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THE IMPACT OF HORMONAL FLUCTUATIONS ON VOICE ACROSS DIFFERENT GENDERS AND AGE GROUPS

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ABSTRACT

This literature review examines the effects of endocrine regulation on voice physiology, with a focus on the effects of testosterone, estrogen, progesterone, and thyroid hormones. Testosterone is responsible for the deepening of the male voice during puberty, while estrogen and progesterone influence the hydration and elasticity of the vocal folds in females, resulting in cyclic variations throughout the menstrual cycle. Abstract Hormonal fluctuations play a crucial role in shaping vocal characteristics across different genders and age groups. Hormonal decline occurs with aging; in men, a decrease in testosterone causes vocal weakness, while in postmenopausal women, a decrease in estrogen causes vocal fold atrophy and dryness. Voice modulation is greatly impacted by endocrine conditions such thyroid dysfunction, congenital adrenal hyperplasia (CAH), and polycystic ovarian syndrome (PCOS). While hypothyroidism causes hoarseness and vocal fatigue, excessive androgens in PCOS induce irreversible masculinization of the voice. The results of hormone therapy differ; for transgender men, testosterone effectively lowers pitch, but for transgender women, estrogen has no effect on feminization. Promising paths for researching hormone-speech interactions are provided by emerging technologies including high-resolution laryngeal imaging and AI-driven voice analysis. Research gaps still exist, nevertheless, especially in the areas of diverse population sampling and longitudinal investigations. Future research should concentrate on individualized voice management techniques, multidisciplinary cooperation between voice specialists and endocrinologists, and the best possible hormonal treatment for vocal health. The need for hormone-aware vocal care is emphasized in this review, especially for people undergoing medical or gender-affirming hormone therapy and those working in vocally demanding occupations. Research in this area will advance methods for diagnosing and treating hormone-related voice alterations.

KEYWORDS: *Hormones; Voice; Vocal Changes; Menstrual Cycle Effects; Hormonal fluctuations*

1. INTRODUCTION

The human voice is a dynamic and intricate feature that is impacted by a number of environmental and physiological factors. Among these, changes in hormones have a big impact on how people speak in different age and gender groups. Through hormones including estrogen, progesterone, testosterone, and thyroid hormones, the endocrine system controls many bodily processes, including the growth and operation of the vocal apparatus. Known as a hormone-sensitive organ, the larynx alters structurally and functionally in response to hormonal fluctuations, which can cause noticeable changes in voice stability, pitch, and quality. Vocal output is affected by distinct hormonal changes that occur during several life phases, including puberty, the menstrual cycle, pregnancy, menopause, and aging [1–3].

Hormonal activity causes changes in both male and female voices throughout life. One of the most significant changes occurs during puberty; in males, testosterone thickens the vocal cords, resulting in a deeper voice, whereas in girls, estrogen and progesterone control a milder vocal shift. The menstrual cycle, in which changes in estrogen and progesterone levels impact vocal fold moisture, flexibility, and vibratory patterns, causes women to continue experiencing cyclical voice variations. Pitch changes, increased phonatory effort, and vocal exhaustion can also result during pregnancy, which is marked by high hormone levels. Reduced pitch control, vocal tiredness, and hoarseness are some of the additional voice changes brought on by hormonal decline as people age, particularly the decrease in estrogen and testosterone [2–6].

Significant vocal changes can result from endocrine problems and hormonal imbalances in addition to physiological changes. Due to their effects on vocal fold anatomy and neuromuscular control, diseases like polycystic ovarian syndrome (PCOS), congenital

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adrenal hyperplasia (CAH), hypothyroidism, and hyperthyroidism have been connected to abnormalities in voice function. Voice deepening and even irreversible masculinization can result from androgen excess, as seen in PCOS and CAH. On the other side, vocal fatigue, breathiness, and weakness might result from thyroid malfunction. These results underline the importance of hormones for vocal health and the necessity to investigate the underlying processes governing hormone-voice interactions in greater detail [3,7]. For those in vocally demanding occupations like singers, actors, teachers, and public speakers, as well as for speech and voice experts, it is essential to comprehend how hormone changes affect voice. Because even slight changes in voice quality might have an impact on their work performance, professional voice users are especially vulnerable to hormone fluctuations. According to research, hormonal factors cause female singers, particularly those in operatic or classical music, to struggle with voice control and timbre. As a result, they require specific vocal training and management techniques. In order to maximize voice function and longevity, our findings highlight the significance of individualized approaches in vocal care, incorporating hormonal considerations into clinical and educational activities [5].

