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Stress hormones in health and illness: The roles of work and gender

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Summary Two neuroendocrine systems are of specific interest in the study of stress and health; the sympathetic adrenomedullary system with the secretion of epinephrine and norepinephrine, and the hypothalamic pituitary adrenocortical (HPA) system with the secretion of cortisol. These hormones have often been used as objective indicators of stress in the individual. However, through their bodily effects, they are also a link between the psychosocial environment and various health outcomes. From a series of studies of women and men, it was concluded that gender roles and psychological factors are more important than biological factors for the sex differences in stress responses.

The stress responses have been important for human and animal survival and for protection of the body. However, in modern society, some of these bodily responses may cause harm rather than protection. The catecholamines have been linked to cardiovascular disorders such as hypertension, myocardial infarction and stroke, cortisol to cardiovascular disease, Type 2 diabetes, reduced immune function and cognitive impairment.

An adequate balance between catabolic (mobilization of energy) and anabolic processes (growth, healing) is considered necessary for long term health and survival. In modern society, which is characterized by a rapid pace of life, high demands, efficiency and competitiveness in a global economy, it is likely that lack of rest, recovery and restitution is a greater health problem than the absolute level of stress.

1. Stress hormones

Two neuroendocrine systems have been of specific interest in the study of stress and health: the sympathetic adrenomedullary (SAM) system with the secretion of the two catecholamines, epinephrine and norepinephrine, and the hypothalamic pituitary adrenocortical (HPA) system with the secretion of cortisol. In response to sympathetic stimulation, epinephrine and norepinephrine are rapidly secreted into the blood stream with pronounced effects on the cardiovascular system and the release of energy (glucose, free fatty acids). Cortisol secretion is regulated by

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the adrenocorticotropic hormone (ACTH) from the pituitary gland and reaches a peak in blood about 30 min after an acute stress exposure. Cortisol influences the metabolism in the cells, the fat distribution and the immune system, and cortisol levels are controlled by a feedback system in the hypothalamus and the hippocampal formation. The stress hormones can be measured in blood and urine, and cortisol also in saliva. They have often been used as objective indicators of stress in the individual. However, through their effects on various bodily systems and functions, they also provide a link between the individual's perception of the psychosocial environment and various health outcomes.

2. Sensitivity

Numerous studies have demonstrated the sensitivity of epinephrine secretion to various kinds of mental stressors in the laboratory, and also to stress in natural settings (Frankenhaeuser, 1983; Lundberg, 1984). Norepinephrine, which is involved in blood pressure homeostasis, is more sensitive to physical demands and body posture. As a consequence, among white-collar workers, who are mainly exposed to mental demands, epinephrine levels are raised about 50% at work compared with work-free conditions, whereas norepinephrine does not increase at all or very little (Lundberg and Johansson, 2000). Among blue-collar workers performing manual tasks and being physically active, epinephrine as well as norepinephrine levels increase significantly—epinephrine by about 100%, and norepinephrine by about 50%. Cortisol levels habituate rapidly to regular work conditions and do not generally increase during daily work. However, cortisol secretion increases in response to novel conditions, emotional challenge, fear, anxiety and helplessness, and during heavy workload (Kirschbaum and Hellhammer, 1989; Folkow, 1993). For example, among women regularly working more than 50 h per week, cortisol levels have been found to be twice as high in the morning compared with women with a more moderate workload (Lundberg and Hellström, 2002). In response to intense stress, such as child birth, women's catecholamine and cortisol levels may increase more than ten times the pregnancy level (Alehagen et al., 2001). Thus, stress hormone levels are highly sensitive to environmental demands and may change quite dramatically.

Epinephrine levels increase in response to pleasant as well as to unpleasant stimulation (Levi, 1972), whereas cortisol seems to be more sensitive to negative emotional conditions (Henry, 1992; Folkow, 1993; Kristenson et al., 2004). However, cortisol levels also seem to be reduced under certain conditions. For example, in a study of five-year-old preschool children investigated at their day care center and compared with each child's corresponding home level, it was found that indicators of sympathetic arousal, such as systolic blood pressure, heart rate and catecholamine output, were significantly elevated, whereas cortisol levels were reduced (Lundberg et al., 1993). It was presumed that stimulation from playing with other children and participating in various activities at the day care centers induced sympathetic arousal, but that these pleasant conditions reduced cortisol levels. In another study of male and female white-collar workers (Lindfors and Lundberg, 2002), it was found that individuals high in psychological well-being had significantly lower cortisol levels at work compared with individuals lower in well-being. However, very low cortisol levels are also associated with burnout and post-traumatic stress disorders (Yehuda et al., 1996).

