Chapter

CORTISOL AND PHYSICAL EXERCISE

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ABSTRACT

Glucocorticoids exert many beneficial effects in humans, increasing the availability of metabolic substrates, while maintaining normal vascular integrity and protecting the body from an exaggerated immune system response in the face of exercise-induced muscle damage. The main glucocorticoid is cortisol, accounting for 90% of the total activity of these substances. It is secreted by the adrenal cortex of the adrenal glands and among other functions, plays important roles during and after exercise, including taking part in gluconeogenesis and accelerating the mobilization and use of fats to produce energy. Cortisol has important metabolic functions such as influencing the metabolism of glucose, proteins and lipids. It raises blood glucose and increases fatty acid mobilization from fat reserves to active tissues. On the other hand, it can inhibit protein synthesis and increase muscle mass by its catabolic action. Cortisol levels are measured by saliva and blood collection, and can be influenced by different factors, such as sleep deprivation, stress and exercise, in addition to variations caused by circadian rhythm. Responses to exercise depend on the characteristics of stimuli and can be classified as acute and chronic responses. This chapter discusses the main biological functions of this hormone, factors that influence its levels and response to various acute and chronic exercise protocols.

Keywords: Hormones, stress and physical exercise, metabolism, acute and chronic responses.

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CORTISOL

Glucocorticoids exert many beneficial effects in humans, increasing metabolic substrate availability, maintaining normal vascular integrity and protecting the organism against exaggerated response of the immunological system to exercise-induced muscle damage [1].

Cortisol is a glucocorticoid secreted by the adrenal cortex of the suprarenal glands [1, 2], which, among other functions, plays important roles both during and after exercise [3], such as helping gluconeogenesis. Cortisol stimulates protein fractionation for amino acid components in all body cells. Amino acids released are transported to the liver, where they participate in glucose synthesis via gluconeogenesis [4]. Among other functions of cortisol are accelerated mobilization and use of fats in order to obtain energy. Adipocytes are specialized in synthesizing and storing triglycerides; their molecules are cleaved in the hydrolysis process in glycerol and three fatty acid molecules. After diffusion into the bloodstream, fatty acids are delivered to the active tissues, where they are metabolized for energy production [5]. Further cortisol functions include: helping the body adapt to stress; maintaining adequate glucose levels even during fasting; decreasing glucose capture and muscle glucose oxidation to obtain energy, reserving it for the brain via an antagonic effect to that of insulin; blocking lysosomal rupture, impeding additional tissue lysis, stimulating protein catabolism for the release of amino acids used in tissue repair, synthesizing enzymes and producing energy in all body cells, except in the liver; acting as an anti-inflammatory agent; reducing immunological reactions to provoke a decrease in the number of lymphocytes; increasing epinephrine-induced vasoconstriction; facilitating the action of other hormones, especially glucagon and growth hormones (hGH), in the gluconeogenesis process [2, 5, 6]. Moreover, this hormone seems to be directly related to a number of cytokines secreted by adipose tissue [7].

FORMS OF MEASUREMENT

The result of cortisol assessment is an important tool for understanding the actions of this hormone in the human body. However, there are different collection and analysis possibilities, each with its specific indications. Possible measurements are those based on data obtained from saliva, urine and blood.

Saliva

Cortisol level measurement from saliva collection aims to assess individual stress levels. This method involves a simple procedure that does not produce sufficient alterations to interfere significantly in the results. Since it is a non-invasive technique, collection is not stressful, in contrast to venipuncture, which many consider painful.

The simple collection method is widely used in research and individual assessments. Samples are obtained without invasive procedures, which involve easy-to-calibrate individuals in clinical analysis laboratories or academic investigations without requiring the

presence of a doctor or nurse. The material collected remains stable at ambient temperature for up to one week without significant loss of information and can be sent through the post without causing any alteration [8].

