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The effect of rehabilitation program on mechanical efficiency, heat rate and Vo2max in spastic children

Eizadi Mojtaba[a] *, Khorshidi Davood[a], Dooali Housein[a], Kiani Fatemeh[a]

[a]*Islamic Azad University, Saveh Branch*

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Abstract

Aim and scope: Cerebral palsy (CP) Children are generally characterised by some movement limitations physiological abnormalities that compromised with able- bodied people. **Objective**: The objective of this study was to estimate the mechanical efficiency and certain cardiovascular indexes before and after exercise-rehabilitation program in children with dipelegic spastic cerebral palsy (experimental group) in comparison with able- bodied children (control group). **Material and Methods**: In this study fifteen spastic cerebral palsy (dipelegic) children participated in exercise-rehabilitation program (three days a week for three month) with 144bpm of average of heart rate. The mechanical efficiency (net, gross), rest and submaximal heart rate and maximal oxygen consumption (VO_{2max}) were measured before (pre-test) and after (post-test) of exercise program on cycle ergometer according to Macmaster ergometer protocol. Then control group performed this protocol and were compared via statical spss ($P<0.05$). **Results**: Mechanical efficiency (net, gross) increased significantly in cp patients after exercise-rehabilitation program, but yet it was lower than control group ($P<0.05$). Rest and submaximal heart rate in cp patients decreased significantly after exercise program ($P<0.05$). Maximal oxygen consumption was similar in patients and normal groups and not changed in patients after exercise-rehabilitation program ($P>0.05$). **Conclusion**: cerebral palsy patients have higher energy cost and lower physical fitness than able bodied people that is because of high muscle tone, severe degree of spasticity and involuntarily movements. The rehabilitation and aerobic exercise can be effective in improving cardiovascular fitness and muscle function in cerebral palsy patients and increases their mechanical efficiency.

Keywords: Spastic cerebral palsy; maximal oxygen consumption; heart rate; mechanical efficiency; rehabilitation.

1. Introduction

Cerebral palsy(CP) is a disorder in neuromuscular system that appears to follow damage cerebral cortex or failure cerebrospinal paths, before and during of birth or early years of life. This disease occurs two in hundred of birth(1,2). The half of the cerebral palsy patients are spastic. Spastic muscles are always contraction, so that there is high muscle tone (spasm) in agonist muscles and weakness in antagonist muscles. These disabilities during deambulation may lead to excessive energy cost and so to compromised energy efficiency (3). Cerebral palsy patients, because of low physical

* Eizadi Mojtaba. Tel.: +989193551960
E-mail address: Izadimojtaba2006@yahoo.com

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activity and movement limitation during exercise have higher oxygen uptake and lower mechanical efficiency and physical work capacity than normal people(1,4) so that, a study showed that submaximal energy expenditure of walking on treadmill in spastic children is threefold of normal children(5).

The researches indicated that exercise–rehabilitation on the side of clinical and physical therapy leads to improving these patients. In this regard, lundberg has pointed out that physical work capacity in cerebral palsy patients is half of normal group and cp group have mechanical efficiency (net, gross) lower than normal people during ergometery exercise, so that in submaximal exercise condition on ergometer, difference in mechanical efficiency between cp patients and able bodied children in light output is little but in high output mechanical efficiency in cp group is very lower than normal people (6, 7). Mechanical efficiency may be a useful objective technique to assess the effects of interventions intended to improve the efficiency of the movement of children with CP. Degroot indicated that aerobic exercise program(3 week) led to an increase of mechanical efficiency in cerebral palsy children(2). The study Bar-or-o on thirty five spastic adolescents for a year, twice a week led to significantly increase in mechanical efficiency (1). Bar-or-o have showed that cardiovascular fitness and aerobic capacity (VO_{2max}) in spastic group almost have been 10-30% lower than the normal group (1). However, Bowen reported no statistically significant differences in the percentage of variability of oxygen cost, oxygen consumption, or physiological cost index between subjects with and without CP with free-walking velocity(8). Many researches did not observe significant difference in oxygen pulse, energy expenditure, and respiratory exchange ratio and cardio respiratory endurance in the CP and able bodied children during walking on treadmill (8, 9, 10). Thus, Piccinini have showed that heart rate (bpm) and oxygen consumption (mL/kg/min) mean values didn't differ significantly between normal subjects and patients CP(3). Despite these observations, there is a lack of comprehensive information in the literature and a lack of relevant postgraduate training programs for physicians in their health care system and further researches are needed.