Using knowledge from previous studies, this review of the literature attempts to investigate how hormone changes affect voice in various age and gender categories. The physiological mechanisms behind hormone-voice interactions, gender-specific effects, age-related variations, and clinical implications of hormonal influences on voice will all be covered in the sections that follow. This review will offer a thorough grasp of how hormones influence vocal traits throughout life by combining the results of several studies.

2. HORMONAL MECHANISMS AFFECTING VOICE

2.1. Hormonal Influence on Vocal Fold Structure and Function

Being a hormone-sensitive organ, the larynx changes constantly throughout life in reaction to changes in hormone levels. The morphology, flexibility, and vibratory function of vocal fold tissues are all impacted by the interactions between sex hormones like estrogen, progesterone, and testosterone. Research has revealed that the vocal folds contain androgen, estrogen, and progesterone receptors, indicating that these hormones have a direct regulatory impact on voice production. For example, testosterone is essential for extending the larynx and thickening the vocal folds, which results in a deeper voice, especially in boys going through puberty [1,2]. On the other hand, estrogen maintains a higher pitch and smoother phonation in females by promoting the hydration and suppleness of the vocal folds [6].

One example of how hormonal changes affect vocal function is the menstrual cycle. Progesterone levels rise during the premenstrual phase, causing fluid retention and minor vocal fold edema, which can cause vocal stability and pitch to decrease. On the other hand, increased vocal fold flexibility and voice control are linked to the follicular phase, which is marked by increased estrogen levels [4]. The involvement of hormones in vocal physiology has been reinforced by the observation of this cyclic change in both objective acoustic investigations and subjective vocal judgments. Furthermore, depth, roughness, and an increase in fundamental frequency variability have been associated with androgen excess in diseases such as polycystic ovarian syndrome (PCOS). These results demonstrate the significant impact of hormonal processes on modulation of voice [3,8].

2.2. Endocrine Disorders and Their Impact on Voice

Vocal traits can be drastically changed by endocrine disorders, especially those involving thyroid and sex hormones. Changes in vocal pitch, stability, and endurance have been associated with menopausal and andropause-related hormonal imbalances, polycystic ovarian syndrome (PCOS), and congenital adrenal hyperplasia (CAH). Excess androgens cause the voice to become masculinized in PCOS and CAH, which is typified by a lower fundamental frequency and more harsh vocals [3,7]. People who work in vocally demanding occupations, such voice actors and vocalists, may find this effect especially upsetting. On the other hand, males who experience testosterone insufficiency, which is frequently observed in aging or endocrine illnesses, may have a weaker, higher-pitched voice as a result of decreased vocal fold mass [2,5].

Voice modulation is also significantly impacted by thyroid disorders. Due to fluid retention in the vocal folds, hypothyroidism, which is linked to decreased thyroid hormone levels, causes vocal fatigue, hoarseness, and a lower pitch. However, because hyperthyroidism increases neuromuscular activity, it might lead to greater voice strain and instability. These results underline the necessity of endocrine examination in patients with unexplained voice alterations, suggesting that maintaining hormonal balance is crucial for maintaining voice quality [1,3].

3. GENDER-SPECIFIC EFFECTS OF HORMONAL FLUCTUATIONS ON VOICE

3.1. Voice Changes in Males Due to Hormonal Variations

Thyroid and testosterone hormones are the main hormones that fluctuate in males, and both have a big impact on voice traits. The larynx grows, the vocal folds expand, and the pitch decreases by around an octave throughout puberty due to elevated testosterone levels [2]. The development of the deep masculine voice depends on this process. However, a weaker, higher-pitched voice with less vocal endurance is the result of older men's falling testosterone levels. Voice feminization and vocal tiredness have been associated with conditions such hypogonadism, which is characterized by inadequate testosterone production [3,6]. Male vocal

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modulation is significantly impacted by thyroid disease. While hyperthyroidism increases vocal tension and instability, hypothyroidism can result in vocal fold edema, which can produce a deeper and coarser voice. Furthermore, studies indicate that males with reduced testosterone levels have more jitter and shimmer, which are auditory indicators of unstable voices [1,3]. According to these results, thyroid and testosterone hormones are essential for preserving a steady and rich masculine voice throughout life [8].

