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Stress and the neuroendocrine system: implications for animal well-being

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Abstract

This article presents an overview of stress and its impacts on the neuroendocrine system as well as on animal well-being. Anything that poses a challenge or threat to well-being is stress. It is a state of threathened homeostasis. An agent or stimulus that causes stress is a stressor. A stressor is a powerful activator of the neuroendocrine system, provided it is of sufficient intensity and/or duration. The neuroendocrine system is one of the most responsive physiological systems to stressors. This responsiveness occur since the neuroendocrine system is a key signaler and modulator of many of the other physiological systems attempting to accommodate stressors and re-establish homeostasis. A persistent threat to homeostasis may lead to prolonged hyperactivity of the neuroendocrine system which impairs rather than contribute to well-being. Long-term stress results in adrenal fatigue, neurotransmitter imbalances or deficiencies and hormone imbalance. When the endocrine system is not functioning properly, an animal can not cope with stress effectively. This results in a vicious cycle where the weakened endocrine system creates more stress and the higher levels of stress continuously weaken the endocrine system the more. The solution is to reduce as much as possible and find ways of coping and managing the stress that cannot be removed.

Keywords

Stress, Neuroendocrine System, Hormones, Adrenal Gland

1. Introduction

The word “stress” is actually a very ambiguous term, as many different definitions can be applied, depending upon the scientific focus and discipline that is under study (Hackney, 2006). Stress is defined as “a real or interpreted threat to the physiological or psychological integrity (i.e., homeostasis) of an individual (animal) that results in physiological and/or behavioural responses” (McEwen, 1998; McEwen, 2000; McEwen, 2005; Hackney, 2006). Stressors have profound impacts upon the physiological workings of the animal’s body. One physiological system that is extremely reactive to stress is the neuroendocrine system (McEwen, 2000; McEwen, 2005; Hackney, 2006). The nervous and endocrine systems interact extensively to form the neuroendocrine system. The neuroendocrine system (NES) of vertebrates can be defined as a set of cells organized in single organs and diffuse elements sharing co-production of amine hormone/transmitters, peptide hormone/transmitters and specific markers of neural determination. In this perspective, the hypothalamic-pituitary-target organ axis (H-P axis), the autonomic nervous system (ANS) and the diffuse neuroendocrine system contribute to the neuroendocrine system (NES) (Toni, 2004). The neuroendocrine system is formed by the diffuse neuroendocrine system and the endocrine system (Canadian Cancer Society, 2013). The neuroendocrine system is made up of a network of cells distributed throughout the body. The word neuroendocrine refers to two qualities of these cells: they have a similar structure to nerve cells (neurons) and produce hormones like endocrine cells (Canadian Cancer Society, 2013). The nervous and endocrine systems act together to regulate the physiological processes of the animal’s body. Neuroendocrine cells release hormones into the blood stream in response to chemical signals from other cells or messages from the nervous system (Canadian Cancer Society, 2013).

According to Hackney (2006), regardless of which theoretical model of stress and stress response a researcher subscribes to the neuroendocrine system is regarded by all as one of the most responsive physiological systems to stressors. This responsiveness occur since the neuroendocrine is a key signaler and modulator of many of the other physiological systems attempting to accommodate stressors and re-establish homeostasis (McEwen, 2000; McEwen, 2005). All the hormones that are substantially affected by stress could be considered as stress response hormones (i.e. mediators). However, a majority of stress researchers focus upon the hormones associated with the sympathetic nervous system and the hypothalomo-pituitary-adrenocortical-adrenomedullary systems as key responders when attempting to quantify and evaluate the neuroendocrine stress response (Hackney, 2006). And what are considered by most scientists as the key hormones of these systems are norepinephrine, epinephrine, adrenocorticotropic hormone (ACTH) and cortisol (Young *et al.,* 2004; Goldstein, 2003; Charmandari *et al.,* 2005; Tsigos *et al.,* 2006; Hackney, 2006). The primary physiological factor that seems to determine the neuroendocrine stress response to a single acute stress is the volume of exposure, where volume is comprised of intensity and/or duration of the stressor (Glabo, 1983; Viru, 1985; Viru, 1992; Brooks *et al.,* 1996; McMurray and Hackney, 2000). The greater the intensity and/or duration of the stressor, the greater the neuroendocrine response, observed in most but not all cases (provided that other modifying factors such as nutrition, age, sex, environmental condition, circadian rhythm etc., do not come to play).

