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The Relationship between Dynamics of Pelvic Floor Muscles and Phonation Patterns: A Narrative Review

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Abstract
Background: Previous research has established a close relationship between the glottis, located at the top of the thoracic cavity, and the pelvic floor, which forms the base of the abdominal cavity. Fascial connections and pressure-regulating mechanisms interconnect these structures both anatomically and functionally. Their interplay is crucial for activities requiring thoracoabdominal pressure modulation, including breathing, phonation, and continence. Recent practices among pelvic floor physical therapists have introduced phonation and vocalization cues to influence pelvic floor movements. However, a significant gap remains in understanding the precise coordination and movement patterns between the pelvic floor and glottis during speech and phonation.
Aims: This study reviewed the existing literature on the relationship between pelvic floor muscles (PFMs) and various phonation patterns to highlight the potential clinical benefits of understanding this interaction**.**
Methods: A literature search was conducted in PubMed, the Cochrane Library, and Google Scholar databases using the keywords "pelvic floor muscles," "glottis," phonation," "larynx," "epiglottis," "vocal folds," and "thoracoabdominal pressure." The reviewed literature was descriptively analyzed and summarized**.**
Results: Most studies demonstrate a relationship between PFMs and phonation patterns, highlighting significant clinical implications
Conclusion: The dynamics of PFMs and phonation patterns are intricately connected through shared physiological mechanisms and biomechanical interactions. Emerging therapeutic approaches leveraging phonation cues hold significant promise for improving pelvic floor function. Further research is needed to enable the development of targeted, effective rehabilitation strategies, ultimately enhancing patient outcomes in both vocal and pelvic health. Keywords: "pelvic floor muscles," "glottis," "phonation"," larynx," "epiglottis," "vocal folds," and "thoracoabdominal pressure."

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Introduction:
In osteopathic medicine, four key diaphragms are recognized: cranial, cervical, thoracic, and pelvic diaphragm. These structures work together to coordinate respiratory and fluid dynamics in the body. The cranial diaphragm is inside the skull and is made up of the dural membranes, such as the falx cerebri and tentorium cerebelli. It supports the brain and helps the cerebrospinal fluid flow. Its subtle rhythmic movements influence the craniosacral mechanism, playing a vital role in overall systemic balance. Tracheal movement during breathing influences the cervical diaphragm, which comprises the tongue, floor of the mouth, and hyoid muscle complex. The thoracic diaphragm, the primary muscle of respiration, contracts and moves downward during inhalation, creating space for lung expansion. Simultaneously, the pelvic diaphragm (pelvic floor muscles) descends, facilitating the coordination of the intra-abdominal pressure (IAP) and thoraco-abdominal pressures (TAP) [1]**.**
The pelvic floor muscles (PFMs) comprise three primary parts: the pubococcygeus, iliococcygeus, and coccygeus. The pubococcygeus muscle, the most forward part of the levator ani group, begins at the inner surface of the pubic bone and extends to the coccyx, with fibers directly connected to the urethra, vagina, perineal body, and anal canal, thus playing a vital role in supporting these areas. The iliococcygeus muscle, which makes up the lateral sections of the pelvic floor, originates from the obturator internus muscle's fascia and extends toward the coccyx. Finally, the coccygeus muscle starts at the ischial spine and extends to the coccyx, contributing to the overall support and stability of the PFMs[2]**.**
PFMs function as a unified group, supporting abdominal and pelvic organs and contributing to essential functions like voiding, defecation, sexual activity, and childbirth. They also stabilize the pelvic girdle and maintain lumbopelvic stability, making voluntary training of these muscles important throughout a woman's life.

Additionally, the PFMs play a crucial role in regulating intra-abdominal pressure (IAP) during activities such as breathing, talking, moving, and limb movements, thereby protecting the internal organs within the pelvis[3,4].

The glottis, on the other hand, is located in the larynx, which is the connection between the posterior tongue and the trachea, at the top of the respiratory system, and plays a pivotal role in phonation (voice production), breathing, and airway protection. The glottis consists of two parts: the membranous portion, which forms the front of the glottis, and the cartilaginous portion, which forms the back in the space between the arytenoid cartilages. Acting as a valve between the lungs and the mouth, the glottis opens (abducts) or closes (adducts) depending on the position of the vocal folds[5].

The epiglottis, a leaf-shaped cartilage, descends to cover the glottis and shield the larynx from aspirating food or liquids during swallowing. The arytenoid cartilages and vocal cords are adducted to produce sound, which causes subglottal pressure while exhaling and pushing air from the lungs upward. This pressure converts to sound as air passes through the vocal folds, causing them to vibrate[6].

