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Overtraining, Exercise, and Adrenal Insufficiency

Brooks KA* and Carter JG

Department of Kinesiology, Texas A&M University, USA

Abstract

Running, or any aerobic training in moderation, has a positive effect on health. There is a point of diminishing returns, where chronic stress from overtraining, which is common in runners, may be linked to problems in the adrenal gland. Overtraining Syndrome (OS) has been linked with adrenal insufficiency. There is a direct link between stress and the adrenal glands, and the physical stress of overtraining may cause the hormones produced in these glands to become depleted. Overtraining Syndrome (OS) has been described as chronic fatigue, burnout and staleness, where an imbalance between training/competition, versus recovery occurs. Training alone is seldom the primary cause. In most cases, the total amount of stress on the athlete exceeds their capacity to cope. A triggering stressful event, along with the chronic overtraining, pushes the athlete to start developing symptoms of overtraining syndrome, which is far worse than classic overtraining. Overtraining can be a part of healthy training, if only done for a short period of time. Chronic overtraining is what leads to serious health problems, including adrenal insufficiency.

Severe overtraining over an extended period can result in adrenal depletion. An Addison-Type overtraining syndrome, where the adrenal glands are no longer able to maintain proper hormone levels and athletic performance is severely compromised has been described by researchers. The purpose of this review is to describe the relationship between overtraining, chronic fatigue, and adrenal insufficiency and to address the overlap in these conditions, as well as examine critical research on the relationship between the dysfunction of the adrenal axis in over trained and stressed athletes.

Keywords: Chronic fatigue; Adrenal axis; Overtraining syndrome; Endurance athletes; Stress

Introduction

Running, or any aerobic training in moderation, has a positive effect on health. There is a point of diminishing returns, where chronic stress from overtraining, which is common in runners, may be linked to problems in the adrenal gland. Overtraining Syndrome (OS) has been linked with adrenal insufficiency. There is a direct link between stress and the adrenal glands, and the physical stress of overtraining may cause the hormones produced in these glands to become depleted.

Adrenal insufficiency: Symptoms and causes

Adrenal insufficiency refers to the inability of the adrenal glands to produce a normal quantity of hormones, which leads to a reduced ability in the individual to cope with stress. Adrenal depletion is a milder form of insufficiency, while Addison's disease is a total adrenal gland shutdown, which involves more extreme symptoms which require longer correcting. Addison's disease is an autoimmune disorder, which has life-threatening complications.

Symptoms of adrenal insufficiency can be directly traced to a reduced secretion of certain hormones when under stress. Within the medulla, or inner core, of the adrenal, both epinephrine and nor epinephrine are released during the fight-flight response to stress. Stress in the body can be physical, mental, emotional, or even imagined stress and all have the same impact on the release of hormones and the effect of stress on our body.

Within the adrenal cortex, or outer shell, aldosterone, cortisol, and cortisone are regulated. These hormones are more critical in body function. Aldosterone helps kidneys retain sodium and excrete potassium. If production falls too low, the kidneys are not able to regulate salt and water balance, causing blood volume and blood pressure to drop, which can result in a life-threatening situation. Cortisol has many functions such as maintaining blood pressure and cardiovascular function, slowing the immune system's inflammatory response, and balancing the effects of insulin in breaking down glucose for energy. Cortisol is also involved in regulation of the metabolism of proteins, carbohydrates, and fats, as it stimulates the liver to raise the blood sugar as needed, in response to metabolic demands, physical activity, and stress. Cortisol has a long half-life in the blood and if often thought to be the body's long-term response to stress, in contrast to adrenaline which is a very immediate and short-term response. Cortisol production is regulated by Adreno Cortico Trophic Hormone (ACTH), made in the pituitary gland.

The Hypothalamic-Pituitary-Adrenal (HPA) axis is highly involved in our body's short-term and long-term response to stress. Other hormones related to the stress response include corticotropin-releasing hormone and adrenocorticotrophic hormone. In cases of adrenal depletion, these other hormones are often found to be in short supply (in early stages of adrenal stress) or they can be found to be abnormally high, while another hormone is in short supply. The HPA axis functions to maintain hormone levels by balancing hormones at each level of the axis. The hypothalamus releases Corticotropin-Releasing Hormone (CRH), which causes the pituitary to release Adreno Cortico Trophic Hormone (ACTH). ACTH causes the outer cortex of the adrenal gland to increase in size and to release cortisol. At times, serum cortisol may be found to be at a normal level, while ACTH is low. Adrenal depletion involves the entire HPA-axis, and the earlier the problem is discovered, the less the axis will be affected.