Studies suggest that the neuroendocrine stress response to an acute stressor appears very transient in nature, and during the recovery from stress, the hormonal levels return to baseline or slightly below basal values relatively rapidly (Hackney, 2006). Typically, prolonged endocrine disturbances only accompany stressful events. Reduced hormonal concentration is seen for the resting basal levels in many situations (Crews and Landers, 1987; Blair *et al.,* 1996; McMurray and Hackney, 2000). However, an augmented stress response to maximal stressful events can actually occur. This greater hormonal responsiveness appears to be due to both the fact that the absolute workload necessary to elicit a maximal response is much greater and there being a glandular adaptation resulting in an enhanced hormonal secretory capacity (Deutser *et al.,* 1989; Kjaer *et al.,* 1992; Korkushko *et al.,* 1995; Park *et al.,* 2005). Chronic exposure to psychosocial, environmental or traumatic stressors can have long-lasting, deleterious effects on an animal's psychological and physiological health (Blair *et al.,* 1995; Borer, 2003; Traustadottir *et al.,* 2005).

Thus, the aim of this review is to examine the effects of stress on animal's neuroendocrine system and on animal well-being as a whole.

2. Stress, Stressors and Stress Response

'Stress', 'stressors' and 'stress response' are terms which represent concepts rather than being precisely definable. No single theory of stress has been universally accepted. Selye General Adaptation Syndrome of stress remains the primary theory for the basis of stress research in food-producing animals; however, other concepts and theories have been developed (Becker, 1987). According to Friend (1991), many researchers view stress theory as having evolved from a specific response of each specific stimulus, through a standardized general adaptation syndrome for a wide variety of stressors, to a newly hypothesized model that suggests a standardized physiological response to stressors.

Nordqvist (2013) reported that anything that poses challenge or threat to well-being is stress. Stress is the feeling an animal has when under pressure. According to Etim *et al.* (forthcoming), stress is an animal's response to a stressor such as environmental condition or a stimulus. Stress is a body's way to react to a challenge. Stress typically describes a negative condition or positive condition that can have impact on an animal's mental and physical well-being. Stress can be positive or negative, but either one triggers the body's biological stress response in the same way and the impact of the body is the same (Perkins, 2012). A little stress is needed for maturation and to maintain neuroplasticity of the brain, however, stress can be dangerous or unhealthy if animals are subjected to it too often or for an extended period of time, and may result in impairment of the nervous system (Perkins, 2012).

