2016-05-04

The Influence of Sex Hormones on the Female Singing Voice: A Review of the Literature, 1971-2016

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THE INFLUENCE OF SEX HORMONES ON THE FEMALE SINGING VOICE: A REVIEW OF THE LITERATURE, 1971-2016

By

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A DOCTORAL ESSAY

Submitted to the Faculty
of the University of Miami
in partial fulfillment of the requirements for
the degree of Doctor of Musical Arts

Coral Gables, Florida

May 2016

UNIVERSITY OF MIAMI

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(May 2016)

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Abstract of a doctoral essay at the University of Miami.

Doctoral essay supervised by Professor Esther Jane Hardenbergh.
No. of pages in text. (55)

Vocal pedagogy is a discipline steeped in traditions that have been passed down for generations, from voice teacher to singer. The mature singer then takes on the role of teacher and the cycle continues. For the twenty-first century voice teacher, the revered tradition of pedagogy must also include science. A voice degree program at most universities will include courses covering laryngeal anatomy, vocal production, and voice disorders. Widely used textbooks by authors such as Barbara Doscher, Scott McCoy, James C. McKinney, and Richard Miller provide a very useful and extensive study of the functionality of the singing voice, but little information is comprehensively dedicated specifically to understanding the lifetime of complexities in the ever-changing relationship of sex hormones and vocal function as it pertains to the female singer. The female voice's relationship to hormones, which was once relegated to assumption and conjecture, is now backed by evidence-based scientific and objective proof. Based on science, a familiarity with how vulnerable the human voice can be in response to changing hormones is imperative for singers as well as singing teachers. This paper explores much of the available literature on the subject, based on scientific research by experts in this field, and presents compelling findings that are useful for voice professionals.

Dedicated to all female professional voice users.

Acknowledgements

I would like to acknowledge my committee chairperson, Dr. Esther Jane Hardenberg, for her guidance in creating this essay, as well as other committee members: Dr. David Rosow, Professor Robynne Redmon, and Dr. Tony Boutté. I would also like to acknowledge Dr. Rosow, Dr. Julia Gerhard, Dr. Maria Denison, and Adam Lloyd for facilitating the voice internship program at the University of Miami Voice Clinic—a valuable experience I will always remember. Thank you to my friends and colleagues for sharing this journey with me. Special thanks to my father, Dr. Brij Khare, for instilling in me the value of education and the desire for knowledge; my mother, Nancy Khare, for teaching me thoughtfulness and compassion; and my husband, Peter Ludescher, for tirelessly and patiently supporting me throughout my years of graduate study.

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CHAPTER 1

Statement of the Problem

The influence of sex hormones on the female singing voice is significant, and research shows "voice problems related to sex hormones are seen most commonly in female singers."[1] It is problematic that the voices of female singers are affected by their hormones, particularly as most do not have an adequate understanding of how and why. There is also is a lack of readily available, reliable information that singers and voice teachers can use as resources. Understanding how the female voice responds to hormonal changes during phases of life is imperative for singers, voice teachers, choral conductors, or any professional voice user, because this knowledge results in better management of challenging vocal issues due to hormonal events. These variations may be as minor as mild vocal fold edema, which is swelling, during a normal menstrual cycle, or as significant as the changes experienced in vocal production due to the dramatic drop in estrogen during menopause. Even something as seemingly benign as progesterone-dominant oral contraception can adversely or even permanently alter the female singing voice.[2]

Most voice teachers are not well versed in the science behind vocal changes experienced by women as the result of hormonal events, but according to otolaryngologist Robert Sataloff, M.D., D.M.A.,"It is important for singing teachers to be familiar with this subject, not only so that they can recognize expected voice changes . . .

[1] Robert Sataloff, "Hormones and the Voice," *The NATS Journal* (1993): 43.

[2] Ibid.

but also especially so they can recognize unexpected voice problems that warrant prompt medical referral."[3] There was little discussion of the correlations between vocal production and hormones prior to 1971, when Friedrich Brodnitz, M.D., identified the relationship and the problem that results when limited vital information makes its way into the hands of singers.[4] Detailed scientific findings on the subject are only found in scholarly journals that are difficult or inconvenient to locate. In addition, the articles contain language that is not always easily understood, and which some readers may find entirely incomprehensible.

In 1991, Sataloff published *Professional Voice: The Science and Art of Clinical Care*, which further addressed the issue of hormones and the voice in greater detail. The National Association of Teachers of Singing's (NATS) *Journal of Singing* then published the article "Hormones and the Voice," which contains excerpts from Sataloff's book and expounds on the correlation of hormones and the voice. Although Sataloff's research brought awareness to the topic, the NATS *Journal* is designed for a specialized group of people (i.e., teachers of singing), and may not be widely read by the general population of singers. Since then, several articles about hormones have been published in the Voice Foundations' *Journal of Voice,* the predominant scholarly resource for such research. In addition to Sataloff, important researchers such as Jean Abitbol and Filipa Lã have published major studies on this subject. However, this information is still not comprehensively included, if at all, in the vocal pedagogy textbooks that are widely used at the university level. Because of this deficiency, even most university-trained voice

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[3] Ibid.

[4] Friedrich S. Brodnitz, "Hormones and the Human Voice," *The NATS Bulletin* (1971): 16.

teachers are not able to educate their female students about the impact hormones has on their voices.

Justification

Without knowledge about the potential effects of hormonal fluctuations on the female singing voice, voice teachers and singers may not be able to identify symptoms that could be linked to a hormonal event and may not seek appropriate treatment when needed. Some vocal symptoms may even be misdiagnosed by a voice teacher or physician. Most gynecologists are not proficient in managing, or even identifying, the subtle hormonal issues that affect the voices of female singers.

A recommendation is for voice teachers to develop a network of professionals familiar with the specialty of *arts medicine*. Shenandoah University describes *arts medicine* as a specialty with the purpose of educating "health care professionals and performing art educators on the prevention, assessment, and management of injuries and disorders specific to dancers, theatre artists, and musicians along with promoting clinical research to determine best practices."[5] An ideal voice team would include an endocrinologist, otolaryngologist, and speech language pathologist who are trained in voice disorders particular to singers.[6]

Purpose of the Study

The purpose of this study, which is a review of the literature, is to provide a resource for singers, voice teachers, and other professional voice users that draw on the most recent scholarly resources. The information provided can serve as a guide for

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[5] Shenandoah University, *Performing Arts Medicine Certificate.* http://www.su.edu/athletic-training/athletic-training-programs/performing-arts-medicine-certificate/ (accessed November 21, 2015).

[6] Sataloff, "Hormones and the Voice," 44.

understanding the influence and impact of sex hormones on the female voice. Variables taken into account will include biological events such as puberty, menstruation, pregnancy, and menopause. This study will also explore the effects oral contraception and hormone therapy have on the female voice. For the convenience of readers who are not familiar with medical terminology, a definition of terms is included (Appendix A).

CHAPTER 2

Method

This document is formatted as a compendium of the biological events experienced by women that are uniquely influenced by sex hormones. These events are systematically outlined in chronological order, along with details about hormone medications and treatments. The topics include puberty, menstruation, pregnancy, menopause, oral contraception, and hormone therapies. Scientific literature related to each subject was examined and described in such a way that a concise narrative could be developed for each topic, with the specific element of interest being the influence and effect of sex hormones on the female singing voice.

With the ultimate goal of creating a comprehensive resource for singers and voice teachers that will serve as a guide for understanding the influence and impact of sex hormones on the female voice, the following questions were addressed:

1. What scientific evidence is available relating sex hormones to the singing voice?
2. What physiological changes take place in the vocal mechanism due to sex hormones?
3. How do sex hormones directly impact vocal production?
4. What kind of treatment or management plan is recommended?
5. Who are the primary researchers and specialists in this field?

Each of these research questions were answered using scientific and scholarly publications based on research by otolaryngologists, speech language pathologists, and

singing voice specialists. Scientific evidence supporting the vocal changes experienced in women due to sex hormones can be found in the following scholarly journals: *Journal of Voice; Journal of Singing; The NATS Bulletin; The NATS Journal; American Journal of Otolaryngology; Logopedics Phoniatrics Vocology; Contraception; Menopause; The Journal of the North American Menopause Society; Maturitas; Journal of Speech, Language, and Hearing Research; Sprache Stimme Gehor; Current Opinion in Otolaryngology and Head and Neck Surgery; The Laryngoscope; Lancet Oncology; Journal of Steroid Biochemistry and Molecular Biology; Andrologia; Climacteric; International Journal of Pediatric Otorhinolaryngology; Journal of Clinical Endocrinology and Metabolism;* and *Clinical Obstetrics and Gynecology.* Academic books that will be cited include, but are not limited to, *The Performers Voice* (Benninger), *Professional Voice: The Science and Art of Clinical Care* (Sataloff), and *Odyssey of the Voice* (Abitbol). Access to these materials was made possible by the resources and research capabilities of the University of Miami library.

Once the material was compiled, each research questions was categorically discussed and answered based on the scholarly research that was discovered. This information was analyzed and organized into a clear and succinct document for use as a helpful resource for singers and voice teachers alike.

By creating a comprehensive resource on the impact of sex hormones on the female singing voice, singers and voice teachers will have the opportunity to gain awareness about this important, relevant, and neglected subject that impacts every female singer. The author of this document is available to present on this subject to further facilitate dissemination of information.

CHAPTER 3

Related Literature

Hormones reach every organ of the human body through the blood stream, and the influence hormones have on all bodily functions is powerful.[7] The following information will specifically address and explain the significant relationship of sex hormones to the female singing voice.

