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BIOCHEMICAL ROLE OF HORMONES IN THE REGULATION OF HUMAN METABOLISM

Shodmonov Usmon Bohodir ugli
Assistant
CAMU International Medical University

https://orcid.org/0000-0003-2247-4672

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Abstract: Hormones are biologically active signaling molecules that regulate numerous physiological and biochemical processes in living organisms. They play a critical role in maintaining homeostasis, coordinating metabolic pathways, and controlling growth, development, reproduction, and adaptation to environmental changes. This review aims to analyze the biochemical functions of hormones and their involvement in the regulation of carbohydrate, lipid, and protein metabolism. The study is based on a comprehensive review of contemporary scientific literature. The findings demonstrate that hormonal regulation is essential for metabolic balance and that disturbances in hormone synthesis, secretion, or receptor function may lead to various endocrine and metabolic disorders.

Keywords: hormones, biochemistry, metabolism, insulin, glucagon, thyroid hormones, cortisol, endocrine regulation.

Introduction

Hormones are chemical messengers synthesized and secreted by endocrine glands and specialized tissues. They exert their effects by binding to specific receptors located on target cells, initiating intracellular signaling pathways that regulate gene expression and enzymatic activity. Hormonal regulation is fundamental to the maintenance of physiological homeostasis and adaptation to changing environmental and internal conditions.

The endocrine system interacts closely with the nervous and immune systems, forming an integrated regulatory network that controls cellular metabolism and organ function. Recent advances in molecular endocrinology have revealed complex biochemical mechanisms through which hormones influence metabolic processes and disease development. Understanding these mechanisms is essential for improving the diagnosis and treatment of endocrine disorders.

The objective of this study was to review and analyze the biochemical role of hormones in metabolic regulation.

Materials and Methods

This study employed a narrative literature review approach. Scientific articles, textbooks, review papers, and international guidelines published in the fields of biochemistry, endocrinology, physiology, and molecular biology were analyzed. Relevant sources were

selected based on their scientific relevance, methodological rigor, and contribution to understanding hormonal regulation of metabolism.

Results and Discussion

Hormones are essential biochemical regulators that coordinate metabolic activities and maintain physiological homeostasis throughout the body. Based on their chemical structure and mechanism of action, hormones are generally classified into three major categories: peptide and protein hormones, steroid hormones, and amino acid-derived hormones. Peptide hormones such as insulin, glucagon, and growth hormone consist of amino acid chains and typically exert their effects through membrane-bound receptors. Steroid hormones, including cortisol, aldosterone, estrogen, and testosterone, are lipid-soluble molecules synthesized from cholesterol and act primarily through intracellular receptors that regulate gene transcription. Amino acid-derived hormones such as thyroxine (T4), triiodothyronine (T3), epinephrine, and norepinephrine are synthesized from tyrosine and display unique biochemical properties depending on their structure and target tissues.

Among all metabolic hormones, insulin plays a central role in maintaining glucose homeostasis. Produced by the β-cells of the pancreatic islets, insulin functions as the primary anabolic hormone of the human body. Following food intake, elevated blood glucose levels stimulate insulin secretion, which promotes glucose uptake into skeletal muscle and adipose tissues through the translocation of GLUT4 transporters to the plasma membrane. In addition to enhancing cellular glucose utilization, insulin stimulates glycogen synthesis in the liver and skeletal muscles, promotes protein synthesis by increasing amino acid uptake, and inhibits the breakdown of lipids in adipose tissue. At the molecular level, insulin activates the phosphoinositide 3-kinase (PI3K)/Akt signaling pathway, which regulates multiple metabolic processes including glycogen formation, protein synthesis, and cell survival. Defects in insulin secretion, receptor sensitivity, or intracellular signaling pathways are major contributors to the development of diabetes mellitus, one of the most prevalent metabolic disorders worldwide.

In contrast to insulin, glucagon functions as a catabolic hormone responsible for maintaining blood glucose levels during fasting and energy deficiency. Synthesized by the α-cells of the pancreas, glucagon stimulates glycogenolysis and gluconeogenesis in hepatocytes, leading to increased glucose release into the bloodstream. This mechanism ensures a continuous supply of glucose to vital organs, particularly the brain, during periods of nutrient deprivation. Glucagon exerts its biological effects through G-protein-coupled receptors that activate adenylate cyclase, resulting in elevated intracellular cyclic adenosine monophosphate (cAMP) concentrations. The increase in cAMP subsequently activates protein kinase A (PKA), initiating a cascade of enzymatic reactions that promote glucose production and mobilization of energy reserves. The physiological balance between insulin and glucagon is therefore crucial for maintaining metabolic stability and preventing disorders associated with abnormal glucose regulation.