A stressor is anything that disrupts the body's physiological balance. A stressor is an agent or stimulus that causes stress (Nordqvist, 2013). Stressors can originate from within an individual (endogenous) or from the environment (exogenous). A sense of control over one's environment (exogenous stimuli) and predictability of stimuli are extremely important in determining the potency of psychological stressors (Friend, 1991). Stress response is the body's adaptation to stressors. The stress response includes two endocrine responses (from the same endocrine gland – the adrenal). The adrenal cortex and adrenal medulla play major roles in response to stress. In general, stress activates nervous and endocrine responses that prepare the body for physical activity even when physical activity is not the most appropriate response to stressful condition. The stress response is subserved by the stress system, which is located both in the central nervous system and the periphery. The principal effectors of the stress system include corticotrophin-releasing (CRH); arginine vosopressin; the proopiomelanocortin-derived peptides alpha-melanocyte-stimulating hormone and beta-endorphin, the glucocorticoids; and the catecholamines, norepinephrine and epinephrine (Charmandari *et al.,* 2005). The rapid, short-term response to stress called the fight-or-flight response, is carried out by hormones epinephrine and norepinephrine. The long-term response to stress, which is an endocrine rather than a nervous system, response is mediated by the adrenal cortex (Boundless, 2013). According to Ulrich-Lai and Herman (2009), the survival and well-being of all species requires appropriate physiological responses to environmental and homeostatic challenges. The re-establishment and maintenance of homeostasis entails the coordinated activation and control of neuroendocrine and autonomic stress systems. These collective stress responses are mediated by largely overlapping circuits in the limbic forebrain, the hypothalamus and the brain stem, so that the respective contributions of the neuroendocrine and autonomic systems are tuned in accordance with stressor modality and intensity. According to Etim *et al.* (forthcoming), physiological stress represents a wide range of physical responses that occur as a direct effect of stressor causing an upset in the homeostasis of the body. One physiological system that is extremely reactive to stress is the neuroendocrine system, many researchers use the responses of the neuroendocrine system to assess the stress effects and reactivity of the animal’s body. Hackney (2006) reported that the neuroendocrine system is regarded by all as one of the most responsive physiological systems to stress since it is a key modulator of many other physiological systems attempting to accommodate stress and re-establish homeostasis (McEwen, 2000; McEwen, 2005). Upon immediate disruption of either psychological or physical equilibrium, the body responds by stimulating the nervous, endocrine and immune systems. The reaction of these systems causes a number of physical changes that have both short and long term effects on the body (Etim *et al.,* forthcoming). Responses to stress illustrate the close relationship of the nervous and endocrine systems and provide an example of their integrated functions. An animal’s ability to respond to stressful conditions depends on the nervous and endocrine responses to stress. Although, responses to stress are adaptive under many circumstances, they can become harmful. For example, if stress is chronic, the elevated secretion of cortisol and epinephrine produces harmful effects. Appropriate responsiveness of the stress system to stressor is a crucial prerequisite for a sense of well-being, adequate performance of tasks, and positive social interactions. By contrast, inappropriate responsiveness of the stress system may impair growth and development and may account for a number of endocrine, metabolic and autoimmune disorders. The development and severity of these conditions primarily depend on the genetic vulnerability of the animal, the exposure to adverse environmental factors, and the timing of the stressful events, given that prenatal life and the period before maturity are critical periods characterized by increased vulnerability to stressors (Charmandari *et al.,* 2005).

3. Mechanism of Stress and Stress Response

A complex interaction of direct influences and indirect feedback mechanisms among the sympathetic nervous system (SNS), the hypothalamus, the pituitary gland and the adrenal glands contribute to the neuroendocrine regulation involved in reactions to stress among other processes (Boundless, 2013).

3.1. Stress and the Sympathetic Nervous System (SNS)

As documented by Boundless (2013) the sympathetic nervous system is the part of the autonomic nervous system that under stress raises blood pressure and heart rate, constricts blood vessels and dilates the pupil. The SNS is known for its role in mediating the fight-or-flight response. This response is also referred to as the sympatho-adrenal response.

3.2. Stress and the Endocrine System

Stress endocrinology is an evolving area of study with many exciting research questions to challenge scientists (Hackney, 2006). As stated by Zimmerman (2013), the word “endo” meaning within and crinis meaning secrete. According to Zimmerman (2013) the endocrine system is the collection of glands each of which secrete different types of hormones. Betterhealth Channel (2012) documented that the endocrine system is made up of glands that secrete chemicals called “hormones” into the blood or surrounding tissues. Guyton and Hall (2006) reported that hormones are chemical messengers that are transported in the extracellular fluid to all parts of the body to help regulate cellular function. According to International labour Organization (ILO) (2006) the endocrine system and the hormones it generates and controls is critical to healthy growth and development, especially sexual differentiation in humans and animals. Zimmerman (2013) posited that each of the endocrine gland secretes hormones that regulate metabolism, growth development, tissue function, sexual function, reproduction, among others. Studies by Betterhealth Channel (2012) indicated that the endocrine system together with the nervous system helps the body cope with events and stresses. Some of the roles of the endocrine system include growth, repair, sexual reproduction, digestion and homeostasis (Constant internal balance). The endocrine system is a tightly regulated system that keeps the hormones and their effects at just the right level. One way of achieving this is through “feedback loops”. The release of hormone is regulated by other hormones, protein or neural signals (Betterhealth Channel, 2012). Complex feedback mechanisms involving the nervous system, endocrine system and diffuse neuroendocrine system control the levels of hormones in the body (Canadian Cancer Society, 2013).