Phonation arises from the continuous vibration of the vocal folds, controlling the airflow passage through the glottis and producing sound. Although voice control mainly relies on the activation of laryngeal and respiratory muscles, the vibration pattern and resulting voice quality are also impacted by the vocal folds' structure and biomechanical features. Variations in vocal fold conditions can result in distinct voice characteristics[7].

The pitch of a sound is determined by the tension and length of the vocal folds: increased tension and length produce higher pitches, while decreased tension results in lower pitches. Subglottal pressure also plays a role, with higher pressure required for higher-pitched sounds. Phonation relies not only on the laryngeal and respiratory muscles but also on the structural and biomechanical properties of the vocal folds, which influence voice quality and characteristics[7].

Furthermore, when breathing, the larynx moves cranially and caudally in addition to tilting anteriorly-posteriorly to alter pitches[5]. During respiration, the glottis, diaphragm, and PFMs work together. As air enters the lungs, the thoracic diaphragm contracts and descends (caudally), and the larynx travels downward due to traction through the trachea. Concurrently, the PFMs relax downwards. Upon exhaling, the PFMs contract slightly before the thoracic diaphragm and larynx relax (upward movement). This coordinated action helps transfer IAP[1].

The vagus nerve[6] innervates both the larynx and PFMs. The vagus nerve (cranial nerve X) provides parasympathetic innervation to multiple regions, including the neck, thorax, foregut, midgut organs, gonads, uterus, and cervix. The parasympathetic system (vagus nerve), often called the "rest and digest" system, operates primarily during restful states and complements the sympathetic system[8].

There is evidence of a close relationship between the glottis and PFMs. Some pelvic floor therapists are exploring the use of vocalization to influence PFMs movements[9,10]. A small pilot study found that singing can serve as a motivating factor for performing PFMs strengthening exercises, with participants reporting enhanced singing techniques and improved PFMs strength[11]. Additionally, vocalizing has been shown to optimize breathing and postural stability by effectively recruiting synergistic contractions of the PFMs and transverse abdominis (TA) muscles.

However, there is a significant gap in understanding the coordination between the PFMs and glottis during speech and phonation, with an urgent need to identify the voices accompanied by increasing PFMs tone and integrate them into PFMs strengthening programs and voices accompanied with lowering PFM's tone and integrate them into PFMs down training programs. Therefore, this study reviewed the existing literature on the relationship between PFMs and various phonation patterns to highlight the potential clinical benefits of understanding this interaction.

Methods:

This review synthesizes findings from studies exploring the relationship between phonation and PFMs function. Literature searches were conducted in the PubMed, Cochrane Library, and Google Scholar databases using keywords such as “pelvic floor muscles," "glottis," "phonation,” "larynx," “epiglottis, “vocal folds,” and “thoracoabdominal pressure." The review focused on articles published up to 2024 and included only those written in English. References from selected studies were also examined to identify additional relevant articles. To provide a comprehensive understanding of this relationship, studies involving both healthy individuals and participants with vocal or pelvic floor dysfunction were included.

Results:

The goal of this review is to thoroughly explore research examining the relationships among the respiratory system, phonation, and PFMs function. A summary of the reviewed studies is provided in **(Table 1).**

Table 1: The characteristics of the studies investigating the relationship between the dynamics of PFMs and different phonation patterns

