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PHYSIOLOGICAL AND BIOCHEMICAL RESPONSES TO GRADED EXERCISE IN YOUTHS WITH DIPLEGIC CEREBRAL PALSY

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Abstract. The aim of the study was to assess the physiological and biochemical responses to graded leg cycle ergometer exercise performed, until exhaustion, by boys aged about 16 years with diplegic cerebral palsy, as compared with their healthy mates. The following variables were recorded: exercise duration, work output, relative pulmonary ventilation (V_E) and oxygen uptake (VO_2), carbon dioxide elimination (VCO_2), ventilatory equivalent ($V_E \cdot VO_2^{-1}$), oxygen pulse ($VO_2 \cdot HR^{-1}$), heart rate (HR), lactate concentration (La) and base excess (BA). Aerobic capacity was determined from relative VO_2max, which in spastic boys amounted to 45.0 $ml \cdot min^{-1} \cdot kg^{-1}$ at maximum load equal to 2.11 $W \cdot kg^{-1}$, and mean HRmax amounted to 180±7 bpm. Maximum load applied to boys from control group amounted to 3.23 $W \cdot kg^{-1}$, which required VO_2 equal to 46.2 $ml \cdot min^{-1} \cdot kg^{-1}$ at HR equal to 199±6 bpm. ***(Biol.Sport 22:81-87, 2005)***

Introduction

Primary reflexes in subjects with cerebral palsy and associated spastic diplegia are not substituted by a mature, cortical control of body posture and equilibrium. Motor disorders may vary in form and intensity and range from incapability to execute a movement to a chaotic, uncoordinated motor activity. Those functional difficulties are due to problems with countering gravity forces, absence of equilibrium reflexes and damages of the musculo-skeletal system.

Damages to the brain bring about changes in muscle tonus. The degree of those changes differs between muscles which induces disequilibrium of forces acting on joints and this, in turn, to defects in positioning lower extremity segments [7,14,17]. The resulting functional disorders and prolonged muscle hyperactivity lead to structural changes. Contractured muscles do not participate in dynamic

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movements, thus becoming inactive. Orthopaedic and rehabilitative treatments bring changes in the expression of those states thus enabling the patient coming closer to the individually attainable level of psychophysical development. The effect of decreased motor activity is a decreased dynamics of physiological processes, compared with healthy population [15,16]. For example, VO_2 values recorded in upper extremity wheelchair ergometer ranged from 36.8 to 39.2 $ml \cdot kg^{-1} \cdot min^{-1}$ [3,4,9]. This implies the necessity of a broad approach to physiological assessment of disabled youths in course of their vocational education.

The aim of the study was to assess the anaerobic capacity of boys with diplegic cerebral palsy, as compared with their healthy mates, by applying lower extremity work.

Material and Methods

Subjects: Two groups of boys participated in the study: those with spastic diplegia of lower limbs (Group I; n=10), and their healthy mates (Group II; n=10). Mean age in Groups I and II was 16.7±0.5 and 16.1±0.3 years, mean body height – 166.5±6.5 and 172.7±4.9 cm, mean body mass – 53.5±5.9 and 59.9±6.2 kg, respectively.

Boys and their parents were fully informed about the scope and risks of the study. They were also informed they could withdraw from the study at any moment. The study was approved by the local Ethics Committee.

All boys were subjected to medical examination prior to the study and all of them were found fit with respect to the cardiorespiratory function.

Subjects from Group I had spastic paresis of lower limbs with flexion-adduction at hip joints, flexion contractures at knee joints, and equinal position of feet, several times corrected surgically. Genuflect gait with a tendency to cross legs was the most frequent functional anomaly. Disabled boys moved by about twice slower than their healthy mates, gait velocity being individually variable. Pelvic anteversion was compensated by increased lumbar and cervical lordosis, chest kyphosis, and a relatively poor stabilisation of head. Ranges of movement of the head, cervical spine, extension and flexion of thoracic spine, and of lateral flexion and rotation of lumbar spine, were restricted. The chest had an inspiratory position and abdominal muscles were relatively weak.

Ambidexterity was frequent, but with domination of the right hand. Movement range at elbow joints was normal, forearm in pronation, hands flexed, extension at dactylo-metacarpal joints. Precise manipulatory movements required more fingers than in healthy subjects, precision of finger or toe movements was low.

Anthropometric measurements: Body height was determined in supine position by using anthropometer (Sieber Hegner, Switzerland), with an accuracy of 0.5 cm. Body mass was recorded using F 150 S02-A balance (Sartorius, Germany), with an accuracy of 10 g. From these two variables, body surface area (BSA) was computed.

Physiological measurements: All boys were subjected to graded exercise test for upper limbs on cycle ergometer (Zimmermann, Germany). The first bout lasted 5 min, the load being 50 W at 50 rpm. The load increased every minute by 15 W, the pedalling rate remaining constant. Respiratory indices were recorded by spiroergotest device (Medikro, Finland), programmed for 30 s cycles, at rest, during warm-up, during every minute of graded exercise and 3 min post-exercise. Gas analysers were calibrated before and after every test by using gas mixtures, whose composition was determined by absorptiometry using a Micro Scholander calibrator.

