HEART RATE AND ITS VARIABILITY IN RESPONSE TO SUBMAXIMAL CYCLE

ERGO-METER IN CHILDREN WITH CEREBRAL PALSY

Yasmin Mohamed Mahmoud[1], Amira Mohamed El-Tohamy[2], Walaa Abd El-Hakiem Abd El-Nabie[3], and Faten Abdo-Almonem Amara[4].

[1]Department of Physical Therapy for Pediatrics, Fevers Hospital, Benha, Qalyubia, Egypt
[2,3]Department of Physical Therapy for Pediatrics, Cairo University, Egypt.
[4]Department of Pediatrics, Health Insurance Hospital, Nasr City

Abstract

Background: Irregular heart rate (HR) and heart rate variability (HRV) are common problems among children with cerebral palsy (CP) which may be associated with low physical tolerance. The aim of the current study was to investigate the response of HR and HRV at rest, during submaximal cycle ergo-meter and at first and second minutes rest post exercise in children with CP.

Methods: Thirty children with spastic CP of both sexes, aged from 7 to 11 years were participated in the present cross-sectional study. They were divided into two equal groups (15 children in each group); A and B.Children with spastic hemiplegia were allocated to group A while children with spastic diplegiawere allocated to group B. HR and HRV were assessed and monitored by the Polar Advanced Heart Rate Monitor (RC800CX) at four-time intervals. Four-time intervals were; five minutes rest pre cycle ergo-meter, during last stage of submaximal cycle ergo-meter, and at first and second minutes rest post cycle ergo-meter.

Results: The results of the current study revealed that, in group A there were significant difference in HR and HRV between the four-time intervals (p=0.001,0.0001) respectively. Also in group B there were significant difference in HR and HRV between four-time intervals (p=0.001, 0.0001) respectively.

Conclusion: In children with CP, HR and HRV responded to submaximal cycle ergo-meter.

Keywords: Cerebral palsy, Heart rate, Heart rate variability, Submaximal cycle ergo-meter.

Introduction

Cerebral palsy describes chronic developmental disabilities, that restrict the control of movement which result from immature brain damage **(1)**. CP is a common cause of physical impairment in childhood.Children with CP in comparison with typically developing (TD) children have lower level of physical activity and aeroic capacity**(2)**. Physical inactivity is due to impaired physical condidtions and motor capabilities as muscle weakness and lowered cardiorespiratory fitness**.** Also physical inactivity among children with CP is caused by deficit in autonomic heart regulation system **(3)**. HRV is the time variation of the period between two consecutive heartbeats,it depends on regulation of HR. HRV reflects the cardiac ability to accommodate changable circumstances by identifying and responding to unexpected stimuli **(4).** In supine position, children with CP have lower HRV and higher resting HR compared with TD children **(5)**. During postural change (sitting,head up and standing), children with CP had limitations in accommodating their heart sympathovagal balance **(6).**

Heart rate variability is non-invasive method used to assess the control ofcardiovascular autonomic system. Analysis of HRV can be accomplished in children affected with different diseases such as: CP, obesity, sleep apnea, attention deficit hyperactivity disorder and Duchene muscular dystrophy **(7).** Analysis of HRV is a valid modality of autonomic nervous system evaluation. It provides valuable information related to neurodevelopmental outcome of children and their regulatory abilities **(8)**.

Submaximal exercise is the physical activity in which its intensity increases at regular intervals, but not exceed than 85 percent of maximum HR according to the American Council of Exercise.Treadmill test and stationary bike are from the types of submaximal exercise tests **(9) .** Submaximal exercise testingis a method of choice for patients seen by physical therapist. It overcomes limitations of maximal exercise testing**(10).** So, the purpose of the current study was to investigate the response of HR and HRV to submaximal cycle ergo-metr .It was hypothesized that ,there was a response of HR and HRV to submaximal cycle ergo –meter in children with CP.

Material and methods:

Study design: Cross sectional study design. (Small sample is Delimitation)

Participants: thirty children with spastic CP ranged in age from 7to 11 years were enrolled in this study from December 2017 to September 2018.They were selected from the Outpatient Clinic of the Faculty of Physical Therapy, Cairo University .The children were divided into two groups; A and B. Fifteen hemiplegic CP children enrolled in group A, while fifteen diplagic CP children allocated in group B as shown in Fig. (1). The diagnosis of hemiplegia and diplagia were confirmed by pediatric neurologist.The children were selected at level I and II according to Gross Motor Function Classification System (GMFCS)**(11)** ,and the degree of spasticity ranged from 1 to 1^{+} according to Modified Ashworth Scale**(12)**. The children were excluded when they hadcognitive or behavioral impairment, cardiovascular disease, visual and auditory problems, fixed deformity of both upper and lower limbs, and if child injected with Botulinum Toxin in the last six months.

