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Impact of stress on the psychological functions and the psychosomatic cardiovascular conditions in humans: assessment by the heart rate variability method

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Abstract. *According to the neurovisceral integration model, several neural structures are involved in adaptations to psychoemotional stress, i.e. medial prefrontal cortex (mPFC), insular cortex, amygdala, hypothalamus, medullar autonomic centers. These structures are organized hierarchically and the higher centers control and inhibit the lower ones. The mPFC is involved in the regulation of cognitive functions, emotion and social cognition, and cardiovascular functions. It constantly inhibits the amygdala and the sympathoexcitatory subcortical circuits responding to stress. The flexible brain system involved in adaptation may be evaluated through the heart rate variability (HRV). Individuals with greater ability for emotion regulation depending on the environment and the goals set have been shown to have greater levels of resting HRV. This parameter may reflect the level at which affective conditions dynamically influence the peripheral autonomic nervous system (ANS). The HRV fluctuations correlate with some somatic and psychological disorders. It is lower in a number of psychiatric conditions and is associated with the risk factors of the cardiovascular morbidity and mortality. Psychological processes, such as emotional and social cognition, as well as psychosomatic conditions affecting the nervous and the cardiovascular system under stress may be easily evaluated by the physiological parameter heart rate variability.*

Key words: heart rate variability, stress, neurovisceral integration model

Background

Stress is a state of threatened homeostasis. The adaptive response to stress includes physiological and behavioral reactions, thus restoring the organism's equilibrium. The key systems activated under stress include cortical and subcortical neural structures, the autonomic nervous system and the endocrine system. The autonomic centers in the brainstem are controlled by the endbrain cortex and by the hypothalamus. The hypothalamus affects most autonomic and endocrine functions, and the emotional behavior.

Neural structures involved in stress responses

In accordance with the neurovisceral integration model (Thayer, J.F., Lane, R.D., 2000; Thayer, J.F., Lane, R.D., 2009), adaptations to environmental dynamics are determined by physiological, emotional, behavioral, cognitive, social, and environmental factors. This allows the adaptation systems to flexibly react to changes. A system of structures functions in the brain, which integrates the signals from the external and the internal environment and regulates the cognitive, perceptual, motor and autonomic processes. It constantly monitors the information inflow for the existence of threatening or favorable stimuli for the organism's functioning. The amygdala and the medial prefrontal cortex (mPFC) are of particular importance for this system. The latter plays a major role for the representation of both internal and external context in the mind and for the use of this information to regulate behavior and physiological processes. The mPFC is characterized by a number of cognitive functions (Cerqueira JJ, Mailliet F, et al., 2007), e.g. the sense of the self (Kelley, W.M., Macrae, C.N., et al., 2002; Northoff, G., Heinzel, et al., 2006) and emotional appraisal (Urry, H.L., van Reekum, C.M., Johnstone, T., et al., 2006; Wager, T.D., Hughes, B., Davidson, M., et al., 2008). It shapes behavior in accordance with superior inner goals set. It integrates information from various stimuli and generates behavioral and physiological responses, such as fear responses (Delgado, M.R., Nearing, K.I., Ledoux, J.E., Phelps, E.A., 2008; Milad, M.R., Wright, C.I., Orr, S.P., et al., 2007; Schiller, D., Levy, I., Niv, Y., et al., 2008.), heart-rate changes related to social threat (Wager, T.D., Waugh, C.E., Lindquist, M., et al., 2009b) and other stress responses (Lane, R.D., Wager, T.D., 2009). Its functions are performed through connectivity with the brainstem (Saper, C.B., 2002; Wager, T.D., Waugh, C.E., et al., 2009b). The mPFC is involved in the regulation of cardiovascular functions (Resstel LBM, Corrêa FM, 2006; Tavares RF, Corrêa FM, Resstel LBM, 2009a) and is morphologically modified under stress, as indicated by volume loss and dendritic atrophy (Cerqueira JJ, Taipa R, Uylings HB, Almeida OF, Sousa N., 2006; Cerqueira JJ, Almeida OF, Sousa N., 2008). This leads to an autonomic imbalance in favor of the sympathetic system and to stress-related cardiovascular diseases (Hilz MJ, Devinsky O, Szczepanska H, Borod JC, Marthol H, Tutaj M, 2006).

The hypothalamus, in particular the n. posterolateralis (NPL) and the n. paraventricularis (NPV), are important integrative centers of viscerosensory information (Allen GV, Cechetto DF, 1992; Allen GV, Cechetto DF., 1993). NPV is functionally involved in cardiovascular reactivity under stress (Tavares RF, Pelosi GG, Corrêa FMA, 2009в), regulates sympathetic activity (Kannan H, Hayashida Y, Yamashita H., 1989) and secrets corticotropin releasing factor that activates the hypothalamic–pituitary–adrenal axis (Kageyama K, Suda T., 2009).

The amygdala has efferent connections with the autonomic nervous system (ANS), the endocrine and other regulatory systems. It is recognized as a rapid sensor of potential threats and an intermediator of adaptive "fear" responses (LeDoux, J., 1996). The "default" response to uncertainty, surprise, and threat is the sympathoexcitatory activation commonly known as the "fight or flight" response (Thayer, J.F., Lane, R.D., 2009. ; Herry, C., Bach, D.R., Esposito, F., et al., 2007). The mPFC may also inhibit the amygdala's activity and reduce stress responses and fear behavior (Amat, J., Paul, E., Watkins, L.R., Maier, S.F., 2008; Quirk, G.J., Beer, J.S., 2006). Thus sympathoexcitatory, cardioacceleratory subcortical circuits responding to stress are under tonic inhibitory control by the prefrontal cortex (Thayer, J.F., 2006). In accordance with the Hughlings Jackson principle of hierarchical integration, higher brain structures constantly inhibit the lower and evolutionally older ones, while the latter are activated when the higher centers are inhibited, i.e. by disinhibition (Jackson, J.H., 1884). The ANS is also organized hierarchically. The inhibitive processes are of utmost importance for the adaptation and their deficit may lead to emotional and psychological disturbances (Beauchaine, T.P., 2001).