Author -year	Study design	participant	Age mean	Assessment methods	outcome	conclusion
Rudavsky, , and Turner 2020	Pilot study	Ten asymptomatic participants (5 men, 5 women) with no urological, gynecological, respiratory or vocal disorders volunteered	(aged 20–51) to participate in the study.	Two-dimensional trans abdominal ultrasound . Participants completed a series of tasks to assess pelvic floor muscle (PFM) responses. These included a maximum voluntary contraction, pelvic floor strain, the Valsalva maneuver, and various phonation tasks such as sustained "ah" sounds at different pitches, vocal sirens, and SOVT exercises using a coffee straw with forced inhalation and exhalation. The study concluded with a quick yell	bladder length change was variable for glottis tasks	When cuing pelvic floor to contract, healthy individuals showed shortening of bladder length and most lengthened during strain. When cuing phonation and respiration tasks, there was a tendency toward bladder lengthening.
Rudavsky & McLean, 2024)	A cross-sectional, observational study	Sixty women (38 incontinent, 22 continent)	Women over the age of 18 years	Trans-perineal ultrasound. The first two tasks involved a maximum pelvic floor contraction (MVC) and a maximal effort straining maneuver. The following four tasks were voicing exercises, where participants counted from one to four in a single exhalation at different pitches and volumes: deep pitch at speaking and shouting volumes, and high pitch at speaking and shouting volumes.	The visualization of the pubic symphysis (PS), bladder neck (BN), and anorectal angle (ARA) was captured within the imaging frame. For each task, a cine loop was recorded from the resting position to the completion of the task.	Voicing, particularly shouting, causes pelvic floor muscle strain, but pitch changes do not affect pelvic floor morphology. Incontinent women showed slight differences compared to continent women. Voicing may safely lengthen the pelvic floor without causing incontinence.
Volløyhaug, et al 2024	Pilot study	10 professional opera singers	25 to 55 years	Examined with transperineal ultrasound. Ultrasound volumes were recorded during rest, PFM contraction, the Valsalva maneuver, and while the participant, in a standing position, performed vocal tasks involving vowel changes, varied intensities, and set pitches.	Changes in hiatal area and AP diameter and in the bladder neck's vertical distance from the symphysis are measured	The classically trained singers had good voluntary PFM contraction and moderate contraction during singing. AP diameter was significantly shortened from supine to upright position, with further shortening during singing, confirming that female opera singers contracted their pelvic floor during singing.
Talasz ,et al 2010	Pilot study	Eight nulliparous women and in good general health	age 18 to 35 years	- Dynamic MRI Subjects were asked to contract, lift inward, and squeeze PFM on demand and to cough forcefully without changing position	Distances were measured in coronal planes relative to three horizontal reference lines: one at the base of the L4/5 intervertebral disc, chosen for its stable and identifiable position; a second at the most cranial level of the vaginal pelvic floor region; and a third through the narrowest abdominal circumference.	In healthy women, real-time dynamic MRI shows coordinated cranio-caudal movement of the diaphragm and pelvic floor (PF) during breathing and coughing, along with synchronous changes in abdominal wall diameter.
Emerich Gordon & Reed, 2020	Multidisciplinary Literature Review	-	-	-	Multiple studies have examined the musculature involved in respiration, breath support, and subglottal pressure generation, but the pelvic floor is rarely mentioned. However, physical medicine literature highlights the pelvic floor's critical role in respiration, intra-abdominal pressure regulation, and as a primary expiratory muscle.	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.

Discussion

This review examined the relationship between PFMs dynamics and glottis activity during phonation, aiming to understand how these systems coordinate to regulate thoracoabdominal pressure. Existing research highlights the interaction between the PFMs and respiratory muscles during exhalation[12]. However, evidence remains scarce regarding the specific effects of vocal tasks, particularly those involving variations in pitch and loudness, on PFMs dynamics.

While most studies agree that the PFMs and thoracic diaphragm work synergistically to regulate intra-abdominal pressure, the precise influence of phonation and vocalization on PFM behavior is underexplored. Preliminary findings suggest task-specific variations in PFM responses, but further investigation is needed to elucidate these interactions fully.

Rudavsky and Turner[5] explored the interplay between PFM activity and glottis dynamics during phonation, respiration, and voluntary PFM contraction tasks. Utilizing transabdominal ultrasound to measure bladder and PFM length, the study revealed that vocal tasks influenced bladder dynamics, demonstrating tendencies for either bladder shortening or lengthening based on the task. Notably, the findings showed that PFMs distortion patterns during glottis tasks—such as singing at various pitches, performing the Valsalva maneuver, engaging in semi-occluded vocal tract (SOVT) breathing or singing, and grunting—differed significantly from the cranial movement of the bladder typically observed during PFMs contraction. This distinction likely represents a normal physiological adaptation, enabling the PFMs to manage increases in intra-abdominal pressure effectively.

While the study offers valuable preliminary insights, its small sample size and pilot design constrain the generalizability of the findings. Moreover, the inclusion of only asymptomatic participants limits the applicability of the results to individuals with PFMs dysfunction. Additionally, the absence of concurrent electromyography (EMG) analysis prevents definitive conclusions regarding PFMs contraction during the tasks. Future studies should try to confirm these results in bigger, more varied samples and use EMG to provide a deeper understanding of PFM dynamics throughout respiratory and phonation tasks

Rudavsky and McLean[12] used transperineal ultrasound to examine temporary changes in PFMs morphology during voicing tasks. Their results showed that voicing tasks in females led to bladder neck (BN) descent, with no significant impact of vocal pitch variations on PFMs strain. However, louder vocalizations were associated with increased thoracic pressure, which could contribute to pelvic organ descent. Furthermore, women with stress urinary incontinence (SUI) experienced greater BN descent during voicing, along with more noticeable BN elevation and levator plate shortening during PFMs contraction compared to continent women.

