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A survey of methods of assessment of the autonomic system dysfunction in athletes after sport injuries

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This paper is a survey on the neurophysiological techniques supplementary to clinical evaluation of a possible dysautonomia. Sympathetic skin response (SSR) and heart rate variability analysis (RRIV) are neurophysiological tests commonly used in this case. Sports injuries related to the cranio-cerebral spinal cord as well as peripheral nerve trauma can determine the function of the autonomic system. The study aimed to find out the normative values of SSR and RRIV tests, which can be used for diagnosis of patients after sport injuries. SSRs were recorded following an electrical stimulation of the median nerve. RRIV tests were carried out during normal and deep breathing. Twenty young volunteers (aged 23 ± 2.1) were examined in order to estimate the reference values of SSR and R-R interval variation (RRIV) tests and to confirm the lack of functional changes in the autonomic nervous system. SSR and RRIV tests evaluating the function of two different types of effectors should be applied to confirm the presence of dysautonomia, especially in subjects who show unclear clinical symptoms.

KEY WORDS: autonomic nervous system, dysautonomia, neurophysiological evaluation, sympathetic skin response, R-R interval variation, sport injuries.

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What is already known on this topic?
Symptoms of autonomic dysfunction include consequences of cranio-cerebral, spinal or peripheral nervous system injuries [1]. Neurophysiological assessment of dysautonomia involves tests ascertaining the function of the sympathetic and parasympathetic systems, which supplement the clinical diagnosis; however, these tests are not routinely performed [2]. Sympathetic skin response is one of methods applied in differential diagnostic of the lower motoneurone function abnormalities encountered in sport related injuries [3].

Introduction

The hypothalamus is considered an integrative brain center responsible for the proper function of the autonomic nervous system. It receives afferent inputs from the limbic and cortical structures. The sympathetic part belongs to the thoraco-lumbar system (Th1-L2), while the parasympathetic part to the cranio-sacral system originating from the brainstem cranial III, VII, IX and X nuclei and from the intermediate grey zone of the S2-S4 spinal cord. Both systems act in an alternate way to each other [4]. Dysautonomia symptoms depend on the type and localization of injury of these structures, and they are predominant in cases of injuries of the central and peripheral nervous systems [5].

The diagnosis of dysautonomia is based mainly on results of clinical studies, which should be often supported by precise neurophysiological examinations according to the rules of Evidence Based Medicine. This approach allows reaching the correct decision on directional treatment, resulting in an early improvement and full recovery of the patient's health status [6].
The commonly accepted clinical assessment of the autonomic abnormalities includes evaluation of the cardiovascular system, activity of sweat and exocrine glands, digestive tract activity as well as the functions of the urinary bladder, sexual organs and pupils [1, 5]. The neurophysiological diagnostic of the autonomic system is precise, non-invasive, simple and repeatable, and includes many types of examinations. They provide analyses of both the sympathetic and the parasympathetic nervous systems [2, 7].
Injuries which may potentially affect the function of the autonomic nervous system include cranio-cerebral injuries, spinal injuries, subarachnoid and intracranial hemorrhages. They result in a trauma of the central autonomic pathways or in an interruption of the descending neural connections from the hypothalamus to the spinal cord centers [3, 6]. In sport as well as in activities of daily living these types of traumas are not rare.
Evaluation of the variability of heart rate depending on the breathing rate is considered to be the optimal test assessing the transmission of the vagus nerve. During inspiration the activation of the parasympathetic system is decreased. It causes an increase in the heart rate, which greatly facilitates the blood flow reaching the right ventricle as the result of decreased pressure in the chest and shortening of the R-R intervals. The reverse occurs during the expiration phase when R-R intervals are increased. The subsequent cycles of shortening and decreasing are repeated every several seconds according to the breathing rhythm. During deep breathing differences of chest pressure are greater, which leads to the relatively increased fluctuations of function within the autonomic system and further to the increase of heart rate variability [2, 8].
The diagnostic of the parasympathetic system often involves an evaluation of the vagal nerve activity and its hypo- or hyperactivity on the basis of heart rate variability. Inefficiency of the tenth nerve transmission leads to changes of the heart rate during the Valsalva maneuver, active vertical body position test and deep breathing test. Hyperactivity of the tenth nerve is recognized when eyeball or sinus cervicalis pressed tests are positive. However, the test of vagus nerve hyperactivity should be performed in cardiological departments because of possible asystole [2, 9].
Contrary to tests evaluating the function of the parasympathetic system, the subject's age has an insignificant influence on the final outcome of sympathetic activity. A significant role in assessment of the sympathetic system is played by sympathetic skin responses. Emotional and sensory stimuli excite the autonomic system in healthy subjects. The activation of sympathetic sudomotor fibres due to a simultaneous reaction of sweat glands leads to a transient change of the skin potential and a decrease of its resistance. With regard to sports traumas, SSR tests provide valuable information in the case of plexus or spinal root injuries as well as in peripheral neuropathy. SSR readings from the hands and the feet allow precise estimation of spinal injury, especially of the thoracic spine [6, 10].
This report presents selected, precise diagnostic tests which can be used for evaluation of abnormalities in transmission of the autonomic system. We also performed studies in healthy young subjects whose reference values could be used for comparison in studies on athletes with traumas of the cranio-cerebral, spinal cord as well as peripheral nerves.