An Overview of Hormones

The Greek etymology of the word hormone is *horman.* Its meaning, first used by Hippocrates, is "to excite" or "to set in motion."[8] In 1905, British physiologist Ernest Starling (1866-1927) first coined the modern medicine term "hormone" for a lecture series he delivered to the Royal College of Physicians in London. He spoke about "the chemical messengers which speeding from cell to cell along the blood stream, may coordinate the activities and growth of different parts of the body."[9] The focus of this paper is on how hormones, once released, affect the human body and, in particular, how they affect the female singer.

The most complex hormonal system is found in the human species. If the delicate balance of hormones is disrupted, the resulting damage could be irreversible.[10] Once the

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[7] Brodnitz, "Hormones and the Human Voice," 16.

[8] Online Etymology Dictionary, http://www.etymonline.com/index.php?term=hormone (accessed November 21, 2015).

[9] Jamshed R. Tata, "One Hundred Years of Hormones." *EMBO Reports* (2005): 490. http://www.su.edu/athletic-training/athletic-training-programs/performing-arts medicinecertificate/ (accessed November 21, 2015).

[10] Jean Abitbol, *Odyssey of the Voice* (San Diego: Plural Publishing, 2006), 207.

body sets hormones in motion, they travel to specific receptor organs and influence their particular target organ in very specific ways. For example, adrenaline excites the heart, testosterone increases libido, and estrogen and progesterone initiate menstruation.[11] Once the sex hormones estrogen, progesterone, androgen, and testosterone are set in motion and reach the larynx, another hormonal target, they modify the quality of the voice.[12]

The estrogen secreted by the ovaries has an overall positive physiological effect on the characteristics of the larynx, resulting in possible benefits to the female singer. The presence of estrogen induces hypertrophy (an increase in volume) and proliferation (an increase in tissue cells).[13] This causes a thickening of the mucous membrane of the vocal folds, which results in greater vibratory amplitude and an improvement in sound timbre. There is a shedding of superficial cells of the vocal folds, which decreases the amount of laryngeal mucous; this can lead to a decreased need for throat clearing. The energy-storing lipid cells under the mucous membrane become stimulated, which makes the voice more supple. Estrogen also increases the oxygenation of the vocal folds and improves the permeability of blood vessels and capillaries in the vocal folds.[14] Another important function of estrogen is to prepare the tissue that enables progesterone to be effective.

Progesterone is also secreted by the ovaries. It enables gestation by preparing the mucous membrane of the uterus for the ovum and, therefore, it is only secreted in the

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[11] Abitbol, *Odyssey of the Voice*, 207.

[12] Ibid, 206.

[13] Ofer Amir and Tal Biron-Shental, "The Impact of Hormonal Fluctuations on Female Vocal Folds," *Current Opinion in Otolaryngology and Head and Neck Surgery* 12, no. 3 (2004): 180.

[14] Abitbol, *Odyssey*, 215.

ovaries from approximately ages 15 to 55.[15] Progesterone thickens the secretions of glands both above and below the vocal folds and, similar to estrogen, causes the shedding of surface cells of the vocal folds. Unlike estrogen, progesterone secretions may cause an imbalance in the distribution of interstitial fluid, the fluid found in spaces between tissue cells, resulting in swelling of the vocal folds. Progesterone restricts capillaries from draining tissues and prevents interstitial fluid from entering vessels (see Appendix B).[16]

There is a continual fluctuating balance between estrogen and progesterone. When these two hormones are in balance, the outcome is a good distribution of fluid within the vocal folds.[17] When these hormones are out of balance, there is asymmetry in vocal fold vibration, which causes irregularity in their oscillatory patterns.[18] An oscillatory pattern is the wavelike pattern in which the vocal folds vibrate with a sustained motion over a period of time.

Most women secrete extremely small doses of male hormones, including androgen and testosterone. Testosterone is a male hormone that both influences libido in women and enhances the low-pitched harmonics in the voice. However, high levels of androgen and testosterone will result in masculinization of the voice. In women with too little testosterone, libido dissipates. Women with too much of the male hormones experience symptoms such as hirsutism (excessive male-pattern hair growth).

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[15] Abitbol, *Odyssey*, 215-216.

[16] Ibid., 216.

[17] Ibid.

[18] Filipa Lã, et al., "The Effects of a Third Generation Combined Oral Contraceptive Pill on the Classical Singing Voice." *Journal of Voice* 21, no. 6 (2007): 759.

Masculinization of the voice due to high levels of male hormones is often an irreversible condition (see Appendix C).[19]

The Larynx and Puberty

Humans are born with primary sex characteristics that make the determination of sex obvious, such as a penis or a vagina. Secondary sex characteristics manifest during puberty and are not essential for reproduction. They include the development of breasts in females, and facial hair growth and changes in the voice in males. The human voice is also considered a secondary sex characteristic.[20]

Voice pedagogues agree that the larynx is a hormonal target.[21] This accepted fact became evident when Abitbol compared tissue smear samples from both the cervix and vocal folds at the same time during a woman's menstrual cycle and found they were indistinguishable. Both samples contained the same squamus epithelial mucous membrane, which is the outermost layer of cells.[22] According to Abitbol, hormones are the mediator in the relationship between our brain and organs, including the larynx.[23] The cry of a male or female baby is not gender specific, but when hormones are secreted at specific moments in time during human development, the voice takes on very distinguishable traits. The hormones' actions are essential for the transition into

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[19] Abitbol, *Odyssey*, 226.

[20] Abitbol, *Odyssey*, 205.

[21] Jean Abitbol, "Normal Voice Maturation: Hormones and Age," in *The Performers Voice*, ed. Michael S. Benninger (San Diego, CA: Plural Publishing, 2006), 34.

[22] Ibid., 37.

[23] Ibid., 35.

adolescence and puberty.[24] Before puberty, both boys and girls have equivalent vocal range and timbre. This is described as the pre-pubertal soprano range.[25] Once a child reaches the age of seven or eight, masculine and feminine voice traits become apparent.[26] For the sake of comparison, and in validating the need for comprehensive knowledge on pubertal voices, both male and female voice transitions will be examined to discern differences.

The evolution of a male voice may be divided into three phases, according to Tamas Hacki and S. Heitmüller. These phases are pre-mutation, mutation, and post-mutation .[27] Their study notes that at the end of the nineteenth century, mutation in boys occurred between ages 14 to 15, but it is currently observed that pre-mutation sets in between the ages of 8 and 9 for boys, and ages 7 to 8 for girls, with both sexes experiencing similar initial changes. Common signs of pre-mutation are restrictions in minimum and maximum levels of speaking and singing intensity, as well as lowering of the habitual pitch—known as the speaking voice.[28] During puberty, the male voice drops approximately an octave. The actual lowering of the voice happens at two distinct age periods: before age 8 and after age 8.[29] This transition is accompanied by breaks in the voice that are caused by accelerated asymmetrical growth of the larynx. Through the

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[24] Ibid., 35.

[25] Ruta Pribuisene, et al., "Voice Characteristics of Children Aged between 6 and 13 Years: Impact of Age, Gender, and Vocal Training," *Logopedics Phoniatrics Vocology* 36 (2011): 153.

[26] Abitbol, "Normal Voice Maturation," 34.

[27] Tamas Hacki and S. Heitmüller, "Development of the Child's Voice: Premutation, Mutation," *International Journal of Pediatric Otorhinolaryngology* 49, no. 1 (1999): 141.

[28] Hacki, "Development of the Child's Voice," 141.

[29] Pribuisiene, "Voice Characteristics of Children," 153.

phases of mutation, there is a significant increase in size of the larynx and a bulking of the laryngeal muscles and ligaments.[30]

The voices of young girls change gradually in two stages between ages 6 to 11.[31] The first change takes place immediately before puberty, and the second occurs at the midpoint of pubertal development. Signs of pre-mutation appear between ages 7 and 8.[32] Typically, girls only experience a drop of a few notes in range, because their laryngeal growth spurt is not accompanied by the surge of testosterone seen in males. Another change in the female singing voice takes place between ages 16 and 17, with a final maturation phase occurring 6 to 12 months after that.[33]

Because of the lack of significant distinctive changes, Wivine Decoster describes the gradual female voice transition from a child's voice to that of a woman's as being part of a "developmental continuum."[34] The laryngeal changes experienced by girls during puberty are part of a smooth transition that is easier to manage in relationship to singing than the change boys go through due to laryngeal growth spurts instigated by testosterone. Physiologically, the transformation of girls' voices is due to the hormonal levels of estrogen and progesterone.[35]

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[30] Sameep Kadakia, et al., "The Effect of Hormones on the Voice." *Journal of Voice* 69, no. 5 (2013): 571.

[31] Pribuisene, 153.

[32] Hacki, 141.

[33] Elisea Meurer, et al., "Menstrual Cycle Influences on Voice and Speech in Adolescent Females." *Journal of Voice* 23, no. 1 (2009): 109.

[34] Wivine Decoster, et al., "Great Talent, Excellent Voices - No Problem for Pubertal Girls?" *Logopedics Phoniatrics Vocology* 33 (2008): 104.

[35] Ibid.

Because many singing teachers are not knowledgeable about the normal vocal ranges of children, both pre-puberty and post-puberty and their respective timeframes, children are often asked to sing at frequency levels that are inappropriate and usually too high, which causes vocal fatigue and can lead to more serious vocal problems.[36] A basic understanding of the physiological changes, as well as signs of voice changes, is important for music teachers of young children. This knowledge could lead them to select material with a tessitura and range that is better suited for young singers.[37] Expectations of vocal performance would also be adjusted to reflect the stage of a child's development.

