Heart rate variability in individuals with cerebral palsy

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Abstract

Introduction: Cerebral palsy (CP) is a non-progressive brain pathology that mainly affects the motor system. Heart rate variability is currently used as an assessment tool for the balance in the sympathetic and parasympathetic branches of the autonomic nervous system (ANS). The aim of the present study was to determine abnormalities in the ANS in patients with cerebral palsy submitted to the Slump Test for analysis of heart rate variability.
Material and methods: The sample was made up of 18 individuals with cerebral palsy, aged 8 to 27 years. For data collection, the Nerve-Express software program was used, performing the orthostatic test on all individuals in the sample. The Slump Test was administered 3 times, with 3-min intervals between tests, collecting data each time.
Results: Average age was 18.7 years; average BMI was 16.0 kg/m^2. The Gross Motor Function Classification System demonstrated predominance in the sample of individuals with level V diparesis. Analysis of the data revealed a decrease in parasympathetic activity and an increase in sympathetic activity. Analyzing the characterization of the sample to the levels of functioning of the physiological systems and adaptation reserve revealed a decrease of these functions after the test, although it was not significant.
Conclusions: The results from the experimental conditions employed allow the conclusion that the individuals with cerebral palsy in the present sample demonstrated no statistically significant difference between SNS and PNS activity. However, after applying the Slump Test an improvement was noted in the chronotropic myocardial reaction, functioning of the physiological systems and adaptation reserve.

Key words: motor assessment, neural mobilization, cerebral palsy, autonomic nervous system, Slump Test, heart rate variability.

Introduction

Cerebral palsy (CP) is not considered a specific infirmity, but rather a set of infirmities in which motor abnormality is the fundamental characteristic. However, there are other associated abnormalities and clinical manifestations vary in accordance with the course and duration of the disease [1-4]. Children with spastic CP are characterized by the loss of selective control of the muscles, depending on primitive reflex patterns for walking, muscle tonus, a lack of coordination between agonist and antagonist muscles and a deficiency in equilibrium reactions [5-9].

Heart rate variability (HRV) is the variation in the duration of intervals between two R waves (iR-R) on an electrocardiogram, in which stimulation or inhibition of sympathetic and parasympathetic activity in the heart modulate the heart rate response, adapting to the needs of each moment [10]. The autonomic nervous system (ANS) performs a fundamental role in the control of blood pressure and heart rate and is therefore an important physiological factor in the development of arterial hypertension. Heart rate varies from beat to beat as a consequence of constant adaptations promoted by the ANS in order to maintain equilibrium in the cardiovascular system. These alterations may be assessed through the variations in iR-R, thereby determining HVR [11, 12].

The assessment of HVR is used as a research tool, as it allows a better understanding of the participation of the ANS in different physiological and pathological conditions of the cardiovascular system [13]. Its use has been prompted by a large number of observations, indicating the potential worth of this approach in the expansion of knowledge regarding abnormalities in blood pressure control mechanisms involved in hypertension. Heart rate variability is currently used as a tool for the assessment of equilibrium in the activity of the sympathetic and parasympathetic branches of the ANS in the control of heart rate. The HRV signal reveals the variation in the period elapsed between consecutive heartbeats over time [14]. Traditional HRV analysis has been performed through methods in the time domain (tachographic analysis) as well as the frequency domain (spectral analysis) and is used as an aid in medical diagnoses, most notably in the stratification of risk and detection of pathologies in adult humans, especially autonomic dysfunction [15]. Thus, HRV was the parameter used in the present study, as significance tests can be performed based on variations in iR-R [16].

Treatment based on the mobilization of the nervous system has been developed with clinical observations and experimental research. Patients with central lesions are more susceptible to the adverse neural tension of the nervous system, which may be aggravated by the immobility that is common in such lesions [17, 18]. Apparently, in the complete Slump Test position, any increase in neck flexion, knee extension or back flexion is limited by the fact that the central and peripheral nervous systems are in complete extension, thereby restricting any additional movement [19].

