Aerobic vs Resistance Exercise—An Endocrine Perspective

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ABSTRACT

Exercise elicits a wide variety of hormonal responses critical for metabolism and consequent tissue growth and development. It is imperative to understand that when we exercise there are acute endocrine responses and subsequent chronic endocrine conditioning. The acute response depends upon the frequency, intensity, and duration of physical exercise. Chronic endocrine conditioning is attained after a long duration of exercises and the magnitude of this conditioning is dependent on persistence, duration, attainment of neuroendocrine responses, and skeletal muscle response which releases myokines. There is ample amount of evidence now to believe muscle as an endocrine organ. Exercise activates various molecular mechanisms in the muscle which alters various endocrine and metabolic milieu inside the muscle. This review aims to provide evidence-based narration of peculiar anabolic and catabolic hormonal responses to exercise and revisit the mechanistic explanation of this occurrence. This review has analyzed the differential endocrine adaptation in aerobic and anaerobic exercises.

Keywords: Aerobic exercise, Exercise endocrinology, Exercise prescription, Overtraining, Resistive exercise.

INTRODUCTION

The physiological and psychological advantages of regular exercise are well known for ages. Exercise elicits a wide variety of hormonal responses critical for metabolism and consequent tissue growth and development. The acute hormonal response is dependent on frequency, intensity, and duration while long-term changes in the endocrine system are a function of persistence, duration, and development of neuroendocrine responses. These neuroendocrine responses change receptor content and binding proteins which in turn alters various endocrine and metabolic responses.¹ There is ample amount of evidence now to believe muscle as an endocrine organ. Exercise activates various molecular mechanisms in the muscle which alters various endocrine and metabolic milieu inside muscle.² This review aims to provide evidence-based narration of peculiar anabolic and catabolic hormonal responses to exercise and revisit the mechanistic explanation of this occurrence. The review was prepared after searching online databases such as PubMed and Google Scholar. Keywords used for the search were exercise and endocrine, exercise and molecular changes, aerobic and resistive exercises, and sports endocrinology. This review has analyzed the differential endocrine adaptation in aerobic and anaerobic exercises (Flowchart 1).³,⁴

DEFINITION OF EXERCISE

Physical activity is defined as any body movement produced by skeletal muscles that result in energy expenditure beyond resting expenditure while exercise is defined as physical activity that is planned, structured, repetitive, and purposeful and is usually aimed at improving or maintaining physical fitness. The exercise can be isotonic or isometric, either of which can be performed aerobically or anaerobically based on usage of energy, intensity, duration, repetition, and frequency.⁵

Aerobic exercise involves repetitive and continuous movements of large muscles (legs, shoulders, chest, and arms) using oxygen as a means of energy, is critical to losing fat and enhancing cardiovascular and respiratory fitness, and involve activities like walking, running, swimming, cycling. The resistive exercises involve short but high-intensity bursts of physical activity independent of oxygen. Resistive exercises involve activities like weight lifting and it increases the number of insulin receptors and its insulin sensitivity. It also improves muscle endurance and strength, increasing lean muscle mass and metabolic rate.⁶ Table 1 summarizes various endocrine adaptations in aerobic and anaerobic exercises.⁷

HORMONES IN EXERCISE

Exercise regulates cellular metabolism by inducing secretory activity of certain hormones [e.g., adrenocorticotropic hormone (ACTH), cortisol], facilitating the cardiovascular response, hormone transport across cell membranes (e.g., insulin). Exercise also stimulates energy production pathways and mobilize energy substrates. Hormones are intimately involved with protein synthesis and degradation mechanisms that are part of muscle adaptations to resistance exercise.⁷,⁸

The other functions of hormones during exercise are the regulation of blood plasma and glucose and fat metabolism. The blood plasma volume is maintained by renin, angiotensin, and aldosterone axis and antidiuretic hormone which help in maintaining blood supply to active tissue. These adaptations ensure increased oxygen-carrying capacity and replenish water for the production of sweat. The blood glucose during exercise

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Exercise, Insulin, and Diabetes