Subjects and measurements

The subjects were 20 young healthy volunteers, including 10 women aged 22 to 27 years (24 ± 2 years), with the body height of 1.67 ± 0.09 m; and 10 men aged 19 to 26 years (22 ± 2 years) with the body height of 1.8 ± 0.06 m. The inclusion criteria were subjects' young age, good health, similar anthropometric traits, and lack of declared history of neurological disorders. The subjects did not use drugs, drink alcohol or smoke cigarettes. All subjects gave their written consent to participate in the study. The study was approved by the local bioethics board in agreement with the Helsinki Declaration.
During the RRIV test a modified electrocardiographic lead was used. The placement of the electrodes is shown in Figure 1.
RRIV records during the normal and deep breathing are shown in Figure 2. During the one-minute recording, both during normal and deep breathing (about 6 breaths per minute), the coefficient of heart rate variability was measured according to the equation: MAX-MIN/MEAN = % BPM (beats per minute).

Figure 3 shows the percentage values of heart rate variability during normal and deep breathing in the examined group of subjects, indicating a great individual variability in both tests.

The mean heart rate values during normal and deep breathing are presented in Figure 4. Their variability depends on the strict cooperation with the subject during the performed test, especially as regards regular breathing. They also depend on the applied measurement method and equipment. Considering the fact that the function of the parasympathetic system changes with age, the heart rate variability can be lower in subjects above 60 years of age. This phenomenon should be considered during the final data analysis [6]. In comparison to study results of other authors [11, 12], our RRIV results in a group of healthy subjects were > 20% during normal breathing and > 40% during deep breathing.