Table 1: Gender-Specific Effects of Hormonal Fluctuations on Voice

Hormone	Effect in Males	Effect in Females
Testosterone	Deepens voice during puberty; maintains vocal strength in adulthood; declines with aging leading to vocal weakening [2]	Excess levels lower pitch (e.g., PCOS); deficiency leads to vocal instability [7]
Estrogen	Minimal direct impact on male voice [6]	Maintains vocal fold hydration and elasticity; fluctuations cause pitch variations [4]
Progesterone	No significant effect [1]	Can cause vocal fold edema and instability, especially premenstrually [4]
Thyroid Hormones	Hypothyroidism lowers pitch; hyperthyroidism increases vocal tension [3]	Hypothyroidism leads to vocal fatigue; hyperthyroidism may cause tremor in voice [3]

3.2. Voice Changes in Females Due to Hormonal Variations

The female voice is significantly impacted by hormonal changes, especially those involving estrogen, progesterone, and androgens. Throughout their reproductive years, females have recurrent vocal alterations that are primarily impacted by the menstrual cycle, pregnancy, and menopause, in contrast to males, whose voices stable after adolescence. Estrogen encourages the hydration and flexibility of the vocal folds during the menstrual cycle, which improves the follicular phase voice quality. However, fluid retention results in minor vocal fold edema as progesterone rises in the luteal phase, which lowers the pitch and decreases voice stability. For professional voice users like vocalists, who report phonation issues during the premenstrual phase, these cyclical voice alterations are especially important [4,5].

Voice masculinization, which results in a deeper pitch and rougher vocal quality, can be caused by excess androgens in disorders such as congenital adrenal hyperplasia (CAH) or polycystic ovarian syndrome (PCOS). As demonstrated by instances of hormone therapy with androgenic effects, this is frequently irreversible if extended exposure to androgens takes place [7,3]. Vocal tiredness and hoarseness are also caused by the substantial drop in estrogen that occurs after menopause, which results in weakening of the vocal folds, dryness, and higher effort during phonation. These results emphasize the necessity of managing vocal health in people with hormonal changes, especially those who work in voice-dependent occupations [6].

4. AGE-RELATED HORMONAL CHANGES AND THEIR IMPACT ON VOICE

4.1. Vocal Changes During Puberty

One of the most important changes in voice growth occurs throughout puberty, which is mostly caused by variations in sex hormone levels. The increase in testosterone causes the larynx to enlarge, the vocal folds to thicken, and the pitch to significantly drop, frequently by an octave, in males. This quick transition, which happens between the ages of 12 and 16, is accompanied with transient vocal instability, such as diminished phonatory control and pitch breakdowns. Studies have revealed that testosterone modulates vocal fold mass, improving the depth and resonance of the male voice [1,2].

On the other hand, females undergo more subtle changes during puberty. Progesterone and estrogen control the development of vocal folds, preserving vocal hydration and flexibility [4]. Although pitch is relatively constant, slight changes in voice timbre and phonation are noted as hormonal levels change, and studies have also indicated that exposure to androgen in adolescent females may result in mild vocal deepening, especially in cases of hyperandrogenism. These findings underscore the crucial role of puberty in determining the course of vocal maturation for the rest of one's life [3,6].

Table 2: Age-Related Hormonal Changes and Their Effects on Voice

Life Stage	Hormonal Influence	Effect on Male Voice	Effect on Female Voice
Puberty	Testosterone surge	Deepens by an octave, temporary instability [2]	Minor pitch change, increased vocal flexibility [4]
Reproductive Years	Estrogen & progesterone fluctuations	Stable pitch, minimal changes [6]	Cyclical voice changes due to menstrual cycle [4]
Menopause/Andropause	Declining estrogen/testosterone	Weaker voice, reduced pitch control [6]	Vocal fold thinning, dryness, hoarseness [6]

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4.2. Vocal Aging and Hormonal Changes in the Elderly

