Changes In Hormonal Response Caused By Different Types Of Physical Exercise: A Literature Review

Flávio Henrique Souza de Araújo (Corresponding author)
PhD in the Health Sciences Graduate Program, Federal University of Grande Dourados, Mato Grosso do Sul –Brazil.
ORCID: https://orcid.org/0000-0000-0000-0000 (optional)
Email: flaviobiosmart@gmail.com

Raquel Borges de Barros Primo
PhD degree in the Health Sciences Graduate Program, Federal University of Grande Dourados, Mato Grosso do Sul –Brazil, UFGD
Email: raquelbbp@ymail.com

Mi Ye Marcaida Olimpio
Master in the Health Sciences Graduate Program, Federal University of Grande Dourados, Mato Grosso do Sul –Brazil.
Email: miye_olimpio@hotmail.com

Nathalia Oliveira da Silva
Specialization in Exercise Physiology and Personal Trainer. FAHE, Dourados, Mato Grosso do Sul – Brazil.
Email: nathy.geenz@hotmail.com

Catherine Alexia Yoshikawa
Graduate Medicine, FCS. Federal University of Grande Dourados, Mato Grosso do Sul – Brazil.
Email: cathyoshikawa@gmail.com

Lígia Harumi Vilela Bartnick Tanaka
Graduate Medicine, FCS. Federal University of Grande Dourados, Mato Grosso do Sul – Brazil.
Email: ligia.htanaka@gmail.com

Vinício Guimarães Freitas
Graduate Medicine, FCS. Federal University of Grande Dourados, Mato Grosso do Sul – Brazil.
Email: vinicioguimaraes1995@gmail.com

Luiz Fernando Benazet de Assunção Pereira
Graduate Medicine, FCS. Federal University of Grande Dourados, Mato Grosso do Sul – Brazil.
Email: luiz.benazet@outlook.com

Thais Gimenes Bachega
Graduate Medicine, FCS. Federal University of Grande Dourados, Mato Grosso do Sul – Brazil.
Email: thais.bachega@hotmail.com

Silvia Aparecida Oesterreich
Professor of Human Physiology, FCS, PPGCS – UFGD, Federal University of Grande Dourados, Mato Grosso do Sul – Brazil.
Email: silviaoesterreich@ufgd.edu.br

Abstract

The regular practice of physical exercises brings benefits to health, as long as it is done correctly. Therefore, it is essential to know the type of activity practiced and its relationship with the individual's organism, especially regarding the endocrine response. The objective of this study was to investigate the main hormonal axes that act in physical exercises and to understand their different responses according to the type of activity. A literature search was carried out in the Scielo, PubMed, and VHL databases with the combinations "exercise AND hormones", "sports AND endocrine", "endocrine regulation AND exercise", and "endocrine regulation". After analysis, seven studies were selected for the development of this paper. The physical exercises were divided into two modalities - strength and endurance - which vary according to the homeostatic change imposed on the body. The responses were analyzed according to the acting hormonal axis, as follows: hypophysary, by the action of a hormonal cascade; adrenal, catecholamines and cortisol; and pancreatic, represented by insulin and glucagon. This review revealed the modulation of endocrine responses varies whether the activity is one of strength, which relates to anaerobic processes, or endurance, which interacts with the cardiovascular system. Therefore, it is recommended that further studies be conducted on this subject so that the practice of physical exercises suits each individual's uniqueness and may contribute to the prevention and treatment of diseases.

Keywords: endocrine response; endurance-type activity; GH; prevention of diseases; regular exercise.

1. Introduction

Regular exercise is widely recommended, as it is a protective factor for several cardiovascular diseases, brings benefits to mental health, and maintains a healthy weight. In Brazil, this practice has increased in recent years - in 2019, 30.1% of people aged 18 years or more practiced the recommended level of physical activity, compared to 22.7% in 2013 (Brazilian Institute of Geography and Statistics - IBGE, 2019). In the year 2020, however, this statistic was reduced by the changes arising from the pandemic of the new coronavirus (Sars-CoV-2), so that many Brazilians stopped exercising during this period (Institute of Communication and Scientific Information and Technology in health - Icict/Fiocruz, 2020).

The practice of physical activities must be encouraged among the population as the current situation allows, as long as it is emphasized the importance of professional monitoring to direct the individual to the appropriate practice and thus prevent injuries, dysfunctions or both. Therefore, it is necessary to consider both the type of exercise and how it relates to the body, especially regarding endocrine responses. Physical exercises may vary according to the energy and physiological demand required from the body, which, consequently, implies in equally varying responses. Thus, it is essential to understand this relationship to guide the individual safely and efficiently.

