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Original Article

The effect of Sub-maximal exercise-rehabilitation program on cardio-respiratory endurance indexes and oxygen pulse in patients with spastic cerebral palsy

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ABSTRACT

***Background**:* Physical or cardio-respiratory fitness are of the best important physiological variables in children with cerebral palsy (CP), but the researches on exercise response of individuals with CP are limited. Our aim was to determine the effect of sub-maximal rehabilitation program (aerobic exercise) on maximal oxygen uptake, oxygen pulse and cardio-respiratory physiological variables of children with moderate to severe spastic cerebral palsy diplegia and compare with able-bodied children.

Methods: In a controlled clinical trial study, 15 children with diplegia spastic cerebral palsy, were recruited on a voluntarily basis (experimental group) and 18 subjects without neurological impairments selected as control group. In CP group, aerobic exercise program performed on the average of exercise intensity (144 beat per minute of heart rate), 3 times a week for 3 months. The time of each exercise session was 20-25 minutes. Dependent variables were measured in before (pretest) and after (post test) of rehabilitation program through Mac Master Protocol on Tantories cycle ergometer in CP group and compared with the control group.

Results: The oxygen pulse (VO_2/HR) during ergometery protocol was significantly lower in CP group than normal group ($P<0.05$). No significant statistical difference in maximal oxygen uptake ($VO_{2\ max}$) was found between groups. The rehabilitation program leads to little increase of this variable in CP group. After sub-maximal exercise in pretest and post test, the heart rate of patient group was greater than control group, and aerobic exercise leads to significant decrease in heart rate in CP patients($P<0.05$).

Conclusion: The patients with spastic cerebral palsy, because of high muscle tone, severe spasticity and involuntarily movements have higher energy cost and lower aerobic fitness than normal people. The rehabilitation exercise program can improve physiological function of muscle and cardio-respiratory endurance in these patients.

Key words: Spastic Cerebral Palsy, Rehabilitation, Oxygen Pulse, Cardio-respiratory Endurance

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Cerebral palsy (CP) is a description, not a specific diagnosis, that covers a number of neurological conditions resulting in abnormal development of movement and postural control, which occurs in prenatal, natal and early postnatal periods [1]. It depend on the type and intensity of injury, influences life condition and leads to neuromuscular disorder, involuntarily movements, mental retardation, abnormal muscle tone, and disturbance in thin and large movements [2]. Medical definition of CP is "a non-progressive (but not unchanging) disorder of movement and/or posture, due to an insult to or abnormal development of brain [3]. Children and teens with CP particularly spastic, usually have weak neuromuscular function [4]. Spastic cerebral palsy is the most common type of cerebral palsy, accounting for half [5] or nearly

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80 percent [3] of all CP cases that have some difficulties in daily movements and resistance against normal movements because of high muscle tone [2]. This failure results in damage to upper motor neuron of brain cortex or spinal pathways [2].

Children with spastic cerebral palsy have stiff and jerky movements and often have a hard time moving from of position to another [3]. Spasticity may be very mild and affect only a few movements, or very severe and affect the whole body. The amount of spasticity usually changes over time [2]. Spastic muscles consume higher energy and oxygen uptake for exercise than the normal muscles [6]. The defect or incorrect adaptation in cardiovascular system decreases the enough transportation of oxygen and nutrition materials to active muscles or other tissues during daily activity or exercise [7].

Maximal oxygen uptake or aerobic capacity (VO_{2max}) is an indicator of cardio-respiratory endurance that is the highest capability of body in the uptake of oxygen during physical activity [8]. If VO_{2max} increases, the cardio-respiratory fitness will increases [8]. Sub-maximal exercise-rehabilitation program increases the capacity of oxygen transportation and the excretion of waste materials [2, 9]. There are limited researches on the exercise response in patients with CP. This may be related to a fact that participation in exercise programs has been limited in this population. Person with CP have also been reported to have increased adiposity [10], low muscle force [11], lower aerobic and anaerobic power [12, 13], decreased mechanical efficiency [13], decreased respiratory function [14] and earlier muscle fatigue [15] than their non-disabled peers.

Lundberg et al. have indicated that during maximal and sub-maximal exercise, spastic patients have lower physical work capacity, pulmonary ventilation, and have higher heart rate, blood lactate concentration and energy expenditure than normal group [6]. Unnitan et al have found that maximal oxygen uptake in spastic children and older is lower than normal group [5]. In addition, Bar-or-o and Dwyer have showed that cardiovascular fitness and aerobic capacity in spastic group almost have been 10-30% lower than normal group [2,6,16]. However, Bowen et al reported no statistically significant differences in the percentage of variability of oxygen cost, oxygen consumption, or physiological cost index between subjects with or without CP that are free-walking velocity [17].