Male and female voices are affected differently by the major hormonal changes that come with aging. Men's vocal fold bulk and suppleness decrease as a result of andropause, a progressive drop in testosterone levels. A higher pitch, less vocal endurance, and a general deterioration in phonation are the outcomes of this. Voice tremors and a loss of control over pitch modulation are also caused by the anabolic effects of testosterone on the laryngeal muscles [2,6]. Vocal fold atrophy, mucosal layer thinning, and increased dryness are all brought on by the dramatic drop in estrogen and progesterone in postmenopausal women, which results in hoarseness and a diminished vocal range. These structural changes have been shown to cause a slight deepening of the voice in postmenopausal women [4,6]. Vocal stability and endurance may also be further impacted by poor neuromuscular control brought on by estrogen deficiency. According to research on professional singers, menopausal vocal alterations can have a major effect on performance and necessitate the use of particular vocal training methods to make up for the loss of vocal flexibility [3, 5]. Individualized vocal care is crucial in controlling age-related voice changes because both men and women experience a reduction in vocal quality as they age, but the underlying hormonal pathways are different.

5. CLINICAL IMPLICATIONS OF HORMONAL EFFECTS ON VOICE

5.1. Hormonal Disorders and Voice Pathology

Pitch and vocal stability are two aspects of voice disorders that are greatly impacted by hormonal abnormalities. Androgen excess is associated with disorders including polycystic ovarian syndrome (PCOS) and congenital adrenal hyperplasia (CAH), which cause the vocal folds to enlarge and cause irreversible deepening of the female voice. According to clinical research, women with PCOS have rougher vocal quality and a lower fundamental frequency than people in good health [3,7].

Voice pathology is also significantly influenced by thyroid dysfunctions. While hyperthyroidism can result in increased neuromuscular activity, which can induce vocal tremors and instability, hypothyroidism causes vocal fold edema, which results in a harsh, lower-pitched voice. The influence of thyroid hormones on voice modulation was further supported by a study that examined the vocal patterns of individuals with thyroid problems and discovered notable changes in jitter and shimmer values [1,3].

Additional hazards for vocal issues are introduced by menopause and andropause. Vocal fold atrophy and dryness are caused by the postmenopausal decrease in estrogen, which raises the risk of vocal fatigue and decreased phonatory effectiveness. A weaker voice with less projection is another effect of testosterone reduction in older males. These results emphasize how important it is to include hormone evaluations in the diagnosis of voice disorders [6,2].

5.2. Hormone Therapy and Voice Outcomes

For people undergoing gender-affirming therapy, menopausal women, and those with endocrine diseases, hormone therapy is especially important in treating vocal alterations brought on by hormonal swings. In transgender men, testosterone therapy causes vocal fold thickening and laryngeal expansion, which results in a deeper voice. Research shows that although the majority of transgender males attain a sufficient pitch drop after the first year of treatment, some may suffer from strain or instability in their voices as a result of the vocal mechanism's poor adaptation [1]. On the other hand, because estrogen does not decrease vocal fold bulk, transgender women undergoing estrogen therapy do not automatically experience voice feminization. Speech therapy and voice training are therefore crucial elements of gender-affirming care [2]. Estrogen-based hormone replacement treatment (HRT) has been investigated as a possible strategy for maintaining vocal quality in menopausal women. According to research, HRT may improve hydration and lessen vocal fold atrophy, which would improve phonatory efficiency and lessen the impacts of estrogen decline. Nevertheless, results are still unclear, with some research indicating negligible advantages [4,6]. Similar to this, testosterone supplementation has been linked to increased vocal strength in older men; however, further research is needed to determine the long-term impact on vocal health [2].

6. FUTURE RESEARCH DIRECTIONS AND CLINICAL RECOMMENDATIONS

Even though our understanding of how hormone changes affect voice has advanced significantly, there are still a number of areas that need more research. The absence of longitudinal studies evaluating long-term hormonal influences on voice across various life stages is one of the most important gaps. There is little information on how these changes develop over decades, with the majority of research concentrating on short-term impacts, such as changes in voice or menstrual cycle irregularities within the first year of hormone therapy [1]. Examining the cumulative effects of hormone exposure may provide further information about endocrine-related voice problems and vocal aging.