Thus, given the above, the present study aimed to investigate the main hormonal axes acting during physical exercise, that is, the pituitary, adrenal, and pancreatic axes, as well as to elucidate and understand the differences in the endocrine response according to the type of activity performed.

2. Materials and methods

This is a literature review based on scientific literature accessible in the Scielo, PubMed, and Virtual Health Library (VHL) databases. The inclusion criteria were studies available in Portuguese, English, and Spanish relating physical activity to the endocrine response. Also, it was defined the publication interval between the years 2014 and 2021 so presented only the most recent publications. Various combinations of descriptors were used, such as "exercise AND hormones", "sports AND endocrine", "endocrine regulation AND exercise", and "endocrine regulation". Among all the studies that met the inclusion criteria, seven were selected to be analysed and develop this study.

3. Results and discussion

After reviewing the selected studies, it was chosen to divide them according to the exercise type for a better presentation and discussion of the theme. Aiming to expand the dialogue about the effects, two modalities that encompass distinct modes of activities were segregated: strength and endurance exercises.

3.1. Strength-type activity

Strength sports, such as weightlifting, abruptly change the body's homeostasis due to the intense and fast stimulus. This momentary change between the individual being in inertia and movement contributes to the activation of anaerobic respiration. The energy support is intense in a short time (MOGHETTI et al, 2016). In order to meet the body's need in such sports, hormonal release acts according to the feedback of this high stress. The main hormonal axes to be studied in anaerobic sports are hypothalamus-pituitary, adrenal, and pancreatic.

3.1.1. Hypothalamus-pituitary axis

Within the interval between the beginning and the first minute of activity, there is the stimulation of hypothalamic hormone action, which produces the hormone cascade's central modulators. In the first moment, there is mainly the action of growth hormone-releasing hormone (GHRH) and corticotrophin-releasing hormone (CRH), followed later by the stimulation of thyrotropin-releasing hormone (TRH) and gonadotrophin-releasing hormone (GnRH). This stimulates the production of trophic hormones, which stimulate local areas to produce specific hormones.

GHRH, produced after the onset of exercise, stimulates somatropin production, the growth hormone (GH), in the adenohypophysis. Its increase most significant in anabolic activities and contributes significantly to performance improvement (CHIKANI et al., 2016). Among the physiological effects caused by this are the stimulation of protein synthesis, lipolysis and glycogenolysis. There is also the production of energy reserves through hepatic gluconeogenesis from the glycerol originated from lipolysis.

Another hormone that increases rapidly after the beginning of activity is CRH, which contributes to the production of adrenocorticotrophic hormone (ACTH) in the adenohypophysis, which stimulates the cortisol production in the cortex of the adrenals. This last hormone varies according to the intensity of physical exercise and the level of stressful activities, i.e., situations that modify the body's homeostasis. Its function is to increase the number of substrates for metabolic use, increasing glycogenolysis, proteolysis, and lipolysis. Moreover, it also contributes to energy reserves production, increasing glycogenolysis, gluconeogenesis, and adipogenesis.

After high-intensity training, there is increased production of TRH, which stimulates the increase of thyroid-stimulating hormone (TSH) in the adenohypophysis, which has the purpose of increasing the amount of T3 and T4 produced in the thyroid. Its main functions are related to cellular metabolism regulation, such as controlling the synthesis or lysis of proteins and lipids, thermogenesis, and stimulating the number of receptors and their affinity to adrenaline.

Finally, the other hormone-stimulated after high-intensity training is GnRH. Its production influences the adenohypophysis to increase the concentration of luteinizing hormone (LH) and follicle-stimulating hormone (FSH), which stimulates the production of sex hormones. In this context, testosterone production is important for muscle anabolism, especially chronically, where it is related to hypertrophy and increased strength. This is supported by the fact that Hooper and collaborators observed a significant increase in basal testosterone rates after five weeks of strength training (HOOPER et al., 2017).

3.1.2. Adrenal axis

In the adrenal axis, the stimulation of catecholamines (noradrenaline and adrenaline) already starts before the beginning of exercise, with the release of noradrenaline generated by the stimulation of sympathetic activity locally, due to the stress caused by anxiety. With this stimulation, the adrenal medulla also produces adrenaline. After the initial moment, there is a high plasma concentration of catecholamines related to the duration and, mainly, the activity's intensity. Anaerobic workouts have the highest concentrations compared to aerobic ones (SELLAMI et al., 2014; HACKNEY et al., 2015).

The effects caused by catecholamines are dependent on the receptors expressed in each organ, but the sets of these actions lead the body to be in a state of alert, whose main characteristics are increased glycogenolysis and gluconeogenesis; inhibition of insulin and stimulation of glucagon; dilation of the vessels of the muscle bed and constriction of mesenteric vessels; and increased heart rate (ANDRADE; de LIRA, 2016). Such physiological actions aim to provide energy support to muscles mainly through glycogenolysis in them and in the liver and increase blood flow so that the nutritional support efficiently reaches the muscles and contributes to increased performance (SELLAMI et al., 2014).