Unfortunately, rehabilitation and therapy services for CP patients often end or dramatically decrease at adulthood, and rarely include fitness related goals. Because of the dangers of inactivity, innovative forms of physical activity and exercise for persons with mobility impairment need to be developed and implemented.

So, our aim was to investigate sub-maximal rehabilitation program on the cardio-respiratory function indexes in spastic cerebral palsy.

Subjects and Methods

In this study, 15 voluntarily selected children with spastic diplegia cerebral palsy (experimental group) and 18 normal children in control group were enrolled in Hamadan, Iran in spring 2004. The mean and standard deviation of age, weight

and height in CP group were 12±2 years, 29.83±5.64 kg and 131±6.34 cm, respectively, which were almost similar with control groups.

Evaluating cardiovascular fitness using some form of wheelchair ergometer (preferably the individuals own chair on wheelchair rollers) provides the most functional assessment for the wheelchair used with CP [18]. However, various forms of arm crank ergometers are frequently used in the research literature [18]. The treadmill will optimize the exercise test response for ambulatory CP patients [19, 20]. Of course, one disadvantage of wheelchair and treadmill is difficulty in accurately calculating of variables, controlling, balance, and other coordination that induced clinician to choose a protocol on leg cycle ergometer [12-14].

So, in our study, for evaluating aerobic capacity (VO_{2max}), oxygen pulse (VO_2/HR) and the other cardiovascular variables, both groups were tested on a leg cycle ergo meter (Tantori model, Taiwan) according to Mac Master protocol [21]. The type and range of damage in spastic patients was moderate to intense, according to Ashword predicated scale [22]. The subjects performed ergometery protocol (CP pretest), with warming up for two minutes (mean power output 5-10 watt) on cycle ergo meter. The Mac Master protocol performed at 4 stages, each stage lasting for two minutes that power output is increased in each stage. Polar telemetry recorded the heart rate at the end of each stage.

If fatigue was seen in the subjects, or those heart rate was approached to 170 (beat/min), the test would stopped in that stage. In spastic group, sub-maximal exercise rehabilitation program was performed with average of exercise intensity (144 beat per minute of heart rate), 3 sessions per week (each session of exercise lasted 20-25 minutes) for 3 months and all variables were calculated. At the end of rehabilitation program, ergometery protocol was repeated in spastic and in control group (CP post test).

All data were presented as mean ± standard deviation. ANOVA (two-way repeated measure) was used to determine significant differences between groups. Statistical significant was accepted at $P<0.05$.

Results

This study had some limitation in its samples and measures which are frequently mentioned in reports of studies of children with CP [23].

The exercise intensity was different in all stages of ergometery test. The mean and standard deviation of physical factors and cardio-respiratory indexes of the subjects in two groups are listed in Table 1.

Three numbers of spastic patients completed all 4 stages of ergometery protocol in pretest, but in post test, the majority (13 numbers) of them completed all stages of protocol. All healthy children performed all 4 stages of ergometery protocol.

Oxygen pulse (mlO_2/beat) that is an indicator of cardiovascular fitness was significantly increased in spastic group after rehabilitation program (Figure1). This figure shows that oxygen pulse in pretest of patients is remarkable lower than control children and increased significantly after rehabilitation program (post test) in the

patients, but is lower than control group yet. Maximal oxygen uptake or aerobic capacity (VO_{2max}) was almost similar in CP and control groups, and have little increased (no significant) in CP group after sub-maximal rehabilitation program (Figure 2).

In the spastic group, the heart rate was significantly more than control group in pre and post test ($p<0.05$). The rehabilitation program decreased heart rate in the patient group (Figure 3). The heart rate of performing in ergometery protocol in the patients (pre and post test) is significantly greater than control group which increased after rehabilitation program in the patients, but is greater than control group yet.