Endocrinology and the Voice

Endocrinology is a specialized medical field focusing on hormones and how the body reacts to alterations and fluctuations in those hormonal levels. In the late 1980s, Sataloff was one of the first otolaryngologists to explore hormonal effects on the human voice. In the article "Hormones and the Voice," he explains how vocal response relates to thyroid levels and sex hormones, noting that many voice dysfunctions are the result of changes in the fluid content in the lamina propria, which is located just beneath the laryngeal mucosa of the vocal folds. He also found that hormonal mutations cause changes in the bulk and shape of the vocal folds, causing a change in voice quality.[38]

A deficiency of thyroid hormone is a condition most often experienced by older women.[39] Singers who suffer from hypothyroidism (low thyroid function) present with

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[36] Pribuisiene, 151.

[37] Ibid, 150.

[38] Sataloff, "Hormones and the Voice," 43.

[39] Abitbol, "Normal Voice Maturation," 49.

symptoms such as hoarseness, vocal fatigue, loss of range, sluggishness, muffled sound, and sometimes the feeling of having a lump in the throat.[40] Abitbol explains that during a severe hypothyroid condition the voice is hoarse due to the significant edema of the vocal mucosa and congested vocal muscle.[41] Although the reason for these manifestations is not entirely understood, it is believed that this is a reaction similar to the response when sex hormones cause a thickening of the vocal folds in females. To complicate matters, hyperthyroidism, also called thyrotoxicosis (high thyroid function), can cause the same symptoms of hoarseness. Both conditions can be controlled with appropriate prescription medication and are reversible after such treatment.[42] [43]

In his article "Hormones and the Human Voice," Brodnitz, describes a scenario of a singer going to a laryngologist with the complaints of a veiled sensation in her voice, decreased upper range, and vocal fatigue. Upon examination, the vocal folds of this singer appear normal or slightly gray. Brodnitz cautions laryngologists not to treat these symptoms as laryngitis, but to test the singer for thyroid function. With the proper diagnosis, treatment for thyroid dysfunction is often successful, leading to an improvement in clarity of sound and increase in range.[44]

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[40] Sataloff, 43.

[41] Abitbol, "Sex Hormones and the Female Voice," 431.

[42] Kadakia, "The Effect of Hormones on the Voice," 572.

[43] Abitbol, "Sex Hormones and the Female Voice," 431.

[44] Brodnitz, "Hormones and the Human Voice," 16.

Premenstrual Vocal Syndrome

Before examining the effects of premenstrual syndrome on the voice, it is essential to understand the unique chain of events that take place in a woman's body throughout her 28-day cycle. Unlike men, women experience cyclic variations of hormone secretions in distinct phases throughout the month. These hormonal variations take place for one reason only—to prepare the body for conception, pregnancy, and childbearing (see Appendix D).[45]

The menstrual chain of events is instigated by a small almond-size region of the brain called the hypothalamus, which is located near the top of the brainstem. The hypothalamus sends gonadotropic-releasing hormones (GnRH) to the pituitary gland—a pea-size gland located at a point that appears to be dangling from the anterior tip of the hypothalamus. The pituitary gland, also known as the "master gland" because it regulates so many important functions, receives the GnRH; in response, it dispatches two different hormones that target the ovaries. These two hormones are follicle-stimulating hormone (FSH) and luteinizing hormone (LH).[46]

Once FSH reaches the ovaries, it stimulates the secretion of estrogen and starts the follicular phase of the menstrual cycle. Estrogen levels increase quickly, acting under the assumption that they are preparing the uterus for the ovum to release and be fertilized. At the beginning of the follicular phase, the lining of the uterine wall is at its thinnest, and

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[45] Clarissa Behr Davis and Michael Lee Davis. "The Effects of Premenstrual Syndrome (PMS) on the Female Singer." *Journal of Voice* 7, no. 4 (1993): 337.

[46] Ibid.

by the end it is at its thickest. The typical follicular phase lasts approximately 14 days, which counts the first day of menstruation as day one.[47]

Estrogen levels are at their highest on day 14 of the cycle, which prompts ovulation and secretion of large quantities of progesterone. This marks the beginning of the luteal phase, which is focused on preparing the uterus for pregnancy. If the ovum is fertilized, progesterone will be secreted for the duration of the pregnancy. If the ovum is not fertilized, levels of both estrogen and progesterone plummet and the thick lining of the uterine wall is shed as menstrual flow, indicating the end of the menstrual cycle (see Appendix E).[48] [49]

Sung Won Chae, et al. acknowledge that "the effect of menstrual cycle on the voice has been an area of much debate and investigation" and that female singers experience unique problems during the premenstrual phase that cannot be classified as psychogenic or related to anxiety.[50] Empirical evidence of a relationship between phases of menstruation relating to quality of the voice is found in the research of Abitbol, who provides understanding of this through his studies. Abitbol examined cervical tissue and vocal fold tissue smears on the same day of both the follicular and luteal phases. Both tissue samples were made up of the same squamus epithelial cells. In his words, “the

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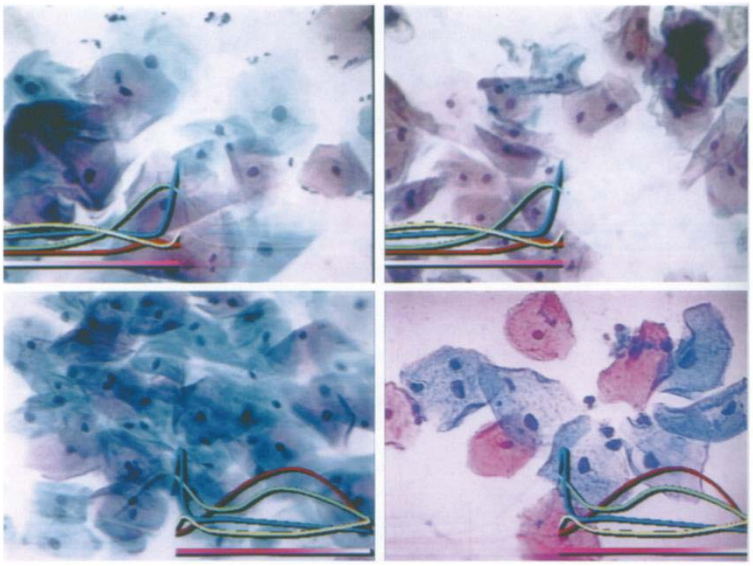
[47] Davis, “The Effects of Premenstrual Syndrome,” 338.

[48] *The Female Reproductive System*, Clevelandclinic.org, (accessed October 25, 2015).

[49] Richard Morris, et al. “Voice Onset Time in Women as a Function of Oral Contraceptive Use,” *Journal of Voice* 23, no. 1 (2009): 114.

[50] Sung Won Chae, et al., “Clinical Analysis of Voice Change as a Parameter of Premenstrual Syndrome,” *Journal of Voice* 15, no. 2 (2001): 278.

correlation was extraordinary and perfectly concordant with all our patients at ovulation and on days 25-27 of the cycle."[51]



Top left: Vocal fold follicular phase smear-test.

Top right: Cervix follicular phase smear-test.

Bottom left: Vocal fold luteal phase smear-test.

Bottom right: Cervix luteal phase smear-test.[52]

The term premenstrual syndrome (PMS) is widely used in reference to a general malaise experienced by some women prior to menstruation during the luteal phase of the menstrual cycle. The symptoms associated with PMS include depression, anxiety, irritability, lethargy, changes in appetite, bloating, headaches, joint or muscle pain, and other emotional and physical changes that may even interfere with social and occupational function of the affected individual.[53] PMS is not experienced by all women, but 75 percent do have some physical changes that take place during the premenstrual phase.[54]

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[51] Abitbol, "Sex Hormones and the Female Voice," 435.

[52] Ibid., 436.

[53] Chae, "Clinical Analysis," 279.

[54] Joseph Mortola, ""Issues in the Diagnosis and Research of Premenstrual Syndrome." *Clinical Obstetrics and Gynecology* 35, no. 3 (1992): 587.

Sataloff explains that the ill-effects of changes during PMS are known as *laryngopathia premenstrualis,* which is "a common condition caused by physiologic, anatomic, and psychologic alterations secondary to endocrine changes."[55]

Changes in the voice can be present during PMS. This is often referred to as PMVS, or premenstrual vocal syndrome, which is the change in vocal fold stability due to fluctuations in hormonal levels.[56] Common symptoms include vocal fatigue, a loss of high tones and the ability to sing very softly, a loss of strength in the voice, and a diminished range of harmonics resulting in a hoarse or husky sound. There is dryness of the larynx in the days leading up to menstruation due to the instability of estrogen and progesterone, and this dryness leads to a need for throat clearing.[57] Abitbol warns that excess vocal strain during this phase could eventually lead to nodules on the vocal folds.[58]

A study by Maree Ryan and Dianna T. Kenny followed trained female singers and examined their ability to sing the aria "O mio babbino caro," from the opera *Gianni Schicchi* by Giachomo Puccini, at various intervals throughout the month to measure changes in their voices. These singers were also asked to keep a diary of their physical symptoms, mood states, and vocal production.[59] They reported the expected vocal symptoms of huskiness, vocal fatigue, loss of power, and decreased range when singing

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[55] Sataloff, "The Professional Voice: Part I. Anatomy, Function, and General Health," 99.

[56] Maree Ryan and Dianna T. Kenny, "Perceived Effects of the Menstrual Cycle on Young Female Singers in the Western Classical Tradition." *Journal of Voice* 23, no. 1 (2009): 99.

[57] Abitbol, *Odyssey,* 216.