Thyroid hormones, particularly thyroxine (T4) and triiodothyronine (T3), represent another critical group of metabolic regulators. These hormones are synthesized by the thyroid gland and influence virtually every tissue in the human body. Their primary biochemical function involves the regulation of basal metabolic rate through stimulation of mitochondrial oxidative phosphorylation and increased oxygen consumption. Thyroid hormones enhance the expression of genes involved in energy production, thereby increasing ATP synthesis and overall metabolic

activity. Furthermore, they regulate carbohydrate metabolism by stimulating glucose absorption and utilization, influence lipid metabolism by enhancing lipolysis and cholesterol turnover, and affect protein metabolism through modulation of protein synthesis and degradation. During childhood and adolescence, thyroid hormones are indispensable for normal growth and neurological development. Deficiency of thyroid hormones leads to hypothyroidism, characterized by reduced metabolic activity, weight gain, fatigue, and cognitive impairment, whereas excessive secretion results in hyperthyroidism, which manifests as increased metabolic rate, weight loss, tachycardia, and nervous system hyperactivity.

Cortisol, the principal glucocorticoid hormone synthesized in the adrenal cortex, plays a fundamental role in stress adaptation and energy metabolism. Under conditions of physical or psychological stress, cortisol secretion increases significantly through activation of the hypothalamic-pituitary-adrenal (HPA) axis. Biochemically, cortisol stimulates gluconeogenesis in the liver, promotes protein catabolism in skeletal muscle, and enhances lipolysis in adipose tissue. These metabolic effects ensure the availability of energy substrates necessary for survival during stress conditions. In addition to its metabolic functions, cortisol exerts potent anti-inflammatory and immunosuppressive effects through regulation of gene expression. While acute cortisol release is beneficial for adaptation and homeostasis, chronic elevation of cortisol levels may have detrimental consequences, including insulin resistance, visceral obesity, hypertension, immune dysfunction, and increased risk of cardiovascular disease. These observations highlight the importance of maintaining hormonal balance for long-term metabolic health.

Growth hormone (GH), secreted by the anterior pituitary gland, also plays a significant role in metabolic regulation. The hormone stimulates tissue growth and cellular proliferation through both direct actions and indirect mechanisms involving insulin-like growth factor-1 (IGF-1). Growth hormone enhances protein synthesis, increases amino acid transport into cells, and promotes nitrogen retention, thereby supporting muscle development and tissue repair. Simultaneously, GH stimulates lipolysis, increasing the availability of free fatty acids as an energy source and reducing dependence on glucose metabolism. This glucose-sparing effect contributes to the maintenance of blood glucose concentrations during fasting conditions. Although growth hormone is most active during childhood and adolescence, it continues to influence body composition, energy metabolism, and tissue maintenance throughout adult life.

The biological activity of hormones depends largely on their signaling mechanisms. Hormonal communication occurs through highly sophisticated intracellular pathways that allow cells to respond rapidly and specifically to hormonal stimuli. Peptide hormones typically bind to membrane receptors and activate second messenger systems involving cyclic AMP (cAMP), inositol triphosphate (IP3), diacylglycerol (DAG), and calcium ions. These signaling molecules amplify hormonal signals and regulate enzyme activity, gene expression, and cellular metabolism. In contrast, steroid and thyroid hormones readily diffuse through cellular membranes and bind to intracellular receptors located in the cytoplasm or nucleus. The resulting hormone-receptor complexes function as transcription factors that directly regulate gene expression. Such mechanisms enable long-term regulation of cellular growth, differentiation, and metabolic adaptation.

The analysis of hormonal biochemical functions demonstrates that endocrine regulation is essential for maintaining metabolic homeostasis and physiological integrity. Disturbances in

hormone production, secretion, receptor function, or intracellular signaling pathways contribute to the development of numerous pathological conditions, including diabetes mellitus, obesity, metabolic syndrome, thyroid disorders, adrenal insufficiency, and growth abnormalities. Advances in molecular endocrinology have significantly improved our understanding of hormone-mediated biochemical processes and have facilitated the development of targeted therapeutic strategies for endocrine diseases.

Overall, the findings indicate that hormones act as central biochemical regulators integrating metabolic, physiological, and adaptive responses. Their coordinated action ensures efficient utilization of nutrients, maintenance of energy balance, regulation of growth and development, and adaptation to environmental challenges. Consequently, understanding the biochemical role of hormones remains fundamental for both basic biomedical research and clinical practice.

dation for developing targeted therapeutic interventions and precision medicine approaches.

Conclusion

Hormones play a central biochemical role in regulating metabolism, maintaining homeostasis, and coordinating physiological functions. Through complex signaling pathways, hormones control carbohydrate, lipid, and protein metabolism, enabling organisms to adapt to changing internal and external environments. Advances in molecular endocrinology continue to reveal the intricate mechanisms underlying hormonal action and their relevance to human health and disease. Further research is necessary to improve understanding of hormone-mediated metabolic regulation and its clinical applications.

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