The need for more inclusive and varied research populations is another urgent concern. The majority of current research is restricted to Western populations, frequently ignoring the possible impact of lifestyle, environmental, and genetic factors on hormone-voice interactions [4]. The findings might be more broadly applicable if study were expanded to encompass additional ethnic groups and geographical areas. Furthermore, more work has to be done on transgender voice research, especially in relation to customized reactions to hormone therapy. Although testosterone treatment successfully lowers pitch in transgender men, little is known about

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the precise neuromuscular changes that occur [2]. Similarly, the lack of estrogenic effects on transgender women's vocal fold mass points to different routes influencing voice feminization that need more research [1].

Interdisciplinary cooperation between otolaryngologists, speech therapists, and endocrinologists is becoming more and more necessary in clinical settings to maximize voice treatment. The evaluation of unexplained voice alterations, especially in professional voice users, should incorporate hormonal testing. Individuals may find it easier to adjust to long-term endocrine changes and cyclical voice variations with personalized voice therapy that is adapted to hormonal swings. Additionally, there is still disagreement on the effectiveness of hormone replacement therapy (HRT) in maintaining voice function after menopause and andropause, which calls for more controlled research to be conducted [4,6].

7. RESULTS

The examination of the body of research demonstrates how important hormonal changes are in determining the traits of voices in various age and gender groups. Male vocal development has been found to be significantly influenced by testosterone, which causes laryngeal growth and pitch deepening during puberty. On the other hand, female vocal fold elasticity is regulated by estrogen and progesterone, which results in cyclical voice alterations linked to the menstrual cycle. While aging males gradually lose their vocal strength due to a decrease in testosterone, postmenopausal women have dryness and shrinkage of the vocal folds as a result of estrogen depletion. Clinical research also shows that voice modulation is significantly impacted by endocrine conditions such PCOS, CAH, and thyroid dysfunction. While hypothyroidism causes hoarseness and vocal tiredness, excessive androgens in PCOS cause vocal masculinization. Hormone therapy has varying effects on voice quality; transgender men who receive testosterone therapy are able to lower their pitch, while transgender women who receive estrogen therapy do not feminize their voices and require further voice training. Cutting-edge research techniques, such as laryngeal imaging and AI-driven speech analysis, hold promise for improving our knowledge of hormone-voice interactions. To completely understand these mechanisms, however, larger longitudinal studies and a wider range of population samples are required.

8. DISCUSSION

The results confirm that voice is a biological indicator of hormone condition and highlight the complex link between endocrine regulation and vocal function. Male vocal depth and resonance are maintained by testosterone's stabilizing action, whereas vocal projection becomes weaker as testosterone levels fall with age. On the other hand, because of changes in estrogen and progesterone, females have more frequent and noticeable voice fluctuations that impact vocal fatigue and pitch stability. These results are consistent with earlier studies on menopausal vocal degradation and premenstrual voice condition. One significant therapeutic implication is the need for vocal control techniques that take hormones into account. Given the variation in hormone therapy results, individualized treatment regimens must to incorporate both pharmaceutical and non-pharmacological approaches. For people impacted by hormone-driven vocal changes, hydration techniques, speech therapy customized to hormonal cycles, and interdisciplinary treatment involving endocrinologists and voice specialists are essential. Furthermore, the absence of established techniques is still a problem even though AI-based vocal analysis offers great potential for the early detection of endocrine-related voice disorders. Future studies should concentrate on combining clinical voice evaluations with machine learning algorithms to improve therapy personalization and diagnostic precision.

9. CONCLUSION

This review of the research shows that changes in hormones have a major effect on voice physiology throughout life, affecting vocal endurance, pitch, and stability. Male voices are primarily deepened by testosterone, but female vocal function is modulated by estrogen and progesterone, resulting in cyclic changes. Voice abnormalities are caused by hormonal imbalances in diseases including PCOS, hypothyroidism, and menopause, underscoring the need for diagnostic and treatment strategies that take hormones into account. Technological developments such as high-resolution imaging and AI-driven voice analysis present exciting opportunities for more study and therapeutic use. There are still gaps in varied population studies and longitudinal data, nevertheless. Future studies should focus on improving hormone-based voice control techniques and growing interdisciplinary partnerships in otolaryngology, speech therapy, and endocrinology. Healthcare practitioners can create more potent interventions for people undergoing hormone-related voice changes by tackling these clinical and research issues, which will eventually enhance vocal health and quality of life.

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