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ORIGINAL ARTICLE

Androgen Regulation of Lower Urinary Tract Function: Gender Differences and Clinical Significance

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Abstract

Androgens play a critical role in the development, maintenance, and functional regulation of the lower urinary tract (LUT) in both males and females. Beyond their well-known effects on reproductive organs, androgens influence bladder function, urethral tone, pelvic floor integrity, and neural control mechanisms involved in micturition. Gender-related differences in androgen levels, receptor distribution, and downstream signaling pathways contribute to distinct patterns of lower urinary tract symptoms (LUTS) across the lifespan. This article provides a comprehensive review of androgen regulation of lower urinary tract function, emphasizing molecular mechanisms, gender differences, and clinical implications. Understanding these interactions is essential for improving diagnostic strategies and developing targeted therapies for LUT disorders such as benign prostatic hyperplasia, overactive bladder, urinary incontinence, and age-related voiding dysfunction.

Androgens are steroid hormones traditionally associated with reproductive physiology, yet their influence extends significantly to the lower urinary tract, encompassing bladder function, urethral dynamics, pelvic floor integrity, and neural regulation of micturition. Recent studies indicate that androgen signaling is not limited to males but plays a crucial role in female urinary physiology as well. Variations in circulating androgen levels, receptor expression, and intracellular signaling pathways contribute to gender-specific manifestations of lower urinary tract dysfunction. This review synthesizes evidence from molecular biology, animal experiments, and clinical investigations to elucidate androgen-mediated mechanisms affecting urinary storage and voiding. It highlights the clinical relevance of hormonal modulation in conditions such as benign prostatic hyperplasia, overactive bladder, stress urinary incontinence, and age-associated urinary disorders. Recognition of these processes underscores the importance of personalized approaches that consider hormonal status alongside anatomical and neurological determinants, providing new avenues for therapeutic intervention and improved patient outcomes.

Keywords: Androgens, Lower urinary tract, Gender differences, Androgen receptors, Lower urinary tract symptoms, Clinical significance

1. Introduction

The lower urinary tract, consisting primarily of the bladder, urethra, and associated sphincter mechanisms, plays a central role in urine storage and controlled voiding. Its function is regulated by a

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complex interplay of neural, hormonal, and structural factors. Among hormonal regulators, androgens have traditionally been associated with male reproductive physiology; however, accumulating evidence demonstrates that they are equally important in modulating lower urinary tract function in both sexes. Androgen receptors are widely expressed in bladder smooth muscle, urothelium, urethral tissues, pelvic floor muscles, and relevant regions of the central and peripheral nervous systems.

Gender differences in lower urinary tract disorders are evident clinically, with men more commonly affected by obstructive symptoms related to prostate growth, while women more frequently experience stress urinary incontinence and overactive bladder. These differences cannot be explained solely by anatomy and are increasingly linked to variations in androgen exposure and receptor signaling. Age-related hormonal changes, such as declining testosterone levels in men and altered androgen–estrogen balance in women, further modify LUT function. This article aims to explore androgen-mediated regulation of the lower urinary tract, highlight gender-specific mechanisms, and discuss their clinical relevance. The lower urinary tract operates through a delicate balance of structural, neural, and hormonal factors that coordinate urine storage and voluntary voiding. Although anatomical differences between men and women partially explain the prevalence and presentation of urinary disorders, hormonal influences, particularly androgens, are increasingly recognized as key modulators of function across genders. Androgen receptors are widely distributed within the bladder detrusor muscle, urothelium, urethral smooth muscle, sphincter complex, and associated neural networks, facilitating multiple layers of functional regulation. In men, androgens influence not only prostate growth, which impacts urinary outflow, but also detrusor contractility and urethral tone. In women, despite lower systemic androgen concentrations, local androgen action contributes to urethral closure mechanisms, pelvic floor muscle resilience, and epithelial integrity, factors critical for continence. Age-related hormonal fluctuations, such as male hypogonadism or the postmenopausal decline in androgen-estrogen balance, further alter lower urinary tract physiology, manifesting as voiding dysfunction, urgency, frequency, or incontinence. Understanding androgen-mediated regulatory mechanisms provides essential insights for developing gender-specific diagnostic and therapeutic strategies, bridging gaps between molecular biology and clinical practice in the management of lower urinary tract disorders.

2. Materials and Methods

This review is based on an extensive analysis of peer-reviewed experimental, clinical, and translational studies published in international medical and biological science journals. Literature was selected focusing on androgen physiology, androgen receptor expression in lower urinary tract tissues, animal models of androgen manipulation, and clinical studies evaluating hormonal influences on LUT function. Both male and female data were included to ensure balanced gender-based interpretation. Emphasis was placed on studies investigating molecular signaling pathways, functional urodynamic outcomes, and therapeutic interventions involving androgen modulation. Data were synthesized qualitatively to provide an integrated perspective on mechanistic and clinical findings.