Table 1. Physical factors and physiologic indexes in the CP patients and controls

group	Age (Year)	Hight (cm)	Weight (kg)	Rest heart rate(bpm)	Exercise heart rate(bpm)	Oxygen pulse (VO2 / HR)	VO2max (L / MIN)
CP (pretest)	12±2	131±6.34	29.83±5.64	88±4.32	139±8.47	.09±.01	1.56±.05
CP (posttest)	12±2	131±6.34	30±5.80	84±5.74	132±5.49	.11±.01	1.59±.08
control	12±2	133±5.4	28.14±4.18	77±6.33	121±9.35	.13±.02	1.60±.11

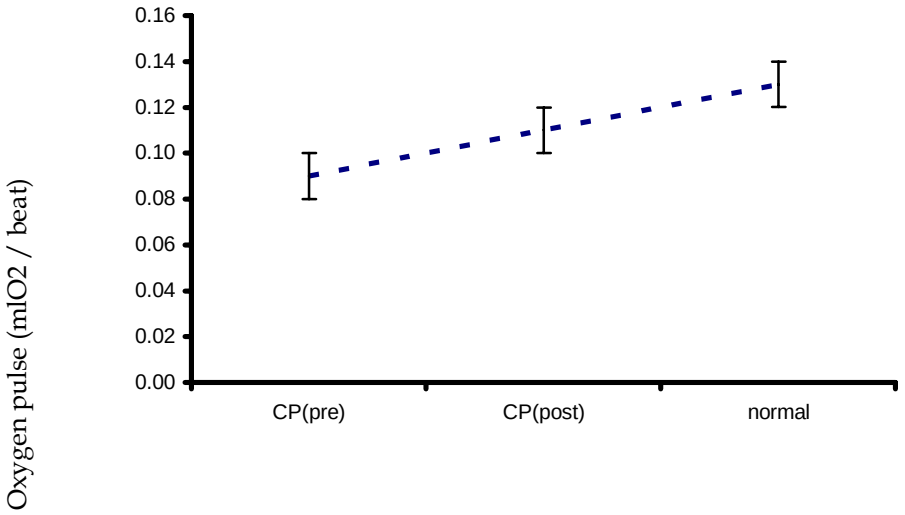

Figure 1. Oxygen pulse during ergometery protocol in the CP patients and controls

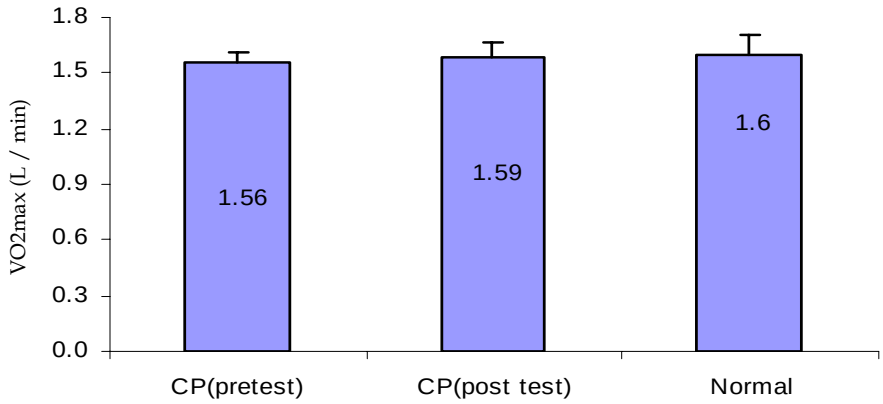

Figure 2. The mean and standard deviation of aerobic capacity (VO2max) during ergometery protocol

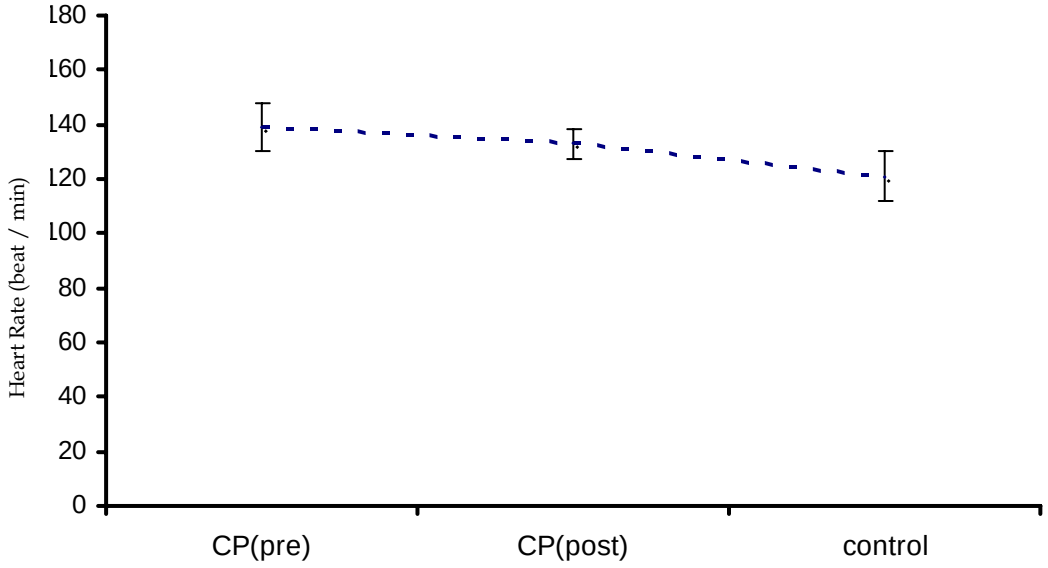

Figure 3. The mean and standard deviation of heart rate during ergometery protocol