Saliva collection has additional advantages over the other techniques, since it is more accurate and low cost, producing faster results than measuring urinary cortisol, for example. Another advantage of this method is the increased possibility of collective collections at different training or competition moments without the need for specific collection environments, making it more dynamic [9-11].

This technique is readily accepted by children and adolescents. Moreover, it allows cortisol investigators to study without undesirable and embarrassing reactions owing to practical, ethical, cultural or religious reasons. These situations often occur in methods involving blood or urine collection. However, it is important to remember that saliva-based measurements have some limitations. Given their structure and composition, they may interfere in the results of oral disorders, the presence of blood in saliva, the Sjögren syndrome, use of oral hormone replacements and some types of birth control pills [9].

There are different ways to collect and analyze salivary cortisol. However, the most common and most complex methods exhibit similar results. An example is a comparison between the results obtained by Raff et al. [12] and those of Castro et al. [13], using different methods. In the former, saliva samples were collected in plastic tubes by direct salivation for 15 minutes. The mouth was previously rinsed with distilled water, saliva samples were centrifuged at 2000 rpm for 5 minutes and the supernatant separated and stored at -20°C for subsequent determination of free cortisol by radioimmunoassay (RIA).

The other technique observed was the use of a collection device (Salivette). Salivette cotton may retain some amount of cortisol, which could produce a lower result than would be obtained if saliva were collected directly. However, cutoff points for salivary cortisol, proposed for interpreting the dexamethasone suppression test, using the Salivette (103 ng/dl) and direct collection (62-112 ng/dl), suggest that the collection technique is an important factor.The most widely adopted reference values for measuring salivary cortisol in adults are collection at 8:00 am (3.5 to 32.0 μmol/l) and at 11:00 pm (< 3.6 μmol/l) [14].

Urine

Urine collection for cortisol determination is the second most frequently used method. One of its advantages over other procedures is the collection of production accumulated over 24 hours, which solves the problem of understanding results in relation to secretion rate. However, this method poses problems, given that collection is accumulative and depends on transport and storage during the entire period. In this case, the following procedure should be adopted: after collection flasks are removed from the laboratory, study subjects must totally empty their bladders first thing in the morning and discard this urine, record the exact time, and keep all subsequent urine (including nighttime urination) until the next morning at the same time urine from the previous day was disposed of (this urine must also be collected and kept). It is essential to send all collected urine to the laboratory to avoid measurement errors [15].

Another technique is to collect urine discharge according to the time of day to be investigated. With respect to studies on anxiety, urine seems to be a viable process when collections are performed at night [16, 17].

The method has a number of limitations, such as falsely low values in individuals with loss of kidney function [18] or those with chronic fatigue syndrome [19]. In the case of individuals with above normal water intake, values may be falsely high during depression and after physical exercise. There also seems to be a difference in urinary excretion of cortisol between men and women, with men exhibiting slightly higher levels. Another significant drawback is that measuring urinary cortisol is scarcely effective for studying acute stress.

Important rules that women must follow include not using creams/vaginal ovules in the 24 hours before collection and avoiding collection during menstrual periods [20].

High levels of urinary cortisol may also indicate secretory tumors of the adrenocorticotropic hormone (ACTH), Cushing's syndrome and pituitary tumors. Reduced levels of urinary cortisol may indicate Addison's disease, adrenal failure, hypopituitarism and congenital adrenal hyperplasia. The most widely used reference values to measure urinary cortisol are: Children 2.0 to 27.0 µg/24 hours; Adolescents 5.0 to 55.0 µg/24 hours and adults 10.0 to 90.0 µg/24 hours [14].

Blood

Assessment of blood cortisol levels is important for pathological or behavioral observations. However, cortisol evaluation from blood collection seems to be the least recommended by researchers when the aim is athletic assessment, with respect to pre-competition stress. This is due to the negative reaction to venipuncture exhibited by most individuals investigated.