[58] Ibid.

[59] Ryan and Kenny, "Perceived Effects of the Menstrual Cycle on Young Female Singers in the Western Classical Tradition,"99.

during menstruation. Recordings were reviewed and rated by reputable voice pedagogues during the various phases of their menstrual cycles. The study revealed that although participants were able to accurately determine at what point in their cycle the recordings were taken, the vocal pedagogues were not able to ascertain any difference in voice sample.[60] This is consistent with Sataloff's observation that PMVS symptoms are often more apparent to the singer than to the listener.[61] This result highlights the complexity of the perceived effect of hormonal shifts on the female singing voice.

The Effects of Oral Contraception on the Singing Voice

Oral contraceptive pills (OCPs) were first approved for use in the United States in 1960. In early generations of the drug, professional singers were advised not to take them due to the risk of permanently damaging the voice. The risk was linked to the fact that previous generations of OCPs contained testosterone and elevated levels of androgen. These are virilizing agents, which are known to cause a permanent masculinization of the voice, thus altering the deepness and steadiness of timbre stability between registers.[62]

Filipa Lã describes the equilibrium within the female registers as being delicate and demanding, in contrast to the speaking voice. Because of the complexity of the balance between the two major antagonistic muscles of the voice mechanism in females, the thyroarytenoid muscle that contracts the vocal folds and the cricoarytenoid muscle

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[60] Ryan and Kenny, "Perceived Effects of the Menstrual Cycle on Young Female Singers in the Western Classical Tradition,"105.

[61] Sataloff, "The Professional Voice: Part I. Anatomy, Function, and General Health," 99.

[62] Filipa Lã, M.B., et al., "The Effects of a Third Generation Combined Oral Contraceptive Pill on the Classical Singing Voice." *Journal of Voice* 21, no. 6 (2007): 754.

that stretches the vocal folds, any changes in the bulk of these muscles and ligaments will compromise the quality of the singing voice.[63]

Current research indicates that the use of oral contraceptives stabilizes hormone levels throughout all phases of the menstrual cycle, which is in stark contrast to what a woman experiences during a natural menstrual cycle. Measurable acoustic changes take place in the voice as the result of fluctuating hormone levels among non-OCP users.[64]

A study by Ofer Amir and Liat Kishon-Rabin confirmed that modern OCP use does not have an adverse effect on the female speaking voice and, contrary to previous versions of the pill, could produce a more stable and better quality voice in relation to frequency and amplitude perturbation, which is a measure of vocal stability.[65] Their findings indicated that women complaining of voice changes during their menstrual cycle could experience improved vocal fold regulation during vibration with use of OCPs.[66]

"The Effects of a Third Generation Combined Oral Contraceptive Pill on the Classical Singing Voice," by Filipa Lã, et al., (2007), is an important study that examines the possibility that use of modern OCPs might stabilize the quality of the singing voice throughout the monthly menstrual cycle by minimizing hormonal fluctuations. Recent advances have led to the development of what are known as "third generation OCPs," containing low doses of synthetic hormones.

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[63] Lã, "The Effects of a Third Generation Combined Oral Contraceptive Pill," 755.

[64] Richard Morris, et al., "Voice Onset Time in Women as a Function of Oral Contraceptive Use." *Journal of Voice* 23, no. 1 (2009): 114.

[65] Ofer Amir and Liat Kishon-Rabin. "Association between Birth Control Pills and Voice Quality." *The Laryngoscope* 114 (2004): 1022.

[66] Ibid., 1026.

The synthetic hormones commonly found in OCPs are a combination of drospirenone and ethinyl estradiol. Drospirenone is similar to the naturally occurring progesterone that is secreted by the ovaries. It is also an anti-androgenic compound. Thus, it can be deduced that drospirenone might potentially mitigate the virilization of the female voice.[67] Lã's study explored these monophasic OCPs, which deliver a steady dose of estrogen and progestin throughout the month and eliminate hormone fluctuations. These OCPs were found to improve voice quality in healthy women compared to their counterparts who were not taking OCPs.[68]

Use of monophasic OCPs also alleviates menstrual symptoms unrelated to the vocal folds. Abdominal cramping associated with PMS is known to compromise the specific breathing technique called *appoggio*, which is used by singers. This technique requires diaphragmatic breath support and use of intercostal and abdominal muscles.

Lã's findings also reveal a new hypothesis, which is that female vocal changes may also be related to changes in the concentration levels of free testosterone.[69] Free testosterone is a form of the hormone that is not bound to proteins and that is responsible for sex traits.[70] Because the highest levels of estradiol (estrogen) and progesterone are found in the luteal phase of the menstrual cycle and vocal differences were only found during menstruation and the follicular phase, she deduces that vocal changes may be

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[67] Ulrike Fuhrmann, et al., "The Novel Progestin Drospirenone and Its Natural Counterpart Progesterone: Biochemical Profile and Antiandrogenic Potential." *Contraception* 54 (1996): 243.

[68] Lã, "The Effects of a Third Generation Combined Oral Contraceptive Pill," 755.

[69] Ibid., 759.

[70] Marianne Fraser, "Free Testosterone," University of Rochester Medical Center, https://www.urmc.rochester.edu/encyclopedia/content.aspx?ContentTypeID=167&ContentID=testosterone_free (accessed November 27, 2015)

caused by an alternate influence. Lã explains that it is is likely the vocal folds are reacting to sensitivity to variations of the levels of free testosterone, which occurs when there is instability in the levels of estrogen and progesterone.[71] Women are more susceptible to the effects of testosterone on laryngeal mucosa than men, regardless of the fact that men have much higher concentrations of testosterone compared to women. Men experience a constant level of testosterone throughout the month, whereas women only experience a change in testosterone levels during the menstrual cycle.[72] As previously stated, although women have trace amounts of free testosterone, elevated levels could have androgenic repercussions. These elevated levels of free testosterone cause higher vocal fold irregularity during both the menstrual and follicular phases of the cycle, resulting in increased fluid retention in the vocal fold mucosa.[73]

Lã's conclusion is that monophasic OCPs could be prescribed to trained female singers whose voices are under the significant demands of Western classical singing. This is because the drospirenone in such OCPs has anti-androgenic properties that mitigate fluid retention, lower levels of free testosterone, and stabilize and regulate the vibratory patterns of the vocal folds.[74] Although the nature of voice production is never perfect, the use of monophasic OCPs can result in a less erratic singing voice and make it possible for women to sing with reduced disturbance throughout all phases of the menstrual cycle.[75]

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[71] Lã, 759.

[72] Ibid., 760.

[73] Ibid.

[74] Ibid.

[75] Ibid.

In addition to the use of oral contraception to regulate voice stability, Sataloff suggests that, "under crucial performance circumstances, OCPs may be used to alter the time of menstruation, but this practice is justified only in unusual situations."[76]

There are many unanswered questions regarding a singer's use of OCPs. How, and if, this useful information is disseminated to singers is of particular interest. Answers to the questions found in Appendix F would shed light on this subject.

The Pregnant Singer

There are two conditions that eliminate the hormonal cycle regulating menstruation. One of these conditions is pregnancy and the other is menopause.[77] Many studies acknowledge the fact that little is known about voice changes during pregnancy. Few studies examine voice quality in the third trimester, and even fewer examine the specific effects of pregnancy on the singing voice. It is widely accepted that a woman's body undergoes major physiologic, anatomic, metabolic, and hormonal changes during pregnancy.[78] In fact, during pregnancy, sex steroid hormones directly affect the genital tract, mucosa, muscles, bone tissue, cerebral cortex, and the larynx.[79]

The voice is susceptible to elevated levels of sex steroid hormones during pregnancy, especially during the last trimester when estrogen and progesterone are higher than normal, with progesterone being the dominant hormone.[80] Pregnancy also eliminates

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[76] Sataloff, "The Professional Voice: Part I. Anatomy, Function, and General Health," 99.

[77] Hancock, "Acoustic and Aerodynamic Measures of the Voice during Pregnancy," 53.

[78] Hamdan, "Effect of Pregnancy on the Speaking Voice," 491

[79] Abitbol, "Sex Hormones and the Female Voice," 431.

[80] Lã, "Pregnancy and the Singing Voice: Reports from a Case Study," 434.

the periodic vocal changes that accompany the menstrual cycle.[81] Instead, pregnant women experience vocal changes on a continuum throughout pregnancy due to the progression of gestation. *Laryngopathia gravidarum* may be a severe complication during pregnancy or less severe condition that relates to changes in the voice, such as hoarseness, which Sataloff describes as being similar to those changes experienced during menstruation. He concludes that some of the vocal changes during pregnancy may even be thought of as desirable.[82] Abitbol concurs and explains that the quality of vocal fold vibration is improved during pregnancy, due to optimal lubrication, which allows professional singers to sing remarkably well while 2 to 7 months pregnant.[83] Singing into the last 2 months of pregnancy presents unique challenges with respect to breath support due to increased abdominal distention. He further describes a pregnant woman's voice as carrying well with a round and beautiful sound because of an increase in hormones.[84]

In the article, "Pregnancy and the Singing Voice", Lã and Sundberg specifically examined professional singers during the third trimester of pregnancy. Their study concluded that during the third trimester there is an increase in phonation threshold pressure (PTP) and collision threshold pressure (CTP).[85] PTP is the lowest amount of subglottal pressure required to initiate and sustain vocal fold oscillation, and CTP is the smallest amount of subglottal pressure needed for vocal fold collision. Initially they

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[81] Hancock, 53.

[82] Sataloff, "The Professional Voice: Part I. Anatomy, Function, and General Health," 100.

