Menopause and the voice: a narrative review of physiological changes, hormone therapy effects, and treatment options

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Abstract

Importance and objective: Voice changes during menopause affect patients' communication and quality of life. This narrative review aims to provide a comprehensive exploration of voice changes during menopause. It presents objective and subjective/symptomatic changes as well as treatment options for this population. Lastly, it identifies areas of research and future directions needed to serve this population through collaboration between voice experts and gynecologists.

Methods: To inform this narrative review, a literature review was conducted using the PubMed database, encompassing publications from January 2005 to January 2025. The review synthesized research on hormonal influences, acoustic analyses, laryngeal imaging, and patient-reported outcomes, with a focus on understanding the physiological mechanisms underlying menopausal voice alterations.

Results: The review reveals a complex narrative of vocal transformation during menopause. Hormonal decline—characterized by reduced estrogen and progesterone levels—precipitates significant laryngeal changes. Up to 46% of menopausal women experience perceptible vocal modifications, including decreased fundamental frequency (by 0.94 semitones), increased vocal instability, and reduced phonation capabilities. Particularly vulnerable are professional voice users, who face unique challenges in maintaining vocal performance. Hormone therapy demonstrates potential protective effects, though findings remain inconsistent.

Discussion and conclusion: Menopause-related voice disorders represent a nuanced and underexplored medical phenomenon. This review underscores the critical need for interdisciplinary research that integrates gynecology, otolaryngology, endocrinology, and speech pathology. Future investigations could focus on developing AI-driven voice biomarkers, conducting longitudinal studies, and creating targeted interventions that recognize the voice and respiratory transitions women experience during menopause.

Key Words: Hormone therapy, Laryngeal physiology, Menopause, Professional voice users, Vocal acoustics, Voice disorders.

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Voice production is a complex physiological process that requires the precise coordination of multiple systems: respiration, phonation, articulation, and resonance. Even minor disruptions in any of these components can significantly impact vocal function, making the voice highly sensitive to both internal and external influences. The vocal folds, housed within the larynx, rely on intrinsic and extrinsic musculature, mucosal pliability, and sufficient airflow from the lungs to generate sound. The balance of tension, mass, and elasticity of the vocal folds determines fundamental frequency, vocal intensity, and overall voice quality.

Among the various factors that influence vocal characteristics, hormonal fluctuations play a critical role in maintaining the structural integrity of laryngeal tissues. The larynx is a target organ for sex hormones—particularly estrogen, progesterone, and androgens—which regulate mucosal hydration, collagen turnover, muscle tone, and neuromuscular coordination.[1] As women transition through perimenopause and menopause, the decline in these hormones leads to structural and functional changes in the voice, often resulting in noticeable alterations in vocal quality. Commonly reported changes include increased vocal fatigue, breathiness, reduced high-frequency range, roughness or hoarseness, loss of vocal stability, and a deeper overall pitch.[1] Studies indicate that up to 46% of menopausal women experience perceptible vocal changes, with one-third reporting vocal discomfort.[2]

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Professional voice users (PVUs)—such as teachers, singers, broadcasters, and other performers—are particularly vulnerable to menopause-related vocal changes, as their occupations rely heavily on voice quality and endurance. PVUs often experience heightened awareness of even subtle vocal deterioration, which can impact their performance, confidence, and career longevity.[3] Research suggests that over two-thirds of female professional voice users notice significant vocal changes around midlife, including increased effort in phonation and difficulty reaching high registers.[4] The combination of sustained voice use and menopausal hormonal decline can accelerate vocal fatigue, reduce vocal endurance, and ultimately impair job performance. Consequences may include decreased work opportunities, financial strain due to medical treatment and voice therapy, and, in severe cases, early retirement.[5]

Despite the well-documented effects of menopause on other body systems, its impact on vocal function remains underrecognized and understudied. This is crucial, as the intersection of voice, hormones, and menopause holds both diagnostic and therapeutic value. Voice changes can significantly affect communication, self-expression, and overall quality of life. While some research has explored menopausal voice changes, findings are often inconsistent due to variations in study methodologies and outcome measures.[6] A systematic review found that while some studies report a significant decrease in fundamental frequency and increased vocal instability postmenopause, others show minimal or no changes, underscoring the need for further investigation.[7] This gap in knowledge prompted us to conduct a review of the past two decades of research. In this informal review, we describe the voice production and the effect of hormones on laryngeal structures, integrate objective acoustic analyses, laryngeal imaging, and patient-reported outcomes to provide a comprehensive understanding of how menopause affects the voice. In addition, we highlight the unique challenges faced by PVUs and underscore the urgent need for targeted research and clinical interventions to support vocal health during menopause. This manuscript is comprised primarily of the author's medical opinion, with supporting evidence provided from the scientific literature.