***Corresponding author:** Brooks KA, Department of Kinesiology, Texas A&M University, USA, Tel: 361-825-2670; E-mail: kbrooks17@gmail.com

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Low serum cortisol is a marker of adrenal depletion. There are several symptoms of low cortisol levels, although they are vague and often related to other disorders. Some symptoms include:

- Fatigue
- Unrefreshing sleep
- Ill-defined malaise
- Loss of ambition
- Increased fear and apprehension
- Scattered thinking
- Decreased concentration and memory
- Short fuse
- Hypoglycemia symptoms
- Sugar cravings
- Slow recovery from illness
- Allergies or autoimmune disease
- Increased achiness or arthritis
- Nausea/no appetite in a.m.
- Excessive consumption of caffeine or other stimulants
- Tendency to feel best towards evening
- Decreased sex drive

Low cortisol levels have been linked to the following

- Personality/lifestyle/occupational factors lead to adrenal insufficiency [1]
- Perfectionism [2]
- A history of severe physical or emotional trauma or prolonged stress
- Shift work [3]
- Teaching or healthcare profession/middle management position
- Overtraining [3-6]
- Any job where the individual feels trapped or powerless [3]
- High consumption of refined flour and sugar [7]
- Hypothyroidism [8]

Adrenal insufficiency can be divided into two types, a primary and a secondary form, depending on the length of disease and the primary hormones affected. Primary adrenal insufficiency results from a loss of both cortisol and aldosterone secretion due to the near or total destruction (Addison's) of both adrenal glands. Most reported cases of primary adrenal insufficiency result from destruction of the adrenal cortex by the body's own immune system and the process takes months to years. Often times, individuals are not aware they have the disease and may be misdiagnosed with another similar disorder [9]. Secondary adrenal insufficiency can be traced to a lack of ACTH, which causes a drop in the adrenal glands' production of cortisol but not aldosterone. This is most commonly found with overtraining in athletes. Symptoms are not usually apparent until over 90% of the adrenal cortex has been destroyed and very little adrenal capacity is left. This is due to the non-specific nature of symptoms and their slow progression. Symptoms are more times than not, often missed or ignored until physically stressful event or crisis, known as an Addisonian crisis, which is characterized by a sudden, penetrating pain in the lower back, abdomen, or legs, along with severe vomiting and diarrhea, followed by dehydration, low blood pressure and a loss of consciousness.

Symptoms of adrenal insufficiency includes the following

- Chronic, steadily worsening fatigue
- Severe fatigue/low stamina
- Irritability and depression
- Weakness/muscle spasm
- Loss of appetite/weight
- Increased pigmentation of the skin
- Inability to cope with stress
- Allergies
- Faintness and low blood pressure
- Nausea/vomiting
- Poor circulation
- Salt loss/salt cravings
- Painful muscles and joints
- Inability to digest food
- Hypoglycemia
- Intolerance to heat or cold
- Lowered resistance to infection

In the recovery from mild cases of adrenal insufficiency, if caught early, correction can occur in a matter of months. In more severe cases, complete correction may require several years; replacement therapy is not suggested in these cases if normal cortisol levels exist, as the body will cease to produce essential hormones naturally. Addison's disease requires lifetime replacement therapy of corticosteroids. The prognosis for those with Addison's disease is that with replacement medication every day, the individual can lead a normal crisis-free life. There are no specific physical or occupational restrictions, though an individual must learn their limitations and find coping methods for stress [10].

Chronic fatigue syndrome

Currently, there is no accepted theory as to what causes Chronic Fatigue Syndrome (CFS). Certain abnormalities are present in all patients, with a common feature of many patients being the underactivation of the Hypothalamic-Pituitary-Adrenal (HPA) axis, especially in response to stress [11]. A lower than normal variation in the normal circadian pattern of HPA axis activation has been discovered by researchers [12,13] who studied the under activation of the HPA axis in CFS patients directly.

Burnout is the body's protection mechanism against unnecessary and potentially dangerous long-term stress. It appears to be caused by under activation of the HPA axis CFS-severe burnout; characterized by the same symptoms and HPA axis disturbances as burnout [11,14,15]. All known cases of CFS begin with: long-term stress, negative mental

attitude to stress/illness/life or a severe viral illness; a large percentage of CFS patients share every trigger [16,17]. Mechanisms in the body act to limit HPA axis activation resulting in a reduced ability to cope with stress and a reduced motivation/energy level, causing the person to rest and conserve energy [7,16,18].