[83] Abitbol, "Normal Voice Maturation: Hormones and Age," 43.

[84] Ibid

[85] Lã, "Pregnancy and the Singing Voice," 435.

expected that PTP and CTP would be lower because of the solubility of vocal fold collagen fibers during pregnancy, but this was not the case. These collagen fibers are found in the lamina propria layer of the vocal folds. Lã and Sundberg came to the conclusion that the viscosity of vocal fold mucosa may be more influential than the increased solubility of collagen fibers.[86] This suggests that the thickness of mucous is more significant than the solubility of the collagenous layer of the lamina propria. Because of increased PTP and CTP, their study verified their hypothesis that pregnancy reduced vocal fold motility, which is unfavorable for singing. This conclusion was supported by perceptible and measurable changes in the voice in response to changes in hormonal level concentrations during pregnancy.[87] Perceptible qualities include a decrease in vocal brightness. This supports the belief that pregnancy is associated with changes related to the increase in tissue viscosity and vocal dryness. These are symptoms that are associated with heightened concentrations of estrogen and progesterone during pregnancy.[88] This conclusion is contrary to the statements of Sataloff and Abitbol.

The detrimental effects of pregnancy on the female singing voice are not entirely hormone related. A study by Ziay Saltürk revealed that common vocal complaints during pregnancy are vocal irritation during the first and third trimesters due to hyperemia (increase in blood flow) caused by vomiting, and gastroesophageal reflux, which is often prevalent in the third trimester.[89] A decrease in maximum phonation time (MPT) was

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[86] Ibid., 436.

[87] Ibid., 437.

[88] Ibid., 438.

[89] Ziya Saltürk, "Objective and Subjective Aspects of Voice in Pregnancy," 72.

found to be due to decreased abdominal volume that limits breath capacity. Verónica L. Cassiraga et al. determined that because of significant changes at the thoracic and abdominal level, it is difficult to maintain good respiratory support, which results in high, clavicular breathing.[90]

The Singing Voice and Menopause

In Greek civilization, 400 years B.C., when the average life expectancy was 23 to 27 years, a woman in menopause was virtually, or at least an unusual exception. Even in the Middle Ages, when life expectancy increased to up to 40 years, menopause was not an issue for women as most did not live long enough to enter that phase of life.[91] The scenario today is quite different. The average age of menopause is 50 to 59 years, which means today's woman will spend nearly a third of her life in an estrogen deficient state.[92] According to a 2015 article published in UK's *Telegraph,* the next generation of females will live beyond 100 years.[93] The implication of this statistic is that a woman could be post-menopausal for 50 percent of her life (see Appendix G).

Menopausal Vocal Syndrome

Postmenopausal women have such low ratios of estrogen and progesterone to androgen that the influence of androgens becomes more significant.[94] During menopause

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[90] Verónica L. Cassiraga, et al., "Pregnancy and Voice: Changes During the Third Trimester," 585.

[91] Abitbol, "Normal Voice Maturation: Hormones and Age," 43.

[92] Bhagu Bhavnani, "Estrogens and menopause: pharmacology of conjugated equine estrogens and their potential role in the prevention of neurodegenerative diseases such as Alzheimer's," 16.

[93] John Bingham, "Average Life Expectancy Heading for 100," *Telegraph.co.uk,* January 15, 2015, http://www.telegraph.co.uk/news/politics/11348561/Average-life-expectancy-heading-for-100.html (accessed February 2, 2016).

[94] Evelien D'Haeseleer, "The Impact of Menopause and Hormone Therapy on Nasal Resonance," 69.

the ovaries cease their production of progesterone, and they eventually function only as an endocrine gland that secretes very little hormone.[95] With estrogen less present, sex hormone receptors receive more androgens, which leads to thickening of the mucous membrane of the vocal folds and results in a voice that is deeper ,with a more masculine quality.[96] In the article "Sex Hormones and the Female Voice," Abitbol explains the numerous effects of androgen on the female voice, beginning with the cerebral cortex and, in particular, the left hemisphere of the brain.[97] Androgens also affect genital organs (uterus, ovaries, and breasts); sebaceous gland; and striated muscle, which includes the vocal muscles.[98] Again, in Abitbol's study, cellular smears of both cervical and vocal fold tissue reveal a similarity related to mucosal atrophy as a result of androgen.[99] Additionally, vocal function is compromised due to age-related muscular atrophy and a thinning of the vocal fold mucosa. Because of these factors there is a decrease in hydration of the free edges of the vocal folds, leading to dryness during phonation that then results in rapid vocal fatigue and dysphonia.[100]

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[95] Abitbol, "Odyssey of the Voice," 224.

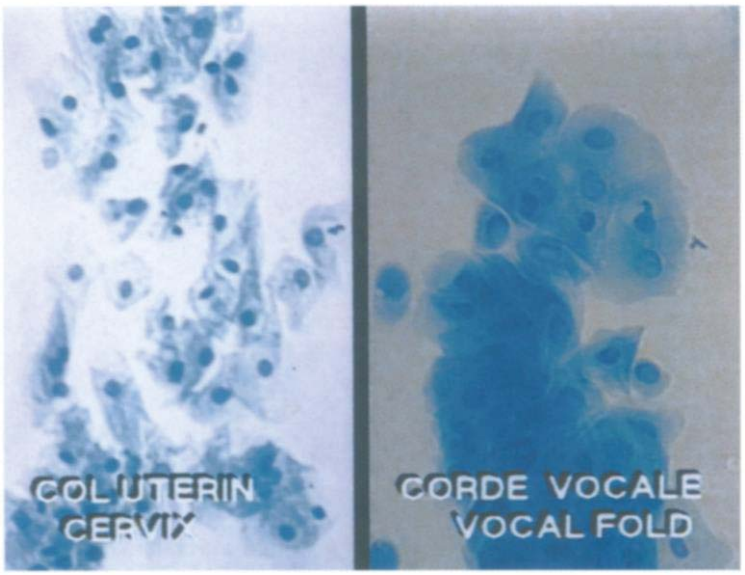
[96] Ibid.

[97] Abitbol, "Sex Hormones and the Female Voice," 439.

[98] Ibid.

[99] Ibid.

[100] Ibid.



Smear-test at menopause.[101]

Other symptoms that are noticeable, and especially concerning for singers, are a loss of high notes and the ability to sing *pianissimo.*[102] Menopausal vocal syndrome takes female singers on a course of slow progressive deterioration of their voices.

The Effects of Hormone Therapies on the Singing Voice

In order to discuss the effects of hormone therapy on the singing voice, it is necessary to have an understanding of the development and history of its use in women. "The scientific and commercial development of pharmaceutical estrogen in the 1930s produced the hormone replacement therapy (HRT) that would become the most popular drug in America by the 1990s."[103] Sustained use of such therapy has been controversial and of great concern after the 15-year-long Women's Health Initiative (WHI) clinical

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[101] Ibid., 440.

[102] Ibid.

[103] Elizabeth Siegel Watkins, *The Estrogen Elixir: A History of Hormone Replacement Therapy in America* (Baltimore: Johns Hopkins University Press, 2007), 1.

trial that involved a double-blind study of more than 10,000 women. In this study, one group of women took Prempro (estrogen and synthetic progesterone) and the other group took estrogen alone.[104] The study began in 1997 and was scheduled to end 8 years later in 2005. However, it was halted in 2002 because of negative results in postmenopausal women that included a small increase in heart problems and breast cancer. Once this was reported, a media panic resulted in women going off of HRT and sales of the drug sharply falling.[105]

Today, 14 years later at this writing, research shows that HRT benefits are numerous. Studies indicate that estrogen replacement therapy does not greatly increase the overall risk of cardiovascular disease or breast cancer.[106] Not only is HRT used to manage early menopausal symptoms such as hot flashes, vaginitis, insomnia, and moodiness, but it may also prevent the risk of cardiovascular disease, Alzheimer's disease, and osteoporosis.[107] Long-term, low-level estrogen replacement therapy has been found to extend the life span of postmenopausal women,[108] and data currently being published show that when women stop hormone therapy, death rate increases.[109]

While many women may experience benefits from HRT, it is important to consult a physician who is an expert in the field. Research shows that it is also the method of

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[104] Cynthia Fox, "Is HRT for Menopause Staging a Comeback?"

[105] Frank H. Comhaire, "Hormone Replacement Therapy and Longevity," 65.

[106] Comhaire, 65.

[107] Bhavnani, "Pharmacology of conjugated equine estrogens: Efficacy, safety and mechanism of action," 16.

[108] Comhaire, 66.

[109] Fox.

HRT delivery that varies the effectiveness and that hormone therapy is a preventative measure and should not be entirely relied on as a combative drug.[110]

Abitbol conducted a study of menopausal vocal syndrome on one hundred women who were completely in menopause (no menstruation for 1 year) and not taking hormone replacement. They were all given a laryngeal assessment, as well as a gynecological and hormonal assessment, to confirm menopause. Of the one hundred women, eighty-three showed minimal adverse effects on their voices due to hormonal changes. Seventeen of the women presented clinically with menopausal vocal syndrome; their specific symptoms were lowered vocal intensity, vocal fatigue, decreased range, loss of high notes, and loss of timbre in both their spoken and singing voice.

Spectral analysis, a method of reviewing data concerning quality of sound, established that there was a decrease in harmonics and formant strength, which confirmed a common complaint of flatness in timbre and a loss of color in the voice.[111] Vocal fold smears and cervical smears were compared, and both had mucosal atrophy with basophils (white blood cells) and a significant reduction of glandular cells.[112] Vocal folds were less supple, with a thinner mucosa and a reduction in vibratory amplitude.[113] The dysphonia experienced by the seventeen women was demonstrated in the start of unilateral muscular atrophy in eight patients, bilateral atrophy in nine patients, and a thinning of vocal fold

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[110] Ibid.