3.3. Maintenance of Homeostasis

For an organism to function normally and effectively, it is necessary that the biochemical processes of its tissues operate smoothly and conjointly in a stable setting. The endocrine system provides an essential mechanism called homeostasis that integrates body activities and at the same time ensure that the composition of the body fluids bathing the constituent cell remains constant. Hormonal systems also provide for the homeostasis of nutrients and fuel that are needed for body metabolism (Schwartz, 2013).

3.4. Adaptive Stress Response

Throughout life, the endocrine system and the hormones it secretes enhance the ability of the body to respond to stressful internal and external stimuli. The endocrine system allows not only the individual organism but also the species to survive. Anciently threatened animals and humans respond to stress with multiple physical changes, including endocrine changes that prepare them to react or retreat. This process is known as the “fight-or-flight” response. Endocrine changes associated with the response include increased secretion of cortisol by the adrenal cortex, increased secretion of glucagon by the islet cells of the pancreas and increased secretion of epinephrine and norepinephrine by the adrenal medulla. Adaptive responses to more prolonged stress occur. For example, in states of starvation or malnutrition, there is reduced production of thyroid hormone, leading to a lower metabolic rate. A lower metabolic rate reduces the rate of consumption of the body’s fuel and thus, reduces the rate of consumption of the remaining energy stores. This change has obvious survival value since death from starvation is deferred. Malnutrition also causes a decrease in the production of gonadotropin and sex steroids, reducing the need for fuel to support reproductive processes (Schwartz, 2013).

3.5. How Stress Affects the Endocrine System

As reported by Mcquillan (2008), the hormonal cascade of the fight-or-flight response which is the emotional aspect of stress response propagates through three main steps:

1) Stimulation of the hypothalamus by the amygdala causes the release of corticotrophin releasing factor (CRF).
2) CRF then stimulates the pituitary gland causing release of adrenocorticotrophin (ACTH) into the blood stream.
3) ACTH travels through the blood stream and stimulates the adrenal glands causing the release of epinephrine and glucocorticoids including cortisols.

Epinephrine (adrenaline) has the following effects:

- Dilates pupils, increases heart rate, stroke volume and blood pressure (blood flow may actually increase 300 – 400% in some cases), constricts arterioles which serve the internal organs and the skin, dilates arterioles which serve the legs, stimulate release of glucose from body stores through two pathways:
- Glycolysis: Splits glycogen stores to release glucose into the blood stream.
- Fat metabolism is increased which also releases glucose into the blood stream.
- Suppresses immune system, increases breathing rate.

Cortisol and other glucocorticoids have the following effects; increase blood pressure, stimulate release of glucose from body stores through three pathways.

- Glycolysis: splits glycogen stores to release glucose into the blood stream.
- Fat metabolism is increased which also releases glucose into the blood stream.
- Protein is broken down.

Inhibits conversion of glucose into glycogen (glycogenesis) anti-inflammatory effects, slows down healing, suppresses immune system, inhibits secretion of CRH (creating negative feedback cycle), inhibits bone formation. Klein (2004) posited the involvement of many other biochemicals in stress response: cytokines, vasopressin, vasoactive intestinal polypeptide, neuropeptide Y, substance P, serotonin, dopamine, nitric oxide, cholecysokinin, estrogen and progesterone.

