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Dossier Research in Vocal Pedagogy in Contemporary Brazil: Perspectives and Interdisciplinary Dialogues

Voice conditioning guidelines for the menopausal singer

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Abstract: Menopause is associated with a significant depletion in concentrations of sex steroid hormones (oestrogens, progesterone and androgens), which may lead to changes in voice function besides other symptoms, such as alterations in cognition and mood. As a result, singers' ability to perform may be jeopardized and reduce career choices. Among possible strategies to prevent and overcome menopause-related impacts, voice training has been identified as effective, although recommendations on specific exercise protocols are scant. The present investigation discusses the impact of menopause on singers' vocal performances and provides guidelines for developing coping strategies and solutions to approach vocal difficulties. Results of studies comparing parameters of voice production and self-reported perceptions of pre and postmenopausal singers are discussed, analysed within a framework of voice science and singing pedagogy. The included vocal exercises are grounded on principles of exercise physiology and propose the use of self-monitoring tools for an enhanced practice. The guidelines are organized to address breath management, vocal dryness, vocal fatigue, reduced vocal endurance, decreased pitch range, and instabilities within transitional areas of the voice range.

Keywords: Singing. Menopause. Voice exercises. Coping strategies. Training and self-monitoring tools.

Diretrizes de condicionamento vocal para cantoras na menopausa

Resumo: A menopausa está associada a uma redução significativa das concentrações de hormônios esteroides sexuais (estrogênios, progesterona e andrógenos), o que pode levar a alterações na função vocal, além de outros sintomas, como mudanças na cognição e no humor. Como resultado, a capacidade de desempenho das cantoras pode ser comprometida, reduzindo suas opções de carreira. Entre as possíveis estratégias para prevenir e superar os impactos relacionados à menopausa, o treino vocal tem sido identificado como eficaz, embora ainda sejam escassas as recomendações sobre protocolos específicos de exercícios. A presente investigação discute o impacto da menopausa no desempenho vocal de cantoras e fornece diretrizes para o desenvolvimento de estratégias de enfrentamento e soluções para lidar com dificuldades vocais. São apresentados e analisados, dentro de um enquadramento científico da voz e da pedagogia do canto, resultados de estudos que comparam parâmetros de produção vocal e percepções autorrelatadas de cantoras pré e pós-menopáusicas. Os exercícios vocais incluídos baseiam-se em princípios da fisiologia do exercício e propõem o uso de ferramentas de automonitorização para uma prática mais eficaz. As diretrizes estão organizadas para abordar gestão da respiração, ressecamento e fadiga vocal, redução da resistência, diminuição da extensão vocal e instabilidades nas zonas de transição entre registros.

Palavras-chave: Canto. Menopausa. Exercícios vocais. Estratégias de confrontamento. Ferramentas de treino e automonitorização.

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Menopause is defined as a single day in a female's life when reproductive ability ceases: the day after 12 consecutive months of amenorrhea (Harlow *et a*l., 2012). During the transitional years that precede menopause (*i.e.*, perimenopause) and the four to five following consecutive years (*i.e.*, post-menopause), alterations in the vocal apparatus may occur, especially in the oscillatory subsystem. Such alterations may include oedema and increased vascularity of the vocal folds, as well as mucosal dryness and laryngeal stiffness, with loss of muscle tone (Abitbol; Abitbol; Abitbol, 1999; Lenell; Sandage; Johnson, 2019; Patel *et al*., 2021; Schneider *et al.,* 2004).

Approximately 29% of singers complain about vocal discomfort during menopause (Boulet; Oddens, 1996). Singers' complaints include loss of high notes, heavier and darker timbre, difficulties with the transitional regions of the voice range, reduced vocal agility and stamina, increased vocal fatigue, vocal dryness, and a weaker voice (Demaio, 2013; Price, 2010; Richie, 2013; Fiuza; Sevillano, Lã, 2021). The presence of these symptoms may contribute to the lowering of self-efficacy with respect to voice function in singing, as confirmed by self-perceptions of postmenopausal singers compared with premenopausal singers (Lã *et al*., 2022). As self-efficacy is a strong predictor of performance achievement (McPherson; McCormick, 2006), menopause-related voice symptoms are not trivial to singers; they may inflict challenges in the management of singing that, in the absence of coping strategies, may result in a forced early retirement (Allen, 2006; Fiuza; Sevillano, Lã, 2021; Price, 2010). Impairment of voice function in singers is a commonly reported menopause-related descriptor (Fiuza; Sevillano, Lã, 2021). Difficulties with voice flexibility, strength, endurance, agility, and/or timbre are some examples of such impairment. Reduced flexibility will impact on the velocity and type of repertoire a singer may perform; some singers adapt to this new reality, while others can be severely affected (Bos; Bozeman; Frazier-Neely, 2020; Demaio, 2013; Fiuza; Sevillano, Lã, 2021). In addition, vocal strength and endurance seem to be reduced during menopause; this will increase perceived effort levels (Abitbol; Abitbol; Abitbol, 1999; Elliott, 2017). As voice timbre may change as a result of alterations in vocal-folds vibrations and adduction force, the menopausal singer may abandon performance engagements prematurely. All these changes naturally seem to contribute to the reported decrease in singers' ability to work (Lã *et al*., 2022). It is urgent that singers who experience menopause-related symptoms learn coping strategies to prevent and find solutions to these problems, guaranteeing the maintenance of their careers.

According to the life expectancy and the mean age at which menopause occurs in industrialized countries (*i.e.,* around 50 years old), it is estimated that approximately 40% of a woman's life is spent in the postmenopausal period. To those singers whose voice is impaired by menopausal changes, preventive strategies and exercise solutions are needed, especially if the aim is to restore voice function and guarantee career's Sustainability.

This investigation proposes guidelines for the management of menopausal singers' voice function based on the results of previous studies comparing self-perceptions and aerodynamic, acoustic, and physiological parameters of voice production in pre and postmenopausal singers (Fiuza; Lã; Sevillano, 2021; Lã *et al*., 2022; Lã et al., 2023; Fiuza *et al*., 2025). In the following sections, singers can find a framework of knowledge based on the available literature on science-informed singing pedagogy to support the guidelines proposed. Factors such as physical conditioning, hydration levels, and principles of exercise

physiology are considered. Additionally, tools to assess singing function, such as the self-efficacy scale (Lã *et al.,* 2023), and real-time visual feedback for monitoring vocal practice are included (Lã; Fiuza, 2022). Finally, examples of vocal exercises and suggestions of practical approaches to these exercises are presented. The goal is to improve vocal flexibility, strength, and endurance, proposing exercises to explore breath management, vocal range, and phonation types.

1. The knowledge framework

1.1. Physical conditioning

Optimal voice production depends on the neural coordination of the three physical subsystems that constitute the vocal apparatus: respiratory, oscillatory, and resonatory (Welch; Sundberg, 2002; Herbst, 2016). Due to the interconnections between the body parts that constitute these three subsystems, one may argue that the coordination of the entire body may affect voice function. Consequently, maintaining good physical condition seems to be essential when the goal is to preserve vocal function.

For example, the practice of aerobic exercises was found to contribute to voice preservation in postmenopausal speakers (Lowery, 1993). Also, aerobic exercises seem to favour singing: they contributes to a less-demanding vocal-specific warm-up (Mchenry; Evans, 2016). Partially, this may be due to a direct result of aerobic exercises on cardiovascular fitness. Cardiorespiratory fitness is critical for improving overall healthy conditioning. It leads to maximal oxygen consumption (*i.e.*, the maximum amount of oxygen that the body can use during intense exercise) (Kriswanto; Setijono; Mintarto, 2019). Higher cardiorespiratory fitness is associated with improved health-related quality of life, greater efficiency in physical activities, faster recovery after exertion, and successful cognitive aging (Badaró; Vaiano; Behlau, 2024; Sloan *et al*., 2009). Thus, engaging in regular physical activities such as walking, running, swimming, and dancing has been highly recommended for women, especially those passing through the menopausal transition (Grindler; Santoro, 2015). Regular physical activity, particularly aerobic exercise, has been shown to reduce physical and psychosocial menopausal symptoms, such as fatigue, irritability, insomnia, and joint pain. It also improves metabolic indicators and overall quality of life in menopausal women (Grindler; Santoro, 2015). The results of a double-blind randomized controlled trial suggested that 12 consecutive weeks of physical group activity did not improve vasomotor symptoms but led to better sleep quality (Sternfeld *et al.,* 2014).