[111] Abitbol, "Sex Hormones and the Female Voice," 440.

[112] Ibid.

[113] Ibid.

mucosa with a reduced amplitude during phonation.[114] Stroboscopy, which is used to visualize vocal fold vibration by using a flashing light to make fast-moving objects appear slow-moving, showed an asymmetry between the right and left vocal folds, and the appearance of the mucosa was dull and lacked the shiny white appearance of healthy vocal folds. Laryngograph measurements revealed reduced vocal fold resistance and were weaker and irregular when compared to those typically found in younger women.[115]

Ultimately, forty-two of the one hundred women received HRT for a variety of reasons. Seventeen of the women with postmenopausal vocal syndrome were given HRT to manage the vocal demands of their profession, and improvement was noticed within 4 to 6 months. Fourteen of the women experienced a normalization in amplitude of vocal fold vibrations of the mucosa, a return to normal muscular contour and no sign of muscular atrophy, and vocal timbre improvement. Only three of the women showed little improvement in amplitude, suppleness, and volume, despite the fact that there was a fair improvement in anatomic appearance.[116]

As optimistic as Abitbol's study sounds, the method of administration of HRT can even further determine its effectiveness. According to a study by Firat, et al., greater improvement in voice quality is observed in intranasal estrogen delivery compared with oral pills, based on measurement of jitter and shimmer values in test groups.[117] Because the benefits of estrogen on vocal quality have been strongly established, these studies are

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[114] Ibid.

[115] Abitbol, 441.

[116] Ibid.

[117] Yezdan Firat, et al. "Effect of Intranasal Estrogen on Vocal Quality," 718.

encouraging for the female singer navigating menopause. After careful consultation with a physician specializing in this field, a woman will be able to determine whether HRT is right for her.

Body Mass Index and the Menopausal Singer

When the production of estrogen in the ovaries ceases, another source of estrogen production can be found in adipose cells, also known as fat cells. The levels of estrogen produced by the body increase as fat cell mass increases, which translates to women with a higher body mass index (BMI) having a higher production rate of estrone than normal-weight women.[118] Estrone is a form of estrogen that is produced in both the ovaries and fat cells (see Appendix H). Variations in estrogen level occurrence, either due to menopause or taking hormone therapy, are related to speaking fundamental frequency (SFF). This was investigated in a study by Evelein D'Haeseler et al. to determine the association of BMI and SFF in pre- and post-menopausal subjects both on and off of hormone therapy. Their findings demonstrated that the postmenopausal subjects with a higher BMI and not on hormone therapy had a higher SFF. This indicates that BMI has a significant influence on the voice quality of postmenopausal women.[119]

Abitbol discusses this BMI menopausal phenomenon using the analogy of Amedeo Modigliani and Peter Paul Rubens women, referring to the size preference each of these visual artists rendered in his depiction of women. The Modigliani type is slim, while the Rubens type is ample.[120] Because of the age-related increase in estrones in

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[118] Ellen Freeman, "Obesity and Reproductive Hormone Levels in the Transition to Menopause," 723.

[119] Evelein D'Haeseler, et al. "The Impact of Menopause and Hormone Therapy on Nasal Resonance," 756.

[120] Abitbol, *Odyssey,* 225.

obese menopausal women, the Rubens woman would have a lower need for HT and the Modigliani woman would likely benefit from HT.[121]

Female Testosterone Therapy and the Voice

Rebecca Glaser's 2016 article, "Effect of Testosterone Therapy on the Female Voice", is the first study of its kind to explore the topic of female testosterone and the voice.[122] This is timely subject amid the current popularity and advertisement blitz of testosterone therapy for men suffering from "Low T" symptoms of depression, lack of energy, and decreased libido. In fact, testosterone therapy (T therapy) may be prescribed for female breast cancer survivors after cancer treatment. Additionally, postmenopausal women use T therapy to improve sexual function, body composition, and bone mass.[123] The findings of her research are counterintuitive and inconsistent with the common warnings against T therapy for women in respect to masculinization of the voice. Although Glaser's study does not examine the singing voice, it is worth discussing what her research reveals about the speaking voice.

In a study of ten female patients who received subcutaneous testosterone implants, four were postmenopausal and six were perimenopausal (pre-menopause). With weight-based dosage, implants were inserted on an average of 3-month intervals. Acoustic samples were then collected to compare pre-implant, 3-month, 6-month, and 12-month voice samples. The study showed that after analysis via Real Time spectrum analyzer there was no significant change in the median speaking fundamental frequency

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[121] Ibid.

[122] Rebecca Glaser, "Effect of Testosterone Therapy on the Female Voice," 202.

[123] Grace Huang, et al., "Functional Voice Testing Detects Early Changes in Vocal Pitch in Women During Testosterone Administration," 2254.

between the pre-treatment and post-treatment subjects at any 3-month or 6-month interval. For all test subjects, the average SFF at the 6-month interval was actually slighter higher, although not significantly so from baseline—3 and 12 months.[124] Out of the ten test subjects, three had lower than expected SFF at baseline. While on T therapy, two of the three increased their SFF while on therapy, and these two subjects also happened to have the highest testosterone levels while on therapy.[125]

This paradox is further discussed with the explanation that side effects of androgenic therapy depend on the structure of the molecule, the method of delivery (oral, topical, or subcutaneous), and dosage.[126] Glaser found that testosterone does not have a masculinizing effect on females outside of suprapharmacologic doses (amounts beyond normal therapeutic doses) of synthetic androgens.[127] The high doses of the anabolic steroid oral danazol, previously warned against for fear of masculinization of the female singing voice,[128] should be compared with caution to the current study; this is because its effects are observed from non-equivalent studies from non-equivalent groups.[129]

Glaser explained that if T therapy was indeed the result of the increase in SFF in three of the test subjects, it could be due to the anti-inflammatory properties of testosterone, as well as the beneficial effects on muscle strength, bone density, pulmonary

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[124] Glaser, 199.

[125] Ibid.

[126] Ibid., 200.

[127] Rebecca Glaser, "Testosterone Therapy in Women: Myths and Misconceptions," 232.

[128] Sataloff, "Hormones and the Voice," 43.

[129] Glaser, "Effect of Testosterone Therapy on the Female Voice," 200.

function, and connective tissue health.[130] The unexpected 6-month measurement of increased SFF that did not persist at 12 months could be attributed to the fact that the sample size was small and normal within-speaker variance.[131] In any case, there was no lowering, deepening, or decrease in SFF noted at any time period during this 12-month study.[132]

Grace Huang, et al. conducted a randomized double-blind study of healthy women, ages 41 to 62, who had undergone hysterectomy and had serum testosterone or free testosterone levels less than the average for a healthy young woman. These women were placed on a regimen of transdermal estradiol so they would achieve nominal delivery of the hormone. They were also randomized in a double-blind manner to receive either weekly injections of placebo or testosterone.[133]

The functional voice assessment of the subjects included both a speaking component and a "sustained 'Ah' test." It was found that the lowering of pitch was more consistently observed during the "Ah" test than any other spoken test.[134] The subjects who experienced the most significant lowering of vocal pitch, compared to those on placebo, were at the highest doses of testosterone.[135] The "Ah" test more closely resembles the sustained act of singing than does speaking and is, therefore, a useful assessment for a singer to be aware of. It was discovered that there was a significant

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[130] Ibid., 201.

[131] Ibid.

[132] Ibid.

[133] Huang, 2255.

[134] Ibid., 2257.

[135] Ibid., 2259.

decrease in average pitch related to significant increases in serum free testosterone concentrations.[136] Although none of the test subjects were professional singers and none experienced a significant effect on their voice-related quality of life, Huang acknowledges that voice professionals would have a different assessment of their voice quality.[137]

With new hormone therapies emerging, despite compelling and sometimes contradictory findings, it must be restated that professional singers have considerable demands placed on their voices that are far beyond the scope of everyday speaking and should, therefore, be very cautious. Singers and professional voice users should consult with a physician who is knowledgeable about the hormone-voice relationship before beginning such treatment.

[136] Ibid., 2256.

[137] Huang, 2258-2259.

CHAPTER 4

Summary

This essay systematically reviewed scholarly literature relating to the influence of sex hormones on the female singing voice. The structure chronologically followed hormonal biological events in a woman's life, beginning with puberty and concluding with menopause. The effects on the voice were examined during each phase. Also addressed were the effects of oral contraceptive pills, hormone replacement therapy, and testosterone therapy on the singing voice. The review of the scientific research on each of these subjects resulted in the compilation of information that is accessible, understandable, and essential for female professional voice users and those who train them. This document also revealed that although there is a considerable amount of research available on hormones and the voice (although often found in obscure places), little research targets the implications of hormonal variance on the vocal demands of elite singers.

Future Studies

There are a variety of medical protocols that involve sex hormone levels in women for which the effects on the singing voice have not yet been thoroughly clinically examined. The following are examples of such treatments that warrant further study in relationship to their specific effect on the female singing voice.

- Fertility treatment involving injections of high levels of sex hormones.
- Gastric bypass surgery, causing rapid fat loss that may affect the body's response to the level of hormones that are stored in adipose cells.

- Polycystic Ovarian Syndrome (PCOS), which is a disease of hormonal imbalance resulting in the overproduction of male sex hormone with a treatment regimen that may involve hormones.
- Hormone therapy as a treatment option for endometriosis.
- Medications and drugs that lower estrogen levels as a preventative measure for breast cancer.
- Testosterone therapy for women. The purpose may be for improving strength, cardio-vascular health, and increasing libido.
- Hormone therapy for transgender women and sex reassignment surgery.