METHODS

A review of the literature was performed using the PubMed database from January 2005 to January 2025 with the objective to find scholarly work related to the effect of hormone fluctuation, menopause, and hormonal therapy on voice and respiratory function. The search terms related to menopause included "menopause," "postmenopause," "perimenopause," "hormonal therapy," "hormones," and terms related to voice included "voice," "vocal chords," "vocal folds," "voice disorders," "dysphonia." Abstracts were reviewed for relevance, and full texts of relevant articles were fully reviewed by two different reviewers. Relevant references were also reviewed. This review reports the most relevant literature over the last 20 years, divided into the following sections: the impact of menopause on voice and respiratory function, the impact of hormonal therapy on voice symptoms and the interventional options to treat women with voice symptoms related to menopause.

DISCUSSION

Impact of menopause and perimenopause on voice and respiratory function

Mechanism of voice production

Voice production relies on the coordinated function of the respiratory system, larynx, and vocal tract. The vocal folds are composed of elastic collagen tissue, mucosal epithelium and striated muscle, which vibrate as pressurized air passes through the glottis, producing organized sound.[8] Importantly, glandular secretions allow for humidification, hydration, and protection against mechanical stress on the areas of contact and exposed vocal cord edges.[9] The cartilage and intrinsic muscles of the larynx give structure and tone to the vocal apparatus.[10]

Phonation is further shaped by the pharynx, which amplifies sound, nasal cavity, which adds resonance, oral cavity (tongue, lips, soft palate, teeth, jaw), which shapes sound and aids in articulation.[11] The respiratory system acts as a power source, propelling the pressurized airflow needed for vocal fold vibration (Fig. 1).

Factors influencing voice production

The physiological determinants of voice production include respiratory and laryngeal factors. Lung capacity and respiratory muscle strength affect subglottic pressure and airflow, while vocal fold tension, elasticity and mass determine fundamental frequency, intensity, and quality.[12] Structural variations in vocal tract length and shape, age-related changes, hydration status, phonotrauma, environmental conditions, smoking, and medications impacting mucosal integrity further contribute to vocal characteristics.[12] Pathological conditions, such as vocal nodules, muscular tension dysphonia, and vocal hyperfunction, also play a role.

How do hormones affect the laryngeal tissues through a woman's life?

Estrogen, progesterone, and androgens (like testosterone) are the primary sex hormones that fluctuate throughout a woman's life and significantly impact laryngeal structure and function. Sex steroid hormone receptors are expressed in the female vocal folds. Estrogen promotes mucosal hypertrophy, proliferation, and resiliency through the reduction of the desquamation of the superficial layers. Regarding the larynx, this leads to hydrated and plump vocal cords with appropriate resiliency. In addition, estrogen causes differentiation and complete maturation of the fat cells and has no effect on striated muscles.[10] Alternatively, progesterone has an antiproliferative effect on mucosa and accelerates

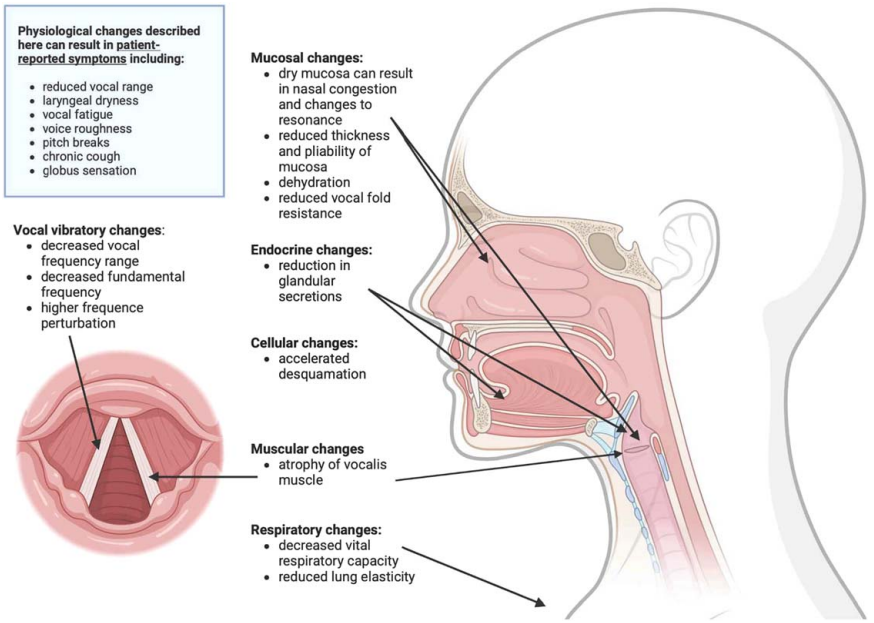

FIG. 1. Physiological changes of the vocal resonance and production system during menopause.

desquamation, resulting in dehydration of the mucosa and a reduction in glandular secretions.[10] Progesterone also decreases capillary permeability, trapping extracellular fluid and causing tissue congestion. With respect to the larynx, this broadly results in dryness, vocal fatigue, and reduced vocal fold hydration. In the mucosa, androgens cause dehydration due to a reduction in glandular secretions.[10] Androgens also cause hypertrophy of skeletal muscle cells and a reduction in the surrounding fat cells.[10] This leads to irreversible changes in vocal pitch and quality.