Physical activity guidelines suggest an exercise routine of three to five times a week, at intensities ranging from 50% to 80% of the reserve heart rate (*i.e.*, the difference between maximum and resting heart rate) (Guedes; De Araújo de; De Araújo, 2021). However, even small session of physical exercises can reduce health deterioration risks in older adults (Grindler; Santoro, 2015). For singers, maintaining good cardiorespiratory fitness may be relevant as phonation requires control of air pressure and lung volume (Sundberg, 1987; Titze, 1994).

1.2. Voice hydration

Vocal dryness is one of the most common symptoms reported by singers during menopause (D'haeseleer *et al*., 2011; Fiuza; Sevillano; Lã, 2021). Reduced hydration decreases the mobility and vibratory capacity of the vocal folds, thus producing more difficulties when initiating vocal folds vibration and increasing phonatory effort. This can contribute to perceptions of increased hoarseness (Alves *et al.,* 2019; Roth; Verdolini-Abbott, 2014; Verdolini-Marston; Titze; Druker, 1990). Additionally, a less lubricated epithelium (i.e., the superficial layer of the vocal folds mucosa) weakens its protective function against inhaled viruses, bacteria, irritants, and injuries (Levendoski; Leydon; Thibeault, 2014).

Vocal dryness can be addressed through both systemic and superficial hydration. Systemic hydration involves intracellular water transportation as a result of increased water intake. The water reaches the tissues of the vocal folds via internal cellular regulatory systems, leading to less fluid glandular secretions (Leydon *et al.,* 2010). However, increased water intake should be monitored as the effects of hyperhydration and individual hydration regulation are not yet fully understood (Hartley; Thibeault, 2014). Superficial hydration, on the other hand, concerns the maintenance of humidity and adequate lubrication of vocal folds' surface (Vermeulen *et a*l., 2021). This can be achieved primarily through nebulizing saline solution or hyaluronic acid using nebulizer devices (Souza *et al*., 2023; Pilsl *et al.,* 2025). Ten minutes of nebulization with a saline solution seems to have positive effects on the voice, as suggested by the results of acoustical and perceptual analysis, and direct laryngeal observations (Plec *et al.,* 2024; Souza *et al.,* 2023). Singers experiencing menopausal-vocal dryness will benefit from a combination of both hydration methods.

To improve hydration levels, the first recommendation is to evaluate individual needs. Fluid intake varies among individuals, depending on body size, physical activity, and environmental characteristics (Hartley; Thibault, 2014). For an individualized evaluation, the most practical way is to observe the colour of the urine (Tahar *et al*., 2024). An eight-gradient colour scale was created to identify hydration levels, from very pale yellow to dark amber. A light-coloured urine will be a sign of good hydration (Armstrong *et al*., 1994). This can be achieved by the daily consumption of 2 litres of water (about eight 250 ml cups). The body also extracts water from solid food, especially vegetables and fruit, so an increase in their intake will also be a useful addition to the increase in water intake.

1.3. Principles of exercise physiology and their sex dependence

Exercise physiology concerns the manner in which exercises modify and affect the body in a particular way depending on type of exercise (e.g., aerobic or anaerobic) and its frequency, intensity, speed and duration (Mcardle; Katch; Katch, 2014). Although these principles have been successfully applied to physical education, the extent to which they can be directly applied to voice education is still controversial (Hoch; Sandage, 2018; Sandage et al., 2019). On the one hand, laryngeal muscles are substantially different from those existing elsewhere in the body (*e.g*., upper and lower limbs) (Sandage *et al.,* 2019). On the

other hand, voice training protocols based on principles of exercise physiology have been fruitfully applied to different contexts of voice education and rehabilitation (Sabol; Lee; Stemple, 1995). For example, applying principles of voice physiology described in Brooks, Fahey, and Baldwin (2005) to voice education, the following principles have been pointed out as relevant: overload, stress, strain, exhaustion, adaptation, load, repetition, rest, frequency, specificity, reversibility and individuality (Titze; Verdolini-Abbott, 2012). From this list, the overload principle seems to be the most widely accepted among voice specialists for obtaining positive effects on voice conditioning.

The overload principle in voice (re)habilitation has been defined as a gradual increase of exercise's difficulty and intensity, leading to a progressive increase in vocal ability (Badaró; Vaiano; Behlau, 2024; Hoch; Sandage, 2018; Johnson; Sandage, 2021; Sandage; Pascoe, 2010; Sandage; Smith, 2017; Sabol; Lee; Stemple, 1995; Titze; Verdolini-Abbott, 2012). Following this principle, the easier the performance of a specific exercise becomes, the greater the load of subsequent exercises must be (Mcardle; Katch; Katch, 2014; Badaró; Vaiano; Behlau, 2024). In voice care and education, overload can be achieved by creating vocal exercises that include different combinations of pitch and loudness, with various repetitions and durations (Badaró; Vaiano; Behlau, 2024).

The expected result of overload in physical training is the increase of muscle capacity (Mcardle; Katch; Katch, 2014). However, with respect to singing, the expected result will be the improvement of phono-respiratory coordination and muscle neuromotor control (Lenell; Sandage; Johnson, 2019). Inferring from studies concerning the effects of vocal exercise in rats' larynxes, overload may reduce neuromuscular junction motor endplate dispersion, thus increasing the precision of nerve-muscle communication (Johnson *et al.,* 2013). Effects of overload in vocal muscle building have not yet been observed; no changes in laryngeal fibre types, strength, nor size were found with an increased number of vocalisations in both young and older rats (Shembel *et al*., 2021). Muscle fibre conversion in rats' laryngeal muscles occurred only after muscle denervation and reinnervation. After four weeks of reinnervation, rats' thyroarytenoid (TA) muscle fibres became faster and less resistant, revealing an increased neural regulation but not an augmented response to increased vocalizations (Rhee; Lucas; Hoh, 2004).

Voice exercise has been used to mitigate effects of vocal senescence (Oates, 2014). The effects were observed not only in muscle conditioning but also in the improved balance between respiratory support and laryngeal effort (Stemple *et al.,* 1994). For example, to reduce the effects of ageing on the voice, common exercises followed the principle of overload by including maximum vocal effort tasks. These included maximum phonation time, i.e., sustaining vowels for as long as possible in a single breath, and using vowels to perform ascending/descending pitch glides (Gorman *et al*., 2008; Kaneko *et al.,* 2015; Lu; Presley; Lammers, 2013; Tay; Phyland; Oates, 2012; Ziegler *et al*., 2014). These types of exercises seem to counteract the age-related observations of reduced number and size of muscle fibres and change the type of fibre composition and metabolic function in the TA muscles in both human and rat models (Kersing; Jennekens, 2004; Martins *et al.,* 2015; Mcmullen; Andrade, 2006, 2009; Nishida *et al.,* 2013).

Considering the anatomical differences between female and male vocal apparatus and given that ageing of the voice is clearly sex dependent, the design of voice exercises for female voices at

menopause should be differentiated, especially because sex steroid hormones also affect muscle conditioning (Lenell; Sandage; Johnson, 2019). For example, sarcopenia (*i.e.,* accelerated loss of muscle mass and strength) seems to be accelerated during perimenopause (Brown, 2008; Maltais; Desroches; Dionne, 2009). This leads to a higher loss of fast-twitch muscle fibres over slow-twitch muscles, as the former have higher concentrations of oestrogen receptors (Brown, 2008). Indeed, the diameter of the TA muscle fibres decreases about 5% (15.5 μm) throughout female adulthood, a decrease that is less significant and less rapid when compared to males. Additionally, as to what concerns laryngeal innervation, the ageing female loses conduction velocity much faster as compared to the ageing male (De Campos *et al*., 2013). As the response to strength exercise in females seems to benefit neural adaptations, such as enhanced motor unit recruitment (Bamman *et al*., 2003; Ivey *et al*., 2000; Kosek *et al.,* 2006; Melnyk; Rogers; Hurley, 2009), it seems that training vocal neuromotor strengthening will be especially recommended for the menopausal singer. Tailoring vocal exercises for the female menopausal singer should also include vocal endurance besides vocal strengthening. As in males, the female vocal endurance training leads to maximization of oxygen intake (Coggan *et al*., 1993). Although in humans the sole effects of menopause are very difficult to identify, one may infer from the results of studies with other mammals on the effects of menopause on hindlimb muscles that it is highly probable that menopause causes adverse effects on intrinsic laryngeal muscles (Bunratsami *et al*., 2015; Kadi *et al*., 2002; Moran; Warren; Lowe, 2006; Velders; Diel, 2013).

