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Hippotherapy acute impact on heart rate variability non-linear dynamics in neurological disorders

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HIGHLIGHTS

- A hippotherapy session induced an acute autonomic response in neurological patients.
- Changes in HRV and HRV complexity were found during the session and during recovery.
- Vagal tone and HRV increased during and after the session, respectively.
- Hippotherapy might benefit disabled children affected by neurological disorders.

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ABSTRACT

Neurological disorders are associated with autonomic dysfunction. Hippotherapy (HT) is a therapy treatment strategy that utilizes a horse in an interdisciplinary approach for the physical and mental rehabilitation of people with physical, mental and/or psychological disabilities. However, no studies have been carried out which evaluated the effects of HT on the autonomic control in these patients. Therefore, the objective of the present study was to investigate the effects of a single HT session on cardiovascular autonomic control by time domain and non-linear analysis of heart rate variability (HRV). The HRV signal was recorded continuously in twelve children affected by neurological disorders during a HT session, consisting in a 10-minute sitting position rest (P1), a 15-minute preparatory phase sitting on the horse (P2), a 15-minute HT session (P3) and a final 10-minute sitting position recovery (P4). Time domain and non-linear HRV indices, including Sample Entropy (SampEn), Lempel-Ziv Complexity (LZC) and Detrended Fluctuation Analysis (DFA), were calculated for each treatment phase. We observed that SampEn increased during P3 (SampEn = 0.56 ± 0.10) with respect to P1 (SampEn = 0.40 ± 0.14, $p < 0.05$), while DFA decreased during P3 (DFA = 1.10 ± 0.10) with respect to P1 (DFA = 1.26 ± 0.14, $p < 0.05$). A significant SDRR increase ($p < 0.05$) was observed during the recovery period P4 (SDRR = 50 ± 30 ms) with respect to the HT session period P3 (SDRR = 30 ± 10 ms). Our results suggest that HT might benefit children with disabilities attributable to neurological disorders by eliciting an acute autonomic response during the therapy and during the recovery period.

1. Introduction

Ample evidence exists that neurological disorders represent one of the most serious threats to public health [1]. They account for 6% of the global burden of disease, as expressed in Disability-Adjusted Life Years (DALYs). Clinical manifestations are determined by the specific disorder, but often include loss of muscle tone, selective motor control and balance [2]. These abnormalities can result in various degrees of physical disability in various facets of body movement, which can restrict physical activity performance and participation in daily life and situations ranging from leisure pursuits to education and social roles [1,3,4]. Taking the disability component of burden alone, neurological conditions account for 14% of worldwide disability, as expressed in Years of healthy life Lost as a result of Disability (YLDs).

Neuromuscular and movement stability control can be altered in neurological patients [2,5]. Changes in muscle synergy recruitment were found in neurological patients and were shown to be related to functional impairment and clinical parameters including selective motor control, strength and spasticity [6]. Moreover, atypical

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movement patterns associated with an impaired ability were documented in neurological patients [7,8,2].

There is evidence that neurological disorders can be associated with autonomic dysfunction [9,10,11,12]. A wealth of evidences demonstrated that evaluation of neural regulation of the heart by means of heart rate variability (HRV) analysis is a helpful clinical tool able to provide useful information regarding not only sympathetic or parasympathetic activity, but also functional integrity of the central nervous system [13]. Besides linear HRV parameters in the time and frequency domains, non-linear complexity metrics have been developed to describe the regularity of heart rate (HR) time series [14]. The application of these novel methods of analysis has led to a higher sensitivity for detecting autonomic dysfunction [15], as non-linear parameters are able to quantify different aspects of the cardiovascular (CV) control related to the system non-linear dynamics, which classical linear tools are not able to adequately assess [16]. Autonomic alterations, reflected in altered HRV indices, were found in patients affected by cerebral palsy (CP), epilepsy, autism spectrum disorder (ASD) and neurodevelopmental disorders [9,2,17,18].

Along with promotion, prevention and treatment, rehabilitation programs are one of the key components of the primary health-care strategy for patients affected by neurological disorders [1]. A wide range of rehabilitation interventions has been shown to contribute effectively to the optimal functioning of people with disabilities attributable to neurological disorders [19]. Hippotherapy (HT) is a therapy treatment strategy that utilizes a horse in an interdisciplinary approach for the physical and mental rehabilitation of people with physical, mental and/or psychological disabilities [20]. Nowadays, HT is not only used for physical rehabilitation, but also for developing attention, communication, learning, and social skills in individuals who have a wide range of disabilities [20]. HT has been used in patients affected by neurological conditions, such as CP [21,22,23,24], ASD [25,26], delayed psychomotor development [27], anxiety and posttraumatic stress symptoms [28], for many years. Reported HT physical benefits include increased postural control and coordination [29,30], enhanced proprioception [31], improved balance [32,30], better weight transference [21], increased muscle tone, improved spatiotemporal parameters of gait [33,34] and relaxation of tensed muscles.