Insulin is a potent anabolic hormone and its serum concentration parallels changes in blood glucose and depends on the ingestion of nutrients before and during exercise. Exercise alters the blood glucose homeostasis depending on the type, intensity, and duration of exercise and the pre-exercise blood glucose levels. Persistent aerobic exercise increases the risk of hypoglycemia during and post-exercise while resistive exercise increases the blood glucose level initially due to the release of counter-regulatory hormones followed by hypoglycemia as their levels decrease. However, both types of exercise improve insulin sensitivity and lower blood glucose. This has an important clinical role in preventive and curative strategies in metabolic syndrome and type II diabetes. The fasting plasma
glucose is more significantly affected by resistance training than aerobic exercise while postprandial hyperglycemia, a marker of decreased endothelial function, increased oxidative stress, and inflammation is improved by the combined training group. However, both aerobic and resistance training can increase insulin sensitivity, improve abnormal lipid profile and visceral adiposity by recruiting more skeletal muscle fibers with enhanced glycogen storage capacity and expression of additional glucose transporters (GLUT4).10 Insulin has a potent upregulating effect on muscle protein synthesis with ingestion of carbohydrates and amino acids before or during resistance exercise is especially important to maximize this protein synthesis. The beneficial effects of exercise are seen with respect to cardiovascular risk factors in diabetes like changes in endothelial function, carotid artery intima-media thickness, left ventricular ejection fractions, and improvements in exercise capacity.5,14

**Exercise and Testosterone**

Resistance exercise results in an increase in the blood concentrations of anabolic hormones. The primary androgen hormone, testosterone, increases in response to sympathetic stimulation and plasma volume reduction. This is more marked in men than in women (androgen remains mostly unchanged).16 This testosterone, upon secretion, interacts with skeletal muscle tissue and causes protein synthesis, increased strength, size of skeletal muscle, and increased force production potential and muscle mass.4 The effects have also formed the basis of the use of precursors of testosterone (i.e., 300 mg of androstenedione + 150 mg of DHEA) as drugs of abuse in sports. Aerobic exercises in women with polycystic ovarian disease (PCOS) offer significant benefits and are an integral part of PCOS management. However, extremely high-intensity resistive exercises may be counterproductive in PCOS by causing delayed menarche, amenorrhea, and anovulation by decreasing the luteinizing hormone (LH) levels.19

**Exercise and Growth Hormone**

Growth hormone affects the target tissues like liver tissue, skeletal muscle, fat cells, and bone. The impact of GH is in coordination with other neuroendocrine feedback mechanisms and is regulated by other secondary hormones. Like testosterone, GH increases significantly in response to high-intensity resistive exercises. Growth hormone decreases glucose utilization and glycogen synthesis which helps in maintaining apt glucose homeostasis during exercises. Growth hormone also facilitates amino acid transport across cell membranes and increases protein synthesis. It enhances lipolysis and promotes the utilization of free fatty acids. Growth hormone supports exercises by stimulating cartilage growth. Exercise also results in acute increases in blood levels of insulin like growth factor 1 (IGF-1) and results in an increase in protein synthesis.20

**Exercise and Cortisol**

The levels of the adrenal hormone and cortisol, which has predominant catabolic effects, increase with resistive training (stimulates lipolysis in adipose cells and increases protein degradation in muscle cells) but the anabolic effects of GH and testosterone normally increase to a greater extent and reduce the negative effects of cortisol due to adaptation processes.21 The main beneficial action of cortisol during exercise is to protect glycogen stores and shift metabolism to other energy sources.22

**Exercise and Catecholamines**

The catecholamines especially epinephrine is released during maximal exercise and augments force production in muscles via central mechanisms and increased metabolic enzyme activity for energy generation. It also increases muscle contraction rate and blood flow to it. It enhances secretion rates of other hormones, such as testosterone.9 The plasma concentrations of catecholamines are increased by acute resistance exercise and the magnitude of its rise is dependent on muscle groups involved, strength, duration of exercise, and the rest intervals. The “anticipatory rise” is a part of the body’s psychological response before the exercise is undertaken.8