Puberty

Voice is one of the secondary sex characteristics, and as such, puberty brings about the introduction of all three sex hormones, which results in a voice with a fundamental frequency a third lower for women and an octave lower for men.[1,10,13] Vocal tract size also increases significantly at puberty, more significantly in men than women due to differences in increasing androgen profiles, though women who have later growth spurts tend to see more dramatic effects.[13] During menarche, rises in estrogen levels lead to proliferation of the mucosa and increased glandular secretory function. Thus, the spike in estrogen preceding ovulation may alter the structure of the laryngeal mucosa and increase production of mucosal secretions, with tone of voice slightly modified.[10]

Premenstrual period

Voice changes can occur during different phases of the menstrual cycle in reproductive years. During the premenstrual period, rising progesterone levels decrease mucus secretions and cause dryness by increasing epithelial desquamation. This pairs with reduced tonicity of laryngeal muscles, vocal fold edema, and venous dilation/congestion to lead to vocal fatigue, decreased range, a loss of power and a loss of certain harmonics.[10] This phenomenon is known as "premenstrual voice syndrome."[10]

Menopause

During menopause, circulating levels of all sex hormones decline, resulting in characteristic changes, most commonly hoarseness, reduced range, vocal fatigue, and dysphonia.[10] In a 1998 study of 100 women, 17 were affected—all of whom showed evidence of vocal muscle atrophy, reduction in the thickness of the mucosa and reduced mobility in the cricoarytenoid joint.[10]

In addition to hoarseness, vocal fatigue, and reduced vocal range, mild changes in vocal tremor, roughness, breathiness, vocal instability, vocal fatigue, reduced respiratory capacity and phonation time (MPT), lowered vocal intensity, vocal fatigue, a perceived deepening of the voice with decreased range and loss of the high tones and a loss of vocal quality are most commonly reported.[10,13] A systematic review of studies performed by D'haeseleer et al[6] demonstrated that the most frequently recorded acoustic changes in postmenopausal women were reported to be decreased vocal frequency range, decreased fundamental frequency, and higher frequency perturbation.

When progesterone is reduced at premenopause, glandular cells in the mucosa decline, leading to decreased secretions and thus dryness, leading to vocal fatigue and dysphonia. In a 1999 study by Abitol and colleagues, androgen-associated characteristic changes were seen, including unilateral and bilateral muscular atrophy, thinning of the vocal fold mucosa with resulting reduction in amplitude, asymmetry, loss of the white appearance of the mucosa, microvarices and reduced mobility of the cricoarytenoid joints.[6,10] In this study,

electrolaryngograms of menopausal women were irregular and weaker compared with younger women, demonstrating reduced vocal fold resistance.

Estrogen decline causes laryngeal edema, muscular atrophy, and increased stiffness.[6] In the study by Abitbol and colleagues, cytological findings demonstrated mucosal subatrophy with a reduction of glandular cells.[6,10] In a recent study by Patel et al,[14] a significant increased stiffness was observed in postmenopausal participants when compared with participants in reproductive stages.

A mouse model of the vocal folds of adult female rats deprived of estrogen demonstrated no change in these neuromuscular parameters; therefore suggesting, vocal changes within the outer vibratory layers of the vocal folds may be responsible for clinically observed changes.[15]

The impact of testosterone on the voice is well known. Testosterone therapy or increased circulating levels of testosterone can cause virilization, deepening the voice. Conversely, the cessation of testosterone production before puberty can result in a female-like voice. During the 15th century, castration was performed before any sign of puberty, before any secretion of testosterone to preserve the beauty/pitch of a female-like voice.[10] Though testosterone is thought to have largely irreversible effects on vocal architecture, there are also potential influences on vocal pitch and quality. In addition, there is a gradual overall muscular atrophy that occurs throughout life that worsens with age and with diminished use of the voice.

Menopause is associated with reduced lung elasticity, decreased vital capacity and phonation quotient. Breathing and voice production are an important part of phonation, and altered breath support may result in increased effort in sustained or loud speech. The impact of comorbidities should not be overlooked, including concomitant asthma, chronic obstructive pulmonary disease, or other conditions that may worsen during menopause. Figure 1 explains the different changes in voice production during menopause.

Acoustic features of the voice after menopause

Several studies have investigated the objective changes in women's voices after menopause by studying specific acoustic features through acoustic analysis.

Fundamental frequency (F0) is the mean pitch at which someone speaks.[16] F0 for a male, ranges between 80 and 180 Hz, while female speakers have an F0 between 150 and 250Hz, with 160 Hz usually being the cutoff between both genders. In female speakers, F0 decreases with age, but research shows a significant drop after menopause.[17] Women speakers with lower fundamental frequency often complain of "not sounding like themselves" or, more commonly, being perceived as male speakers over the phone, which can highly impact their quality of life.

In a meta-analysis performed by Lã et al, a statistically significant reduction of F0 by 0.94 semitones (ST) was found.[7] Higher F0 in premenopausal speakers is thought to be due to the adequate vocal cord vibration because of optimum thickness and hydration under the effect of optimum levels of estrogen and lower levels of testosterone.[1]

Jitter (JR) is the cycle-to-cycle variation of fundamental frequency and shimmer (SR) is the cycle-to-cycle variation in amplitude, and represent features of perturbation of the sound. They are found to be slightly raised after menopause, largely because more pressure is put on the vocal cords for phonation, as the mass of vocal cords changes due to androgenic alterations and because F0 is lower than normal.[1] This correlates to a rougher quality of the voice that women often report as hoarseness.