3. Gender differences

Up to the early 1970s, almost all studies of stress-hormone responses had been performed on men. Reasons for this were tradition, convenience, the 'nuisance' of women's biological rhythms, the risk of harming pregnant women and the general assumption that men and women would respond similarly to stress. However, when researchers in Marianne Frankenhaeuser's group in Stockholm started to compare the stress responses of men and women under standardized conditions, systematic differences were found. In response to performance stress in the laboratory, men increased their epinephrine response significantly (50–100%). By contrast, women did not respond at all or very little, despite the fact that women performed as well or even better on the various tasks (Frankenhaeuser, 1983). In response to a more intense real-life stressor, such as an important examination, female students did show a significant increase in epinephrine output, but still less than their male colleagues (Frankenhaeuser, 1983).

In a series of studies (Lundberg, 1996), different hypotheses regarding gender differences were tested, such as type of stressor (performance stress versus emotional and interpersonal stress), type of education, gender roles (masculinity, femininity) and the role of sex hormones (testosterone, estrogens). For example, it was found that mothers following their child to hospital for a routine check-up had higher epinephrine levels than the fathers (Lundberg et al., 1981), and that women who had chosen a male-dominated line of education had similar epinephrine responses to performance stress as their male colleagues (Collins and Frankenhaeuser, 1978). In addition, it was found that estrogen-replacement therapy (Collins et al., 1982) and high testosterone levels (Lundberg et al., 1983) did not influence women's epinephrine output markedly during stress. The general conclusion drawn was that gender roles and psychological factors were more important than biological factors in explaining differences in epinephrine response.

In subsequent studies, men and women at the same occupational level were found to respond similarly to stress at work (Frankenhaeuser et al., 1989; Lundberg and Frankenhaeuser, 1999). However, pronounced gender differences appeared off work. Comparisons between stress levels during and after work in matched groups of female and male white-collar workers show that women's stress levels tend to remain elevated also after work, whereas men seem to unwind and relax rapidly at the end of the working day (Frankenhaeuser et al., 1989; Lundberg and Frankenhaeuser, 1999). A possible explanation for this gender difference is that women have a greater unpaid workload due to household chores and child care (Lundberg et al., 1994). Significant correlations have also been found between women's physiological stress levels at work and in the evening at home (Frankenhaeuser et al., 1989) and between number of extra hours at work and epinephrine levels during the weekend (Lundberg and Palm, 1989).

4. Health implications

The role played by catecholamines in stress-related health problems has mainly been linked to the cardiovascular system and disorders such as hypertension, myocardial infarction and stroke. Folkow (1982) described a model of how elevated blood-pressure responses could lead to sustained hypertension by successive thickening of the artery walls and narrowing of the blood vessels, thus increasing the peripheral resistance in the cardiovascular system. The catecholamines also contribute to elevated blood lipid levels, increased blood clotting, and atherosclerosis—factors that are associated with elevated risk of myocardial infarction.

With regard to cortisol, overactivity of the HPA axis and/or disturbance to the regulation of this system, has been associated with increased risk of several health problems, such as cardiovascular disease, Type 2 diabetes, reduced immune function and cognitive impairment. These health problems are caused by a series of effects of high cortisol levels. Elevated cortisol levels contribute to an accumulation of fat in the abdominal region, due to the high density of cortisol receptors on the fat cells there. The abdominal or visceral fat is readily released into the blood stream, and will thus increase free fatty acid levels and contribute to cardiovascular risk. High cortisol levels also increase insulin resistance. Despite normal or even elevated insulin levels, blood glucose cannot be taken up by the cells due to the blocking effect of cortisol, thus causing Type 2 diabetes. Cortisol has anti-inflammatory effects, and chronically high levels will impair immune functions and thus increase the risk of infections. Cortisol enters the brain and may cause a degeneration of the hippocampal formation, where important memory functions are located (Sapolsky, 1996). Inadequate cortisol responses to stress may also cause health problems, and attenuated cortisol responses combined with elevated baseline levels have been found in individuals exposed to chronic psychosocial stress (Kristenson et al., 1998).