Discussion

Sub-maximal training depend on intensity and duration, increases maximal oxygen uptake [1, 7], or through decrease in difference between arterial and venous blood oxygen, increase in cardiac output and then greater capability of skeletal muscle in oxygen uptake [24].

There is not enough evidence for direct relation between cerebral palsy and cardio-respiratory function. Certain studies showed that 9-10.5% of adults with cerebral palsy have cardiovascular disorder [25]. Thus, quadriplegic patients are suffering from gradually enhanced dispnea [25].

The Ashword scale is the most common method of measuring spasticity, using categories of "mild tone", "moderate tone", "severe tone" and "extreme tone" to define an individuals level of spasticity [22]. Despite limitation, the literature variable has clearly documented the positive adoptions of people with CP to both muscular strength and cardiovascular exercise programs [18, 19]. Many researches did not observe significant difference in oxygen pulse, energy expenditure, and respiratory exchange ratio and cardio-respiratory endurance during walking on treadmill in CP children and able subjects [17, 26].

We showed that VO_{2max} in the spastic group is similar to the control group, and sub-maximal exercise rehabilitation program causes little improving of VO_{2max} in CP patients, but it is remarkable from clinical perspective.

Bao-or-O stated that local endurance of muscle and peak aerobic power in CP children is 3-4 standard deviations lower than normal people [2]. The basic cause of decreasing exercise sustain in CP children is high metabolic cost of mechanical movements and low aerobic capacity, although many studies have not indicated difference between Cp patients and normal people [17, 26]. Ten week swimming or Judo program leads to increasing of VO_{2max} [9]. Moreover in Wandenberg study, exercise-rehabilitation program (2-4 time per week for 9 months) increased VO_{2max} in cerebral palsy children significantly [12].

For person with CP, aerobic capacity and endurance can be enhanced through exercise done at intensity equal to 40-85 percent peak VO_2 for 20-40 minutes per session, three to five days a week [15]. In our study, possibility, little increasing in VO_{2max} may be due to low intensity and limitation time in each session of training.

Untrained people have lower aerobic fitness and higher heart rate in rest or exercise than normal people. Bar–or-O observed that heart rate in CP children have significantly decreases after endurance training [2]. In our study, sub-maximal training program significantly decreased the rest and sub-maximal heart rate in spastic group. Because of high physical fitness in the normal group, the rest and sub-maximal heart rate of them was lower than spastic group. Dressen observed that heart rate is equal in light exercise, but during heavy exercise, it will be higher in spastic group than normal people [4]. We also observed this finding in our study.

The other indexes of cardiovascular function is oxygen pulse (VO_2/HR) that depends on amount of oxygen in arterial blood in each heart rate and volume of tissue oxygen uptake [8].

More oxygen pulse results in more cardio respiratory fitness [8]. Increased Oxygen pulse indicates that stroke volume is increased in each heart rate. Our study showed increase in the oxygen pulse after sub-maximal exercise rehabilitation program, but it is less than control group yet. Increase in oxygen pulse points out much difference in arterial-venous blood oxygen [17].

Dependent variables, particularly aerobic capacity, are less in cerebral palsy children than normal people [2]. The endurance exercise improves these variables, depending on its intensity and duration [27]. In cerebral palsy children of this study, sub-maximal exercise rehabilitation program for 3 months resulted in little increasing of VO_{2max}. Because of insufficiency in physiological and mechanical efficiency, the heart rate responses on ergo meter bicycle is more in CP children and the energy cost of mechanical work is increased to over-come the high muscle tone and involuntarily movements.

These results point out that aerobic training relatively improves cardiovascular indexes, and so, increases cardio-respiratory endurance in spastic cerebral palsy children. Such improvement in CP patients, regardless to limiting in neuromuscular tract function and less sustain in intense exercise, is remarkable from clinical perception.

Finally, because of various categories in cerebral palsy types or in the intensity of spasticity in CP patients, our results cannot be generalized to all children with cerebral palsy. So, future studies are necessary to determine and design exercise program with suitable frequently, intensity and duration in each session or in total period of rehabilitation program for this patients.

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