In addition, frequency range (FR) is typically decreased in postmenopausal women, as vocal cord movements are more unstable and fail to reach rapid vibrations to attain a high-frequency range.[1] Similarly, the Harmonic to Noise Intensity Ratios (HNR) are thought to be lower than normal, with an increased number of breaks due to the same alterations.[1]

Mean phonation duration (MPD) also experiences a significant decrease after menopause.[7] In a study performed in 2021 by Patel et al,[14] during sustained phonation, significant changes in glottal area waveform were observed between the reproductive and postmenopausal groups. This was attributed to changes in Neuropeptide Y. For the sustained emission of /s/ and /z/ and the s/z ratio, menopausal patients presented significantly lower values to the "s" MPT.[13] MPD and the s/z ratio reflect the ability to properly control the aerodynamic forces of pulmonary airflow and the larynx myoelastic forces, this therefore suggests instability of vocal cords and decreased vital capacity.[13]

Impact of hormonal therapy on voice in perimenopause and menopause

Effect of hormonal therapy (HT) on tissues

Hormone therapy (HT) traditionally involves estrogen and progestogen supplementation to mimic hormones produced by the ovaries when women go through decreased hormonal levels due to natural menopause or surgical menopause after oophorectomy.[18] HT is commonly indicated to treat severe vasomotor symptoms of menopause, including hot flashes and diaphoresis.[18] Another common menopausal symptom indicating HT, either systemic or locally, is vaginal atrophy and dryness.[19] In addition, estrogen therapy does benefit in the management and prevention of osteoporosis by decreasing absorption.[20] While FDA-approved indications for hormone therapy include the treatment of moderate to severe vasomotor symptoms, prevention of osteoporosis in postmenopausal women, treatment of hypoestrogenism linked to hypogonadism, and management of moderate to severe vulvovaginal symptoms, there are also some risks associated with HT. Estrogen therapy does have risks including coronary artery disease, stroke, venous thromboembolism, making it less beneficial in women when starting at 60 years or older or more than 10 years past menopause.[21]

Effect of HT fundamental frequency

Most studies report a protective effect of HT on fundamental frequency.[22] Lindholm and colleagues demonstrated the change in the fundamental frequencies of voice in their study on menopausal women. After 1 year, participants not on HT experienced significant decreases in the fundamental frequency of their speech in free speech (27.7 Hz, CI: 9.9-45.4, $P = 0.005$) or reading sentences (11.6 Hz, CI: 2.7-20.5, $P = 0.015$). The estrogen therapy (ET) group experienced a smaller decrease in F0 for spontaneous speech (16.5 Hz, CI: 1.9-31.1, $P = 0.03$) and no significant decrease in F0 for reading ($P = 0.194$). The estrogen plus progestin group also had a smaller decrease in F0 for spontaneous speech (22.4 Hz, CI: 5.1-39.8, $P = 0.015$) compared with no HT and no change in F0 for reading ($P = 0.055$). All groups experienced a decreased F0 during menopause; however, given the broad overlap of the confidence intervals in the amount F0 decreased for all three groups, it is not possible to draw a strong conclusion on the effectiveness of HT from their study.

A systematic review and meta-analysis by Lin and Wang[23] found a higher mean F0 by a difference of 11.85 Hz (95% CI: 7.35-16.36 Hz) for postmenopausal participants on HT versus those not on HT. The different regimens of HT included oral ET, progestogen only, or estrogen plus progestogen therapy (EPT).[23] This effect applied to participants with a normal body mass index, while participants with a high BMI did not have a change in F0.[23] The authors hypothesized that the difference demonstrates the significance of the peripheral production of estrogen by adipose tissue when estrogen production by the ovaries decreases during menopause. While the meta-analysis by Lin and colleagues demonstrates an overall consensus in the literature that menopausal changes in F0 are moderated by HT, two studies by Firat et al[17,24] did not find a significant difference in F0 based on HT use. These two studies did have relatively small sample sizes, with Firat and colleagues having a total of 23 participants in the HT groups, and Mendes-Laureano and colleagues having a total of 15 participants in the HT group.[17,24] It is important to understand that most studies reported results based on HT without specifying the type of HT(ET, progestogen therapy, or EPT).