Boundless (2013) reported that the Hypothamic-Pituitary-Adrenal (HPA) axis is an endocrine cascade that mediates several aspects of physiological stress including response to acute stressors (i.e. fight-or-flight response) but also causes chronic stress. The glucocorticoids of the HPA axis have many functions, including modulation of stress reactions, but in excess they may be damaging. Researchers have hypothesized that the hormonal changes brought about by stress may contribute to the neural atrophies seen in many neurodegenerative disease states (Boundless, 2013).

4. Implications of Stress for Animal Well-Being

4.1. Effects of Acute Stress

Acute stress is an immediate reaction to a stressful situation. The physical effects of this kind of immediate stress range from an increased heartbeat to shallow breathing. This is because there is a greater flow of oxygen into the body. All these happen because of the release of adrenaline – the body’s main stress hormone. There is also the release of cortisol, another stress hormone by the adrenal gland. Cortisol raises blood pressure and blood sugar. The liver begins to manufacture glucose to provide the animal with extra energy. After the stress, the animal may become physically weak, because of the extra glucose burned off leaving a low supply of sugar. The key to combating acute stress is to reach a point of homeostasis, then the blood pressure and blood sugar return to normal state, together with the heart rate (Betterhealth Channel, 2012; Discovery Fit and Health, 2013).

4.2. The Role of the Hypothalamic-Pituitary-Adrenal Axis and the Sympathetic Nervous System in Models of Acute Stress in Farm Animals

Minton (1994) reported that in response to stressors, the central nervous system of farm animals (and other mammalian species) evokes physiological responses that ultimately result in activation of the hypothalamo-pituitary-adrenocortical (HPA) axis and the sympatho-adrenal axis. The responses of these major systems are presumed to have adaptive and homeostatic value during periods of stress. The major hormone regulating the synthesis and secretion of the adrenal glucocorticoids is ACTH (Adrenocorticotrophic hormone). In sheep, cattle and pigs, CRH is the more potent peptide, whereas vasopressin (VP) is the more potent in sheep. In addition to its better known role in regulating pituitary function, CRH also may participate as a neurotransmitter acting centrally to enhance sympathetic activation of the adrenal medulla. Minton (1994) reported that many experimental models of stress have been evaluated that reliably activate the HPA axis and the sympatho-adrenal medullary axis, and some of these model systems also reduce functions of cells of the immune system. Recent data from research conducted by Minton (1994) support an important role of stressor-activation of the sympathetic rather than increased glucocorticoids per se in modulating some measures of immune function in response to stress. Thus, current dogma of glucocorticoids as the primary mediator of stressor-associated alteration in immune function of domestic livestock may require re-evaluation (Minton, 1994).

4.3. Effects of Chronic Stress

Chronic psychological stressors are the most problematic area of stress research and animal care. Chronic stress is a stress of prolonged and continuous stress and has drastic effects on the body of the animal (Bryant, 2013). Animals may respond behaviourally to chronic stressors by either achieving adaptation or by showing such conditions as learned helplessness, intensification of drives, stereotyped behaviour and absence of normal behaviours. A chronic endogenous buildup of motivation to perform specific behaviours that an animal has been prevented from performing can be quantified and result in animal displaying signs of chronic stress, i.e., altered metabolism (hormones), suppressed immune system and learned helplessness (Friend, 1991).

The sympathetic nervous system that helps deal with fight-or-flight response is always turned on. But in this case, (chronic stress) the animal is not facing an immediate danger and then comes down from achieving homeostasis. It is not good for the animal's body to be in constant state of danger management. The liver normally monitors the release of the stress hormone cortisol and other corticoids by the adrenal gland. But when an animal is chronically stressed, the liver is by passed and the corticoids run rampant (Bryant, 2013).