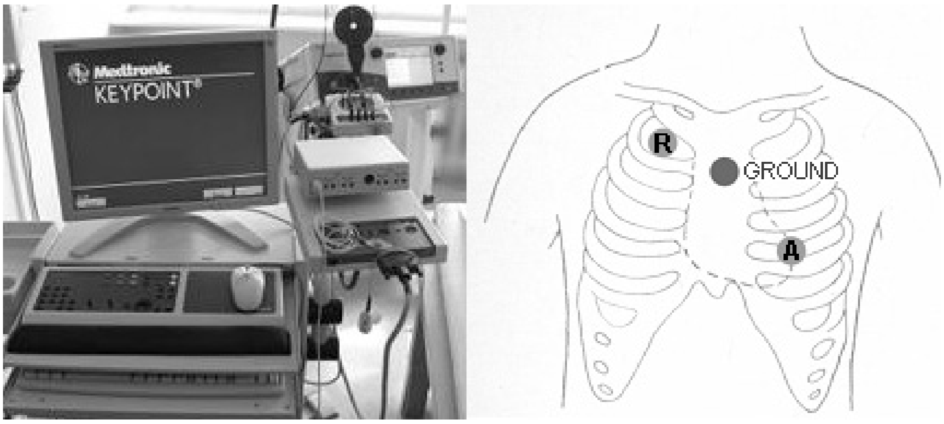

Figure 1. Electromyograph (Keypoint, Medtronic A/S, Skovlunde, Denmark) used for recordings SSR and RRIV signals (left), and location of electrodes used in the RRIV test (right). Active electrode (A) is placed on the 4th left intercostal space, the reference electrode (R) on the 1st right intercostal space, and the ground electrode on the sternum

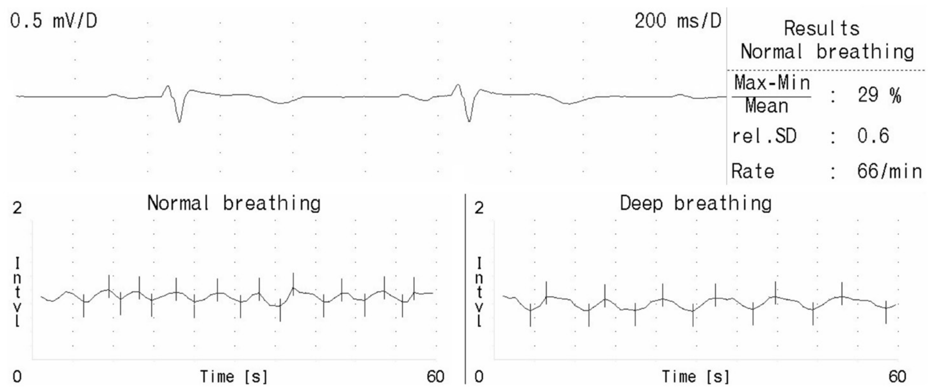

Figure 2. RRIV recordings during normal and deep breathing in healthy subjects

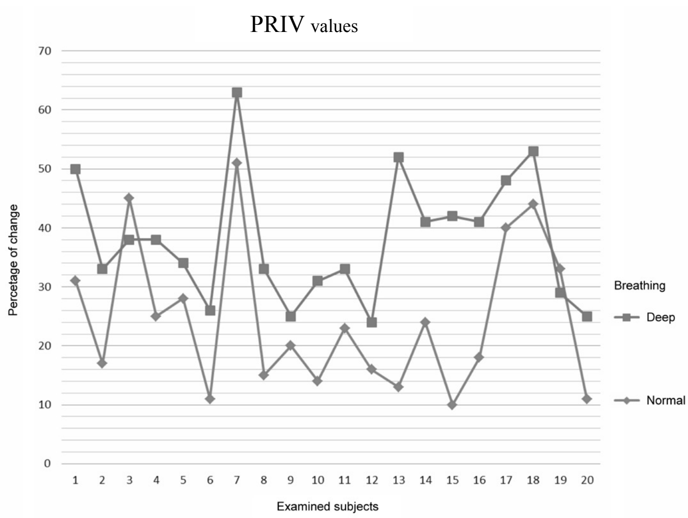

Figure 3. Subjects' heart reate variability (in percent)

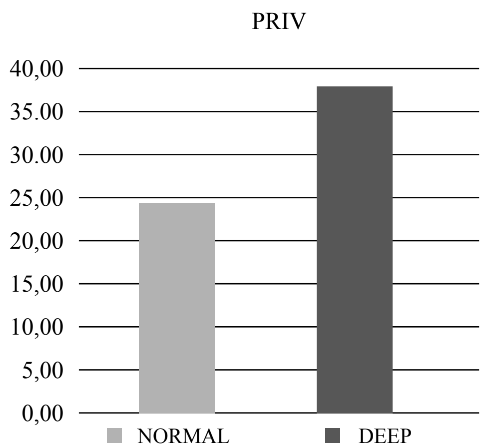

Figure 4. Mean heart rate variability during normal (left) and deep (right) breathing