1.4. The importance of breathing exercises to voice function

Menopause can negatively affect breath management; a decline in lung function was observed in post- as compared to premenopausal women (Campbell *et al*., 2017). Additionally, the rate of lung function decline is higher in post- as compared to premenopausal women (Triebner *et al.,* 2017). With ageing, the number of breath cycles increases; thus, engaging more muscle activity will be necessary to counteract the observed reduced laryngeal valving (Hoit; Hixon, 1987). Also, vital capacity, residual volume and expiratory volume decrease (Hoit *et al*., 1989), and lung elasticity also diminishes (Rossi *et al.,* 1996) with ageing; training breathing function in menopausal singers seems therefore necessary.

The benefits of practicing respiratory exercises isolated from phonation have been questioned in voice training (Titze; Verdolini-Abbott, 2012; Ray; Trudeau; Mccoy, 2018). For example, following respiratory muscle strength with progressive threshold training, participants showed an increased respiratory muscle strength after completing the training program; however, no consistent effects on aerodynamic measures of voice production were observed (Ray; Trudeau; Mccoy, 2018). Despite these mixed results, the use of devices that regulate inspiratory and/or expiratory airflow resistance has been recommended by some studies when the aim is to improve the voice (Badaró; Vaiano; Behlau, 2024; Ray; Trudeau; Mccoy, 2018).

To train the inspiratory part of the breath cycle, devices such as RESPIRON® and POWERbreathe® Plus LR have been referred to improve inhalatory muscle capacity. A study with 22 vocally

healthy women reported significant reduction in shimmer, jitter and period perturbation quotient immediately after use of RESPIRON® (Lopes *et al*., 2024). It is recommended to start at the lowest resistance offset as possible offered by these devices, followed by a gradual increase in resistance. This is because adding challenges during training stimulates improvement without causing damage (Badaró; Vaiano; Behlau, 2024).

If singers do not have access to specialized airflow resistance devices, alternative methods can be used, such as inhalation through straws of different diameters (the thinner, the greater the resistance) or partially covering the nose or the mouth with a finger or the hands during inhalation. Resistive inhalation requires the abduction of vocal folds and inspiratory muscle activity during inhalation, thus contributing to a maximal inspiratory pressure during inhalation (Lopes *et al*., 2024).

As to what concerns the expiratory part of the breath cycle, and according to author's experiences, this should be trained together with phonation, especially when referring to more experienced singers, such as the case of the menopausal singer. The training of such phono-respiratory exercises can be achieved by practicing semi-occluded vocal tract exercises (SOVTE), with and without an artificial elongation of the vocal tract, and with a single or a dual source of vibration (Badaró; Vaiano; Behlau, 2024; Ferreira et al., 2023; Hencke et al., 2024; Lã; Ternström, 2020; Natale *et al*., 2024; Ray; Trudeau; Mccoy, 2018).

Starting with vocal exercises using artificial elongation of the vocal tract, these can be performed using specialized devices, such as ACAPELLA Choice®, Shaker® and New Shaker®, glass tube in water (*e.g.,* Dr. Vox®, Lax Vox®, VocalFeel®), FlowBall® (Lã *et al*., 2017), and straws. The use of ACAPELLA Choice® seems to lead to a reduced vocal fatigue (Guzman *et al*., 2022) and improved vocal economy (Saccente-Kennedy *et al*., 2020). The use of a Shaker® device seemed to produce an improvement in acoustic parameters and a reduction of self-perceptions of vocal discomfort in both male and female voices (Laukkanen; Horáček; Radolf, 2019; Dantas et al., 2025). The practice of vocal exercises with glass tubes in water leads to an increase in collision threshold pressure, or, in other words, to an increase in the minimum pressure required to set the vocal folds into collision; this seems to contribute to an overall improved voice quality (Enflo; Sundberg; Mcallister, 2013). As to what concerns the use of a FlowBall®, it seems that singers, after practicing *messa di voce* exercises with this tool, reveal less phonatory adduction (Lã; Sundberg; Granqvist, 2022) and reduced vocal fold collision impact stress (Lã; Ternström, 2020) while applying larger amounts of phonatory airflow, as visually monitored by its ball height.

SOVTE can also be practiced without the artificial elongation of the vocal tract, phonating with voiced fricatives (/z/, /v/, /ʒ/, /β/) (Maxfield *et a*l., 2015). Phonation with nasal consonants (/m/, /n/, /ŋ/, /ɴ/) is also beneficial. The use of nasal consonants is common in exercise protocols, such as Vocal Function Exercises (Stemple *et al.,* 1994) and Resonant Voice Therapy (Verdolini *et al.,* 1998). The latter has been reported to promote flow phonation or, in other words, the optimal relationship between glottal adduction and subglottal pressure, producing a complete vocal closure with the highest amount of glottal airflow and acoustic excitation of the vocal tract (Sundberg et al., 2007). Indeed, contrary to classically

trained singers' perceptions, a slight velopharyngeal opening (VPO) is often used in singing and this does not lead to perceptions of increased sound nasality (Birch *et al*., 2002). On the contrary, the effects of different degrees of VPO on singers' spectrum balance suggest that, across all vowels and pitches analysed, the level of higher spectral partials is increased without requiring an increase in vocal loudness (or vocal effort) (Gill; Herbst, 2016). A slight VPO also contributed to a reduction in vocal folds' vibratory instabilities; fewer fundamental frequency (f_o) disturbances, such as pitch jumps, were produced by choir singers when the bandwidth of the first formant frequency was widened by means of a slight VPO (Sundberg; Lã; Granqvist, 2023).

SOVTE can also be performed involving a secondary source of oscillation, such as bubbles of air in water, lip trills and tongue vibrations (Calvache *et al*., 2020; Hencke *et al.,* 2024; Natale *et al*., 2024; Saccente-Kennedy; Andrade; Epstein, 2020; Saldías *et al*., 2020; Saters *et al*., 2018). The air pressure generated in the mouth by these oscillations creates vibrations throughout the pharynx and larynx, reducing muscle tension, vocal effort, and voice fatigue through a mechanism known as the "massage effect" (Guzman *et al*., 2020; Saters *et al*., 2018). It seems that the use of ACAPELLA Choice® provides the strongest massage effect due to its greater oral pressure amplitude oscillation and stable modulation (Guzman et al., 2020; Saccente-Kennedy; Andrade; Epstein, 2020).

In addition to using airflow resistance devices, there are other effective training methods of breathing that can be used to train singers, such as the Accent Method (Kotby *et al.,* 1991). This method enhances phonation through rhythmic voice accentuation and abdominal and diaphragmatic movement coordination. The Accent Method has been shown to improve speaking voice disorders (Bassiouny, 1998; Kotby *et al*., 1991) and is also used in singing for breathing-phonation coordination. Although no studies have directly assessed its effectiveness in singers, it is reasonable to assume that it can also be beneficial to singers. In fact, a preliminary study recommended the use of this method to menopausal singers, as it may improve respiratory capacity, agility, awareness, and control, particularly when combined with phonatory exercises (Kelloniemi, 2024).

1.5. Maintaining voice function

Impairment of voice function in singers is a commonly reported menopause-related descriptor (Fiuza; Sevillano, Lã, 2021). Difficulties with voice flexibility, strength, endurance, agility, and/or timbre are some examples of such impairment. Reduced flexibility will impact on the velocity and type of repertoire a singer may perform (Bos; Bozeman; Frazier-Neely, 2020; Demaio, 2013; Fiuza; Sevillano, Lã, 2021). Vocal strength and endurance seem to be reduced during menopause, a factor that seems to contribute to the increased perceived effort levels reported elsewhere (Elliott, 2017) and less ability to work (Lã *et al*., 2022).