Exercise capacity in chronic fatigue syndrome

One study included a large cohort of female patients with CFS [13]. They performed a maximal test with graded increase on a bicycle ergometer. The RHR of the patient group was higher than controls, while MHR reported at exhaustion was lower. CFS patients had significantly decreased exercise capacity when compared with controls. Reaching the age-predicted target HR seemed to be a limiting factor of the patients with CFS in achieving maximal effort, which could be due to autonomic disturbances [19-21].

Research has found the maximal workload and oxygen uptake attained by patients with CFS using a bicycle ergometer [22]. RHR was higher in patients with CFS, suggesting that "alteration in cardiac function is a primary factor associated with the reduction in exercise capacity in CFS."

Baschetti [13,23,24] noted that CFS and AD share persistent fatigue and debilitation after exercise, but also reduction in cardiac dimensions and increased HR at rest. Similar research noted that adrenal insufficiency, rather than alteration in cardiac function, may primarily account for the reduction in exercise capacity in CFS [14,25]. An insufficient production of adrenal hormones results in impaired physical capacities. In patients with CFS (using a bicycle ergometer), working capacity, total volume of work done, and maximum oxygen consumption were lower in patients with AI [26].

Baschetti [11,27] studied viral reactivation and immunological abnormalities observed in patients with CFS. The abnormalities were accounted for by the cortisol deficiency that characterizes these patients. There are striking similarities between CFS and AD. The conviction that CFS is an AI similar to Addison's disease lies primarily in the fact CFS patients in the previous study recovered from chronic fatigue syndrome symptoms in the course of a few days with consumption of licorice [28,29], which is known to aid in the recovery of AI.

Similarity of symptoms in chronic fatigue syndrome and Addison's disease were again reported by Baschetti [28], through observation that AD is characterized by many CFS-like symptoms. This study revealed evidence of reduced adrenal production of cortisol, both basal and after activity, in patients diagnosed with CFS. Reasons why cortisol levels are lowered is unclear; many factors influence cortisol secretion, including changes in sleep, physical activity and appetite.

Chronic fatigue syndrome, decreased exercise capacity, and adrenal insufficiency

Baschetti [11] reported that working capacity, total volume of work done, and maximum oxygen consumption were lowered in patients with chronic AI, and noted that CFS shares 39 features with AI, including all the physical and neuropsychological. Others added to research by finding that CFS and AD share persistent fatigue and debilitation after exercise and found a reduction in cardiac dimensions and an increased heart rate at rest in both patients [30,31].

CFS and AI patients both share a reduction in exercise capacity. This reduction in exercise capacity in CFS is primarily due to adrenal insufficiency. It is possible that there may be an overlap of CFS with Addison disease, and other related adrenal disorders.

Overtraining syndrome

Overtraining Syndrome (OS) is also described as a form of chronic fatigue, burnout and staleness. It is defined as an imbalance between training/competition, versus recovery. Training alone is seldom the primary cause. OS appears to be caused by the total amount of stress on the athlete exceeding their capacity to cope

Gastmann et al. [4,32], and Budgett [2,33] were among the first researchers to find that severe overtraining over an extended period can result in AD. They described an Addison-Type overtraining syndrome, where adrenal glands are no longer able to maintain proper hormone levels, and athletic performance is severely compromised. Lehmann et al. [34-36] described the autonomic imbalance hypothesis and its relationship with OS. He suggested that prolonged training produces an autonomic imbalance. During heavy endurance training or over-reaching periods, there is evidence of reduced adrenal responsiveness to ACTH, which is compensated by an increased pituitary ACTH release. During the early stages of OS, despite increased pituitary ACTH release, the decreased adrenal responsiveness is no longer compensated and the cortisol response decreases. During the advanced stage of OS, the pituitary ACTH release also decreases [37].

ACTH response

Researchers [21,38] found reduced ACTH-stimulated adrenal cortisol release in chronically fatigued horses, while human models being noted significantly increased ACTH plasma concentrations in ultra marathoners during an early morning period between 3 and 8 am [39,40]. Cortisol plasma levels or 24-h renal cortisol excretions did not show any significant differences. This may point to decreased adrenal responsiveness to ACTH.

The decreased adrenal responsiveness can be the consequence of an overload during heavy preparatory training sessions before the ultra marathon, the ultra marathon stress itself, and incomplete regeneration [25,41].

Lehmann has conducted extensive research on the adrenal axis and OS [3,5,6,34-37,42]. He found a 60-80% higher pituitary CRH-stimulated ACTH response in experimentally over trained athletes in an early stage of OS. The increased response could no longer prevent reduced cortisol response compared to baseline. Measurements were still amplified after 2 weeks of incomplete regeneration. The decreased adrenal responsiveness was no longer completely compensated by increased pituitary ACTH response. Lehmann also found decreased exercise-related maximum cortisol levels observed in over trained distance runners [3,5,42] and in recreational athletes [36] when compared to baseline.

