SPECTRAL ANALYSIS OF HEART RATE VARIABILITY IN PATIENTS WITH SPINAL CORD INJURY

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BACKGROUND: Yearly, 200–300 new spinal cord injuries (SCI) happen in the Czech Republic. Some of these patients suffer from autonomic disturbances, especially concerning their cardiovascular and genito-urinary systems. Autonomic disturbances markedly decrease quality of life in patients with SCI. It is important to assess the severity of the autonomic nervous system (ANS) involvement in these subjects.

OBJECTIVE: The main aim of this study was to assess the spectral analysis of heart rate variability as a marker of cardiovascular autonomic regulation in patients with spinal cord injury and to compare it with findings in healthy controls.

METHODS: Ten paraplegics (with a mean age of 53.1 ±15.8 years, seven males and three females) participated in this study. There were five patients with incomplete and five patients with complete spinal cord injury. The ASIA – American Spinal Injury Association, the modified Ashworth scale and the Questionnaire on Autonomic Functions were used. Autonomic reactivity was evaluated by means of the spectral analysis of heart rate variability (SAHRV) method (short-term registration) using the supine-sitting-supine test. Diagnostic system VarCor PF7, which is an innovation of the VarCor PF6 system, was used. Twenty four healthy subjects (with a mean age of 51.9 ±9.4 years) were enrolled as a control group.

RESULTS: A marked decrease of the reactivity of the autonomic nervous system as a response to orthostatic changes was found in patients after SCI (paraplegics). In particular, characteristic responses of low frequency (LF) and high frequency (HF) spectral components during the body position changes were suppressed in these patients in comparison with healthy controls. Furthermore, a significant decrease in the spectral power of the LF and HF components was found in patients after SCI. The value of the spectrum's total power (TP) was significantly lower in the group of paraplegics in comparison with healthy volunteers, both in the first and in the repeated supine positions. A significant degree of orthostatic hypotension was registered only in two paraplegics in a sitting position. A lower increase in the LF/HF ratio was registered in a sitting position in a group of paraplegics in comparison with healthy subjects.

CONCLUSIONS: A decrease in the reactivity of the autonomic nervous system to orthostatic changes, which evidences disturbances of cardiovascular regulation, was found in patients after spinal cord injury (paraplegics). The reduction of the low-frequency component (LF) of the spectral analysis of heart rate variability reflects a lowered sympathetic activity in these patients in a sitting position. It reflects ortostatic disturbances in situations with body position changes associated with a modified orthostatic load. Blood pressure measurement and SAHRV contribute to a more precise assessment of the autonomic dysfunction in patients after SCI.

Keywords: Spinal cord injury, spectral analysis, heart rate variability, autonomic nervous system.

INTRODUCTION

Yearly, 200–300 new spinal cord injuries (SCI) happen in the Czech Republic. Some of these patients suffer from autonomic disturbances, especially concerning their cardiovascular and genito-urinary systems. Autonomic disturbances markedly decrease quality of life in patients with SCI. It is important to assess the severity of the autonomic nervous system (ANS) involvement in these subjects. The assessment of heart rate variability (HRV) with the use of the spectral analysis of heart rate variability (SAHRV) represents a method available in clinical practice. Using computer based programs, specific frequency bands and their oscillations can be quantified to estimate vagal and sympathetic activity contributions to heart rate.

A relatively low number of studies concerning autonomic nervous system function in subjects with spinal cord injury focused on this topic can be found in the literature (Bunten et al., 1998; Claydon et al., 2008; Chen et al., 2006; Wecht et al., 2003). The main aim of this study was to assess heart rate variability as a marker of cardiovascular autonomic regulation in patients with spinal cord injury and to compare it with findings in healthy controls.

MATERIAL AND METHODS

Ten paraplegics (with a mean age of 53.1 ±15.8 years, seven males and three females), participated in this study. There were five patients with incomplete and five patients with complete spinal cord injury. The ASIA – American Spinal Injury Association (Wise, 2009), modified Ashworth scale (Bohannon & Smith, 1987), and the Questionnaire on autonomic functions (Opavský, 2002) were used. Autonomic reactivity was evaluated by means of the SAHRV method in the supine-sitting-supine test (SSS test), which is a modification of the supine-standing-supine test (Opavský, 2002; Salinger, 1999). SAHRV was used as a sensitive, non invasive method for the evaluation of autonomic nervous system activity. The areas of the frequency spectrum are divided into three major components:

1. VLF (very low frequency, from 20 to 50 MHz) component, its origin hasn't been fully explained, yet.
2. The LF (low frequency, from 50 to 150 MHz, mainly about 100 mHz) component is explained mostly as a reflection of arterial baroreceptor sympathetic activity (Pagani et al., 1992).
3. HF (high frequency from 150 to 400 MHz) component represents a vagal activity associated with breathing (Malik & Camm, 1990).

