers.[35] Postural alignment is essential for the muscles of respiration to function properly.[67]

## OVERVIEW OF PHYSICAL MEDICINE LITERATURE

There is a reasonable amount of information in the physical medicine literature on the role of the PFM and breathing, its role in contributing to IAP, and the physiologic interaction between the pelvic floor and other abdominal muscles. There is a clear overlap of information that exists in the voice science literature regarding the physiology of respiration and subglottal pressure generation. The main difference is the inclusion of PFM in the anatomical and physiological descriptions of respiration and pressure generation, both IAP and subglottal. Because the pelvic floor is a unique subject in the singing voice and voice science literature, a description of the anatomy, physiologic and biomechanics relevant to respiration and muscular support is presented.

### The pelvic floor

The pelvic floor is a complex, multilayered structure that forms the base of the abdominal capsule and is comprised of a superficial, intermediate, and deep layer. The primary muscles include the levator ani, coccygeus, and the piriformis. The basic functions of the pelvic floor include abdominal and pelvic organ support, generation of IAP with the combined activity of the diaphragm, TA and OI, bladder and bowel control and sexual arousal, and respiratory and postural support.[68]

The diaphragm separates the thoracic and abdominal chambers. The thoracic cavity contains the interthoracic pressure which is sealed by the vocal folds superiorly (closed glottis) and the diaphragm caudally; the abdominal chamber or "canister" begins at the diaphragm and is sealed at the bottom by the pelvic floor to maintain IAP.[69] The diaphragm uses the pressure differences between the two chambers in the canister for respiration and postural stability. The glottis modulates airway resistance and interthoracic pressure for postural control and the pelvic floor modulates IAP for both respiratory and postural functions. EMG data of PFM shows activity prior to resisted expiration demonstrating some neural pre-planning.[69,70]

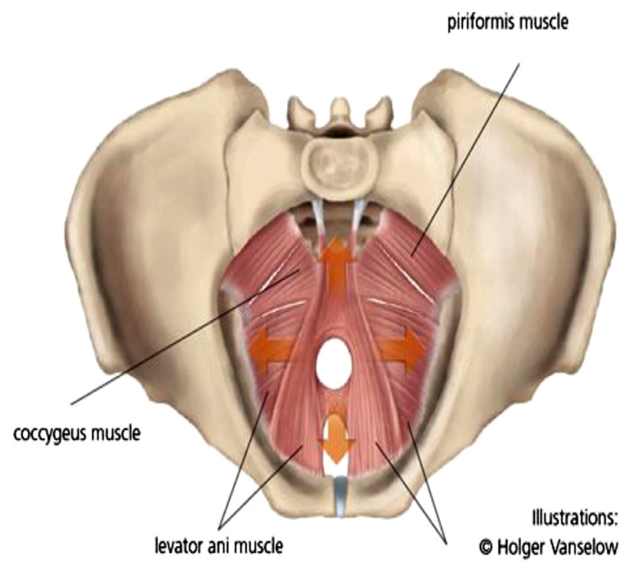


**FIGURE 1.** Cranial view of the muscular connections of the pelvic floor.

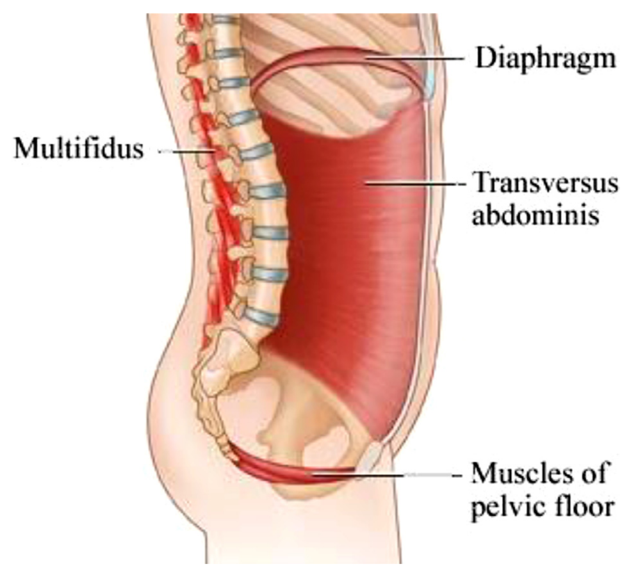


**FIGURE 2.** A lateral view of the abdominal canister. The diaphragm, transversus abdominis and pelvic floor comprise this abdominal core. Figure used with permission.