Muscles develop strength and endurance through isotonic (changing length) and isometric (static) contractions, and the degree of endurance will depend on the intensity, duration, and repetition of the vocal exercise (Knuttgen, 2007; Mcardle; Katch; Katch, 2014). Strength training relies on short, intense, anaerobic efforts that recruit fast-twitching fibres, while endurance training involves continuous, lower-

intensity, oxygen-based activity that promotes fatigue resistance (Sandage; Smith, 2017). In the larynx, adductor muscles responsible for glottal closure are primarily constituted by fast fibres, whereas the posterior cricoarytenoid muscles responsible for the abduction contain more slow and resistant fibres. However, the balance between fast and slow fibres in laryngeal intrinsic muscles can be modified as the consequence of type and degree of voice exercise (Sandage; Smith, 2017).

Intense isotonic contractions seem to improve strength, and this can be achieved through rapid and controlled pitch jumps (*e.g.*, octave exercises), ascending and descending *glissandi*, and *staccato* exercises. On the other hand, isometric contractions seem to contribute to the building of endurance, applying long sustained vocalizations, such as maximum phonation time, long scales, and *messa di voce* exercises. These concepts are employed in previous suggested exercise protocols to (re)habilitate the voice, such as Vocal Function Exercises, which use sustained pitches and *glissandi* to promote endurance and efficient vocal fold adduction (Sabol; Lee; Stemple, 1995; Stemple *et al.*, 1994). Sustained phonation strengthens endurance through prolonged muscle engagement, though excessive use should be avoided to prevent vocal fatigue or abuse (Hoch; Sandage, 2018; Sandage; Pascoe, 2010; Johnson; Sandage, 2021). To mitigate the risk of excessive impact stress between the vocal folds, and thus potential phonotrauma, the exercises can be practiced using nasality and other SOVTE postures. The SOVTE tends to increase vocal economy when performed correctly (Calvache *et al.*, 2020) and can be combined with other types of exercises. Comparisons between Vocal Function Exercises and SOVTE exercises have shown similar positive effects on voice, such as a better self-evaluation, and a reduction in subglottal pressure, the pressure needed to initiate phonation (i.e., phonation threshold pressure, PTP), and glottal resistance (Antonetti *et al.,* 2022; Guzman *et al.*, 2020). Comparisons of effects of Vocal Function Exercises with and without the use of semi-occluded vowels (*e.g.*, /i/, /u/ and /o/) reported better results when accompanied with these vowels (Bane *et al.*, 2019). Furthermore, a comparison of vocal warm-ups using traditional open vowels versus phonation using glass tubes in water showed similar effects on self-perceived resonant voice quality, with a slight improvement in voice economy after phonating with glass tubes in water (Saldías *et al.*, 2020). However, it is also worth mentioning that SOVTE exercises also have some limitations as singers do not perform songs with a closed mouth or a glass tube in water. Thus, vowel and consonant articulation can be used without losing the benefits of a semi-occluded vocal tract if one performs exercises using a ventilation mask (Frisancho *et al.*, 2020) or a silicone mask attached to the tube (Natale et al., 2024). Covering the mouth and/or the nose with hands in a shell shape position or using a flexible cup while singing are other more affordable options that may offer similar results.

Well-conditioned muscles in the body show the ability to maintain their flexibility (Mcardle; Katch; Katch, 2014). Similarly, vocal folds flexibility should be promoted, as stretching and stiffening are required to reach high pitches (Sundberg, 1987; Titze, 1994). Laryngeal muscles perform intricate and coordinated movements to vary vocal folds' vibratory mass during pitch changes (Herbst, 2020; Unteregger *et al.*, 2017; Zhang, 2016). A reduced vocal fold flexibility will be related to a reduced vocal range, which

is another frequently mentioned complaint in menopausal singers (Fiuza; Sevillano, Lã, 2021), corroborated by laryngeal observations of loss of vocal fold suppleness (Abitbol; Abitbol; Abitbol, 1999).

To improve vocal folds flexibility, it is recommended that menopausal singers practice different types of vocal stretching. In physical workout, these types of stretching are static and dynamic. The first is achieved when the same muscle contraction is sustained over time, whereas the second when the muscle changes its contraction frequently over time (Behm; Chaouachi, 2011). Although the effects of these exercises in singers' voices have not yet been tested with randomised-controlled trials, one may argue that they will have a similar effect to the one obtained for other body muscles (Johnson; Sandage, 2021). In singing, dynamic stretching would involve exploring the voice with movement, such as varying pitch, intensity, and/or adduction degrees. For example, performing scales, *arpeggi*, or *glissandi* at a moderate pitch range and then increasing the amplitude of the intervals. Vocal folds stretching from their minimum to maximum length requires the capacity to activate and control almost all intrinsic laryngeal muscles. These movements seem to be controlled by contracting different muscles, such as the thyroarytenoid (TA), cricothyroid (CT), lateral cricoarytenoid (LCA), and posterior cricoarytenoid (PCA) (Chhetri *et al.,* 2014; Unteregger *et al.,* 2017; Zhang, 2016). However, the degree of muscle contraction and engagement is different, depending on pitch and loudness. Traditionally in singing, the lower notes that a person can produce are sung in "chest register", while the higher ones in "head register", "falsetto", or "whistle voice" (Stark, 1999). Because the term register may raise some controversy (Roubeau; Henrich; Castellengo, 2009), in the following sections, pitches sung with different degrees of laryngeal muscle contraction will be referred only as those sung in low and high range of the voice, or within transitional areas of the voice.

2. Tools to assess singing voice function during the menopausal transition

2.1. Self-efficacy in singing with respect to voice function

A significant menopause-related factor that seems to affect the ability to sing is the decline in self-confidence to control voice function. Postmenopausal as compared to premenopausal singers reveal less self-efficacy with respect to voice function in singing, at least at the higher range and within the transitional regions of voice, the latter commonly referred as *passaggio* regions (Lã *et al*., 2023). This scale comprises 18 items that include the ability to sing comfortably at a combination of different pitch ranges, degrees of vocal loudness, and phonation durations. As scores seem to be higher in pre- as compared to postmenopausal singers, and as self-efficacy is a strong predictor of performance success (McPherson; McCormick, 2006), its assessment seems relevant across the menopausal transition period, that may last several years. Comparing scores longitudinally will assist the identification of specific challenges at specific points of reproductive ageing, guaranteeing a more individualized approach and a better tailoring of vocal exercises. So far, descriptions of singers' complaints of menopause-related voice changes include subjective descriptors, such as "my voice is worse" or "I can't control my voice as I used to" (Fiuza; Sevillano, Lã, 2021).

The implementation of this scale will be an important addition to such descriptions. For example, if scores are low on items related to sustaining the voice across different ranges, this may be indicative of reduced respiratory capacity or excessive airflow due to inadequate vocal fold closure. The approach in such case could be, for example, the practice of exercises that counteract inadequate vocal closure, such as *staccato* exercises using a hard onset. To practice these types of exercises more effectively, the use of visual displays of electroglottography (EGG) or electrolaryngography (ELG) signals may be beneficial; this type of feedback was shown to be efficient when modifying a female singer's incomplete posterior vocal closure, diminishing the pre-existing vocal gap (Herbst; Howard; Schlömicher-Thier, 2010).

2.2. Real-time visual feedback tools

Real-time visual feedback improves the effectiveness of vocal training by providing simultaneous information on vocal outcomes while the singer is training. The coupling of visual with auditory and verbal feedback promotes the achievement of vocal goals, minimizes variability between task attempts, improves communication between singers and teachers, and enhances coordination between kinaesthetic proprioception and the resulting vocal sound (Callaghan *et al.,* 2008; Herbst; Howard; Schlömicher-Thier, 2010; Hoppe; Sadakata; Desain, 2006; Howard, 2005; Jeanneteau *et al*., 2022; Lã, 2012; Lã *et al*., 2017; Nair, 1999; Nair; Howard; Welch, 2019; Welch *et al.,* 2005; Lã; Fiuza, 2022).