Diagnostic system VarCor PF7, which is innovation of the system of VarCor PF6, was used. The ECG signal is obtained with the help of an electrode belt POLAR or electrodes placed on the thorax. A transmitter of this system works at a frequency of 433 MHz. (Štěpaník et al., 2005). The ECG signal was processed in PC with the use of special software for this diagnostic system (Salinger et al., 2005).

Twenty four healthy subjects (with a mean age of 51.9 ±9.4 years) were enrolled as a control group. Blood pressure values in the first supine position and at the end of their stay in the sitting position were measured.

RESULTS

A marked decrease in the reactivity of the autonomic nervous system to orthostatic changes was found in patients after SCI (paraplegics). In particular, characteristic responses of low frequency (LF) and high frequency (HF) spectral components during changes of body positions were suppressed in comparison with healthy controls (Fig. 1 and Fig. 2).

Furthermore a significant decrease in spectral power of the LF and HF components was found in these patients (TABLE 1 and TABLE 2). The value of the total power (TP) was significantly lower in the group of paraplegics in comparison with healthy volunteers, both in the first and in the repeated supine positions (TABLE 3 and Fig. 3). A significant orthostatic hypotension was registered only in two paraplegics when in a sitting position. A lower increase in LF/HF ratio was registered in a sitting position in a group of paraplegics in comparison with healthy subjects (TABLE 4 and Fig. 4).

Fig. 1
Spectral power of the LF component in a group of paraplegics and age-matched healthy controls in the supine-sitting-supine test

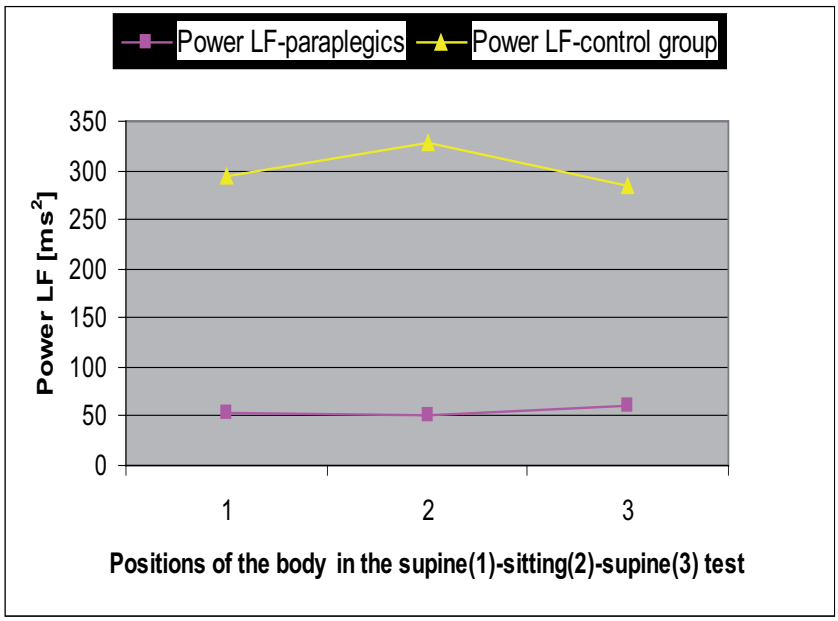


Fig. 2
Spectral power of the HF component in a group of paraplegics and age matched healthy controls in the supine-sitting-supine test