The aim of the present study was to determine abnormalities in the ANS in patients with CP submitted to the Slump Test for analysis of HVR.

Material and methods

The present analytical, consecutive, non-controlled cross-sectional study was carried out at the Anne Sullivan School of Special Education and received approval of the Ethics Committee under process number H132/2006/CEP/UNIVAP in compliance with the norms for experimentation involving human beings established by the Brazilian Health Ministry (resolution 196/96). The individuals and/or their guardians were made aware of the objectives of the study and signed terms of informed consent.

The sample was made up of 18 male and female individuals between 6 and 27 years of age, all with mild/moderate spastic cerebral palsy, according to the modified Ashworth scale (MAS). All participants had cognitive skills that allowed the understanding of simple verbal commands regarding sitting, standing and reporting sensitivity to pain, whether or not being capable of walking independently. The following exclusion criteria were considered separately: neonatal orthopaedic pathologies; inability to maintain an orthostatic position without assistance; recent surgeries (≥ 1 year); use of botulinum toxin within the six-month period prior to the study; congenital heart pathology; heart arrhythmia; heart disease; and pathologies associated with infectious or viral states.

Data collection using the Nerve-Express system and the neural technique were performed on a gurney with the back raised to 90° for stability of the hip in children who were unable to place their feet on the ground. The Gross Motor Function Classification System employing five levels was used for the assessment of motor function. The Orthostatic Test modality was used for the assessment of heart rate. The first data collection using the Nerve-Express system was performed with the individual lying on his/her back on the gurney, awaiting the beat-to-beat count to reach 192. The participant was then asked to place himself/herself in the orthostatic position, maintaining this position until reaching a count of 448 heart beats.

The Slump Test was then carried out for one minute, with the individual seated on the edge of the gurney and asked to oscillate the ankle on the limb with the least extension. The same procedure was performed three times, with three-minute rest intervals. Following the Slump Test, data collection was performed once again using the Nerve-Express system [16]. The data from both collections were transformed into graphs and rhythm grams and compared for the same individual as well as between different individuals.

Data were analyzed using STATGRAPHICS Centurion XV.I for the distribution of normality, using the paired *t*-test. Analyze-it (for ORIGIN 6.0 Microcal) was used to test the sum of the Wilcoxon orders. The level of significance for all statistical tests was set at 5% ($p < 0.05$).

Results

Age ranged from 8 to 27 years, with an average of 18 years 7 months. Minimum height was 132 cm and maximum height was 162 cm. Mean BMI was 16.0 kg/m^2, which was below the ideal range (20 to 25 kg/m^2).

The Gross Motor Function Classification System (GMFCS) revealed that 38.88% of the individuals in the sample were in level V, 27.77% were in level III, 22.22% were in level IV and 5.55% were in levels I and II. Regarding topographic distribution, 44.44% (8 individuals) had diparesis, 27.77% (5 individuals) had quadriparesis, 16.66% (3 individuals) had monoparesis and 11.11% (2 individuals) had hemiparesis. Regarding muscle tonus, spastic cerebral palsy was predominant (13 individuals); the 5 remaining individuals had athetoid cerebral palsy.

Figure 1 displays the characterization of the sample regarding chronotropic myocardial reaction (CHMR) prior to and following the application of the Slump Test. We can see a decrease in this reaction after application of the test.

Analyzing the characterization of the sample to the levels of functioning of the physiological systems and adaptation reserve revealed a decrease of these functions after the test, although it was not significant (Figure 2).

Regarding the CP type, individuals with athetoid CP predominated in level XI prior to the Slump Test. Following the test, individuals with spastic CP migrated from level X to level XI, thereby distancing themselves from the normal level.

Table I displays mean values and standard deviation regarding the high and low frequencies in the orthostatic positions. The values presented are absolute values obtained from the equipment following the Fast Fourier Transform (FFT). High frequency (HF) represents predominance of the parasympathetic nervous system (PNS), whereas low frequency (LF) represents predominance of the sympathetic nervous system (SNS). The mean value for high heart frequency prior to the Slump Test was 431.44 before and 229.14 after in the erect position. Regarding low frequency, mean value prior to the Slump Test was 899.72 before and 672.94 after in the erect position.