The three most serious and common effects from long-term stress are adrenal fatigue, neurotransmitter imbalances or deficiencies and hormone imbalance. Each of these conditions leads to a list of debilitating symptoms. Neurotransmitters play a vital role in overseeing practicing all systems and functions of the animal's body like weight regulation, appetite, perception of pain etc. When homeostasis is not maintained, then a variety of psychological and physiological disturbances occur. The adrenal glands, along with the hypothalamus and pituitary are one of the main organs involved in stress response systems. If they are not functioning adequately, then the ability to cope with stress adequately is lost (Perkins, 2013). Adrenal fatigue occurs when the adrenal glands become exhausted from too much stress and then they can no longer perform their functions as required which leads to problem regulating blood sugar, the immune system, inflammation, blood pressure and managing stress and fatigue. The animal is left vulnerable to chronic pain disorder, immune system conditions, and many more. Hormones also have a crucial role in regulating psychological and physical health like metabolism, development and more are extremely sensitive to high levels of stress. When thrown out of balance by stress, they result in numerous disruptive and debilitating symptoms (Perkins, 2013). As documented by Abovestress (2013), long term chronic stress disorders are serious matters which can lead to other serious health conditions associated with endocrine or hormonal system e.g., thyroid dysfunction, inflammation etc. Hormonal imbalance is one of the three most serious common effects of long-term stress. Hormones play a crucial part in regulating physical health including metabolism, sexual function and development among others. Some of the most common effects of stress on the animal's body include aggressive behaviour, respiratory interference among others and all these affect the well-being of farm animals.

4.4. Stress and Immunity

Another of the most significant effects of stress is that it suppresses and weakens the immune system, leaving the animal's body vulnerable to colds, flu and other possible health conditions. According to Bryant (2013), too many corticoids, produced when an animal is chronically stressed, can lead to a reduction in the immune system and the animal gets sick easily. The body's reaction to stress also lowers the body's white blood cell count which reduces the systems ability to heal itself. Abovestress (2013) reported that one of the body's responses to stress is the release of regulatory hormones from the pituitary and cortisol from the adrenal glands. In short term, these biochemical responses are beneficial, releasing sugars, adjusting insulin, boosting immune system and against inflammation and allergies. Chronic or intense stress disrupts this delicate balance of biochemistry. Sex hormones can be inhibited.

Endocrine problems may become activated Bryant (2013) stated that too much corticoids produced as a result of chronic stress make the body more resistant to another of its hormone adrenaline. According to Minton (1994), current dogma of glucocorticoids as the primary mediator of stressor associated alteration in immune function of domestic livestock may require re-evaluation.

However, when the endocrine system is not functioning properly, an animal can not cope with stress effectively. This results in a vicious cycle where the weakened endocrine system creates more stress and the higher levels of stress continuously weaken the endocrine system the more. The solution is to reduce the stress as much as possible and find ways of coping and managing stress that cannot be removed (Perkins, 2013). Tsigos and Chrousos (2002) reported that the stress system coordinates the adaptive responses of the animal to stressors of any kind. Minton (1994) documented that the responses of the major systems (HPA axis and the sympatho-adrenal axis) are presumed to have adaptive and homeostatic value during periods of stress. According to Tsigos and Chrousos (2000) activation of the stress system leads to behavioural and peripheral changes that improve the ability of an animal to adjust homeostasis and increases its chances for survival. And Friend (1991) documented that the performance of highly repetitive, stereotyped behaviours has been shown to help animals cope with environment containing little or unvaried stimulation. Kumar *et al.* (2013) reported that with a better understanding of the basic biology, altered physiological processes involved in stress adaptability, it would be possible to develop methodologies for selection of animals with better performance and devise strategies for animal welfare.

5. Conclusion

A stressor is a powerful activator of the neuroendocrine system, provided it is of sufficient intensity and/or duration. The neuroendocrine stress response to stressors appear to be directly proportional to the volume of exposure (i.e., intensity and/or duration of exposure to stressors). Acute stress enables the neuroendocrine system to respond and prepare the body for anticipated needs, both in the present and future challenges. However, chronic exposure to stressors allows adaptation and accommodation within the neuroendocrine system, such that the stress response to subsequent acute stressor is lessened. If the stressor presents a challenge beyond the ability of the neuroendocrine system to compensate, there can be more prolonged and profound disruption of homeostasis and a decrement in the function of other bodily systems or the animal as a whole thereby affecting animal well-being. The solution is to reduce as much as possible and then find ways of coping and managing stress that cannot be removed.