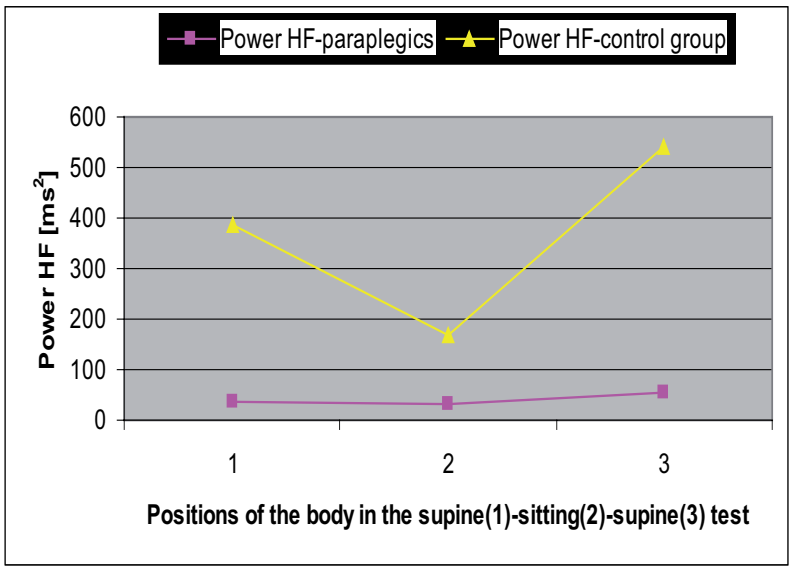


TABLE 1
Spectral power of the LF component in a group of paraplegics and age-matched healthy controls in the supine-sitting-supine test

LF [ms^2]		PARA	CONTR	p
1	mean	53.8	293.1	0.001
	SD	30.3	378.6	
2	mean	51.5	328.1	0.0013
	SD	42.8	350.7	
3	mean	61.8	283.2	0.003
	SD	40.4	398.5	

TABLE 2
Spectral power of the HF component in a group of paraplegics and age matched healthy controls in the supine-sitting-supine test

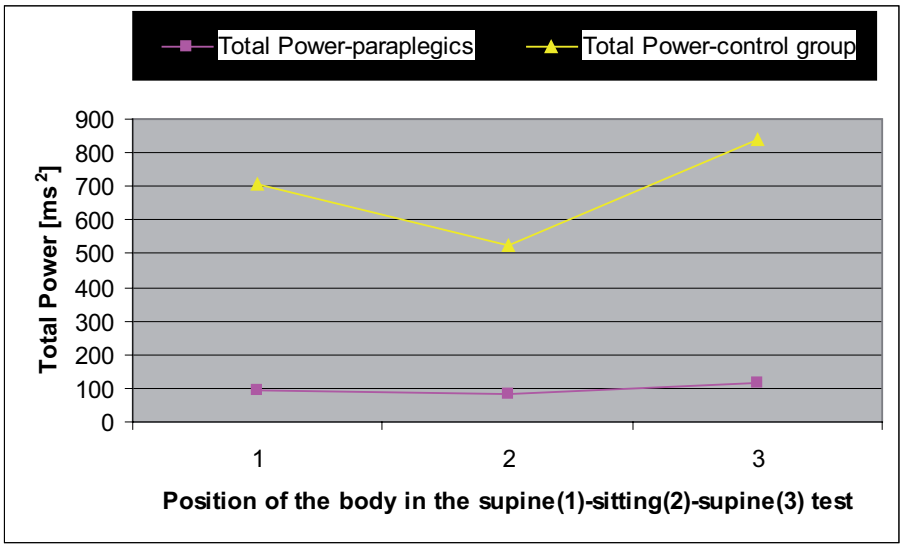
HF [ms^2]		PARA	CONTR	p
1	mean	38.0	387.9	0.0004
	SD	27.5	639.6	
2	mean	34.0	169.8	0.03
	SD	43.7	333.2	
3	mean	56.4	539.3	0.001
	SD	50.3	830.9	

Legend:
body positions in the supine-sitting-supine test: 1 – supine, 2 – sitting, 3 – repeated supine
PARA = paraplegics
CONTR = control group
LF = low frequency component of the spectral analysis of a heart rate variability (0.05–0.15 Hz)
Power LF [ms^2] = spectral power of the LF component of the SAHRV
HF = high frequency component of the spectral analysis of a heart rate variability (0.15–0.4 Hz)
Power HF [ms^2] = spectral power of the HF component of the SAHRV
p = level of significance

TABLE 3
Total spectral power (TP) in a group of paraplegics and age-matched healthy controls in the supine-sitting-supine test

TP [ms^2]		PARA	CONTR	p
1	mean	91.8	705.8	0.008
	SD	53.3	949.4	
2	mean	85.5	524.9	
	SD	67.0	717.9	
3	mean	115.6	840.3	0.007
	SD	80.8	1218.6	

Fig. 3
Total spectral power (TP) in a group of paraplegics and age-matched healthy controls in the supine-sitting-supine test