The current study was carried out and approved according to the rules of Ethical Committee of the Faculty of Physical Therapy, Cairo University (NO:P.T.REC\012\001704).

Measurement procedures:the polar advanced heart rate monitor (RC800CX) is a valid and reliable tool used to measure HR and HRV. Also it is non-invasive, economical and portable device(13) .It consists of Polar wear link ,wrist and chest sensor . The wrist sensor part linked with computer which displays and records the heart rate and other data like position and velocity during examination (14).

The evaluation procedures included the measurement of HR and HRV at rest, during submaximal cycle-ergometer exercise and post exercise (1 and 2 minutes rest post exercise) as the following:

Measurement at rest: Each child was asked to sit quietly for 5 minutes on a chair, with the sensor of polar advanced HR monitor around his trunk and computer device was attached to his wrist. Then the HR and HRV were recorded during this position**.**

Measurement during submaximal cycle-ergometer exercise: McMaster protocol is a protocol of submaximal cycle-ergometer that was applied in the current study. It is a protocol of submaximal exercises specific for children**(15).** All children performed the McMaster protocol on an electronically Braked cycle ergometer. Protocol started by 2mint warm up. The protocol is performed in 4 stages byinitial power 10W, then power increased by 25W every 2 minute. Child was instructed to maintain a constant pedal rate during test. All children were verbally encouraged to continue exercise until final stage. For each child, HR and HRV were monitored and recorded at the end of the last stage of the Macmaster ergometer protocol **(16)**.

Stage (1): 2mint, (10w).

Stage (2): 2mint, (10+25=35w).

Stage (3): 2mint, (35+25=65w)

Stage (4): 2mint, (65+25=90w)

The exercise was ended when HR reached the value of the predicted maximal HR for 80% intensity of effort (based on Karvina formula target HR = [(max HR − resting HR) × %

intensity] + resting HR) or when the child asked to stop the test because of inability to continue**(3).**

Post exercise measurement: Heart rate and HRV were measured at 1and 2mint post exercise the same as measurement at rest.

Statistical analysis:

Descriptive statistics including mean, median and standard deviation were performed for presentation of variables. ANOVA with repeated measures was conducted for comparison between pre exercise, last test stage, 1 minute after exercise, 2 minutes after exercise of HR and HRV in each group.

Results

Group A: Fifteen children with spastic hemiplegia were included in this group. Their mean ± SD age, weight, height and BMI were 8.66 ± 1.23 years, 28.3 ± 9.34 kg, 123.26 ± 7.65 cm and 18.21 ± 4.15 kg/m² respectively.

Group B: Fifteen children with spastic diplegia were included in this group. Their mean ± SD age, weight, height and BMI were 9.06 ± 1.33 years, 27.8 ± 6.62 kg, 125.86 ± 5.09 cm and 17.39 ± 3.27 kg/m² respectively.

The sex distribution of group A revealed that there were 3 (20%) girls and 12 (80%) boys. The sex distribution of group B revealed that there were 4 (27%) girls and 11 (73%) boys.

Results of group (A)

I: Mean values of HR pre exercise, last test stage, 1 minute after exercise, 2 minutes after exercise of group A: The mean ± SD HR of group A pre exercise was 98.06 ± 4.46 beat/min, while at last test stage was 140.23 ± 0.77 beat/min and at 1 minute after exercise was 128.46 ± 1.93 beat/min; and at 2 minute after exercise was 103.06 ± 2.49 beat/min. Comparison between pre exercise, last test stage, 1 minute after exercise, 2 minutes after exercise revealed a significant difference in HR between the four-time intervals (p = 0.0001), (Table 1).