The standard location of electrodes during the SSR test is shown in Figure 5. The active recording electrode was placed in the middle of the palms and soles in the areas between the 2nd and 3rd metacarpus and metatarsus, respectively. The reference electrode was placed centrally on the dorsal side of the hands and feet. The ground electrodes were placed unilaterally on the wrist and the ankle proximately to the recording electrodes. The bipolar stimulating electrode was placed on the skin along to the anatomical passage of the median nerve.

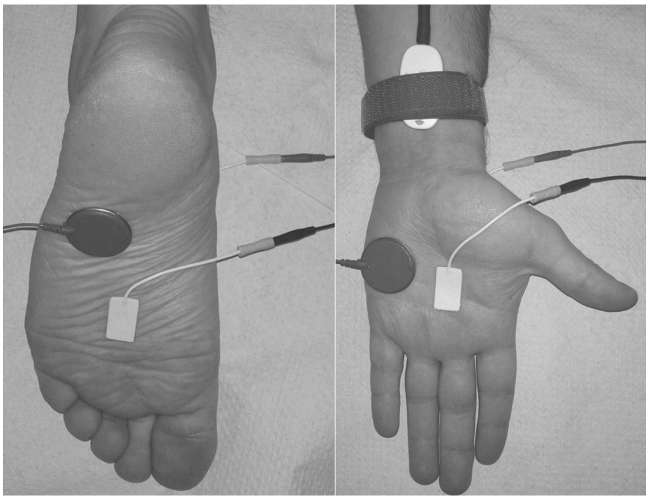

Figure 5. Location of recording, stimulating and ground electrodes during SSR on the lower and upper extremities

During stimulation of the median nerve a train of rectangular stimuli was used with a 10-15 mA intensity, 0.1 ms in duration, at the frequency of 3Hz. Considering the habituation phenomenon the pause between the trains of applied stimuli was irregular at about 1 minute. Diagnostically useful parameters included latencies, amplitudes, areas of potentials and the SSRs morphology. Figure 6 presents normative, bilaterally recorded SSRs from the upper and lower extremities.

Concluding remarks

Clinical neurophysiological examinations have become commonly used for the assessment of diseases of the central and peripheral nervous system. The frequency and intensity of the autonomic system abnormalities differ from one patient to another. Standard clinical studies are greatly supplemented with a neurophysiological assessment of the autonomic nervous system.

Taking into account the variety of sport injuries, RRIV and SSR techniques presented in this study are of immense importance. The cranio-cerebral and brainstem injuries within the integrative centers and the descending autonomic pathways lead to a reduction in the heart rate variability, which confirms the abnormality in the parasympathetic fibers. This phenomenon does correlate with the level of the neurological deficits and disability [13, 14].