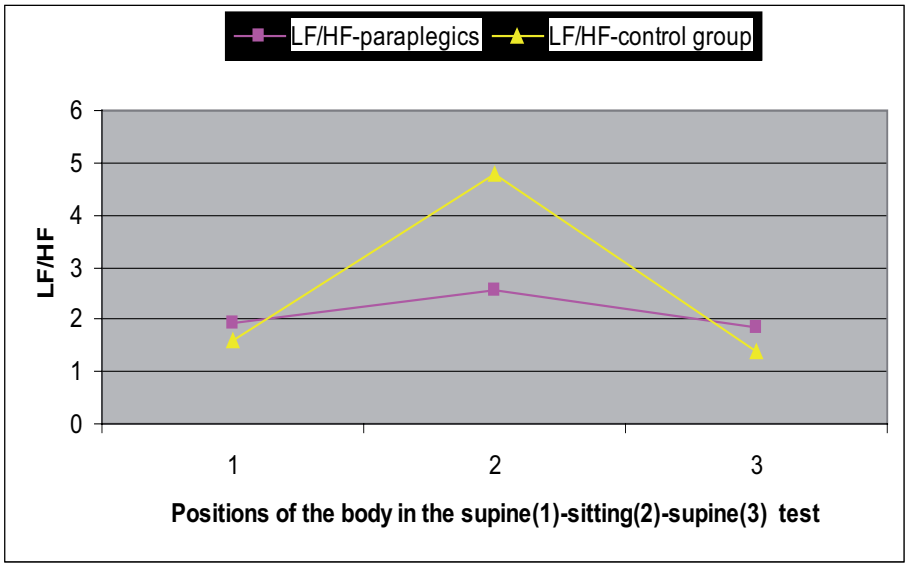


Legend:
body positions in the supine-sitting-supine test: 1 – supine, 2 – sitting, 3 – repeated supine
PARA = paraplegics
CONTR = control group
Total power [ms^2] = sum of the spectral power of the low frequency (LF) + high frequency (HF) components
p = level of significance

TABLE 4
Ratio LF/HF in a group of paraplegics and age-matched healthy controls in the supine-sitting-supine test

LF/HF		PARA	CONTR	p
1	mean	1.9	1.6	N.S.
	SD	1.0	1.4	
2	mean	2.6	4.8	N.S.
	SD	2.2	5.1	
3	mean	1.8	1.4	N.S.
	SD	1.4	1.6	

Fig. 4
Ratio LF/HF in a group of paraplegics and age-matched healthy controls in the supine-sitting-supine test



Legend:
body positions in the supine-sitting-supine test: 1 – supine, 2 – sitting, 3 – repeated supine
PARA = paraplegics
CONTR = control group
LF/HF = ratio of the low frequency (LF) and high frequency (HF) spectral power
p = level of significance
N.S.= non significant

TABLE 5
Questionnaire on autonomic functions in paraplegics

Patient	A	B	C
1	6	9	1
2	8	7	1
3	8	7	1
4	8	6	2
5	10	5	1
6	6	8	2
7	8	7	1
8	8	5	3
9	7	7	2
10	7	8	1
mean	7.6	6.9	1.5
SD	1.11	1.22	0.67

Legend:
A – answers for sympathetic responses
B – answers for parasympathetic (vagal) responses
C – indifferent responses

A ratio A/B (7.6:6.9) in paraplegics demonstrates a minimal (non significant) prevalence of responses for sympathetic function.

DISCUSSION

Heart rate variability has been investigated during postural stress as a means of identifying changes within the frequency spectra corresponding to a sympathetic stimulus (Vybiral et al., 1989) and vagal withdrawal. In the able bodied population, increase in the low frequency component of heart rate variability was registered and reported during postural stress and was associated with significant reductions in the high frequency component, suggesting augmented sympathetic and diminished vagal cardiac control (Montano et al., 1994).

Cardiovascular autonomic functions are markedly disturbed in SCI patients. It can lead, as one of the important factors, to an increase in mortality in these patients.

Time domain, amplitude, and power spectral analyses were used to study HRV and autonomic functions. The paraplegic subjects demonstrated a significant loss of the low frequency component during 24-hour HRV registration compared to able bodied controls. This was interpreted as being consistent with predominantly sympathetic denervation uninfluenced by the degree of physical activity (Bunten et al., 1998). The group with paraplegia demonstrated a significantly lower HF baseline and LF composite levels than controls (Grimm et al., 1997).

Decreased autonomic reactivity in patients after SCI shows a markedly decreased adaptation to orthostatic load. SCI patients are known to suffer from autonomic failure as a result of their injury (Bunten et al., 1998). We have described disturbed cardiovascular control in subjects after SCI, both in a supine position and during a situation with orthostatic load (sitting position).

A significant decrease in the power of LF and HF spectral components (in frequency domain) in patients after SCI (paraplegics) was found in our study. It corresponds to the results published by Ditor et al. (2005).