Table 1.*Comparison of heart rate mean values between pre exercise, last test stage, 1 minute after exercise, 2 minutes after exercise of group A (Anova with repeated measures for comparison measurement over time):*

Heart rate (beat/min)				**F- value**	**p- value**	**Sig.**
$\bar{X}$ ±SD						
Pre exercise	**Last test stage**	**1 minute after exercise**	**2 minutes after exercise**			
98.06 ± 4.46	140.23 ± 0.77	128.46 ± 1.93	103.06 ± 2.49	967.55	0.0001	**S**

Multiple comparison (Bonferroni test)

	MD	**% of change**	**p- value**	**Sig**
Pre exercise Vs last test stage	-42.17	43	0.0001	**S**
Pre exercise Vs 1 minute after exercise	-30.4	31	0.0001	**S**
Pre exercise Vs 2 minutes after exercise	-5	5.09	0.01	**S**
Last test stage Vs 1 minute after exercise	11.77	8.39	0.0001	**S**
Last test stage Vs 2 minute after exercise	37.17	26.5	0.0001	**S**
1 minute after exercise Vs 2 minute after exercise	25.4	19.77	0.0001	**S**

$\bar{x}$: Mean, SD: Standard Deviation, MD: Mean difference, p value: Probability value, S: Significant.

II: Mean values of HRV pe exercise, last test stage, 1 minute after exercise, 2 minutes after exercise of group A: The mean ± SD HRV of group A Pre exercise was 48.38 ± 2.66 msec, while at last test stage was 9.74 ± 1.09 msec and at 1 minute after exercise was 17.36 ± 1.18 msec; and at 2 minute after exercise was 30.9 ± 1.63 msec. Comparison between pre exercise, last test stage, 1 minute after exercise, 2 minutes after exercise revealed a significant difference in HRV between the four-time intervals (p = 0.0001) (Table 2).

Table 2: ***Comparison of HRV mean values between pre exercise, last test stage, 1 minute after exercise, 2 minutes after exercise of group A:(Anova with repeated measures for comparison measurement over time):***

Heart rate variability (msec)				**F- value**	**p- value**	**Sig**
$\bar{X}$ **±SD**						
Pre exercise	**Last test stage**	**1 minute after exercise**	**2 minutes after exercise**			
48.38 ± 2.66	9.74 ± 1.09	17.36 ± 1.18	30.9 ± 1.63	3572.27	0.0001	**S**

Multiple comparison (Bonferroni test)	**MD**	**% of change**	**p- value**	**Sig**
Pre exercise vs last test stage	38.64	79.86	0.0001	**S**
Pre exercise vs**1 minute after exercise**	31.02	64.11	0.0001	**S**
Pre exercise vs**2 minutes after exercise**	17.48	36.13	0.01	**S**
Last test stage vs**1 minute after exercise**	-7.62	78.23	0.0001	**S**
Last test stage vs**2 minute after exercise**	-21.16	217.24	0.0001	**S**
1 minute after exercise vs**2 minute after exercise**	-13.54	78	0.0001	**S**

$\bar{X}$ Mean, SD: Standard Deviation, MD: Mean difference, p-value: Probability value, S: Significant.

Results of group B:

I: Mean values of HR pre exercise, last test stage, 1 minute after exercise, 2 minutes after exercise of group B: The mean ± SD HR of group B pre exercise was 96.8 ± 2.7 beat/min, while at last test stage was 142.8 ± 1.23 beat/min and at 1 minute after exercise was 130.4 ± 2.29 beat/min; and at 2 minute after exercise was 105.26 ± 1.83 beat/min. Comparison between pre exercise, last test stage, 1 minute after exercise, 2 minutes after exercise revealed a significant difference in heart rate between the four-time intervals (p = 0.0001), (Table 3).

Table 3: ***Comparison of HR mean values between pre exercise, last test stage, 1 minute after exercise, 2 minutes after exercise of group B:(Anova with repeated measures for comparison measurement over time):***

Heart rate (beat/min) $\bar{X}$ ±SD				F- value	p-value	Sig
Pre exercise	**Last test stage**	**1 minute after exercise**	**2 minutes after exercise**			
96.8 ± 2.7	142.8 ± 1.23	130.4 ± 2.29	105.26 ± 1.83	4054.92	0.0001	**S**

Multiple comparison (Bonferroni test)

	MD	% of change	p- value	Sig
Pre exercise Vs last test stage	-46	47.52	0.0001	**S**
Pre exercise Vs 1 minute after exercise	-33.6	34.71	0.0001	**S**
Pre exercise Vs 2 minutes after exercise	-8.46	8.73	0.0001	**S**
Last test stage Vs 1 minute after exercise	12.4	8.68	0.0001	**S**
Last test stage Vs 2 minute after exercise	37.54	26.28	0.0001	**S**
1 minute after exercise Vs 2 minute after exercise	25.14	19.27	0.0001	**S**

$\overline{X}$ **:** Mean, SD: Standard Deviation, MD :Mean difference, p-value: Probability value,S: Significant.