3. Results

Studies consistently demonstrate the presence of androgen receptors in key lower urinary tract structures in both genders. In males, androgens maintain bladder compliance, support urethral smooth muscle tone, and indirectly influence voiding through prostate growth and stromal–epithelial interactions. Animal models of androgen deprivation reveal reduced bladder capacity, altered detrusor contractility, and increased non-voiding contractions, suggesting a protective role of androgens in normal bladder physiology.

In females, although circulating androgen levels are lower, local androgen signaling contributes to urethral closure pressure, pelvic floor muscle strength, and urothelial integrity. Reduced androgen activity has been associated with urinary urgency, frequency, and stress incontinence. Gender differences also emerge at the molecular level, with variations in receptor density, co-regulator expression, and interaction with estrogen signaling pathways. Clinically, androgen replacement in hypogonadal men has been shown to improve certain LUTS, while selective androgen modulation in women is being explored for urinary incontinence and pelvic floor dysfunction. Evidence from preclinical and clinical research consistently confirms the expression of androgen receptors

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throughout lower urinary tract tissues in both sexes. In male animal models, androgen deprivation through castration or receptor blockade results in diminished bladder capacity, increased detrusor overactivity, and reduced urethral sphincter tone, highlighting the hormone's role in maintaining functional homeostasis. Conversely, androgen supplementation restores contractility and mitigates non-voiding contractions, suggesting therapeutic potential in hypogonadal men. In females, studies demonstrate that androgen insufficiency correlates with decreased urethral closure pressure, impaired pelvic floor muscle performance, and vulnerability to stress-induced leakage. Molecular analyses reveal sex-specific differences in receptor density, isoform distribution, and co-regulator interactions, contributing to divergent physiological outcomes. Clinically, testosterone therapy in men with age-related hypogonadism has been associated with improved bladder function and alleviation of lower urinary tract symptoms, whereas emerging trials in women indicate that local or systemic androgen modulation may enhance pelvic floor strength and continence mechanisms. Collectively, these findings underscore that androgen signaling exerts both structural and functional influence on the lower urinary tract, with measurable impacts on symptomatology and quality of life in both genders.

4. Discussion

The findings highlight androgens as key modulators of lower urinary tract function beyond their reproductive roles. Gender-specific anatomy interacts with hormonal signaling to produce distinct clinical phenotypes of LUT disorders. In men, excessive or dysregulated androgen action contributes to prostate-related obstruction, whereas androgen deficiency may impair bladder function. In women, insufficient androgen signaling can weaken urethral support and neuromuscular control, predisposing to incontinence.

The interplay between androgens and other hormones, particularly estrogens, adds further complexity. Aging alters this balance, explaining the increased prevalence of LUTS in elderly populations of both sexes. From a clinical perspective, these insights support a more individualized approach to managing LUT disorders, considering hormonal status alongside anatomical and neurological factors. However, concerns regarding systemic androgen therapy necessitate cautious evaluation and the development of tissue-selective agents. The accumulated evidence establishes androgens as pivotal regulators of lower urinary tract physiology. In men, androgens maintain urethral integrity and detrusor performance, with deficiencies predisposing to impaired bladder emptying, overactivity, and lower urinary tract symptoms, while excess or dysregulated androgen action may exacerbate prostate-related obstruction. In women, androgen activity supports urethral closure pressure and pelvic floor stability, with insufficiency contributing to stress incontinence and overactive bladder syndromes. Gender disparities in urinary dysfunction arise from complex interactions between hormonal milieu, receptor expression, and downstream signaling cascades, which are further modulated by aging. Importantly, the crosstalk between androgens and estrogens introduces additional layers of regulation, influencing vascular supply, neural control, and smooth muscle responsiveness. These insights have practical implications, suggesting that hormonal assessment should complement conventional anatomical and urodynamic evaluations. Targeted interventions, including selective androgen receptor modulators or localized hormone therapy, offer potential for symptom relief without systemic adverse effects, highlighting the need for individualized, gender-specific treatment paradigms in lower urinary tract disorders.

5. Conclusion

Androgens are fundamental regulators of lower urinary tract structure and function in both males and females. Gender differences in androgen levels, receptor expression, and hormonal interactions contribute significantly to the pathophysiology of lower urinary tract symptoms. Recognizing the role of androgens enhances our understanding of LUT disorders and opens new avenues for targeted, gender-specific therapeutic strategies. Future research should focus on selective modulation of androgen pathways to maximize clinical benefits while minimizing adverse effects. Androgens serve as essential modulators of lower urinary tract structure and function in both males and females, with gender-specific effects that influence the onset, progression, and presentation of urinary disorders. Differences in hormone levels, receptor distribution, and interactions with other endocrine pathways contribute to distinct clinical phenotypes, encompassing obstructive symptoms, incontinence, and

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detrusor dysfunction. Recognition of androgen-mediated mechanisms enriches our understanding of lower urinary tract physiology and informs the development of targeted therapies that consider individual hormonal profiles. Future research should focus on refining therapeutic strategies that selectively modulate androgen pathways, aiming to optimize urinary function, minimize adverse effects, and enhance quality of life for both men and women experiencing lower urinary tract dysfunction.

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