5. Health-promoting or health-damaging effects?

Various responses to stress exposure have been important for human and animal survival and for protection of the body. The acute responses to stress involve elevated blood pressure, increased heart rate, redistribution of blood from the gastrointestinal system to the muscles and the brain, release of energy (fat, glucose), suppression of reproductive functions, increased blood coagulation, suppressed pain sensitivity, and cognitive changes. These responses are important for successful coping in both humans and animals in response to an acute physical threat. In modern society, however, stress is more often of a psychological or psychosocial rather than a physical nature, which means that some of the bodily responses may give rise to harm rather than protection.

In order to describe whether stress responses are beneficial or harmful, the Allostatic Load Model has been proposed (McEwen, 1998). 'Allostasis' refers to the ability of various physiological systems to adapt to the environmental demands imposed by change. According to this model, rapid activation of the allostatic systems is necessary for successful coping with a stressor. However, rapid shut-off of any such response is important for rest and recovery. As a consequence, repeated activation of responses without time for rest and recovery as well as sustained activation, will cause overexposure to stress hormones, high blood pressure, and high levels of blood lipids, thereby increasing the risk of various health problems. Also, lack of an adequate response—as a result, for example, of exhaustion of any one system—may cause health problems due to an imbalance between different systems or compensatory over-activation of a particular system.

An adequate balance between catabolic processes (mobilization of energy), induced by stress hormones such as epinephrine, norepinephrine and cortisol, and anabolic processes (repair, healing, growth), induced by steroid sex and growth hormones, is necessary for health and survival. In modern society, which is characterized by a rapid pace of life, high productivity, efficiency, and competitiveness in a global economy, it is possible that lack of rest, recovery and restitution is a greater health problem than the absolute level of stress on and off the job.

6. Concluding remarks

Thus, a reasonable balance between activation and rest is necessary for health and survival. The human body is rather resistant to short-term demands, but in a long term perspective, we need periods of rest and recuperation to activate anabolic processes—both short-term periods of recovery, such as a lunch break or an evening rest, and longer periods, such as weekends or vacation. Regular moderate physical exercise is also known to contribute to such anabolic effects and to a more flexible stress system. One of the most important rest periods is sleep, when a number of important anabolic processes are activated (Åkerstedt, 1997).

Several countries, such as Sweden and Norway, have seen a dramatic increase in absenteeism during the last 10 years, particularly among women, due to health problems. These include burnout, depression, muscular pain, headache, gastrointestinal problems, and so on. Most of these disorders have been regarded as stress-related, and described as 'medically unexplained symptoms'. It is possible that the more rapid pace of modern life, increased workload, and continuous adjustment to changes and new demands have contributed to a change in the balance between catabolic and anabolic processes. However, as demonstrated by Eriksen et al. (2004), subjective health complaints are not restricted to modern civilization but are also frequent among individuals living under primitive conditions.

References

Åkerstedt, T., 1997. In: Kinney, J.M., Tucker, H.N. (Eds.), Overview of brain metabolism and stress. Lippincott-Raven, Philadelphia, pp. 131–150.

Alehagen, S., Wijma, K., Lundberg, U., Melin, B., Wijma, B., 2001. Catecholamine and cortisol reaction to child birth. Int. J. Behav. Med. 8, 50–65.

Collins, A., Frankenhaeuser, M., 1978. Stress responses in male and female engineering students. J. Hum. Stress 4, 43–48.

Collins, A., Hanson, U., Eneroth, P., Hagenfeldt, K., Lundberg, U., Frankenhaeuser, M., 1982. Psychophysiological stress responses in postmenopausal women before and after hormonal replacement therapy. Hum. Neurobiol. 1, 153–159.

Eriksen, H.R., Hellesnes, B., Staff, P., Ursin, H., 2004. Are subjective health complaints a result of modern civilisation? Int. J. Behav. Med. 11, 122–125.

Folkow, B., 1982. Physiological aspects of primary hypertension. Physiol. Rev. 62, 347–504.