Effect of HT on voice symptoms and acoustic parameters

While the fundamental frequency has been shown to be significantly different, the evidence of HT on other acoustic parameters is controversial. Hamdan and colleagues found a difference in jitter (higher for participants on HT with a P value of 0.033) and no difference in shimmer. And Firat et al[24] found significantly lower jitter and shimmer values for intranasal versus oral HT participants. However, the systematic review by Lin and Wang[23] found no difference in jitter or shimmer. Similarly, Mendes-Laureano et al[25] found no difference in jitter or shimmer in postmenopausal women on HT versus not on HT or premenopausal women not on hormonal contraceptives. HT did not affect nasal resonance in postmenopausal women.[26]

Evidence has also been varied concerning patient-reported voice symptoms. These symptoms are commonly measured by the Voice Handicap Index (VHI) or the abbreviated version VHI-10, which is a validated assessment of the function, physical, and emotional severity of voice disorders.[27] Firat et al reported a deterioration in the VHI scores for patients on no HT after one year compared with no deterioration in patients on oral or intranasal HT.[24] Caruso et al[28] found an improvement in subjectively reported voice symptoms based on a questionnaire in patients with surgically induced menopause treated with transdermal estrogen. However, Hamdan et al[29] found no significant difference in phonatory symptoms measured by the VHI-10 for postmenopausal women on HT versus no HT, regardless of BMI. D'haeseleer et al[26] found no differences in the VHI in postmenopausal women on ET versus EPT therapy.

Effect of testosterone and anabolic steroids on the voice

Testosterone therapy can be a part of HT for menopause as well as treating decreased libido.[30,31] However, the benefit of testosterone has not been well defined. Testosterone supplementation includes more common side effects of hirsutism and acne, and less commonly hepatic dysfunction.[30] What remains understudied and very infrequently described during side effect discussions with the patients is the effects on voice.

Testosterone therapy has been found to significantly lower the fundamental frequency of the voice in postmenopausal patients.[30–32] However, the method of testosterone supplementation may lower this risk, with Glaser et al[33] finding no change in the fundamental frequency of voice with subcutaneous testosterone implant. As testosterone is an androgen steroid, it causes the vocal fold muscles to become thicker, which increases their density and therefore produces a lower F0, which can often reach the male speaking range.

Similarly to testosterone supplementation, anabolic steroids have a virilizing effect on the voice.[34] Two studies found this effect to be permanent despite discontinuation of the anabolic steroids during the study follow-up time of 4 years.[34,35] Specifically for postmenopausal patients, anabolic steroid supplementation has been associated with a lower fundamental frequency of voice and increased voice instability in early studies.[36,37] Similarly, a rarer adverse effect is hepatic dysfunction.[37]

Since testosterone therapy is not routinely used and there is no FDA-approved testosterone formulation for the management of menopausal symptoms, there are no studies to this day comparing the effect of traditional HT and testosterone therapy on voice. However, the experience of the senior authors of this manuscript has been that postmenopausal female patients on testosterone therapy have F0 significantly lower than with traditional HT, with important complaints of being perceived as male speakers on the phone.

The results are often considered to be permanent even after withdrawal from testosterone therapy. For that reason, further research is needed to understand the effect of testosterone therapy on voice as well as the risks related to different dosages to better counsel patients when initiating this therapy.

Menopause and professional voice use

PVUs—such as teachers, singers, actors, broadcasters, and call center workers—comprise nearly one-third of the global workforce.[4] These individuals rely on their voices as primary occupational tools, often placing them under significant strain due to prolonged voice use and high vocal demands. Unlike the general population, PVUs are acutely aware of even minor vocal alterations, as small changes in pitch stability, endurance, or resonance can impact their professional performance and career longevity.[38] A recent meta-analysis of voice disturbances in a group of 63,126 professional voice users across 73 studies found a high prevalence of dysphonia in PVU, especially amongst teachers, especially those with high and prolonged vocal demand. Given the predominance of women in vocally intensive professions, menopause introduces unique challenges that can significantly affect occupational voice function.

Menopause-related hormonal fluctuations can alter the structural and functional properties of the larynx, leading to vocal fatigue, breathiness, reduced pitch range, and difficulty reaching high notes.[26] These voice symptoms, which can be subtle in the general population, are particularly problematic for PVUs who depend on vocal precision and endurance. A study of professional singers found that 77% of female singers and 71% of male singers reported noticeable vocal changes around age 50.[4] Female singers, in particular, describe increased difficulty reaching high registers, diminished vocal control, and breathiness. While aging alone contributes to some of these changes, the decline in estrogen and increase in androgenic influence during menopause are believed to intensify these effects, leading to a perceived deepening of the voice and loss of brilliance in the upper vocal range.

Research also suggests that postmenopausal PVUs experience greater difficulty with vocal stability and projection, making it more challenging to sustain performances or maintain vocal quality throughout a workday.[39] The combination of sustained occupational voice use and hormonal decline places PVUs at heightened risk of vocal strain and diminished professional capacity.

The impact of these changes extends beyond perceptual alterations. Sovani and Mukundan demonstrated that PVUs exhibit a unique interaction effect between occupational voice use and postmenopausal voice changes.[39] While professional voice users are often aware of vocal strain resulting from overuse, they may be less attuned to the insidious effects of hormonal changes, which can present as increased vocal effort and instability rather than overt dysphonia. The Menopausal Voice-Related Work Limitation Scale (MenoVWL), developed by Lã and colleagues, has provided objective evidence that postmenopausal PVUs report significantly greater work-related vocal limitations than their premenopausal counterparts.