3.1.3. Pancreatic axis

Considering that the sympathetic nervous system's stimulation inhibits the stimulation of the parasympathetic system, physical exercise inhibits insulin secretion since the beta-cells in the pancreas (where its production occurs) are stimulated mainly by the parasympathetic system and by food ingestion/digestion. Besides, adrenaline and noradrenaline release also acts by reducing its production (ANDRADE; de LIRA, 2016).

Physiologically, the decrease in insulin implies decreased glycogen production and an increase in glycogenolysis and lipolysis. Such effects contribute to glycogen use in the muscles as the significant energy source in strength exercises. Parallel to this, exercise also stimulates the production of another pancreatic hormone, glucagon, which contributes to a significant increase in hepatic and muscle glycogenolysis and lipolysis.

Concurrent to the reduction in insulin levels, there is also a decrease in resistance to this hormone. In this context, anaerobic exercises are better at regulating sensitivity when compared to aerobic exercises or both, even showing more significant reduction of insulin during their execution. A possible explanation for this would be to contribute to the high affinity between receptor and hormone and, consequently, increase the response (BOTEZELLI et al., 2016).

3.2. Endurance-type activity

Endurance physical exercises, characterized by aerobic activities that depend on effective responses in the cardiovascular system, such as running, walking, and cycling, are also responsible for great physiological and metabolic stress. The body's effort to maintain internal conditions in balance generates an endocrine response, which depends on both energy and physiological demands and the intensity of the exercise. Concerning endurance exercises, hormonal changes occur for various physiological reasons that are linked, above all, to the necessary cardiovascular adjustments, the type of predominant fiber in the muscle, energy production, and increased oxygen demand (MOGHETTI et al., 2016).

The excitation of stimulatory, inhibitory secretion or both factors on a gland is part of the cascade of effects of the endocrine system when in a regime of physical exercise, which in the case of the endurance type, has its most relevant responses in the pituitary gland, the adrenals, and the pancreas (HACKNEY et al., 2015). The research around the hormonal changes caused by endurance training and such glands' behavior is of great need since it reveals mechanisms and processes that are useful to adapt training and diets of high-performance athletes such as marathon runners and swimmers, for example.

3.2.1. Pituitary response

One of the fundamental and initial effects of endurance exercise on adeno-pituitary hormone secretion is the stimulation of GHRH to adaptive change. The physiological stress generated has its feedback on the release of GH, which acts on glucose homeostasis, increased utilization of free fatty acids, and regulation of the IGF system (ROSA et al, 2015), responsible for several anabolic processes in the human body and of utmost importance for bone and muscle tissues.

Although there are some differences among the reviewed articles, GH secretion was shown to be lower in endurance exercises when compared to strength exercises. However, there are reports that the combination of both methods lead to more effective acute hormonal responses in anabolic processes (ROSA et al., 2015).

The action of sex hormones during physical activity comes from the release of LH and FSH by the adenohypophysis, as mentioned before. Such release, however, has a significant dependence on intensity, time, and training methods. Clinical studies describes the decrease in testosterone in high-intensity aerobic activities (HACKNEY et al., 2018). On the other hand, this release in moderate activity is a contributing factor in bone and muscle catabolism.

3.2.2 Adrenal response

The stimulation from ACTH production after physical and psychological stress promotes the release of cortisol by the adrenal cortex. To help the body control homeostasis, cortisol is an essential hormone linked to exercise and sports, with dichotomous effects and dependent on several factors. According to the to the data mentioned above, the intensity of exercise is a determining factor in studying the results of the hormonal dysregulation generated. Particularly in the adrenal glands, the variation in intensity can either stimulate or inhibit secretion. Some studies have considered similar effects to hypercortisolism during simulated workouts. In others, with variations in intensity and methods, the results were a reduction in basal cortisol during resistance exercise (ARRUDA et al., 2013).

Also, in the adrenal axis, the energy supply and the activation of pathways such as glycogenolysis and lipolysis have their feedback in catecholamines. When observing the consequences of this axis's hormonal stress, one should also consider the intensity in endurance exercises, which has been reported only in moderate to strong situations.

The sympathetic nervous system's activation at the onset of exercise is the beginning of the cascade of hormonal responses in the suprarenal medulla. The adrenaline and noradrenaline released in the target tissues induce different energy pathways, such as glucose catabolism, insulin inhibition, and fatty acid utilization (HACKNEY et al., 2015). Among the effects are increased heart rate and output, vascular resistance, and other fight-or-flight type reactions.