References

[1] Above Stress (2012). How does stress cause symptoms related to your endocrine system? Stress tracker. Available at: abovestress.com/stress-symptoms/end

[2] Becker, B. A. (1987). The phenomenon of stress: Concepts and mechanism associated with stress-induced responses of the neuroendocrine system. Vet. Res. Commun., 11(5): 443-56.

[3] Betterhealth Channel (2012). Hormonal (endocrine system). Available at: www.betterhealth.vic.gov.au/bhcv2/bhcarticles.nsf/pages

[4] Blair, S. N., Kampert, J. B., Kohl, H. W. (1996). Influence of cardio respiratory fitness and other precursors on cardiovascular disease and all cause mortality in men and women. JAMA; 276(3): 205-210.

[5] Borer, K. T. (2003). Exercise endocrinology, IL, USA: Human Kinetics Publishing, pp. 77-96.

[6] Boundless (2013). Stress. Available at: www.boundless.com

[7] Brooks, G. A., Fahey, T. D., White, T. P. (1996). Exercise physiology: Human bioenergetics and its application, (2nd edition). Toronto, Canada: Mayfield Publishing; 1996. Neural-endocrine control of metabolism; pp. 56-196.

[8] Bryant, C. (2013). What are the physical effects of stress? Available at: www.health_howstuffworks.com>Discoveryfitandhealth>wellness>stressmanagement.

[9] Canadian Cancer Society (CCS) (2013). Anatomy and Physiology of the neuroendocrine system. Available at: www.cancer.ca/../%3fregion%3Dnu

[10] Charmandari, E., Tsigos, C. and Chrousos, G. (2005). Endrinology of the stress response. Ann. Rev. Physiol. 67:259-284.

[11] Chrousos, C. P. and Gold, P. W. (1992). The concept of stress systems disorders: Overview of physical and behavioural homeostasis. JAMA, 267:1244-1252.

[12] Crews, D. J., Landers, D. M. (1987). A meta-analytic review of aerobic fitness and reactivity to psychosocial stressors. Med. Sci. Sports Exerc. 19(5): 5114-5120.

[13] Deuster, P. A., Chrousos, G. P., Luger, A. (1989). Hormonal and metabolic responses of untrained, moderately trained, and highly trained men to three exercise intensities. Metabolism, 38(2):141-148.

[14] Discovery Fit and Health (2013). Physical effects of acute stress. Available at: www.health_howstuffworks.com>Discoveryfitandhealth>wellness>stressmanagement

[15] Etim, N. N., Evans, E. I., Offiong, E. E. A. and Akpabio, U. (Forthcoming). Endocrine system: indicators of stress and a means of evaluating animal welfare. European International Journal of Science Technology.

[16] Friend, T. H. (1991). Behavioural aspects of stress. J. Dairy Sci., 7(1): 292-303.

[17] Galbo, H. (1983). Hormonal and metabolic adaptation to exercise. Stuttgart, Germany: Georg Thieine Verlag; pp. 2-117.

[18] Goldstein, D. S. (2003). Catecholamines and stress. Endocrine Reg. 37:69-80.

[19] Guyton, A. C. and Hall, J. E. (2006). Textbook of Medical Physiology. 11th Ed. Philadelphia. Pa: Elsevier.

[20] Hackney, A. C. (2006). Stress and the neuroendocrine system: The role of exercise as a stressor and modifier of stress. Expert Rev. Endocrinology Metab., 1(6): 783-792.

[21] International Labour Organization (ILO) (2006). Taking Child Labour in Agriculture, Guidance and Policy and Practice. ILO Publications. International Labour Office, Ch. 1211, Geneva 22, Switzerland.