In addition to hormonal effects, the physical and environmental demands of certain professions further exacerbate menopausal voice changes. Teachers, for example, are required to project their voices for prolonged periods, often in acoustically challenging environments. Research by Kıncal and Irklı[40] found that teachers and other instructors experience the highest levels of vocal fatigue among PVUs, with inadequate vocal rest and poor hydration contributing to long-term strain.[41] A systematic review by Ramachandran et al[42] also found that many PVUs adopt passive coping mechanisms—such as reducing voice use rather than implementing proactive vocal hygiene measures—potentially accelerating long-term vocal decline.[43]

The professional and financial consequences of menopause-related voice disorders are substantial. PVUs experiencing vocal fatigue or instability may find themselves limiting performances, avoiding strenuous vocal tasks, or even reducing work hours. A study by Przysiezny and Przysiezny[5] found that untreated voice disorders significantly increase absenteeism, reduce productivity, and, in severe cases, force career changes or early retirement. In Brazil, multiple studies have advocated for voice disorders to be formally recognized as occupational diseases, emphasizing their financial and public health impact. Given that women make up a significant proportion of vocally intensive professions, particularly in teaching, this issue demands urgent attention.

Despite the evident challenges faced by PVUs during menopause, research on this topic remains limited. While studies have explored age-related vocal changes, few have specifically examined the impact of menopause on professional voice users or developed targeted interventions to support them. The absence of standardized guidelines leaves many PVUs navigating these changes without clear medical or professional support.

Future research should focus on developing preventative and therapeutic strategies tailored to this high-risk group, ensuring that female PVUs can maintain vocal function and occupational longevity. Key interventions could include targeted voice therapy, workplace accommodations such as structured vocal rest breaks and amplification tools, and greater awareness among healthcare professionals regarding menopause-related voice disorders. Addressing these gaps will be crucial in preserving not only the vocal health of PVUs but also their professional stability and quality of life.

Treatment options for women suffering from voice disorders related to menopause

When female patients present to a voice clinic with complaints of vocal symptoms, including voice changes, globus sensation, chronic cough, or throat dryness, they first get a workup through history and a physical examination, including voice analysis and stroboscopic examination.

Careful history should include hormonal status as well as hormonal supplements in any form, as well as hydration status, profession, vocal use and with a specific focus on medications that can have a drying effect. Use of continuous positive airway pressure and comorbidities that affect the voice, such as hypothyroidism or Sjogren disease, should also be investigated.

Laryngoscopic and stroboscopic examination consists of a small endoscopic camera that is passed through the nose to analyze the integrity of the laryngeal structures, presence of lesions or abnormal tissue and function of the vocal folds while vibrating. Although this exam can reveal anomalies described below, it most often does not reveal significant visible structural anomalies, and therefore, postmenopausal women are often told their symptoms could be due to acid reflux, without a confirmatory workup.

Common findings on stroboscopy in postmenopausal women with complaints of vocal symptoms can include the following:

- Vocal fold atrophy: thinning of the vocal folds due to atrophy of the thyroarytenoid muscles and loss of collagen, resulting in incomplete closure during phonation and causing a breathier, weaker voice.
- Dryness of the laryngeal tissues.
- Supraglottic squeeze and muscle tension: squeezing of the muscles around the vocal folds that compensate for weakened or inefficient phonation, or due to an irritation or globus sensation. This results in an effortful voice production that can cause discomfort to the patient and a rough sound quality.
- A normal appearance of the laryngeal structures and vocal fold tissue, and therefore, no visible explanation for the patient's symptoms.

Laryngologists and speech pathologists can help address these symptoms based on the findings of voice evaluation and stroboscopic evaluation (Fig. 2).

(1) Voice therapy: Voice therapy is provided by a speech pathologist and usually consists of 4 to 10 sessions where the patient learns to produce voice in a less effortful way and optimize phonorespiratory coordination. As an analogy, we often explain to patients that their laryngeal instrument is changing and that a speech therapist will teach them to play their new instrument. Patients with muscle tension of the laryngeal muscles and even muscle atrophy can highly benefit from voice therapy to improve the quality and projection of their voice.
(2) Steaming and hydration: As dryness of mucosal tissues in the larynx can be the culprit of voice changes, focus is made on daily hydration, focusing on multiple small amounts of water throughout the day. Another method to direct hydration at the laryngeal tissue is steaming, which consists of inhaling steamed sterile water with a mouth device once to twice a day.
(3) Medical therapy
    (a) Systemic HT: As mentioned in the previous sections, HT can be considered to help with voice symptoms in the context of other menopausal symptoms. Collaboration between the laryngology team and the gynecology team is key to following the effects.
    (b) Intranasal HT: A few studies have investigated intranasal hormonal therapy (estradiol) compared with systemic therapy, with the underlying intent to provide more local treatment. Again, care should be taken to discuss the treatment plan with the gynecologist or family physician.
(4) Procedure/surgery:
    (a) Bilateral vocal fold injection augmentation: Vocal fold injection augmentation is a procedure that can be performed on an awake patient with local anesthesia or in the operating room under general anesthesia. The goal of the surgery is to "plump up" the vocal folds or "augment" them to counteract the vocal fold atrophy, causing the vocal folds to not fully contact when they vibrate. The injections are performed with resorbable products with various lengths of effect (from 3 weeks to 18 months) such as hyaluronic acid, carboxymethylcellulose, or calcium hydroxyapatite. Patients will often report an increase in volume of the voice, clearness, and ability to project. Complications are rare and include infection and undesirable voice quality.
    (b) Thyroplasty: A thyroplasty is a surgical procedure performed in the operating room under sedation. It consists of placing a small implant lateral to the vocal fold to augment paraglottic support and alter three-dimensional shape, which may be needed after the loss of muscle and/or fat that occurs with menopause. The implant is placed through an incision in the neck with a small window through the thyroid cartilage. This is considered a permanent solution. Goretex or silastic can be used for the implant. Complications are rare and include postoperative hematoma, infection, undesirable voice quality, and extremely rarely, implant extrusion.
    (c) Fat injection laryngoplasty: Fat injection laryngoplasty consists of injecting fat, usually obtained from the patient's abdomen, into the vocal fold. It is usually performed under general anesthesia. It is considered a permanent solution, although fat is known to be partially reabsorbed and less predictable than the other materials. Complications are rare and include vocal fold hematoma, infection, stiffness due to fat inflammation, and undesirable voice quality.