Furthemore, a registration of an orthostatic hypotension gives us important information for the rehabilitation strategy in patients after SCI. Paraplegic subjects also had significantly lower baroreflex effectiveness and greater blood variability, compared with the control group (Castiglioni, 2007). Abnormal blood pressure responses have been repeatedly described in these patients (Ditor et al., 2005). Therefore, a blood pressure measurement for the basic assessment of autonomic reactivity, in situations with different orthostatic load, should be performed in patients after SCI. Frequency analyses of autonomic function are related to clinical measures of autonomic control after SCI and provide useful noninvasive clinical tools with which to assess autonomic completeness of an injury following SCI (Claydon & Krassioukov, 2008).

CONCLUSION

1. A decrease in the reactivity of the autonomic nervous system to orthostatic changes, which evidences disturbances of cardiovascular regulation in patients after spinal cord injury (paraplegics) was found.
2. The reduction of the low-frequency component (LF) of the spectral analysis of heart rate variability reflects a lowered sympathetic activity in these patients in a sitting position. Furthemore, it reflects orthostatic disturbances in situations with body position changes.
3. An examination of the blood pressure in different body positions and the examination of autonomic reactivity by means of the SAHRV method contribute to the checking of the autonomic dysfunctions in patients after spinal cord injury.

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SPEKTRÁLNÍ ANALÝZA VARIABILITY SRDEČNÍ FREKVENCE U PACIENTŮ S PORANĚNÍM MÍCHY

(Souhrn anglického textu)

VÝCHODISKA: Každoročně se v České republice vyskytne 200–300 nových poranění míchy (SCI). Někteří z těchto pacientů trpí autonomními poruchami, jež zasahují zejména jejich kardiovaskulární a genitourinární systém. Autonomní poruchy značně snižují kvalitu života pacientů s SCI. U těchto subjektů je důležité posoudit závažnost postižení autonomní nervové soustavy (ANS).

CÍL: Hlavním cílem této studie bylo posoudit spektrální analýzu variability srdeční frekvence jako indikátoru kardiovaskulární autonomní regulace u pacientů s poraněním míchy a porovnat ji s nálezy zjištěnými u zdravých kontrolních jedinců.

METODY: Této studie se zúčastnili paraplegici (průměrný věk 53,1 ±15,8 let, sedm mužů a tři ženy). U pěti z nich byla mícha poraněna částečně a u zbylých pěti zcela. Byla použita klasifikace ASIA (American Spinal Injury Association), modifikovaná Ashworthova stupni-

ce a Dotazník autonomních funkcí. Autonomní reaktivita byla hodnocena pomocí metody spektrální analýzy variability srdeční frekvence (SAHRV; krátkodobá registrace) za použití testu leh-sed-leh (supine-sitting-supine). Byl použit diagnostický systém VarCor PF7, což je inovace systému VarCor PF6. Kontrolní skupinu tvořilo dvacet čtyři subjektů (průměrný věk 51,9 ±9,4 roku).

VÝSLEDKY: U pacientů po SCI (paraplegiků) byl v rámci reakce na ortostatické změny zjištěn výrazný pokles reaktivity autonomní nervové soustavy. Ve srovnání se zdravými kontrolními jedinci byly u těchto pacientů během změn pozice těla potlačeny zejména charakteristické reakce nízkofrekvenčních (LF) a vysokofrekvenčních (HF) spektrálních složek. Navíc byl u těchto pacientů zaznamenán významný pokles spektrálního výkonu u LF a HF složek. Hodnota celkového výkonu (TP) spektra byla výrazně nižší ve skupině paraplegiků ve srovnání se zdravými dobrovolníky, a to jak při první pozici vleže, tak i při opakovaných pozicích vleže. Významná míra ortostatické hypotenze byla zaznamenána pouze u dvou paraplegiků v poloze vsedě. Menší zvýšení poměru LF/HF bylo zaznamenáno v poloze vsedě ve skupině paraplegiků ve srovnání se zdravými jedinci.

ZÁVĚRY: U pacientů s poraněním míchy (paraplegiků) byl zjištěn pokles reaktivity autonomní nervové soustavy na ortostatické změny, což dokazuje poruchy kardiovaskulární regulace. Snížení nízkofrekvenční (LF) složky spektrální analýzy variability srdeční frekvence u těchto pacientů reflektuje sníženou sympatickou aktivitu v poloze vsedě. Odráží ortostatické poruchy v situacích, kdy se mění poloha těla, což je spojeno se změnou ortostatického zatížení. Přesnější hodnocení autonomní dysfunkce u pacientů po SCI je podpořeno měřením krevního tlaku a SAHRV.

Klíčová slova: poranění míchy, spektrální analýza, variabilita srdeční frekvence, autonomní nervová soustava.

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