Folkow, B., 1993. Physiological organization of neurohormonal responses to psychosocial stimuli: implications for health and disease. Ann. Behav. Med. 15, 236–244.

Frankenhaeuser, M., 1983. The sympathetic-adrenal and the pituitary-adrenal response to challenge: comparison between the sexes. In: Dembroski, T.M., Smidt, T.H., Blümchen, G. (Eds.), Biobehavioral Bases of Coronary Heart Disease. Karger, New York, pp. 91–105.

Frankenhaeuser, M., Lundberg, U., Fredrikson, M., Melin, B., Tuomisto, M., Myrsten, A.-L., Hedman, M., Bergman-Losman, B., Wallin, L., 1989. Stress on and off the job as related to sex and occupational status in white-collar workers. J. Org. Behav. 10, 321–346.

Henry, J.P., 1992. Biological basis of the stress response. Integr. Physiol. Behav. Sci. 1, 66–83.

Kirschbaum, C., Hellhammer, D.H., 1989. Salivary cortisol and psychobiological research: an overview. Neuropsychobiology 22, 150–169.

Kristenson, M., Orth-Gomér, K., Kucienskiene, Z., Bergdahl, B., Calcauskas, H., Balnyiene, I., Olsson, A.G., 1998. Attenuated cortisol response to a standardised stress test in lithuanian vs swedish men: the LiVicordia study. Int. J. Behav. Med. 5, 17-30.

Kristenson, M., Eriksen, H.R., Sluiter, J.K., Starke, D., Ursin, H., 2004. Psychobiological mechanisms of socioeconomic differences in health. Soc. Sci. Med. 58, 1511–1522.

Levi, L., 1972. Stress and distress in response to psychosocial stimuli. Act. Med. Scand., Suppl., 528.

Lindfors, P., Lundberg, U., 2002. Is low cortisol release an indicator of positive health? Stress Health 18, 153–160.

Lundberg, U., 1984. Human psychobiology in Scandinavia: II Psychoneuroendocrinology—human stress and coping processes. Scand. J. Psychol. 25, 214–226.

Lundberg, U., 1996. The influence of paid and unpaid work on psychophysiological stress responses of men and women. J. Occup. Health Psychol. 1, 117–130.

Lundberg, U., Palm, K., 1989. Total workload and catecholamine excretion of families with preschool children. Work Stress 3, 255–260.
Lundberg, U., Frankenhaeuser, M., 1999. Stress and workload of men and women in high ranking positions. J. Occup. Health Psychol. 4, 142–151.
Lundberg, U., Johansson, G., 2000. Stress and health risks in repetitive work and supervisory monitoring work. In: Backs, R., Boucsein, W. (Eds.), Engineering Psychophysiology: Issues and Applications. Lawrence Erlbaum Associates, New Jersey, pp. 339–359.
Lundberg, U., Hellström, B., 2002. Workload and morning salivary cortisol in women. Work Stress 16, 356–363.
Lundberg, U., de Chateau, P., Winberg, J., Frankenhaeuser, M., 1981. Catecholamine and cortisol excretion patterns in three year old children and their parents. J. Human Stress 7, 3–11.
Lundberg, U., Hanson, U., Andersson, K., Eneroth, P., Frankenhaeuser, M., Hagenfeldt, K., 1983. Hirsute women with elevated androgen levels: psychological characteristics, steroid hormones and catecholamines. J. Psychosom. Obstet. Gynaecol. 2 (2), 86–93.
Lundberg, U., Westermark, O., Rasch, B., 1993. Cardiovascular and neuroendocrine activity in preschool children: comparison between day-care and home levels. Scand. J. Psychol. 34, 371–378.
Lundberg, U., Mårdberg, B., Frankenhaeuser, M., 1994. The total workload of male and female white collar workers as related to age, occupational level, and number of children. Scand. J. Psychol. 35, 315–327.
McEwen, B.S., 1998. Protective and damaging effects of stress mediators. N. Engl. J. Med. 338, 171–179.
Sapolsky, R., 1996. Why stress is bad for your brain. Science 273, 749–750.
Yehuda, R., Teicher, M.H., Trestman, R.L., Levengood, R.A., Siever, L.J., 1996. Cortisol regulation in posttraumatic stress disorder and major depression: a chronobiological analysis. Biol. Psychiatry 40, 79–88.