Therefore, the aim of our study is to estimate the effect of aerobic exercise–rehabilitation program for three months with exercise intensity equal to 144_{bpm} of heart rate on mechanical efficiency, aerobic capacity and other cardiovascular factors in spastic cerebral palsy children in comparison with normal children.

2. Methods: subjects and

Fifteen spastic cerebral palsy boy children (Dipelegic) with 10-12 years of age, were selected as experimental group (cp group) by voluntarily and with their parents satisfaction, and eighteen peer's able bodied children with similar conditions were selected by accidentally (control group). The physical factors were similar in both groups (height 131 ± 6/34, weight = 29/83 ± 5/64). According to opinion of specialist physician, spastic intensity in cp group was average to severe or three degree of Ashworth scale (5). Mechanical efficiency(net and gross) and certain physiological indexes in cp patients were measured before(pretest) and after(posttest) exercise–rehabilitation program, on bicycle ergometer according to Macmaster protocol(11) and then control group performed this protocol. The exercise–rehabilitation program in cp group was three times a week for three month with exercise intensity equal to 144_{bpm} of heart rate. The Macmaster protocol was performed in 4 stages on cycle ergometer and range of work is increased in each stage. The time of each stage was 2 minutes and in the end of each stage, the heart rate was recorded by polar telemetry. If in each time of protocol, the heart rate reached to 150_{bmp} (beat per minute of heart rate) or the subject felt tired voluntarily, the protocol was finished. All data were presented as mean ± standard deviation. A two-way repeated measure ANOVA was used to determine significant differences between the two groups. Statical significant was accepted at ($P<0.05$).

3. Results

The Macmaster protocol consisted of 4 stages and the subjects depend on their surface of capability performed this protocol. Some cerebral palsy children (three numbers) were not able to complete all stages of protocol before of exercise–rehabilitation (pretest) but those performed all stages of protocol after exercise-rehabilitation program (posttest). Thus the control group completed the total test (all stages). The results of variables in each 3 tests are shown in the table 1.

Table 1.The mean and standard deviation of variables during ergometery protocol in study groups

Study group	Rest heart rate(bpm)	Exercise heart rate(bpm)	Net mechanical efficiency (%)	Gross mechanical efficiency (%)	VO_{2max} (L/min)
CP(pretest)	7.12 ± 88	8.5 ± 139	14 ± 1.4	12.7± 1.1	1.17 ± 0.08
CP(posttest)	6.29 ± 84	6.31 ± 133	15.8± 1.1	14.3 ± 0.9	1.19 ± 0.06
Normal	9.51 ± 77	7.42 ± 133	1.4 ± 16.3	14.8± 1.9	1.20 ± 0.11

Mechanical efficiency (net, gross) in patients after exercise–rehabilitation increased significantly comparing to pretest, so that it was very close to that of control group. The maximal oxygen consumption was almost similar in patient and control groups and this factor increased a little (not significantly) in patients after rehabilitation program. Exercise–Rehabilitation program in patients Led to decrease significantly of rest and submaximal heart rate in posttest with regard to pretest but heart rate of control group was lower than patients in pre and posttest.

4. Discussions and Conclusions

The effect of aerobic exercise-rehabilitation program was examined on mechanical efficiency and some cardiovascular indexes in cerebral palsy children. The study findings demonstrated that the range of mechanical efficiency and exercise intensity in spastic patients was close to normal people under given work followed by aerobic exercise. Spastic children because of being immobile and sedentary or having low physical activity have lower physiological capability than the peers able bodied children (12).

Untrained people have lower aerobic fitness and higher heart rate in rest or exercise than the normal people. Disability type influences the heart rate response to physical activity, and may affect the ability to sustain training intensities associated with fitness improvement (13). Suzuki observed that in the cp patients with high physical activity level, the heart rate was significantly closed to normal group while walking on treadmill (14). Bar–or-O observed that heart rate in CP children significantly decreases after endurance training (1). In our study, sub-maximal training program significantly decreased the rest and sub-maximal heart rate in the spastic group. Because of high physical fitness in the normal group, the rest and sub-maximal heart rate of them was lower than the spastic group. Dressen observed that heart rate is equal in light exercise, but during heavy exercise it will be higher in the spastic group than the normal people (15). We also observed the same finding in our study.