Studies have been conducted on the use of this method in sport, demonstrating the possibility of detecting this hormone in the blood in different volumes and at different phases of competition [21]. Girardello [15] studied high-performance karate athletes, concluding there was no significant correlation between blood cortisol levels and applied inventory of stress symptoms [22] and the perceived stress scale [23]. In this case blood cortisol can be considered a predictor of pre-competition stress. Furthermore, it is highly likely that this alteration significantly influences athletic performance, since all subjects exhibited a significant difference between basal and pre-competition cortisol. Athletes with less variation finished in the top three places. Thus, the presence of this hormone in blood, in pre-competition situations, may be an indicator of stress level, which could cause some type of reaction (useful or not), in pre-competition athletes.

To understand adequate amounts of circulating cortisol, it is important to determine reference values and be aware that they vary depending on collection time. In other words, when collected at 8:00 am, the proposed value ranges between 5.0 and 25.0 µg/dl, at 4:00 pm cortisol values should decline by more than 35% of the morning value, while at 6:00 pm the drop should be greater than 50% [14].

INFLUENCING FACTORS

Circadian Rhythm

Levels of a number of hormones demonstrate circadian fluctuation and variation [24]. In some cases, these variations are due to regulatory endocrine axis pulses [25]. In others, they are related to humeral stimulus alterations caused by environmental or behavioral factors of the individual [26]. Morning cortisol levels are generally twice as high as at the end of the day [27].

Sleep and Stress

Sleep deprivation and stress are factors known to influence a number of hormones [24]. Emotionally disturbed individuals have high levels of cortisol [28]. Furthermore, hormones that exhibit a circadian pattern, such as cortisol, may show alterations in this pattern in cases of interrupted sleep cycles [29].

Physical Exercise

According to Lapin [30], physical exercise can become a stressor agent for the body, resulting in an increase in cortisol concentrations. This may influence exercise results with respect to weight loss, but, on the other hand, it may be an inhibitor of protein synthesis and muscle growth by its catabolic action [4].

Canali [2] reports that both the type and intensity of exercise in relation to individual training levels provoke alterations in hormone responses, making it somewhat difficult to identify them.

Charmas [31] assessed the effects of a moderate aerobic exercise session accompanied by music, on metabolic and hormonal responses in 11 women aged between 30 and 50 years. Blood samples were collected at four different times: in the morning while fasting (measure I), in the evening just before the exercise session (measure II), immediately after the 1-hour exercise session (measure III), and in the morning of the day following the exercises after a 12-hour rest period (measure IV).

Cortisol results show high values in measure I and measure IV; however, there was no significant difference between measures II and III. Therefore, a one-hour aerobics session provoked no alterations in cortisol plasma levels.

Kraemer [32] examined the effects of amino acid supplementation on physiological adaptations as a response to 12 weeks of strength training. To that end, hormonal and muscle damage markers, including cortisol, were measured.

Seventeen healthy men were randomly allocated to experimental and placebo groups. The experimental group received amino acid solution containing β-Hydroxy-β-Methylbutyrate, whereas the placebo group was given only an isocaloric solution.

After 12 weeks of strength training for the primary muscle groups, ranging from 3-5 series of 8-14 repetitions, no alterations were observed in cortisol concentrations at rest.

However, the experimental group exhibited reduced levels immediately before exercise, when compared to basal values.

In order to determine the effect of moderate-intensity aerobic training on muscle strength in relation to hormonal alterations, Grandys [33] conducted a study with 15 physically active male subjects. The research lasted five weeks and used stationary bicycle training. Tests were carried out to obtain VO_{2max} in individuals and 20 ml fasting blood samples were collected at rest, before and after the training program.

Following the intervention period, a significant rise in VO_{2max} was observed. Cortisol plasma levels showed a tendency to increased concentrations. However, these alterations were not statistically significant.

Izquierdo [34] examined the effects of two strength training methods on cytokines and hormonal responses. The training program, involving 12 male volunteers, lasted seven weeks.