Table II shows the data of the sympathetic and parasympathetic system activity before and after the application of the Slump Test. Median values for the sample demonstrated a decrease in parasympathetic and sympathetic activity.

Discussion

The individuals with CP in the present study had a mean BMI of 16.00 kg/m^2. Sichieri and Allam (1996) report that the ideal BMI is between 18.50 and 24.90 kg/m^2 [20]. This signifies that the individuals in the sample of the present study were underweight.

A previous study carried out with 50 individuals (33 with CP and 27 with Down's syndrome) sought to evaluate subjects with CP in order to certify the reliability of using the gross motor classification. Mean age of the individuals was 13 years 9 months and the largest part of the sample was situated in level II [21, 22]. In the present study, the decision was made to observe the individuals freely in their activities, resulting in a greater number of subjects in level V, in the age group between 6 and 12 years.

A study addressing heart rate variability in 34 obese and non-obese male adolescents reported autonomic cardiac hyporesponsivity to orthostatic stress in the obese group [23]. In the present study, individuals with CP also exhibited autonomic cardiac hyporesponsivity after the Slump Test in orthostatic position showing an adjustment in the autonomous system.

Studies seeking evidence of a correlation between age group and heart rate variability following a cardiovascular test performed on individuals between 15 and 19 years of age found no direct correlation between these variables under the conditions studied [24, 25]. Data from the present study reveal similar results regarding the lack of an association between HRV and age.

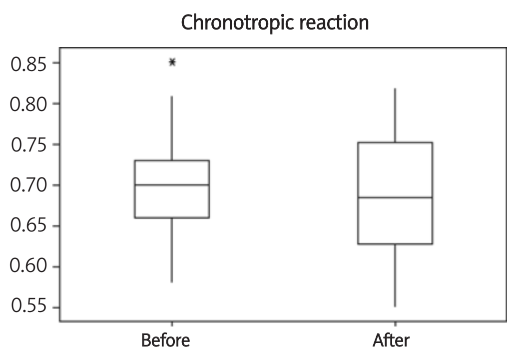

Figure 1. Median before and after the Slump Test in individuals with cerebral palsy, $p < 0.251$

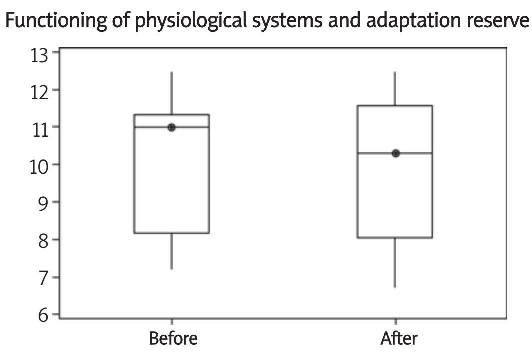

Figure 2. Median before and after the Slump Test in individuals with cerebral palsy, $p < 0.716$

Table I. Values of SNS and PNS activity before and after the Slump Test in individuals with cerebral palsy

Patients	SNPSa	SNPSd	SNSa	SNSd
1	–0.05	–1	1	1.5
2	–2	–0.5	3	1.5
3	0.5	0	1	1.5
4	–2.5	–1.5	2.5	2
5	–3	–2.5	2.5	2
6	–2	–2.5	2.5	2
7	1.5	–2.5	1.5	3
8	1.5	0	2	2
9	–2.5	–2.5	2	1
10	–3	–2	3.5	3.5
11	–0.5	0.5	2.5	1.5
12	–2.5	–3	3.5	4
13	–2	–2.5	4	4
14	0.5	–1.5	1	1.5
15	–2	–1	3	3
16	1	1	1	0.5
17	–2	–3.5	3.5	4
18	1	0.5	0.5	1.5
Median	**–2**	**–1.5**	**2.5**	**2**
Average	**–1.01**	**–1.36**	**2.25**	**2.23**
DP	**1.65**	**1.36**	**1.06**	**1.08**