HT therapeutic value for neurological disorder patients is well accepted, especially when applied during critical periods of development in children whose neurological condition is known to prevent the acquisition of normal motor skills [27,35]. Nonetheless, current literature is scarce and often limited to case reports and descriptive studies [36,25] and there is a dearth of rigorous scientific evidence to support the many observations from case studies examining these therapeutic benefits [37]. Recent evidence suggests that the cardiac autonomic regulation system can be influenced by active movements and passive standing training in patients with disabilities attributable to neurological disorders, including, for example, CP children [38]. However, to the best of our knowledge, no studies have been carried out to evaluate the effects of HT on the CV autonomic control mechanisms in children affected by neurological disorders. Therefore, the objective of the present study was to investigate the effects of a single HT session on autonomic CV control in a group of children affected by neurological disorders by means of time domain and non-linear analysis of HRV.

2. Methods

2.1. Study population

Children participating in the HT program offered by the *Instituto Marcos Sahium*, Uberlândia, MG, Brazil, were recruited through verbal invitation to their parents/guardians. Children between the ages of 4 and 12 years affected by neurological disorders were eligible. Participants were excluded if they presented with atlantoaxial instability, coxofemoral luxation, structural scolioses > 35°, osteoporosis, spinal disc herniation or severe cardiomyopathy. A total of 12 children provided assent to participate in the study and their parents/guardians signed the written informed consent document. The study was approved by the medical ethics committee (process n° 649.851).

2.2. Experimental protocol

At the beginning of the test, the protocol was explained to the participants and their parents/guardians, who afterwards signed the informed written consent. The whole test consisted in a 10-minute sitting position rest (P1), a 15-minute preparatory phase sitting on the horse (P2), a 15-minute HT session (P3) and a final 10-minute sitting position recovery (P4). During rest and recovery, participants were seated on chairs or in their own wheelchairs. During the preparatory phase and the HT session, participants were seated in straddle position, using a horse blanket and surcingle (no saddle) to experience the warmth and multidimensional movements of the horse. A trained instructor directed the horse with a lead line attached to its halter. During the HT session, the horse was led in a slow, steady walk, in circles or on a straight line.

2.3. Measurements

Anthropometric measures, including weight and height, were collected before the test. HR, breathing frequency (BF), peripheral oxygen saturation (SpO_2), systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured while resting in seated position, 5 min before the preparatory phase and 5 min after the HT session. During all phases, interbeat intervals (IBI) were continuously measured using a portable, digital telemetry system (Polar® RS800CX, *Polar Electro Oy*, *Kempele*, *Finland*) that consisted of a transmitter placed on the patient's chest and a HR monitor placed on the patient's dominant wrist or, if no dominant limb was indicated, on the right wrist. This system is able to detect ventricular depolarization (corresponding to the electrocardiogram (ECG) R wave) at a sampling rate of 500 Hz. Collected signals were transmitted to a receiver for subsequent analysis.

2.4. Data analysis

Data analysis was performed in the MATLAB® environment (version R2012a, *The Mathworks Inc.*, *Natick*, *MA*). For each period and for each patient, the corresponding tachogram was considered and the first minute of signal was discarded from each signal portion recorded during each protocol phase, in order to exclude possible artifacts due to the transition between a phase and the subsequent one. Then, stationary and free of artifacts 600 beat portions were selected on the remaining signal portion. A set of time domain and non-linear complexity measures (which will be described in the following) were derived for each signal portion. For each period, the average values ($\pm$SD) of each time domain parameter and non-linear measure were calculated for the whole population, in order to comprehensively assess the HRV behavior in our study sample. The parameters that were considered are defined in the following sections.

2.4.1. Time parameters

i) Mean RR interval:
the interbeat (RR) intervals average value, in ms.
ii) SDRR:
the RR intervals standard deviation, in ms.

2.4.2. Non-linear parameters

i) Sample entropy (SampEn)
SampEn is a widely used complexity measure which, by comparing a time series to a given pattern of length *m*, provides an