## The pelvic floor and respiration

EMG data[71,72] and ultrasound imaging confirms the synergistic relationship between the PFM and diaphragm, TA and OI during respiration.[73] Upon inhalation, the thoracic diaphragm contracts and moves caudally to draw air into the lungs. At the same time, the anterolateral abdominal wall distends slightly to make room for the displaced abdominal viscera and the pelvic floor relaxes caudally. Upon exhalation, PFM and anterolateral abdominal muscles (TA and OI) contract as or slightly before the thoracic diaphragm relaxes to transfer IAP from the abdomen to the thorax.[74]

## Breath support

The same respiratory muscular action exists during forced expiration task (eg, coughing, sneezing, nose blowing, and Valsalva), just with variations in strength and power of the musculature and resultant pressure exchange.[75,76] The literature reports that abdominal musculature must be trained to perform specific tasks because they found a high percentage (33%-49%) of women in their studies were not able to perform a voluntary PFM contraction.[77,78] Inclusion of PFM contraction with TA and IO demonstrated an increase in EMG activity as well as an increase in IAP.[79]

**FIGURE 3.** A dynamic MRI video of the lower abdominal musculature (anterior view) during forced expiration. The top red arrows point cranially and are at the level of the thoracic diaphragm. The bottom red arrow points to the pelvic floor. The video demonstrates the parallel phase-locked movement of the thoracic diaphragm and the pelvic floor. Video used with permission from the University of Innsbruck, Innsbruck, Austria. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

**FIGURE 4.** A dynamic MRI video of the lateral view of the lower abdominal musculature during forced expiration. The red arrows point to the diaphragm above and the pelvic floor below. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

The strength of the PFM matters. An improved pulmonary function (with statistical significance) was demonstrated in studies looking at the effect of a strong PFM contraction on respiration, primarily with forced vital capacity and forced expiratory volume.[73,79] Diaphragmatic motion was assisted by and more effective with a strong pelvic floor contraction during breathing.[80,81] Strong PFM contractions resulted in increased muscle recruitment and strength of the respiratory muscles and an increase in the speed of inhalation and exhalation.[82] Women with stronger voluntary contractions of their PFMs were able to exhale more efficiently, particularly at the end of the exhalation.[75] Vocalizing is an effective strategy to optimize breathing and postural stability as it was effective in recruiting synergistic PFM and TA contractions.[83] Singing was a motivator to perform strengthening PFM exercises (a small pilot study) Subjects reported an improvement of singing technique and PFM strength.[84]

## DISCUSSION

The overlap of information among the three disciplines of singing voice, voice science, and physical medicine literature is evident. The singing voice literature speaks to the importance of training in respiration and breath support as well as optimal posture for singing, although the specific muscular support physiology is not agreed upon (with the exception of the diaphragm as the primary inspiratory muscle). The voice science literature presents a much clearer look at the anatomy, physiology and biomechanics of respiration, muscular support, and phonation and adds specific insights on the generation of subglottal pressure necessary for phonation. The description of abdominal musculature for breath support is consistent and the research looks specifically at the TA and IO and its relationship with the diaphragm and rib cage for subglottal pressure, as well as specific parameters of voicing that influence subglottal pressure. The main difference between the voice science and physical medicine literature is the inclusion of the PFM in the physical medicine literature as essential abdominal musculature involved in respiration and support. The PFM is presented not necessarily as a stand-alone force, but one that has a synergistic role with anterolateral abdominal muscles that the voice literature consistently acknowledges for playing an important role in expiration and support. The parallel caudal-cranial movement of the two diaphragms illustrates their physical relationship during respiration and forced expiration, and the functional relationship is complimentary (ie, as one contracts the other relaxes). The important synergy between the PFM and diaphragm, TA and IO in IAP generation is described for expiration with supportive data demonstrating the effect of PFM strength on TA and IO contractions, diaphragmatic behavior, and pulmonary function. The role of the pelvic floor in generation and regulation of IAP for muscular support is clear and supported with EMG data. The inclusion of this unique physical medicine data and perspective on the PFM could add more clarity for the singing and voice science disciplines.

## CONCLUSION

The information gleaned from this literature review suggests that a cross-pollination between areas of science is needed, because quite obviously the pelvic floor is a topic in physical medicine and it is not (so much) in voice science. It was evident in the physical medicine literature that the pelvic floor musculature plays both a phasic and a postural role. It is also well accepted that the pelvic floor forms the base of the abdominal capsule generating IAP, opposite the thoracic diaphragm. There was also a consistent reporting of the relationship between the thoracic diaphragm and the pelvic floor during respiration, and the synergistic cocontraction of the pelvic floor and the transverse abdominis for both postural and phasic purposes. This information could be of great benefit to the field of voice research and vocal pedagogy and could aid in the understanding of breathing for speech and singing. Since the physical medicine research only reported on PFM activity during breathing, forced expiration and the generation of IAP, there cannot be a specific generalization to singing. Further research is needed to specify the role of the pelvic floor musculature in breathing for voice and singing and to ascertain the behavior of the PFM during phonation (Figures 1−4).

## SUPPLEMENTARY DATA

Supplementary data related to this article can be found online at doi:10.1016/j.jvoice.2018.09.024.

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