Acute cortisol responses were significantly lower in the group submitted to 5 series of 10 repetitions with the same absolute overload (Kg), compared to the group that performed 5 series of 10 repetitions with the same relative intensity [%].

In another study, which examined the chronic effects of aerobic and strength training conducted separately over four months on hormonal concentrations, Izquierdo [35] found no significant intergroup differences (aerobic training X strength training X control) for plasma cortisol levels.

Hormonal responses induced by different strength training intensities were compared in research conducted by Oliveira [36]. His results showed reduced cortisol levels in the acute phase for the group that performed exercises at 50% 1RM and increased levels in the group that exercised at 80% 1RM.

França [5] used 20 male athletes to analyze serum cortisol levels after a marathon race. To that end, blood samples were collected at three different times: in the morning, 48h before the marathon (control), immediately after the race (final) and on the following morning, 20 h after the race (recovery). His results show a significant rise in cortisol levels at the end of the race, with values returning to basal levels during recovery.

The study concluded that behavior exhibited by the variable confirmed marathon racing causes intense physical stress, which can lead to hormonal imbalance.

Uchida [37] examined the influence of two training methods on hormonal responses. Individuals were randomly divided into two groups, both of which were submitted to multiple series and tri-set methods. The author reports that the group that underwent the tri-set method showed a significant increase in cortisol levels as a response to acute and chronic stress levels compared to the group submitted to the multiple series method.

Results obtained in this study suggest that the tri-test method imposes greater organic stress and that the multiple series method promotes a more favorable environment to anabolism after eight weeks of intervention.

Tremblay [38] sought to determine acute anabolic and catabolic hormonal responses to strength and aerobic exercise of equal volume in subjects with different training levels.

Subjects engaged in strength training, aerobic training and sedentary individuals were used. They completed one rest period, a 40-minute race at 50-55% VO_{2max}, and one strength training session. Blood samples were collected before the exercise session and 1, 2, 3 and 4 hours after onset of exercise.

Findings for this study demonstrated that cortisol concentrations exhibited a tendency to decrease in the rest period. This behavior was attributed to the typical daytime cortisol

pattern. However, when groups were compared, cortisol concentrations were significantly higher as a response to strength training than to rest or the race. Moreover, the race obtained more elevated values than the rest period.

Vale et al. [39] investigated the effect of 12 weeks of different exercise protocols on the cortisol levels of elderly subjects. The sample was divided into a strength training group, aerobic training group and a control group. After the intervention there were no significant alterations in intra and intergroup cortisol concentrations

The acute effect of physical exercise on serum cortisol levels was analyzed by Rosa et al. [40]. A significant reduction was observed immediately after the concurrent training protocols.

Rosa et al. [41] analyzed the behavior of cortisol levels as an acute response to physical exercise. To that end, a concurrent training session composed of an indoor stationary bicycle class followed by a weight training session was used as intervention protocol. Results showed a significant reduction in cortisol concentrations after concurrent training.

Rosa et al. [42] analyzed the effect of different sequences of concurrent training on cortisol concentrations. In one session aerobic exercise preceded strength training, while the reverse occurred in another session. Data showed a significant reduction in cortisol levels, irrespective of exercise sequence.

CONCLUSION

Cortisol is closely linked to individuals that engage in physical activities, especially the high-intensity variety. It is catabolic, since it exerts an opposite effect to that of testosterone, insulin and the growth hormone (hGH), decomposing muscle tissue, causing muscles to suffer from sarcopenia. Cortisol, which is released when the body is in situations of high physical and mental stress and high temperature, is the main catabolic hormone.

Considering the above, there is an increasing need for habitual activities practiced in physical activity and sports sciences to be controlled by means of safe, reliable and viable biochemical markers. These activities include: sport, physical activity for health and quality of life, recreation, rehabilitation and physical exercise for individuals or groups with special needs.

This study sought to demonstrate the potential of cortisol to act as a marker of both physical and mental stress. The importance and complexity of the issue calls for new studies to complement and extend the findings obtained in the present research.

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