In addition to its pedagogical function, real-time visual feedback supports vocal efficiency and prevention of misuse. Tools such as spectrograms, power spectra and airflow-based real-time visual feedback devices (*e.g.,* the FlowBall®) make often-inaccessible physiological processes perceptible to the learner, including glottal adduction and airflow regulation (Lã, 2012; Lã *et al*., 2017; Lã; Ternström, 2020; Lã; Fiuza, 2022; De Brito; Lã, 2025). Ultimately, these systems align with science-informed principles of voice pedagogy and support the development of sustainable vocal techniques. By allowing singers to monitor voices more objectively, they reinforce both artistic and functional goals during their vocal education.

3. Suggestions on vocal exercises for continuous singing before and after menopause

Previous studies have suggested that regular singing and voice lessons may help the menopausal singer (Allen, 2006; Demaio, 2013; Price, 2010; Kelloniemi, 2024). It has been suggested that regular practice counteracts the effects of menopause on muscle atrophy, improving vocal folds' contact and strengthening laryngeal muscles (Abitbol; Abitbol; Abitbol, 1999; Allen, 2006). In the following sections, exercises will be proposed, aiming at improving vocal function of menopausal singers. Thus, the core principles applied for suggesting the following exercises over others is that these are designed to contribute to improve vocal flexibility, strength, and endurance. The following subsections include suggestions of exercises for maintaining or even improving breath management, vocal flexibility, strength and endurance, and transitional areas within voice range. They must be adapted and tailored to individual needs and not followed as a voice protocol. To enhance control, monitoring, and progress, voice training

devices may be integrated, such as inspiratory and expiratory resistance tools or devices to promote a SOVT. Real-time visual feedback is also recommended and incorporated in these guidelines, to facilitate individual practice. Each exercise duration and repetition should be tailored to individual needs.

3.1. Categories of voice exercises

Pre-existing exercise protocols

As already mentioned, potential beneficial exercises for the menopausal singer are those included in Vocal Function Exercises (VFE) (Stemple *et al*., 1994) and Resonant Voice Therapy (RVT) (Verdolini-Marston *et al*., 1995). Also, practicing SOVTE with and without tools that artificially elongate the vocal tract may be beneficial (Titze, 2006), not only as a generalised practice for singers, but also for those singers going through menopausal transition and just after menopause (Kelloniemi, 2024; Price, 2010). There are several reasons that contribute to the rationale for practicing this type of exercises. For the case of VFE, one may mention the endurance component, as several exercises require maximum phonation time to sustain the closed vowels proposed to practice these exercises. As to what concerns the RVT, one may argue the use of nasal consonants and the practice of these exercises within transitional regions of the voice. As described in previous sections, the use of a slight VPO reduces the number of disturbances in the vibration of the vocal folds, thus assisting with transitional regions of the voice (Sundberg; Lã; Granqvist, 2023).

For the case of SOVTE exercises, semi-occluding the vocal tract at the lips increases the oral pressure and, with it, the pressure required to drive the vocal folds into vibration. The ultimate result with this type of exercise is vocal economy (Titze *et al*., 2021). Exercises involving the stretching of the vocal folds and phonation with minimal contact between the vocal folds, particularly in the middle-to-upper parts of the vocal range, have also been suggested as a strategy to restore vocal flexibility (Price, 2010). This may be achieved using thin straws to sing higher pitches (Titze *et al*., 2021). With this type of straw, the back pressure is high, and the vocal folds are stretched so that phonation may occur with a smaller area of vocal fold contact and thus, a small impact stress, or even occur without collision of the vocal folds.

Duration of exercises

The proposed exercises should not be performed in block at the beginning. It is recommended that the singer performs multiple sessions throughout the day, for example, every 2 to 3 hours, as mapping versus block sessions (Nix, 2017). In this context, block sessions correspond to massed practice, in which a similar amount of work is undertaken in a relatively short, continuous period. Nix notes that some massed practice is essential for developing the endurance required for extended performances, such as long operatic roles or song recitals, and recommends introducing such sessions closer to the performance date to approximate performance conditions (Nix, 2017). Mapping sessions, by contrast, align with distributed

practice, in which the same overall workload is divided into several shorter sessions spaced over a longer period of time, a scheduling strategy that is described as less fatiguing to all muscle groups and to the lamina propria than massed practice and therefore appropriate for building and developing vocal technique (Nix, 2017). In his example of recital preparation, Nix illustrates how shorter, distributed sessions predominate in the earlier stages of training, with more extended, block-like sessions being reserved for the final weeks before the event to simulate its demands (Nix, 2017). Distributing exercises has been proposed to support more effective neuromuscular learning and to reduce the risk of vocal fatigue, in contrast with relying exclusively on long, continuous sessions (Schneider; Dennehy, 1997).

Series and repetitions

Each exercise can be structured as a series of repetitions. For example, 3 sets of 6 repetitions for a chosen exercise, if we borrow the concepts from the exercise physiology (Mcardle; KATCH; KATCH, 2014). Alternatively, one can use a repetition of a full sequence, as recommended in the VFE (Stemple *et al*., 1994; Sabol; Lee; Stemple, 1995). A rest period should be respected between sets, as the muscles need time to recover and restore energy after effort (Mcardle; Katch; Katch, 2014). It is recommended to start with less repetitions, and reduced load, and then gradually increase it according to the singer's individual vocal development (Sandage; Smith, 2017; Badaró; Vaiano; Behlau, 2024).

Loudness

Control of vocal loudness is crucial in any voice exercise. Loudness increases with increasing subglottal lung pressure, vocal fold adduction, and applied resonance strategy (Sundberg, 1987; Titze, 2008; Titze, 2023; Herbst; Story, 2022; Titze *et al*., 2011). However, the exaggerated increase of vocal adduction and lung pressure is a high-risk factor for phonotrauma and should be avoided (Galindo et al., 2017; Herbst; Story, 2022). Loudness is one parameter that can be used to increase muscle overload in a conditioning context, but it must be manipulated cautiously and progressively (Badaró; Vaiano; Behlau, 2024). Independently of phonation type, increases in loudness generally result in increased intrinsic laryngeal muscle activity, and this should be taken into consideration when designing the vocal exercise (Herbst *et al.,* 2015; Zhang, 2016; Titze, 2023).

Vowels and phonemes

Voiced and unvoiced fricatives can be used to train phono-respiratory coordination. For example, when the habitual phonation type is pressed, using consonants such as /f/ followed by a vowel will set the vocal folds into vibration with less adductory force and more airflow; the choice of vowel will depend on pitch, as each vowel provides specific vocal tract resonances that may or may not facilitate sound production (Sundberg, 1987; Titze, 2008; Titze *et al.,* 2011). It has been claimed that more open vowels tend to facilitate heavier, more thyroarytenoid-dominant productions, whereas more closed vowels

favour lighter productions, a relationship that should be considered when choosing vowels for different pitch ranges and stylistic goals (Titze et al., 2011; Herbst; Howard; Svec, 2019).

Phonation types

Phonation types are a paramount aspect when designing specific exercises. The use of breathier phonation, for example, require less active adducturory forces, while firmer phonation increases engagement of laryngeal muscles responsible for holding the vocal folds together for longer periods of the vibratory cycle. Beyond aesthetic goals, a singer can benefit from practicing different adduction degrees to improve vocal function (Sundberg, 1995; Lã; Fiuza, 2022). The choice of phonation type to be used in each training session must be intentional, with its potential risks and benefits carefully monitored.

3.2. Specific exercises

Maintaining and developing breath management

The singer may benefit from observing and feeling which parts of the body move during breathing in singing. How differently the abdominal wall, epigastric area, ribcage, and back are engaged. The goal is to identify potential movement restrictions, body weaknesses, or excessive tension. To do so, Singers can place their hands on the specified areas of the body while performing breathing exercises to enhance kinaesthetic awareness of respiratory movements (see Figure 1). If body movement restrictions are detected, specific bodywork is recommended. Stretching of these body parts and activities that promote body balance (*e.g.* Pilates, Alexander Technique, Yoga), may be beneficial.