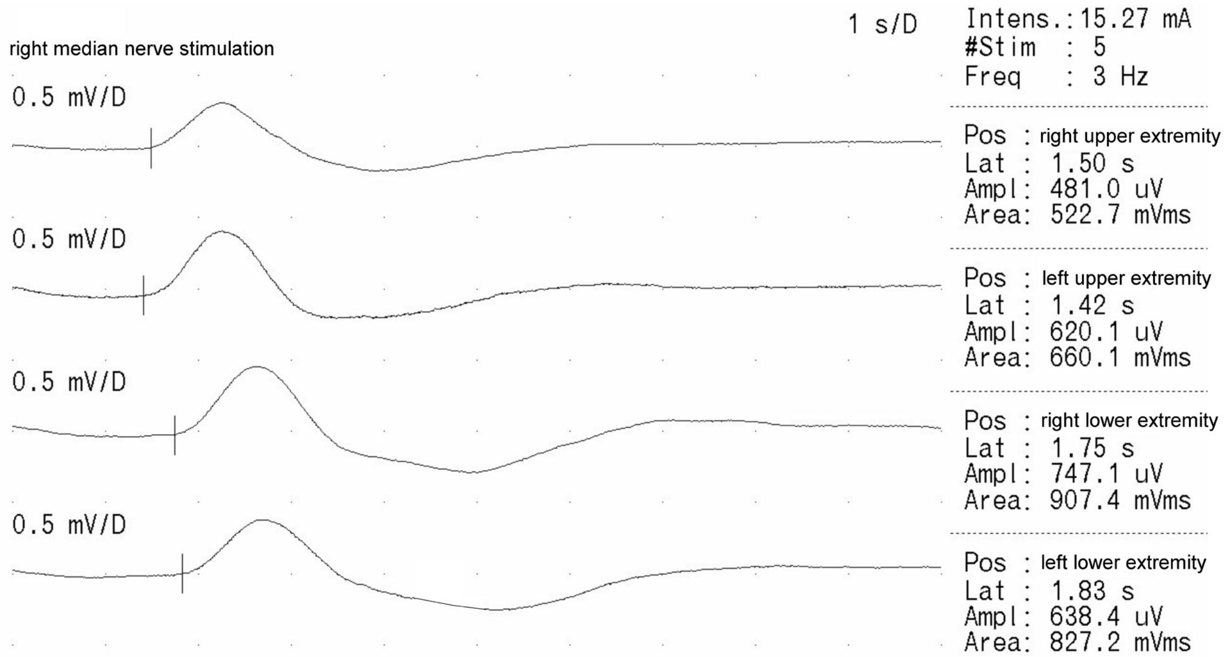

Figure 6. Examples of SSR recordings in healthy subjects following electrical stimulation of the median nerve

The SSR test is highly significant for the evaluation of the peripheral nervous system dysfunctions. Such pathologies are very often accompanied with sport injuries. An improper SSR may involve its increased latency value, recordings asymmetry or lack of responses. The amplitude parameter is variable; therefore, it presents a limited diagnostic value. A traumatic injury of the cervical spinal roots does not alter the normative results of SSR studies. An improper result may suggest the "mixed" (also involving the brachial plexus fibers) type of the injury. In cases of the plexuses injuries, especially within the lower trunk of the brachial plexus and lumbo-sacral plexus, SSR are characterized with increased latencies or lack of responses. There is a correlation between the electroneurographic and SSR results in traumatic peripheral neuropathies such as carpal tunnel syndrome or ulnar nerve mononeuropathy. The SSR results form the basis for differential diagnostic of the total nerve interruption with traumas accompanying compressions. An application of motor evoked potentials induced with the magnetic field (MEP), and somatosensory evoked potentials (SEP) together with SSR tests enable the precise localization of the spinal pathologies. The specificity and sensitivity of SSR studies in the evaluation of the spinal injury level are 80% and 78%, respectively [13, 15, 16].

The choice of methods assessing the function of the sympathetic and parasympathetic systems is wide and can be adjusted depending on the type of pathology. Results of clinical assessments of pathologies of the autonomic system do not give a precise diagnosis; therefore the application of neurophysiological diagnostics ensures their objectivization. Traumas of the peripheral nervous system often coexist with sport injuries, and SSR plays a special role in their differential diagnosis.

What this study adds?

Results of clinical assessment regarding pathologies of the autonomic system do not give the precise diagnosis; the application of neurophysiological diagnostics makes the diagnosis more objective. The compilation of two tests, i.e. SSR and RRIV, in differential diagnostics of dysautonomia is an objective means of clinical evaluation when the location of the disorder origin is unclear. RRIV measurements are greatly individualized, age-related and significantly influenced by the cooperation with the patient.

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