Table II. Values of high and low frequency bands regarding heart rate in individuals with cerebral palsy

Patients	HF before	HF after	LF before	LF after
1	387	139	2861	695
2	261	244	916	684
3	469	276	863	1631
4	28	20	378	768
5	167	17	645	1867
6	154	143	162	273
7	2251	76	1790	253
8	757	547	612	1207
9	38	40	196	384
10	17	7	99	218
11	621	420	1403	690
12	4	4	40	43
13	202	21	255	200
14	494	259	1277	384
15	154	181	383	182
16	746	944	2991	1386
17	59	34	190	78
18	957	753	1134	1170
Median	**231.5**	**141**	**628.5**	**534**
Average	**431.44**	**229.17**	**899.72**	**672.94**
DP	**539.69**	**273.70**	**890.83**	**559.41**

The results of the present study revealed a moderately low chronotropic reaction after the Slump Test in most individuals, suggesting that these individuals are three levels below the normal chronotropic reaction.

The Nerve-Express system used to assess the bands of high and low frequency of physiological functioning in the sample before and after the Slump Test only found statistically significant differences with regard to the high frequency. Mean values following the administration of the Slump Test were 9.57 and 6.33. In a study carried out on children with cerebral palsy and a normal control group, Park *et al.* found no significant differences regarding the autonomic heart response [26].

Yang *et al*. found no significant difference in sympathetic response between children with CP and a normal control group [6]. The authors also report that heart rate variability was greater in the group with athetoid CP than the group with spastic CP when the determination employed 10-s intervals (the time domain used was 1 min 20 s). In the present study, individuals classified with spastic CP did not differ statistically from those with athetoid CP, although there was greater SNS activity in relation to PNS activity in absolute values.

Heart rate variability was analyzed by iR-R in milliseconds and a statistically significant difference in HRV was found between the different positions employed in this study [27].

Marães *et al*. state that the Valsalva manoeuvre causes an overload in the cardiovascular system, activating arterial baroreceptors, chemoreceptors and cardiopulmonary receptors [28]. This activation induces an interaction between the sensitive receptors and the central nervous system, triggering autonomic responses that modulate the heart rate response.

The autonomic fibres of the peripheral nervous system and neuroaxis must adapt similarly to the neighbouring sensory and motor fibres. The author states that movements of the kyphotic thoracic spine, with flexion of the lumbar spine and extension of the upper cervical spine, may possibly place the sympathetic trunk under tension. Excitatory symptoms and deficiencies of the ANS may be provoked by chemical irritation or mechanical stimuli, such as stretching and compression. Similarly to the findings described by Ketelaar *et al*., the present study found a reduction in function of the PNS and an increase in SNS activity following flexion of the trunk in individuals with cerebral palsy.

Winsley *et al*. carried out a short-term study (5 min) of high and low frequency waves of HRV in 12 children between 11 and 12 years of age [30]. Data on HRV at rest in the supine position were collected and the authors reported low correlation coefficients.

In the present study, some individuals obtained improvement regarding the chronotropic myocardial reaction, thereby suggesting a better physiological response when moving from a supine to erect position. However, analyzing the total SNS and PNS activity, individuals exhibited a tendency toward a higher level of tension, with a predominance of SNS activity.

As individuals with CP, the subjects in the present sample had a chronic pathology. However, an analysis of the results found no statistically significant difference between SNS and PNS activity. Therefore, although SNS activity exhibited a change in the level of functioning, the analysis of heart rate variability in individuals with CP, as assessed through administration of the Slump Test, revealed no statistically significant variations.

In conclusion, the results from the experimental conditions employed allow the conclusion that the individuals with cerebral palsy in the present sample demonstrated no statistically significant difference between SNS and PNS activity. However, after applying the Slump Test an improvement was noted in the chronotropic myocardial reaction, functioning of the physiological systems and adaptation reserve.

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