Based on the research presented in this paper that establishes the sensitivity of the voice to hormonal variations, there are a wide variety of unexamined health issues that warrant in-depth study relating to voice changes.

Common conditions that have been addressed but require more in-depth probing include prescribing hormones, either OCPs or HRT, for the explicit purpose of the improvement of the singing voice. An unexamined dynamic is the use of HRT specifically for a professional voice user and the understanding of a physician when it comes to managing the effects of menopause on the singing voice. Useful sample questions addressing this subject are found in Appendix I.

Conclusions

In examining this topic, it was discovered that there was a 22-year gap between the *NATS Journal* publication of Brodnitz's article on sex hormones and the voice and Sataloff's article on the subject. The greatest increase in the amount of scientific articles

on the subject appears during the first decade of the twenty-first century, however the predominant focus is on the effects of sex hormones on the speaking rather than singing voice. Current trends at the writing of this document seem to be in the direction of examining and debunking myths regarding deleterious effects of testosterone therapy on the voice.

Regardless of this observation, the significance of hormonal events in a woman's life is often not routinely discussed in the voice studio. This is due to a lack of awareness, education, and accessibility to research on this specific topic. Women may be uncertain of the validity of changes in their voices due to hormonal fluctuations or may even be unaware that voice abnormalities can be hormone related. Surprisingly, this lack of knowledge is widely the case, despite the fact that decades of research has been done on the topic. What Brodnitz observed in 1971 still holds true today: "Most of the studies and observations on hormonal induced dysphonia . . . have been published in phoniatric and laryngological journals and books where they do not reach the singer and the singing teacher who need information on the subject."[138]

[138] Brodnitz, 16.

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Appendix A

Definition of Terms

Anabolic steroid: a synthetic variation of the male hormone that resembles testosterone.

Androgenic: effects referring to the development of male characteristics.

Body mass index (BMI): the ratio of weight to height that measures body fat.

Collision threshold pressure (CTP): the minimum pressure required to initiate vocal fold collision.

Epithelium: the outermost thin layer of the vocal folds made up of squamous epithelial cells.

Estrogen: a sex hormone released primarily by the ovaries. Estrogen contributes to the development of secondary sex characteristics in women during puberty. Men have small amounts of estrogen.

Follicle stimulating hormone (FSH): a hormone secreted by the pituitary gland necessary for development during puberty for both men and women. In women it stimulates the growth of the follicle in the ovary causing an increase in estradiol (a form of estrogen).

Gonadotropic releasing hormones (GnRH): a hormone produced and released by the hypothalamus that travels to the pituitary gland. From there it stimulates the release of follicle stimulating hormone and luteinizing hormone.

Habitual pitch: the central speaking pitch tendency. The average pitch an individual habitually uses in speaking.

Hormone replacement therapy (HRT), also Hormone therapy (HT): a medication of synthetic estrogen and progesterone typically used for the treatment of menopausal symptoms.

Hyperemia: an increase in blow flow to different tissues in the body.

Interstitial fluid: fluid found around and between the cells of the body.

Lamina propria: the secondary layer of the vocal folds below the epithelium made up of loose connective tissue forming three fibrous layers that vary in density.

Laryngeal mucosa: the lining of the structures of the larynx.

Laryngopathia gravidarum: may be a serious complication or minor condition during pregnancy. It could result in vocal dysfunction (may be hoarseness, heaviness, or breathiness) during pregnancy caused by an increase in hormonal levels. This can cause fluid retention resulting in vocal fold edema.

Laryngopathia premenstrualis: vocal dysfunction associated with menstruation that has similar vocal symptoms as *laryngopathia gravidarum* (hoarseness, heaviness, or breathiness).

Luteinizing hormone (LH): a hormone produced by the pituitary gland and is important in regulating the function of the ovaries and testes.

Maximum phonation time (MPT): the maximum time, measured in seconds, that a person can sustain a vowel sound.

Oscillatory patterns: the wavelike patterns in which the vocal folds vibrate with a sustained motion over a period of time.

Otolaryngology: a specialized medical field focusing on the ear, nose, and throat.

Perturbation: a disturbance in sound.

Phonation threshold pressure (PTP): the minimum level of subglottal pressure required to initiate and sustain vocal fold oscillation.

Premenstrual Vocal Syndrome (PMVS): usually occurs in the days leading up to menstruation. Symptoms include vocal fatigue, loss of power, decrease in range, change in timbre due to loss of harmonics.

Progesterone: a sex hormone secreted by the ovaries that is responsible for stimulating the uterus and preparing the body for pregnancy. Men also have small amounts of progesterone.

Sex hormones: biochemicals that are essential for the growth and development of sex characteristics and are responsible for reproduction.

Speaking fundamental frequency (SFF): the measurement of the average speaking pitch which varies dependent on sex, age, emotional, and hormonal state.

Spectral analysis: a method of analyzing data with respect to frequency and quantities of energy present in sound.

Squamus epithelial cells: an outermost layer of thin, flat cells with the ability to regenerate every few weeks.

Stroboscopy: a method of using a synchronized flashing light to make a fast-moving object appear to be slow-moving. This technique is used for evaluating the function of the vocal folds.

Testosterone: the primary androgenic hormone that is responsible for the development of male genitalia and secondary sex characteristics. In females it appears in small amounts and is an estrogen precursor.

Testosterone therapy (T therapy): a form of hormone replacement therapy, usually non-oral, for men and women which is used to treat symptoms such as low libido, muscle weakness, and promote cardiac health.

Vibratory amplitude: the measurement of a sine wave from zero to its maximum excursion point away from the equilibrium point.

Virilization: the development of characteristics associated with males such as increased body hair and deepening of the voice.

Appendix B

Chart of Female Sex Hormones and Relation to the Voice

Hormone (Female)	**Function**	**Benefit to the voice**	**Risk to the voice**
Estrogen	Essential in the development of female sex characteristics. (Small amounts found in men.)	Improves timbre by thickening the mucous membrane of the vocal folds. Improves permeability of blood vessels making the voice more flexible. Promotes shedding of superficial cells of vocal folds which decreases mucous.	
Progesterone	Secreted by the ovaries to prepare the body for pregnancy. (Small amounts found in men.)	Promotes shedding of superficial cells of vocal folds which decreases mucous.	Causes imbalance of interstitial fluid resulting in vocal fold edema. Restricts capillaries from draining tissue making the voice less supple.

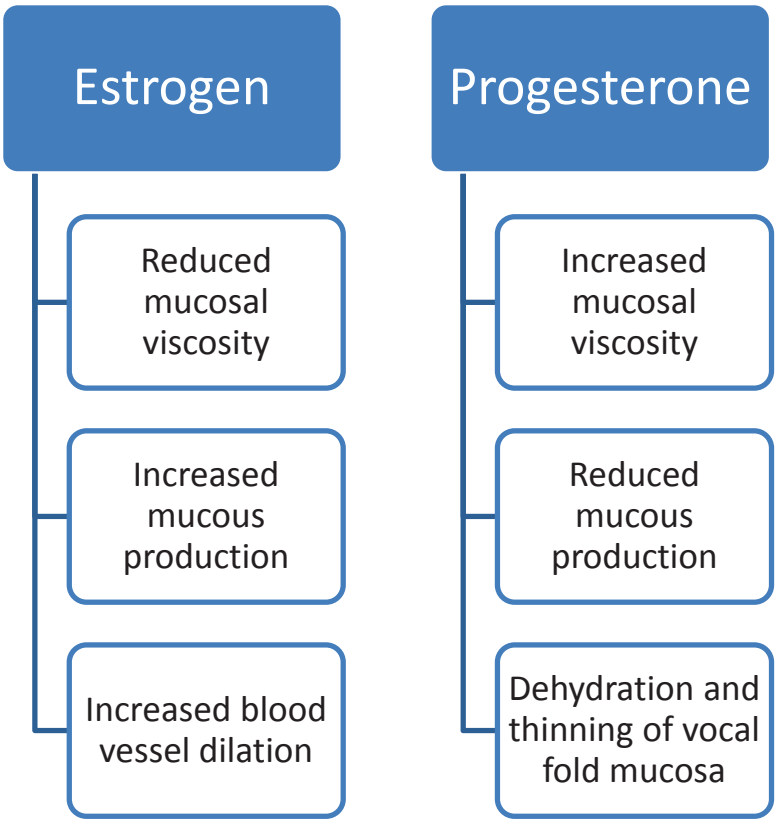
Appendix C

Chart of Male Sex Hormones and Relation to the Voice

Hormone (Male)	**Function**	**Benefit to the voice**	**Risk to the voice**
Androgen & Testosterone	Present in both men and women. Essential in the development of sex characteristics. Only small amounts of testosterone are secreted by women.	Enhances low-pitch harmonics in the female voice.	High levels may result in permanent masculinization of the female voice.