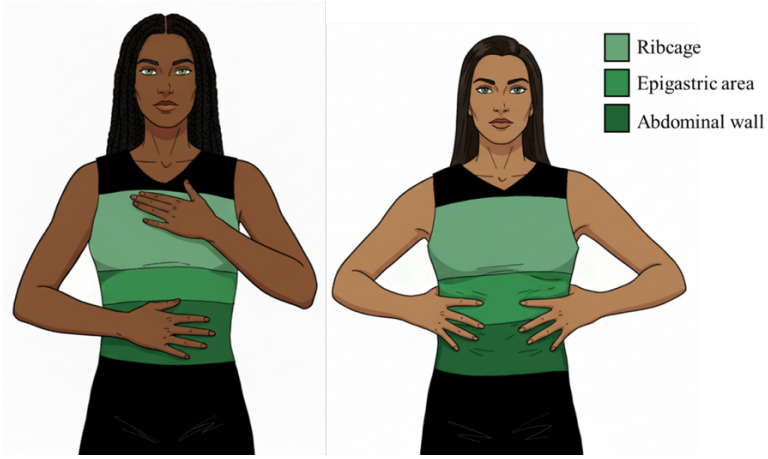

Fig. 1: Hands placement for increased awareness of moving body parts during singing and breathing. Green colour shades indicate abdominal wall, epigastric area and ribcage.

As suggestions to increase inspiratory strength and endurance, the singer may practice inspiratory exercises with an external resistance (for example, a finger restricting mouth inhalation with lips

almost sealing the air passage). Use elastic bands wrapped around the ribcage to enhance awareness of inspiratory muscles (see Figure 2.1).

To incorporate phonation into breath management exercises and to improve phono-respiratory coordination, introduce phonation in the exercise. The singer can use the elastic band, (see Figure 2.1) or sing with raised arms, to increase ribcage opening (see Figure 2.2). SOVT using voiced fricatives (/z/, /v/, /ʒ/, /β/), lip trills, tongue trills, raspberries or nasal consonants (/m/, /n/, /ŋ/, /ɴ/) can be used at the beginning. These body postures can also be used while singing repertoire to consolidate awareness of breathing movements.

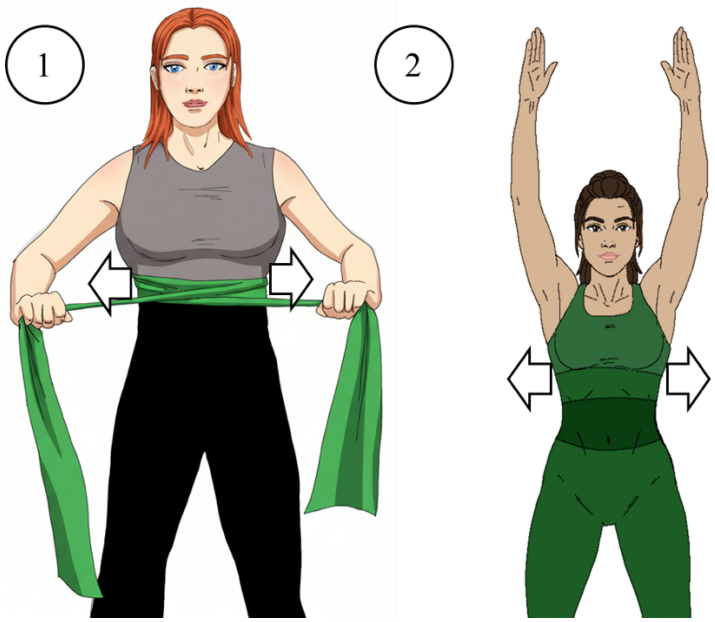

Fig. 2: Inspiratory muscle strength and endurance training. 1 – use of elastic band around the diaphragm, 2 - Raised arms posture. Arrows indicate the ribcage expansion during the postures.

Another exercise could be to start breathing exercises without additional breathing resistance, and then gradually introduce inspiratory training devices such as RESPIRON® and POWERbreathe® Plus LR to increase difficulty (see Figure 3.1 and 3.2, respectively). If these devices are unavailable, inhale through placing a finger in front of tight lips or use thin straws as an alternative. To experiment with different degrees of breathing resistance, use different straw diameters, starting with thicker ones and progressively switch to thinner ones to increase resistance. Another approach is to use multiple straws initially and gradually reduce their number until reaching the desired inspiratory load (see Figure 3.3).



Fig. 3: Devices to increase breathing training resistance. 1 – RESPIRON®, 2 – POWER breathe® Plus LR, 3 – Different diameter tubes

To improve breathing capacity during phonation, a device that facilitates airflow monitoring, such as the FlowBall®, can be used (see Figure 4). Keep the ball floating in a constant height for as long as possible after a deep inhalation. Slightly increase the time that the ball is floating in the air to increase maximum exhalatory time capacity.

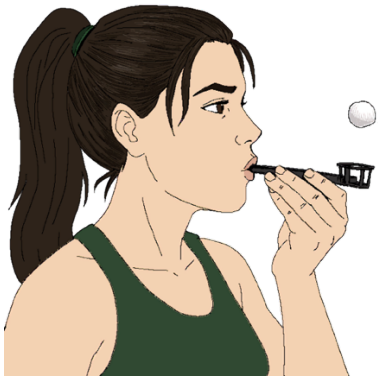

Fig. 4: Phonation with FlowBall® with the ball height kept constant

Maintaining and developing vocal coordination, strength and endurance

Staccato exercises can be used to improve vocal coordination, as they require control between subglottal pressure, vocal fold adduction and vibration of the vocal folds. *Staccato* can be 'aspirated', i.e., the subglottal pressure (P_{sub}) builds up first, followed by vocal adduction and phonation; this type of *staccato* is beneficial to counteract potential pressed phonation. *Staccato* can also be 'coordinated', meaning that the vocal folds adduct and start vibrating simultaneously with a P_{sub} increase. The third type of vibrato is the 'hard' one, when vocal folds adduction precedes P_{sub} and vocal folds vibration. Depending on the individual needs, different types of *staccati* can be performed on the same pitch or within ascending and descending *arpeggi* and scales, in order to alter habitual less efficient behaviours, or to enhance an efficient vocal onset or even to enhance expressivity.

If during the menopause, the voice becomes breathy as, for example, a consequence of incomplete closure, singers may practice sustained vowels using different types of phonation, i.e., breathy, flow, neutral, firm, and pressed. The goal is to create awareness of different degrees of vocal folds

adduction. It can be beneficial to those who report loss of vocal strength and weaker voices associated with menopause. It is recommended the use of a flow ball device to change phonation types, as there is a direct visualization of phonatory airflow and thus, of phonation types. A sustained pitch while singing through the flow ball and not lifting the ball will mean that the singer will be using a phonation type towards firm or pressed phonation, whereas a phonation with a ball height of 5 cm will correspond to a less phonatory adduction and an airflow of approximately 0.3 L/s (Lã *et al.,* 2017), thus higher than the one required for neutral phonation (Wistbacka, 2017). Another more accurate way to visually monitor phonation types is using narrow band spectrograms or the shape of the vibratory patterns of the vocal folds by means of electrolaryngographic displays in real-time while singing (Lã; Fiuza, 2022).

Singing at different pitches requires changing the length, thickness and stiffness of the vocal folds. Exercises that can promote constant adjustments in these three domains are scales, *arpeggi*, and *glissandi*. These types of exercises are considered isotonic, and they tend to improve muscle strength (Sabol; Lee; Stemple, 1995). The singer can experiment different speeds and explore different dynamic ranges while performing this type of exercises, to improve neuromotor precision and phono-respiratory coordination. If during the menopause the voice becomes breathier, starting the scales or *arpeggi* at low pitches and ending at higher pitches is recommended. The ascending nature of the melodic contour promotes low lung volumes at higher pitches, as airflow was consumed during the proceeding pitches, and low lung volumes promote stronger vocal folds adduction (Sundberg, 1987). Thus, a breathier phonation in high pitches will be counteract with a stronger vocal fold adduction and a more complete vocal folds closure (Lã; Gill, 2014). On the contrary, a descending melodic counter in a scale or *arpeggio* will counteract pressed phonation at the higher tones, as a high lung volume promotes an abductory force known as tracheal pull (Sundberg, 1991; Herbst, 2016).