Sub-maximal training depending on intensity and duration of exercise increases maximal oxygen consumption. The results of shinohara study demonstrated that cycle ergometer exercise at the AT point is effective in improving the physical endurance and VO_{2max} of children with CP (16). This change can be due to decreasing of difference between arterial and venous blood oxygen and increasing of cardiac output and greater capability of skeletal muscle in oxygen uptake (10). We showed that VO_{2max} in the spastic group (pretest) is similar to the control group. Maltais have stated that the individuals' physical activity level was not related to their peak VO2 (17). Our study showed that sub-maximal exercise rehabilitation program causes little improving of VO_{2max} in these 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 the normal people (1).

The basic cause of the decrease of exercise sustain in CP children is high metabolic cost of mechanical movements and low aerobic capacity (1), although many studies have not indicated the difference between Cp patients and normal people (10). Exercise program of judo and swim for ten weeks leads to the increase of VO_{2max} and decrease (%10) of oxygen cost during ergometer exercise in cp patients (18). Moreover in Vandenberg study, exercise-rehabilitation program (2-4 times a week for 9 months) increased VO_{2max} in cerebral palsy children significantly (19).

For the 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 (11). In our study, possibly, little increase in VO_{2max} may be due to low intensity and time limitation in each session of training.

Net mechanical efficiency is calculated by ratio performing work to total energy cost of exercise minus metabolism basal cost. But in calculation of gross mechanical efficiency, metabolism basal cost is not diminished (5, 18). Kang

stated that during exercise on cycle ergometer, the changes in net and gross efficiency is equal (20). Depending upon the base-line used, each mechanical efficiency index provided different values and was differently affected by the exercise intensity (21). Gross or net efficiencies better reflected the actual mechanical efficiency than work or delta efficiencies investigated the efficiency (21). Luhtanen indicated that the highest mechanical efficiency is in aerobic threshold and the lowest is in anaerobic threshold (22). Therefore measure of mechanical efficiency must be under steady state submaximal exercise, so that lactate threshold is not simulated (12). All the same, net mechanical efficiency increases with enhanced work intensity and reaches to plateau in adults and young boys in $\%40VO_{2max}$ and $\%60VO_{2max}$ respectively(23).

There are two primary factors determinative of mechanical efficiency during exercise or other daily physical activities. The first factor is muscle efficiency that converts storage of chemical energy of carbohydrate and fat to mechanical energy for muscle contraction and another factor is neuromuscular proficiency during exercise. Mechanical efficiency thus depends on velocity of contraction in muscle filaments. The greatest efficiency is produced when velocity of muscle contraction is $\frac{1}{3}$ of maximal velocity (12). Kind of muscle fiber has remarkable influence on mechanical efficiency. The researches showed that the slower twitch fibres in vastus latralis, the more mechanical efficiency during exercise on ergometer or cycling. This anatomical specialty indicates that slow twitch fibres in converting energy of ATP to mechanical energy have more efficiency than fast twitch fibres during submaximal exercise on ergometer (12). Therefore, it seems that mechanical efficiency has remarkable influence on submaximal aerobic ergometery protocols or endurance exercise and depends on the kind of muscle fiber and particularly neuromuscular proficiency (12). So, probably neuromuscular failure and chronic spastic disorder in cp patients leads to limitation in working muscles function that is the decreased mechanical efficiency.

Rowland stated that mechanical efficiency is 13-23(%) in normal people on ergometer (23). Thus, Taylor indicated that mechanical efficiency is 19/7(%) in able bodied boys (7-15 years) (24). The medicine studies diagnosis that mechanical efficiency in children and adults with cerebral palsy is lower than normal people (1, 6). In addition, lundberg showed that the mechanical efficiency is 12-18(%) in cp children (6). Bar-Haim has showed that mechanical efficiency was significantly lower in CP patients than normal group (25). Compared with the age-matched controls without CP, the children with CP were mechanically efficiency less in their gait (26). The findings of our study showed that mechanical efficiency (net, gross) in patients was lower than normal group and exercise–rehabilitation depending on duration, intensity and frequency of exercise leads to enhanced mechanical efficiency in cerebral palsy children.

Current data clearly show the need for improving both physical activity patterns and aerobic capacity in most children who have disabilities. The findings showed that physiological variables of spastic patients are remarkably weaker than able bodied people. This inefficiency characteristic of CP deambulation is probably directly connected to the presence of simultaneous contraction of agonist and antagonist muscle in these patients. Thus insufficiency in mechanical and physiological indexes is because of low physical activity and sedentary in their daily work and the other cause is spasticity and high tone in the involved muscles of these patients. Exercise program depending on duration and intensity of training leads to improving these indexes, but yet there is a long distance to reach to normal condition and needs more exercise and more study.

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