3.2.3. Pancreatic response

The adrenergic effect related to endurance exercise plays a vital role in inhibiting insulin secretion by the pancreas. By decreasing blood glucose uptake, peripheral insulin sensitivity is increased, and cells become more responsive to this hormone (ESCRIBANO et al., 2017).

In contrast, prolonged exercise can culminate in a reduction of muscle glycogen and consequent glucose metabolism. The reaction to such a physiological mismatch is the stimulation of glucagon release. Processes such as glucose uptake by the liver, gluconeogenesis, and fatty acid metabolism are part of glucagon's effects in endurance exercise. (HACKNEY et al., 2015).

4. Conclusion

The data found in this review revealed that physical exercises could modulate endocrine responses since they induce changes in the pituitary, pancreatic, and adrenal axes' activity. This occurs due to the physiological stress to which the organism is submitted and the need to adapt. Moreover, this modulation can vary depending on the type of physical demand, strength, or endurance activity. The first type is related to the anaerobic process and fast and intense movements, while the second has a strong interaction with the cardiovascular system. Thus, there is a need for further studies in this field, not only for exercise to be appropriate according to each individual's body but also so that specific activities can be used in the treatment of metabolic diseases and effectively increased in a preventive manner.

5. References

ANDRADE, M. S.; DE LIRA, C. A. B. **Fisiologia do exercício**. 1. Ed. São Paulo: Manole, 2016.

ARRUDA, A. F. S. de. et al . Resposta imuno-endócrina associada à partida de futsal. **Motriz: rev. educ. fis.** Rio Claro, v. 19, n. 2, p. 460-466, 2013.

BOTEZELLI, J. D. et al. Strength training prevents hyperinsulinemia, insulin resistance, and inflammation independent of weight loss in fructose-fed animals. **Sci Rep [Internet]**. 2016. Aug 4;6:31106. Disponível em: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4973231/. Acesso em: 10 fev. 2021.

CHIKANI, V. et al. Growth hormone (GH) enhances anaerobic capacity: impact on physical function and quality of life in adults with GH deficiency. **Clinical Endocrinology**. 2016; Oct;85(4): p. 660-668. doi: 10.1111/cen.13147. Epub 2016 Jul 22.

ESCRIBANO, L. G. et al. Revisión y análisis del ejercicio físico a nivel hormonal, cerebral y su influencia en el apetito. Clín. investig. arterioscler. (Ed. impr.) ; 29(6): p. 265-274, 2017.

HACKNEY, A. C.; LANE, A. R. Exercise and the regulation of endocrine hormones. **Prog Mol Biol Transl Sci**. 2015. 135: p. 293–311.

HACKNEY, A. C.; LANE, A.R. Low testosterone in male endurance-trained distance runners: impact of years in training. **Hormones (Athens)**. 2018. Mar;17(1): p. 137-139. doi: 10.1007/s42000-018-0010-z. Epub 2018 Apr 27.

HOOPER, D. R. et al. Endocrinological roles for testosterone in resistance exercise responses and adaptations. **Sports Medicine**. 2017. Sep;47(9): p. 1709-1720.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. Coordenação de Trabalho e Rendimento. **Pesquisa nacional de saúde : 2019 : percepção do estado de saúde, estilos de vida, doenças crônicas e saúde bucal : Brasil e grandes regiões**. Rio de Janeiro, IBGE. 2020. v. 4. ISBN: 978-65-87201-33-7. Disponível em: https://biblioteca.ibge.gov.br/visualizacao/livros/ liv101764.pdf. Acesso em: 10 fev. 2021.

INSTITUTO DE COMUNICAÇÃO E INFORMAÇÃO CIENTÍFICA E TECNOLOGIA EM SAÚDE. Fiocruz. **ConVid - Pesquisa de Comportamentos**. Fiocruz, 2020. Disponível em: https://www.convid.fiocruz.br/. Acesso em: 10 fev. 2021.

MOGHETTI, P. et al. Metabolic effects of exercise. **Front Horm Res**. 2016.47: p. 44-57. doi: 10.1159/000445156. Epub 2016 Jun 27.

ROSA, C. et al. Order effects of combined strength and endurance training on testosterone, cortisol, growth hormone, and IGF-1 binding protein 3 in concurrently trained men. **The Journal of Strength & Conditioning Research.** 2015. Jan; 29(1): p. 74-79.

SELLAMI, M. et al. Effect of age and combined sprint and strength training on plasma catecholamine responses to a Wingate-test. **European Journal of Applied Physiology**. 2014. 114(5), p. 969–982.

WORLD HEALTH ORGANIZATION. **WHO guidelines on physical activity and sedentary behavior**. Geneva: World Health Organization, 2020. Licence: CC BY-NC-SA 3.0 IGO.