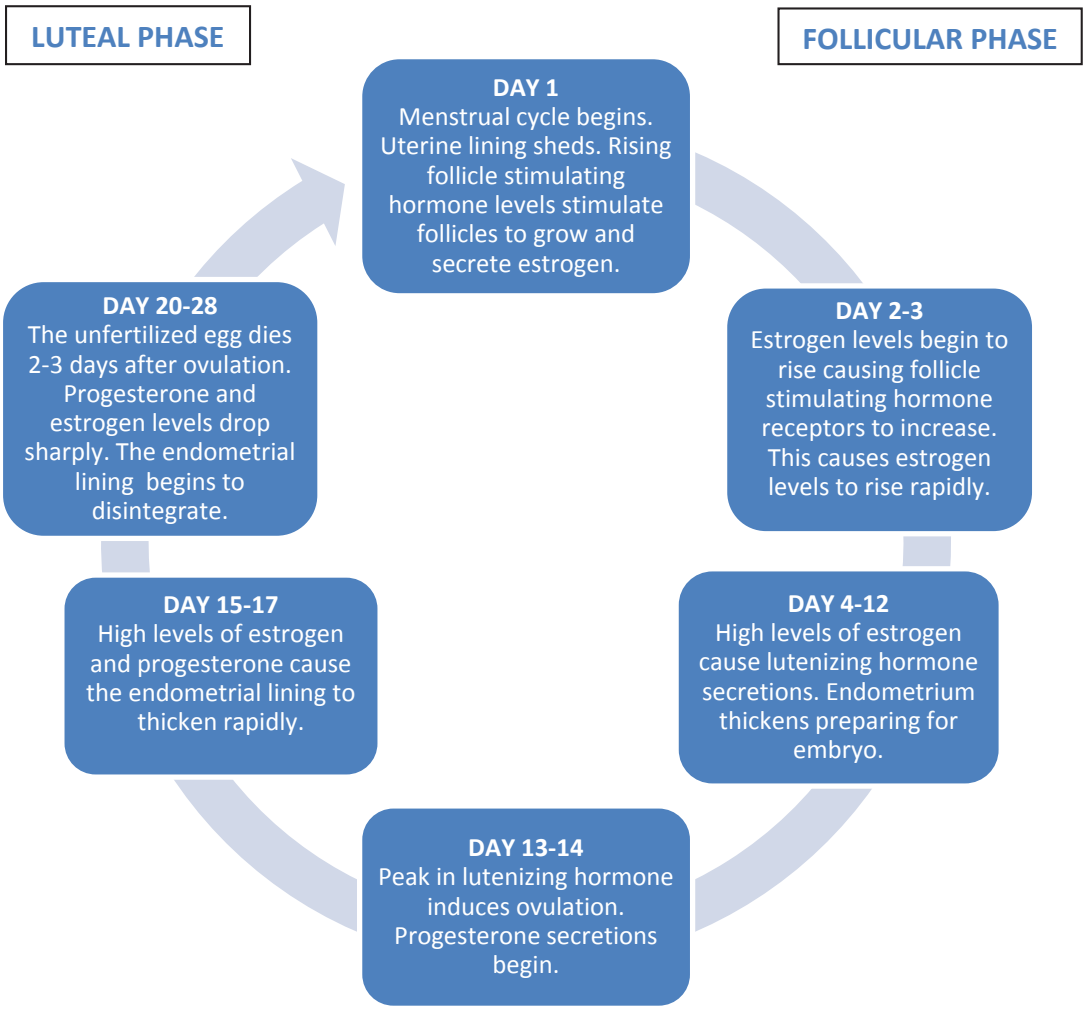
Appendix D

Estrogen versus Progesterone - Impact on Vocal Fold Mucosa



Appendix E

Normal Menstrual Cycle Timeline



Appendix F

Questionnaire for Singers Regarding Use of OCPs

Have you ever taken oral contraceptive pills (OCPs)? If so, when and for how long?

Were you ever informed that OCPs could have a positive effect on your singing voice? If so, who informed you?

Were you ever informed that OCPs could have a negative effect on your singing voice? If so, who informed you?

Did you notice a change in your singing voice while taking OCPs?

Did taking OCPs improve the overall quality of your singing voice? Describe.

Did taking OCPs have a negative effect on the quality of your singing voice? Describe.

Were you informed of the possibility of any effects of stopping use of OCPs?

Was there a change in your voice when stopping use of OCPs? Explain.

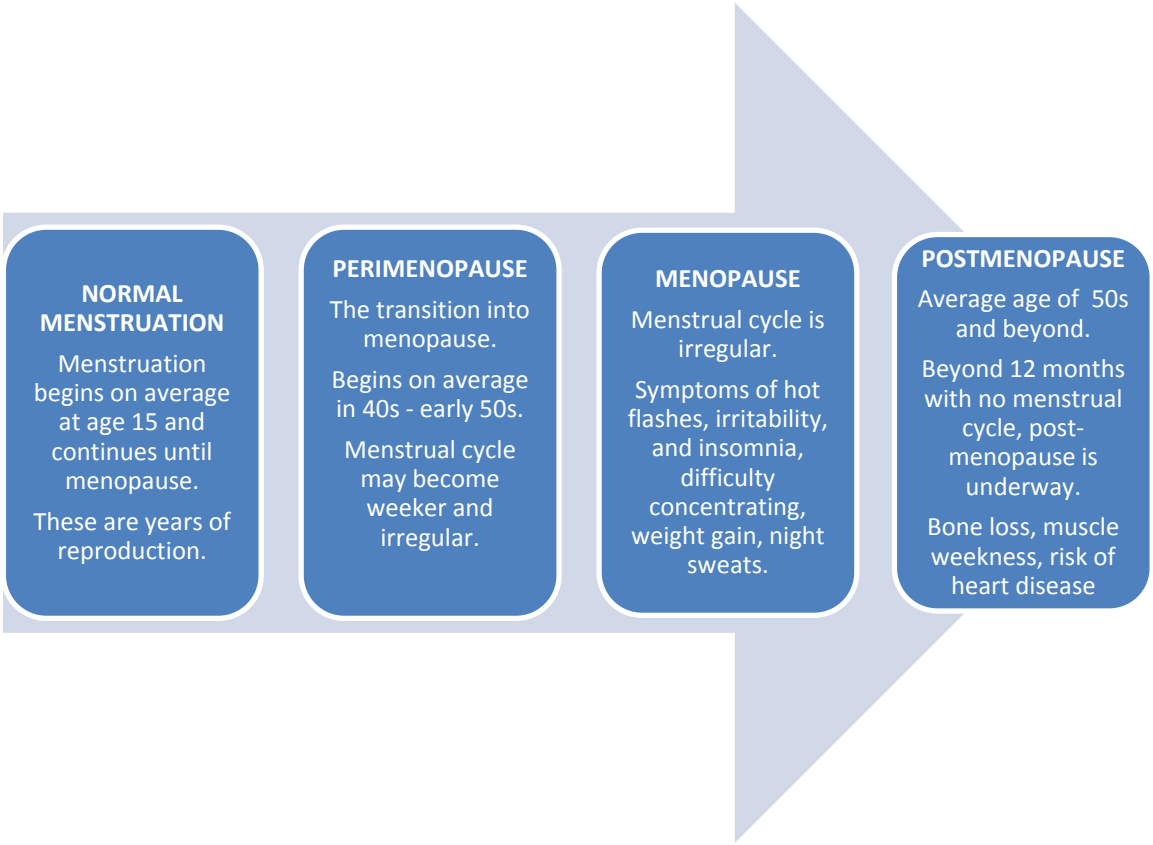
Have you ever adjusted your performance schedule based on your menstrual cycle?

Have you ever cancelled a performance due to your menstrual cycle?

Have you ever manipulated the timing of your menstrual cycle with OCPs to accommodate your performance schedule? If so, how many times?

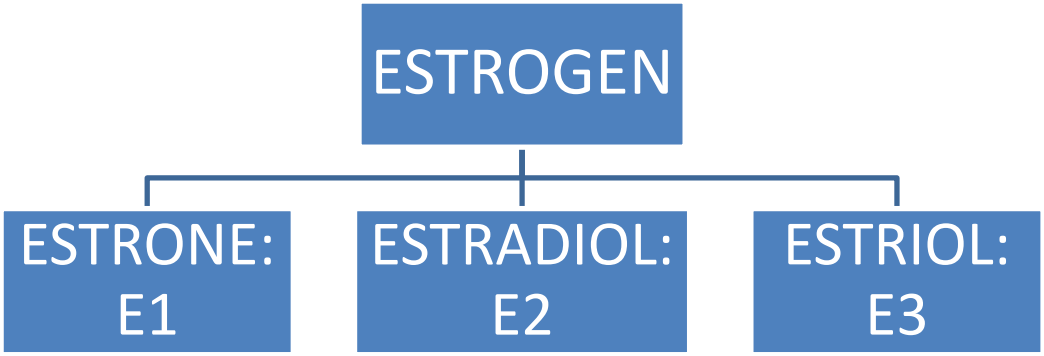
Appendix G

Normal Menopause Timeline



Appendix H

Estrogen Derivatives



ESTRONE: E1	ESTRADIOL: E2	ESTRIOL: E3
Predominant estrogen found in postmenopausal women	Primary estrogen essential for developing and maintaining the female reproductive system.	Most common type of estrogen found in non-pregnant women.

Appendix I

Questionnaire for Singers Regarding Use of HRT

Have you ever taken hormone replacement (HRT)? If so, when and for how long?

Did your physician initiate the suggestion to begin HRT?

Did you initiate the discussion of HRT with your physician?

Were you cautioned about long term use of HRT?

Were you ever informed that HRT could benefit your singing voice?

Did you notice a change in your singing voice while on HRT?

If there was a change in your singing voice, how soon did it occur once you began HRT?

Did taking HRT improve the overall quality of your singing voice? Describe.

Did taking HRT have a negative effect on the quality of your singing voice? Describe.

Was there a change in your voice when stopping use of HRT? Explain.

Was testosterone therapy ever suggested for treatment of menopause symptoms?

Were you cautioned about possible effects of testosterone on the voice?

During reproductive years, did you take OCPs?