II. Mean values of pre exercise, last test stage, 1 minute after exercise, 2 minutes after exercise of group B: The mean ± SD HRV of group B pre exercise was 51 ± 2.76 msec, while at last test stage was 10.93 ± 1.55 msec and at 1 minute after exercise was 18.53 ± 1.97 msec; and at 2 minute after exercise was 31.93 ± 2.87 msec. Comparison between pre exercise, last test stage, 1 minute after exercise, 2 minutes after exercise revealed a significant difference in heart rate variability between the four-time intervals (p = 0.0001), (Table 4).

Table 4: ***Comparison of heart rate variability mean values between pre exercise, last test stage, 1 minute after exercise, 2 minutes after exercises group B:(Anova with repeated measures for comparison measurement over time):***

Heart rate variability (msec)				**F- value**	**p- value**	**Sig**
$\overline{X}$ **±SD**						
Pre exercise	**Last test stage**	**1 minute after exercise**	**2 minutes after exercise**			
51 ± 2.76	10.93 ± 1.55	18.53 ± 1.97	31.93 ± 2.87	6542.66	0.0001	**S**

Multiple comparison (Bonferroni test)

	MD	**% of change**	**p- value**	**Sig**
Pre exercise Vs last test stage	40.07	78.56	0.0001	**S**
Pre exercise Vs 1 minute after exercise	32.47	63.66	0.0001	**S**
Pre exercise Vs 2 minutes after exercise	19.07	37.39	0.0001	**S**
Last test stage Vs 1 minute after exercise	-7.6	69.53	0.0001	**S**
Last test stage Vs 2 minute after exercise	-21	192.13	0.0001	**S**
1 minute after exercise Vs 2 minute after exercise	-13.4	72.31	0.0001	**S**

$\bar{x}$: Mean, SD: Standard Deviation, MD: Mean difference, P-value: Probability value, S: Significant

Discussion

The present study aimed to investigate the response of HR and HRV during submaximal cycle ergonomic exercise in children with CP.

The current work adds a unique donation by demonstrating the response of HR and HRV during submaximal cycle-ergometer and post exercise in children with CP as most of previous studies evaluated HR and HRV during passive manipulation and/or rest.

The current results showed that there were significant differences in HR and HRV between the four-time intervals in both groups. HR increased gradually during submaximal exercise and decreased gradually at 1and 2 mint post exercise while HRV decreased gradually during submaximal exercise then increased gradually at 1and2 mint post exercise.

Izadi et al(17)reported that submaximal exercise could be employed to evaluate and monitor the cardiorespiratory fitness of a child with CP by increasing the capacity of oxygen transportation and the excretion of waste materials.

Cycle ergometer has an essential advantage in the area of exercise testing. This is supported by **Bongers et al .(18)**Who clarified that several physiological parameters such as; HRV and blood pressure are easier to be assessed during exercise by using cycle ergometer than treadmill.

Kholod et al.(19)demonstrated that the mean value of HR was significantly higher and value of HRV was significantly lower in children with CP during exercises compared with TD children.

The current significant increase in HR and decrease in HRVduring submaximal cycle-ergometer may be due to inability of CP children to achieve the required demand to stimulate the cardic autonomic system. This is conformed by **Amichai. (3)** who reported that the increase in HR and decrease in HRV during submaximal exercise in children with CP may be due to limited ability of autonomic and motor systems to produce a demand of the cardiac system above the resting state**.**

The significant difference in recovery period (small decreases in HR and a small increases in HRV in the first minute post exercise, and a greater decrease and greater escalation, respectively, in the second minute post exercise) may be due to reactivation of the parasympathetic system immediately following the exercise. This is confirmed by**Ahmadian**. **(20)** who report that the recovery stage following submaximal exercise was represented by a small decrease in HR and a small escalation in HRV in the first minute post exercise, and a greater decrease and greater escalation, respectively, in the second minute post exercise.

Yang et al.(21) reported that children with CP have an impairment in autonomic system which may be due to spasticity in their muscles that leads to sedentary life .

Lundberg et al. (17) demonstrated that during submaximal exercise, spastic CP children have lower physical capacity and higher HR, lactate concentration and energy expenditure than TD childre

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