Research has uncovered significantly decreased pituitary ACTH response in over trained distance runners, which reflects a decreased hypothalamic and/or pituitary responsiveness and a reduced adrenal responsiveness to ACTH [8,16]. Researchers commonly describe a decreased pituitary release of growth hormone [43-45]. These findings are paralleled by clearly reduced adrenal cortisol response as also observed in chronically fatigued horses [8] and in over trained human athletes [5,35-37,42]. This is characteristic of an advanced stage in the overtraining process.

Gastmann and lehmann [4,32] observed a reduced pituitary

ACTH response to CRH in experienced road cyclists. The study was performed at the end of a heavy road pacing season after an additional 2-wk high-volume training stress without a preceding regeneration period. Researchers found an impaired pituitary hormonal response to exhaustive exercise in over trained endurance athletes. Urhausen et al. [41] studied short-term exhaustive endurance test on a cycle ergometer at intensity 10% above anaerobic threshold. In OS, the time to exhaustion was significantly decreased by 27% on average. Lower maximal exercise-induced increase of the ACTH and growth hormone was discovered, as well as a trend for a decrease of cortisol and insulin Hypothalamo-pituitary dysregulation during OS was expressed by an impaired response of pituitary hormones to exhaustive short-endurance exercise.

ACTH response summary

There is evidence of a reduced adrenal responsiveness to ACTH in the stage of overreaching or early OS. Reduced responsiveness is initially compensated by an increased pituitary ACTH response. This reduction is no longer compensated in an early stage of an Addison-type overtraining syndrome, thus, the cortisol response decreases. A decreased hypothalamic/pituitary responsiveness (CRH) is common in an advanced stage of Addison overtraining syndrome.

Conclusion

CFS could be caused by or mistaken for AI. There is commonly a decrease in exercise capacity in CFS, which may be result of AI. Overtraining may contribute to or even cause AI. Cortisol levels are lowered and ACTH is increased during overtraining, while a reduced responsiveness to ACTH, and a reduced responsiveness to CRH are found. If the physical stress of overtraining is not removed, adrenal issues may continue or become more severe. Severely over trained athletes may develop Addison's Disease.

Overtraining Syndrome (OS) has been described as chronic fatigue, burnout and staleness, where an imbalance between training/competition, versus recovery occurs. Training alone is seldom the primary cause. In most cases, the total amount of stress on the athlete exceeds their capacity to cope. A triggering stressful event, along with the chronic overtraining, pushes the athlete to start developing symptoms of overtraining syndrome, which is far worse than classic overtraining. Overtraining can be a part of healthy training, if only done for a short period of time. Chronic overtraining is what leads to serious health problems, including adrenal insufficiency.

Severe overtraining over an extended period can result in adrenal depletion [46-48]. An Addison- Type overtraining syndrome, where the adrenal glands are no longer able to maintain proper hormone levels and athletic performance is severely compromised has been described by researchers [11,13,49-51]. Other studies have suggested the autonomic imbalance hypothesis is what happens in overtraining syndrome [32,34]. This suggests that prolonged training produces an autonomic imbalance, and during heavy endurance training or over-reaching periods, there is evidence of reduced adrenal responsiveness to ACTH. This is compensated by an increased pituitary ACTH release. During the early stages of OS, despite increased pituitary ACTH release, the decreased adrenal responsiveness is no longer compensated and the cortisol response decreases. In the advanced stage of OS, the pituitary ACTH release also decreases.

Decreased adrenal responsiveness can be the consequence of an overload during heavy preparatory training sessions before an ultra marathon, for example, or the ultra marathon stress itself, and incomplete regeneration. If a runner continues to chronically overload the adrenals, OS will occur.

There is evidence of a reduced adrenal responsiveness to ACTH in the stage of overreaching or early OS [52-54]. This reduced responsiveness is initially compensated by an increased pituitary ACTH response. No longer compensated in an early stage of an Addison type overtraining syndrome; the cortisol response decreases. A decreased hypothalamic/pituitary responsiveness (CRH) will be present in an advanced stage of Addison overtraining syndrome.

Recent research has suggested new avenues for further research including influences from gene expression [55], injury [56], tissue damage markers [57], and computer diagnostics [58]. Overall, prevention, proper nutrition, balancing training and recovery, and stress-management are all important factors to consider in competitive athletes, as well as recreational athletes. Knowing the signs and symptoms of OS can help aid in intervention, which may prevent adrenal complications.

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