Voice stability across transitional regions of the voice can be visually assessed by looking at, for example, narrow band spectrograms of ascending and descending *glissandi*. When voice coordination is balanced, a smooth transition between higher and lower pitches will occur in both ascending and descending parts of the pitch glides. Figure 5 shows an example of such exercises and their corresponding spectrographic representation for a soprano voice. In the ascending part of the first *glissando*, the display shows an abrupt f_o jump, i.e., a step like shape discontinuity in the first harmonic partial tracing. During the second attempt of the same exercise, a smaller f_o disturbance is observed (slight interruption of the f_o contour), as a consequence of adjustments in the articulatory structures (i.e., tongue, soft palate, lips, mandible and larynx height) that change the resonances of the vocal tract. In the third attempt, the f_o jump is not visually observed (nor audible), as a consequence of a well adjustment between registers.

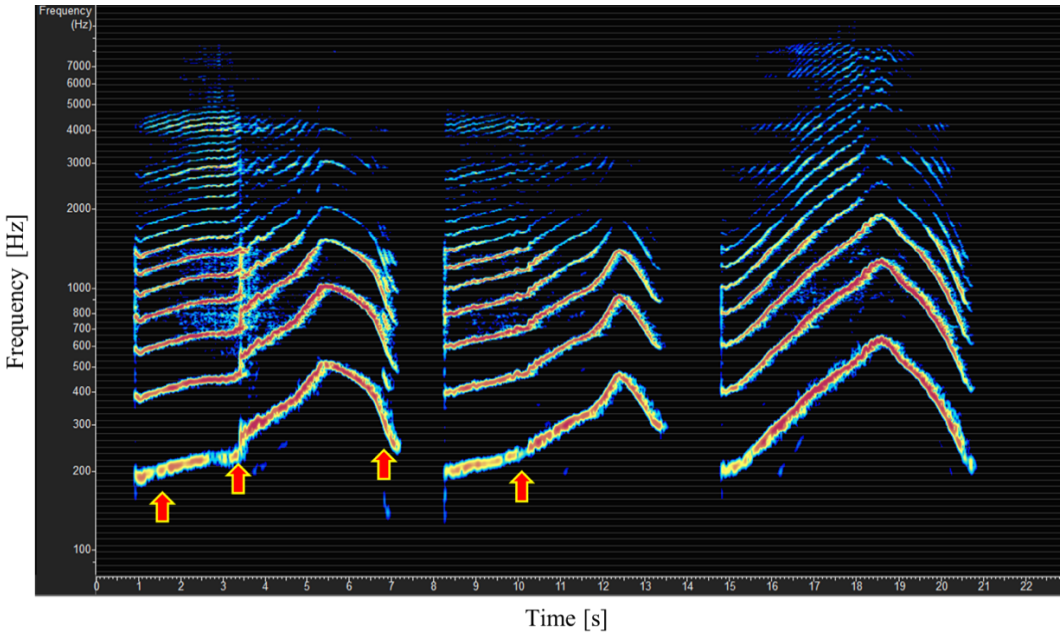

Fig. 5: Narrow-band spectrograms of ascending and descending glissandi using the VoceVista Video Pro. Arrows point out at instabilities of fundamental frequency. From left to right, there is a decrescent degree of disturbances, so that by the third attempt, the voice break was circumvent.

Sustaining phonation on a same pitch, with the same phonation type and vocal loudness and for a long period can promote the development of muscle endurance; this is an isometric type of exercise (Sabol; Lee; Stemple, 1995). To keep the same pitch without changing phonation time and vocal loudness can be taxing; thus, to facilitate this task, visual feedback such as the one provided by the ball height using a flow ball can help. The recommendation will be to keep the ball in the air at a constant height to guarantee that the same amount of airflow and vocal loudness are used throughout the whole sustained note. Repeating the exercise progressively increasing the starting pitch and in an ascending manner, using semitone steps will be recommended, so that endurance is developed at different conditions of vocal fold mass tensioning. Again, the melodic contour of the exercise (ascending or descending) should be tailored according to individual needs of the singer, as well as the number of repetitions and the duration of the sustained pitch.

To increase phono-respiratory coordination, instead of using the same vocal loudness while sustaining the pitch, changing loudness in a *messa di voice* exercise will also require the adjustment of intrinsic laryngeal muscles to keep glottal configuration similar despite the increase and decrease in P_{sub} in this *messa di voice* exercises. Once again, this type of exercise can be monitored by real-time visual feedback using a flow ball; the louder the voice, the higher the ball height will be. Likewise, phonating into a tube immerse in water is also an alternative way of visually monitoring the phono-respiratory control developed during this exercise; the number of bubbles produced should increase with increasing loudness, while keeping constant the pitch and the depth of the tube inside the water. Another way to monitor this type of exercise is by visualising a sound envelop display (see Figure 6). The evenness of the the *messa di voce*

can be observed: the variation in loudness should be gradual and equally distributed in time for the crescendo and the decrescendo parts of the exercise.

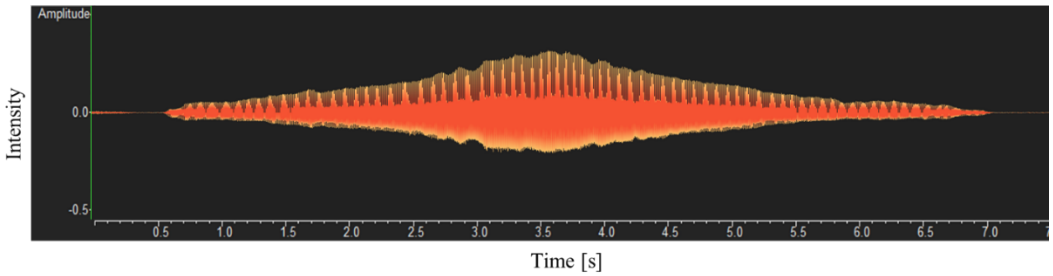

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Figure 6. Sound envelope displayer on the Voce Vista Video Pro software. The larger contour in the middle part correspond to maximal loudness.

Maintaining and developing vocal flexibility

The flexibility of a singer's voice is commonly worked in singing lessons with dynamic stretching of the vocal folds, or, in other words, by gradually increasing the length of scales or *arpeggi* or *glissandi*. Normally, a dynamic stretching starts with short scales, such as five-note scales, or *glissandi* with the same interval. These begin at a vocal range within the singer's speech range, smoothly progressing to higher ranges, avoiding the extremes of the vocal range. The shorter scales are then substituted by longer scales, such as nine-note scales, octave arpeggios, and *glissandi* covering an octave interval grange. Finaly, more complex melodic designs can be applied, such as two-octave interval *arpeggi*. These exercises can be initiated using closed vowels (e.g. /u/ or /i/), or phonemes that facilitate flow phonation, such as those starting by a voiceless consonant (e.g., /fu/, /shu/). Once flow phonation is achieved and stabilized, the exercise can incorporate more open vowels and phonemes that incorporate voiced consonants (e.g., /va/, /bo/).

Expanding vocal range requires further stretching and stiffening or shortening and thickening the vocal folds, if higher and lower notes are sung, respectively. Even if these tones are not commonly included in the singer's repertoire, the exploration of such range will allow full contraction of the cricothyroid and of the thyroarytenoid, respectively. This can be tough to the vocal folds, so thus, to avoid strain or fatigue, singing these pitches with soft phonation and using SOVT postures (e.g., using a thin straw or humming) is recommended. Another way to exercise vocal flexibility would be to alternate between registers, as in the following protocol:

- Find "vocal fry" to promote maximum contraction of the thyroarytenoid muscle but with a low P_{sub} (Blomgren et al., 1998) by slowing down the fry pulses as much as possible.
- Stretch the voice up to the upper vocal range, aiming at the highest range but with medium loudness until achieving the top available pitch either in *falsetto* or "whistle" register. To progressively ascend pitch by means of *staccato* scales and *arpeggi* with medium to low

loudness helps reaching these higher pitches. The top notes can be sustained for further endurance development.