Although the study did not include electromyographic (EMG) analysis, leaving uncertainty about whether PFMs contracted actively during the voicing tasks, further research is necessary to explore the underlying mechanisms and develop targeted interventions to improve both vocal and PFMs function.

The **Volløyhaug et al's.[13]** study confirmed that 2D and 3D/4D transperineal ultrasound can effectively assess PFMs dynamics during singing. Classically trained female singers demonstrated good voluntary PFMs contraction, with moderate contraction observed during singing. A significant shortening of the anteroposterior levator hiatal diameter was noted from the supine to the upright position, with further shortening occurring during singing, indicating PFMs contraction. These findings support the idea that female opera singers engage their PFMs as part of their breath support mechanism during singing.

This study suggested that the PFMs might have been passively yielding to the movement of the thoracic diaphragm and increased intra-abdominal pressure, particularly during tasks like singing.

The small sample size in the study limits the ability to explore potential correlations between PFMs dynamics and various factors during singing. A larger sample size would help investigate these relationships more thoroughly. Additionally, since all participants were opera singers, the findings may not be directly applicable to individuals with PFMs dysfunction. More research involving diverse populations, including those with PFMs disorders, would help generalize these results.

Talasz et al.[9] used real-time dynamic MRI to investigate the movement patterns of the diaphragm and PFMs during breathing and coughing. The study revealed synchronized cranio-caudal displacement of the diaphragm and PFMs, accompanied by concurrent changes in abdominal wall diameter. These findings underscore the coordinated interplay between the respiratory system and the PFMs in regulating intra-abdominal pressure during dynamic tasks.

Comparable diaphragm, abdominal, and PFM movement patterns were found in this study during coughing and breathing. After an inspiratory phase, coughing progresses into two expiratory phases: an expulsive phase that involves glottal opening and forced air expulsion, and a compressive phase in which expiratory muscles contract against a closed glottis. Although the compressive phase was challenging to visualize, three participants showed an increase in abdominal diameter at the diaphragm's peak position during coughing, which may suggest paradoxical displacement due to superficial abdominal muscle contraction. Further investigation is needed to confirm and better understand this finding.

This study exclusively examined the relationship between the diaphragm and PFMs during normal breathing patterns and respiratory tasks without incorporating vocal tasks. Additionally, it was conducted on a small sample size and limited to healthy individuals, which may restrict the generalizability of the findings.

Emerich Gordon and Reed[1], a multidisciplinary review of the literature covering physical medicine, voice science, and singing voice, was carried out in this study. The goal was to find similarities, differences, and contradictions between these domains regarding the muscles used for support and breathing.

The study highlights the diaphragm's role as a structural divider between the thoracic and abdominal cavities, contributing to respiration and postural stability through pressure modulation. The glottis regulates airway resistance and intrathoracic pressure for postural control, while the pelvic floor modulates intra-abdominal pressure (IAP) for both respiratory and postural functions. Electromyography (EMG) data reveal pre-activation of pelvic floor muscles (PFM) before resisted expiration, indicating neural pre-planning.

The study also reports that pelvic floor muscle (PFM) strength significantly influences respiratory function. Powerful PFM contractions were associated with improved pulmonary function, demonstrated by statistically significant enhancements in forced vital capacity and forced expiratory volume. Strong PFM contractions during breathing aided in more efficient diaphragmatic motion, leading to faster inhalation and exhalation as well as greater recruitment and strength of the respiratory muscles. Exhalation was more effective in women who had stronger voluntary PFM contractions, especially near the end of the expiration phase. Vocalization, including singing, was proven to effectively recruit synergistic contractions of the PFM and transversus abdominis (TA), optimizing both breathing and postural stability. Additionally, singing served as a motivator for PFM strengthening exercises, with participants reporting improvements in both singing technique and PFM strength in a small pilot study.

This study primarily examines the role of breathing in singing and briefly suggests the contribution of PFMs in enhancing vocal performance. However, additional targeted research is needed to explore the relationship between pelvic floor muscles and various phonation patterns.

In conclusion, while a relationship between PFMs and phonation has been confirmed, there is still a scientific gap in understanding how the PFMs respond to different phonation tasks. Further research is essential for a better understanding of this dynamic and the underlying mechanisms.

Moreover, advancing our understanding of the synergy between vocalization and PFMs function has important clinical implications. With this knowledge, healthcare providers could develop more effective, integrated treatment strategies that help individuals maintain optimal vocal and PFMs health throughout their lives.

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