[22] Kjaer, M., Mikines, K. J., Linstow, M. V., Nicolaisen, T., Galbo, H. (1992). Effect of 5wk of detraining on epinephrine response to insulin-induced hypoglycaemia in atheletes. J. Appl. Physiol; 72(3): 1201-1204.

[23] Klein, J. (2004). Involvement of other biochemicals; How does stress affect endocrine system. WikiEducator. Available at: wikieducator.org/How_stress_affects the endocrine system.

[24] Korkushko, O. V., Frolkis, M. V., Shatilo, V. B. (1995). Reaction of pituitary-adrenal and autonomic nervous system to stress in trained and untrained elderly people. J. Auton. Nerv. Syst. 54(1):27-32.

[25] McEwen, B. S. (1998). Protective and damaging effects of stress mediators. N. Eng. J. Med. 338(3): 171-179.

[26] McEwen, B. S. (2000). Stress, definition and concepts of. In: Fink G., editor Encyclopedia of stress, Volume 3 CA USA: Academic Press, pp. 508-509.

[27] McEwen, B. S. (2005). Stressed or stressed out: What is the difference? J. Psychiatry Neurosci. 30(5): 315-318.

[28] McMurray, R. G., Hackney, A. C. (2000). Endocrine responses to exercise and training. In: Garrett, W., editor. Exercise and Sport Science. PA, USA: Lipincott Williams and Wilkins, pp. 135-162.

[29] Mcquillan, D. (2008). How stress affect the endocrine system. WikiEducator. Available at: wikieducator.org/How_stress_affects the endocrine system.

[30] Melinda Smith, M. A., Robert Segal, M. A. and Jeanne, S. (2013). Stress, symptoms, signs and causes. Help guide.org.

[31] Minton, J. E. (1994). Function of the Hypothalamic-pituitary-adrenal axis and the sympathetic nervous system in models of acute stress in domestic farm animals. J. Anim. Sci., 72(7): 1891-8.

[32] Nordqvist, C. (2013). What is stress? How to deal with stress. Medical News Today.

[33] Park, E., Chan, O., Li, Q. (2005). Changes in basal hypothalamic-pituitary-adrenal activity during exercise are centrally mediated. Am. J. Physiol. 289: R1360-R1371.

[34] Perkins, C. (2012). The effects of stress on health. Holistic help. Available at: www.holistichelp.net/effectsofstress.

[35] Schwartz, T. B. (2013). The endocrine system and human system. Encyclopaedia Brittanica Inc.

[36] Toni, R. (2004). The neuroendocrine system: organization and homeostatic role. J. Endocrinol Invest. 27(6 supp.):35-47.

[37] Traustadottir, T., Bosch, P. R., Matt, K. S. (2005). The HPA axis response to stress in women: Effects of aging and fitness. Psycho-neuroendocrinol; 30:392-402.

[38] Tsigos, C. and Chrousos, G. P. (2002). Hypothalamic-pituitary-adrenal axis, neuroendocrine factors and stress. J. Psychosom. Res., 53(4): 865-71.

[39] Tsigos, C., Kyron, I., Chrousos, G. (2006). Stress, endocrine physiology and pathophysiology. Available at: www.endotext.com/adrenal.

[40] Ulrich-Lai, Y. M. and Herman, J. P. (2009). Neural regulation of endocrine and autonomic stress responses. Nat. Rev. Neurosci., 10(6): 397-409.

[41] Viru, A. (1985). Hormonal ensemble in exercise-hormones in muscular activity, Volume 1. FL, USA: CRC Press, pp. 34-96.

[42] Viru, A. (1992). Plasma hormones and physical exercise. Int. J. Sports Med., 13:201-209.

[43] Young, E., Abelson, J., Lightman, S. L. (2004). Cortisol pulsatility and its role in stress regulation and health. Front Neuroendocrinol, 25:69-76.

[44] Zimmerman, K. A. (2013). Endocrine system, facts, functions and diseases. Live Science. Available at: www.livescience.com/26496_endocrinesystem_facts_functions_and_diseases.