**Exercise and Endorphins**

The levels of endorphins vary during exercise, i.e., rises during exercise and post-exercise reductions may be seen. The increased levels are seen more during resistive exercises than during aerobic exercises.14 The acute elevation in β-endorphins is dependent on muscle mass used, intensity, duration of resistance exercise, and rest intervals. β-endorphins are implicated in several processes like pain modulation, immune function, and assisting in glucose and lipid homeostasis. They increase the pain threshold in response to exercise training especially resistance training.23

**Exercise and Thyroid Hormones**

The thyroid hormones, T3 and T4, are important for maintaining the metabolic rate and allowing other hormones to bring about their

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**Table 1: Comparison of endocrine adaptation in aerobic vs resistive exercises**

| Endocrine/metabolic adaptations | Aerobic exercise | Resistive exercises |
|---------------------------------|-----------------|---------------------|
| Quality of life                  | ✆               | ✆                   |
| Muscle strength/muscle mass     | ↔               | ✆                   |
| Bone mineral density            | ↔               |                     |
| Glycemic control                | ↑               | ↑                   |
| Insulin signaling               | ↑               | ↑                   |
| Immune function                 | ↑               | ↑                   |
| HDL-C                           | ↑               | ↑                   |
| LDL-C                           | ↓               | ↓                   |
| Triglycerides                   | ↓               | ↓                   |
| ACTH/cortisol                   | ↑               | ↑                   |
| Aldosterone                     | ↑               | ↑                   |
| β-Endorphin                     | ↑               | ↑                   |
| Epinephrine                     | ↑               | ↑                   |
| Estrogen                        | ↑               | ↑                   |
| FSH/LH                          | ↓               | ↔                   |
| GH                              | ↑               | ↑                   |
| Prolactin                       | ↑               | ↑                   |
| Testosterone                    | ↑               | ↑                   |
| T4                              | ↑               | ↑                   |
| T3                              | ↓               | ↓                   |
| TSH                             | ↔               | ↔                   |

ACTH, adrenocorticotrophic hormone; FSH, follicle-stimulating hormone; GH, growth hormone; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; LH, luteinizing hormone; TSH, thyroid-stimulating hormone.
full effect, i.e., the permissive action. However, there is no significant change in levels of thyroid hormones with exercise.\textsuperscript{24} T4 (FT4) increases, T3 (FT3) decreases, and thyroid-stimulating hormone (TSH) remains unaffected in exercise and is more pronounced in calorie deficiency or ultradistance exercise and is reversed by high-calorie intake.\textsuperscript{25} The trained athletes may have increased production and turnover of T4 but baseline thyroid hormone levels do not appear to be affected substantially by chronic exercise (i.e., endurance).\textsuperscript{26}

**Exercise and Fluid Homeostasis Hormones**

The blood volume critical for fluid homeostasis is maintained by renin, angiotensin, and aldosterone axis and anti-diuretic hormone and their levels increase proportionately with exercise intensity, duration, and hydration status of an individual to maintain fluid volume within normal limits.\textsuperscript{24}

**Exercise and Adipokines**

Adipokines like leptin and apelin are also secreted by adipose tissue and play a role in lipid metabolism, regulation of appetite, and energy homeostasis.\textsuperscript{11}

Leptin, a peptide hormone from adipose tissue, relays satiety signals to the hypothalamus to regulate appetite and energy balance, reduces testicular steroidogenesis (both as a direct effect and central by decreasing levels of LH and FSH). The resistive exercises lead to a reduction in leptin concentrations.\textsuperscript{8}

Apelin promotes insulin sensitivity and lipolysis and its levels are directly proportional to insulin levels, total cholesterol, and LDL-C. The levels of apelin decrease after both aerobic and resistance exercise.\textsuperscript{1,19}

**Summary**

Exercise elicits a range of hormonal responses responsible for cellular metabolism, facilitation of cardiovascular response to exercise and growth, and remodeling of the tissues. Exercise has been shown to improve insulin sensitivity, increase lipid catabolism, improve arterial compliance and endothelial function, and maintain muscle metabolic capacity.

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