FUTURE DIRECTIONS

While awareness of menopause-related voice changes has increased, our understanding of the underlying mechanisms, risk factors, and effective management strategies remains incomplete. Current research is limited by inconsistencies in study methodologies, small sample sizes, and a lack of longitudinal data. To bridge these gaps, future research should focus on four key areas: (1) AI-driven voice biomarkers, (2) interdisciplinary and

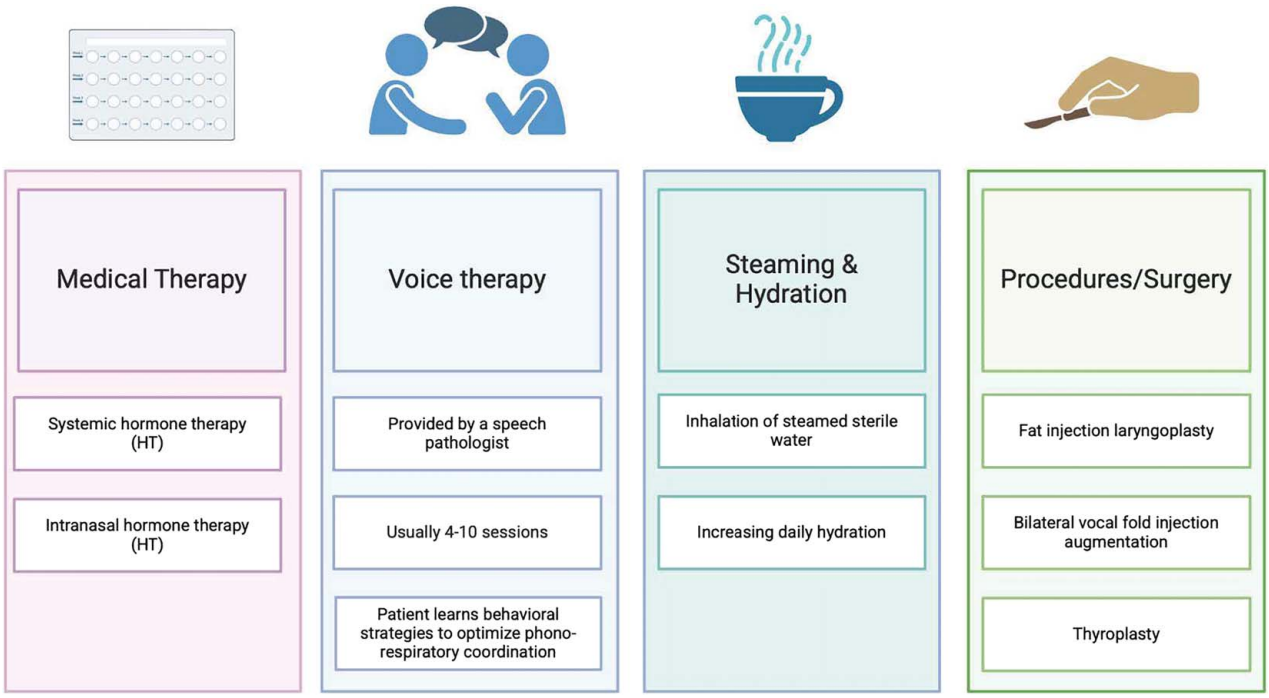

FIG. 2. Symptom treatment and management options.

longitudinal research, (3) workplace interventions for professional voice users, and (4) cultural and ethnic variability in vocal aging.

AI-DRIVEN VOICE BIOMARKERS FOR HEALTH MONITORING AND DIAGNOSTICS

Artificial intelligence (AI)-powered voice biomarkers offer a promising, noninvasive tool for detecting subtle changes in vocal function, including those associated with hormonal fluctuations during menopause. AI models can analyze vocal features such as fundamental frequency, jitter, and shimmer to track changes in vocal stability and endurance over time. Studies have demonstrated the potential of AI-driven voice analysis in diagnosing neurological and respiratory conditions, but its application to menopause-related voice disorders remains largely unexplored.[44] Future research should assess whether AI can reliably differentiate menopausal voice changes from normal aging-related alterations, and whether AI-based monitoring could guide early interventions for professional voice users.