- Sustain a high yet comfortable pitch for about three to ten seconds to maintain contraction levels of engaged laryngeal muscles.
- Abruptly switch from high pitched phonation to vocal fry and maintain vocal fry for few seconds before returning to the upper extremes of the vocal range, but this time attempting to reach a higher pitch than before.

Another important parameter related to vocal flexibility and menopause is neuromotor coordination of the voice, including the ability to quickly adduct and abduct the vocal folds. Through ageing, the neuromotor control of adductory and abductory laryngeal muscles may be reduced (Lombard; Solomon, 2020). This type of exercise, also called laryngeal diadochokinesis (LDDK), might be a good way to maintain this control. Like *staccato* repetitions, LDDK exercises requires a fine coordination between P_{sub} and vocal folds adduction and vibration (Lombard; Solomon, 2020). LDDK can start at a slow tempo and gradually increase velocity of execution. In a narrow-band spectrogram, the exact moments when sound is being produced or when silence occurs is quite clear (see Figure 7.1). In the correct example (upper panel) the /h/ sound coincides with the moment with no tracing, while the /i/ sound matches the moment with tracing. In the less correctly performed task (see Figure 7.2), the tracing keeps almost continuous, as observed by the trace of the harmonics.

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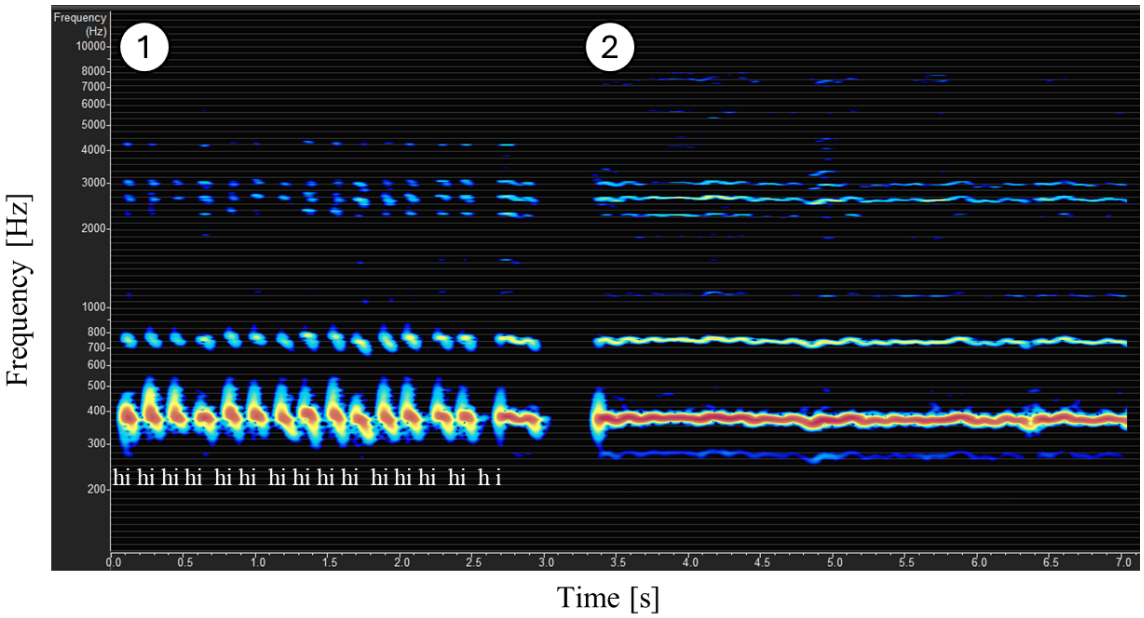

Figure 7. Laryngeal diadochokinesis with the syllable /hi/ sung by a female singer. 1. Narrow band spectrogram of the task performed in a correct manner: short phonation periods separated by non-phonation. 2. Narrow band spectrogram of the syllable /hi/, showing absence of contact and de-contacting of the vocal folds. Narrow-band spectrograms were recorded using the software VoceVista Video Pro.

Maintaining and developing transition between regions of the voice range

Singers perceive sudden involuntary f_o jumps or even voice breaks associated with menopause. Thus, connecting different registers of the voice seems reasonable. By practice experience as teachers of singing, the authors find training glissandi exercises to achieve this goal. A suggestion of exercise protocol is as follows:

- Perform slow octave *glissandi* throughout the entire utterance while maintaining a consistent phonation type across the octave.
- Execute a full-range *glissandi*, from the lowest to the highest pitch, striving to maintain a similar phonation type throughout the exercise.
- Perform scales or *glissandi* of only few notes, withing a specific transitional area of the voice where difficulties and/or voice instabilities occur. Flow phonation, straws, and other SOVT postures can be incorporated.
- Sing a scale from high to low range according to the following descending pattern: octave, fifth, fourth, major third, second, and octave bellow (see Figure 8). The melodic line must begin with a voiceless fricative (e.g. /f/, /sh/) to promote air flow through the rest of the exercises. Vowels such as /u/ and /i/ are recommended. The top note is to be sung in a soft flow phonation and the fifth and subsequent notes applying more 'full' voice.

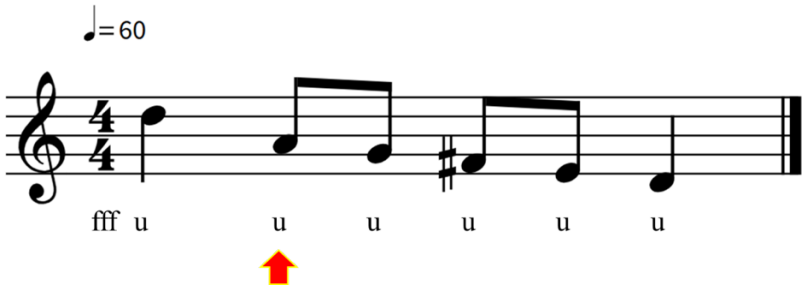

Fig. 8: Octave with five stepwise descending scale. Starting with unvoiced fricative consonant and following with /u/ vowel. The red arrow marks where the voice should transit from soft to intermediate voice type (head to mix register).

4. Final remarks

Although the effects of vocal exercise are not yet fully understood, particularly with respect to the specificities of female voices and the effects that each voice exercise has on specific muscles, this study constitutes the first attempt to support singers' practices based on science-informed information. Continuing voice education is a powerful tool to the prevention and restoration of vocal function; these guidelines, summarized in Table 1, are a step towards helping singers with strategies for a continuous singing practice when the voice may change and continuing education and support may not be sufficed for supporting the female professional maturing singer.

Goals	Possible strategies	Additional considerations
Improve vocal dryness	1. Evaluate current state of hydration by looking at urine colour, and water ingestion habits 2. Adapt water consumption to current needs 3. Perform 10 minutes of nebulization with saline solution	Do not over hydrate
Breathing management	1. Improve respiratory-related movement awareness by monitoring ribcage, abdominal wall, epigastric area, and lower back movements 2. Use resistive inhalation to increase inspiratory strength and phono-respiratory coordination 3. Perform exercises to increase MTP, with and without expiratory tools (e.g., FlowBall®, and changing or using specific body postures)	Stretching different body parts, such as neck and back, might be needed to cope with movements restrictions
Vocal coordination, strength and endurance	1. Perform isotonic type of voice exercises, such as scales, *arpeggi*, and *glissandi* 2. Perform staccato exercises 3. Become aware of what feels to produce different types of phonation 4. Perform isometric vocal exercises, such as sustained tones, *messa di voce* and using SOVT tools to artificially elongate the vocal tract (e.g. straws and tubes inserted in water).	Visually monitor the performed exercises for self-correction and self-appraisal (e.g. using narrow-band spectrograms, FlowBall®, phonating with tubes in water).
Vocal flexibility	1. Strech the vocal folds varying from top to bottom range 2. Perform LDDK	Start with small intervals, like 5-note scales and then increase the range of the exercises towards 2 or more octaves.
Transition between regions of the voice	1. Perform *glissandi* at different regions of the voice range 2. Perform 8, 5, 4, 3, 2, 1 descending scales	Visually monitor the performed exercises for self-correction and self-appraisal (e.g. narrow-band spectrograms)

Tab. 1: Guidelines' summary, emphasising most important goals and suggestions of strategies to achieve it.

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