The COVID-19 pandemic significantly accelerated research into vocal biomarkers due to the need for remote and contact-free diagnostic tools. Studies demonstrated that AI-driven voice analysis could successfully detect COVID-19-related symptoms, such as fatigue and respiratory distress, even in asymptomatic individuals.[44,45] This rapid expansion of voice-based diagnostics has paved the way for broader applications in cardiovascular health, mental health, and neurological disorders.

Several research initiatives are currently pioneering AI-driven voice analysis for health monitoring:

- The Bridge2AI Voice Consortium (NIH) is developing a vast database of voice recordings linked to multimodal biomarkers to enhance AI-driven health diagnostics[41]
- The Mayo Clinic is pioneering research on AI-based voice biomarkers for cardiovascular disease, demonstrating that vocal changes can predict coronary artery disease with high accuracy.[43]
- Sonde Health has created AI models to monitor mental health conditions such as depression and anxiety by analyzing voice-based biomarkers.[46]
- Zana AI is applying AI-powered voice analysis to detect early signs of heart disease, showcasing the potential for vocal biomarkers in cardiology.[47]
- TELL is using AI-assisted voice analysis to detect neurological disorders, such as Parkinson and Alzheimer disease.[48]

Given these advancements, future research should assess whether AI can reliably differentiate menopause-related voice changes from normal aging-related alterations and whether AI-based monitoring could guide early interventions for PVUs. Developing a comprehensive AI-powered voice biomarker database specifically for menopausal individuals would be instrumental in advancing this field. In addition, AI tools could be integrated into clinical voice assessments to provide real-time analysis of menopausal voice changes, aiding in both early diagnosis and personalized treatment recommendations.

INTERDISCIPLINARY AND LONGITUDINAL RESEARCH

Addressing menopause-related voice changes requires collaboration among otolaryngologists, speech-language pathologists, endocrinologists, and gynecologists. While some studies suggest that hormone therapy (HT) may help preserve vocal function, findings remain inconsistent due to variations in hormone dosages, treatment durations, and vocal outcome measures.[26] Future clinical trials should standardize these variables to clarify the efficacy of HT in maintaining vocal quality. In addition, longitudinal studies tracking voice changes from perimenopause through postmenopause are needed to identify individual risk factors and determine the optimal timing for interventions. These studies should incorporate both objective acoustic measures and patient-reported outcomes to provide a comprehensive understanding of menopausal voice alterations.

OCCUPATIONAL HEALTH POLICIES FOR PROFESSIONAL VOICE USERS

The professional and financial impact of menopause-related voice disorders on PVUs underscores the need for workplace accommodations and interventions. Research suggests that voice-related absenteeism is a growing issue in vocally intensive professions such as teaching.[49] Employers in vocally demanding fields could implement policies that promote:

- Vocal hygiene education to prevent strain.
- Structured vocal rest breaks to mitigate fatigue.
- Amplification technologies (eg, microphones for teachers) to reduce excessive phonation effort.

Additionally, integrating vocal health education into occupational training programs could help PVUs adopt preventative strategies before symptoms become debilitating. Future studies should evaluate the effectiveness of these interventions in reducing voice-related work limitations and improving career longevity in menopausal PVUs.

ADDRESSING ETHNIC AND CULTURAL VARIABILITY IN VOCAL AGING

Menopause-related voice changes may differ across ethnic and cultural groups due to variations in hormone metabolism, vocal tract anatomy, environmental exposures, and healthcare access. Research indicates that Black, Latina, and Asian women experience menopause earlier and with more severe symptoms than White women.[50] However, little is known about how these disparities influence vocal function. Future studies should assess whether menopause-related voice symptoms vary across populations and whether diagnostic criteria and treatment recommendations should be adjusted accordingly. Incorporating diverse participant samples into clinical voice research will be essential for developing equitable and culturally sensitive vocal health guidelines.

As research in these areas progresses, it will be crucial to translate findings into clinical practice and occupational policies. Ensuring that PVUs and healthcare providers are equipped with evidence-based strategies for managing menopause-related voice changes will be essential in preserving vocal health, career stability, and overall quality of life for affected individuals.

CONCLUSIONS

Voice changes during menopause result from a complex fluctuation of hormonal, structural, and functional transformations that may impact the quality of life for a significant proportion of women affected. Despite growing recognition of these changes, they remain underdiagnosed and undertreated. This review highlights the critical role of interdisciplinary collaboration in understanding and managing menopausal voice disorders. While hormone therapy shows potential in preserving vocal quality, inconsistencies in research findings call for further rigorous and longitudinal studies. Emerging technologies, such as AI-driven voice biomarkers, offer promising avenues for early detection and personalized care. As awareness grows, targeted assessments and interventions must evolve to support vocal health throughout the menopausal transition and beyond.

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