The following variables and indices were recorded: pulmonary ventilation (V_E), oxygen uptake (VO_2), carbon dioxide elimination (VCO_2), ventilatory equivalent ($V_E \cdot VO_2^{-1}$) and oxygen pulse ($VO_2 \cdot HR^{-1}$). Heart rate was monitored by using sport tester PE-3000 (Polar-Electronic, Finland) and averaged at 15-s intervals.

All tests were conducted in the morning, after a light breakfast and one-hour rest. Ambient temperature was 21 ± 1^oC, relative humidity about 60%, pressure about 1020 hPa, air flow ranging from 0.2 to 0.4 m/s.

Stabilisation of VO_2 in the final phase of exercise served as the criterion of attaining maximal value (VO_2max), the load in the last minute of exercise when the subject could not maintain the exercise intensity serving as the individually maximal exercise. The value of RQ>1 or heart rate exceeding 200 bpm served as auxiliary criteria.

Hydrogen ion concentrations (H^+) and base excess (BE) were determined pre-exercise and 3 min post-exercise in blood sampled from fingertips by using Ciba-Corning 238 (UK) device. Lactate (La) was assayed enzymatically in the same samples by using Lactate PAP kits (BioMerrieux, France) and Specol 11 colorimeter (Germany).

Student’s t-test for independent groups was used in data analysis, the level of $p\leq0.05$ being considered significant.

Results

Maximum values of power and work outputs, as well as physiological and biochemical responses to laboratory exercise are presented in Table 1.

Table 1
Mean values (±SD) of physiological and biochemical variables recorded in 16-year old boys with diplegic cerebral palsy (Group I) and in control ones (Group II), subjected to graded exercise until exhaustion

Variable	Group I (n=10)	Group II (n=10)	Percent difference (vs. Group II)
Workout duration (min)	9.1±1.5	14.3±1.0	36.2***
Load ($W \cdot kg^{-1}$)	2.11±0.50	3.23±0.45	34.7***
Work output ($kJ \cdot kg^{-1}$)	0.68±0.20	1.43±0.26	52.5***
VO_2 max ($ml \cdot min^{-1} \cdot kg^{-1}$)	45.0±5.0	46.2±5.4	2.6
$V_E \cdot kg^{-1}$	1.38±0.17	1.75±0.30	21.1***
V_E max ($l \cdot min^{-1}$)	73.6±8.1	104.5±15.6	29.6***
VCO_2max ($l \cdot min^{-1}$)	2.32±0.22	3.20±0.29	27.5***
$V_E \cdot VO_2^{-1}$	30.8±1.7	38.5±5.7	20.1**
HR max (bpm)	180.1±7.0	199.0±6.5	9.5***
$VO_2 \cdot HR^{-1}$ ($ml \cdot bpm^{-1}$)	13.38±0.85	13.91±0.90	3.8
La ($mmol \cdot l^{-1}$)	8.77±2.44	14.37±2.89	39.0***
H^+ ($nmmol \cdot l^{-1}$)	54.3±5.7	66.8±5.8	18.6***
BE ($mmol \cdot l^{-1}$)	-9.79±2.67	-14.70±2.42	33.4***

**p<0.01; ***p<0.001

The mean duration of laboratory exercise performed by spastic subjects was significantly shorter (by 36%; p<0.001) compared with their healthy mates. Similarly, all studied parameters were significantly (p<0.01-0.001) lower in spastic than in healthy boys, the only exceptions being VO_2max and oxygen pulse, for which no significant differences were found. Of particular importance for work capacity are respiratory indices. Spastic subjects not only had lower (by 21.1%) relative ventilation, but also lower (by 20.1%) utilisation of oxygen in relation to ventilated air ($V_E \cdot VO_2^{-1}$).

Discussion

Spastic boys were significantly shorter and lighter than their healthy mates, and corresponding to the age of about 15 years. Since body height is very strongly determined genetically, only factors which act for a very long time are likely to affect it. It seems that muscle spasticity, together with circulatory and nervous factors, as well as gravitation, may influence bone growth. In effect, the rate of biological development would be decreased compared with healthy boys. It should be noted that the mean body mass expected for body height was in both groups alike.

Relative lung ventilation, like total oxygen uptake, is related to body size, and amounted to 1.38 and 1.75 $l \cdot min^{-1}$ in spastic and healthy boys, respectively. It could thus be inferred that it was work capacity which significatly affected strength and work output in both groups. Furthermore, an abnormal muscle tonus and the resulting abnormal psychomotor development, were among factors affecting work capacity. A deficient postural tension, lack of interaction between stabilisation and mobility of all body segments, shape abnormal antigravitational mechanisms based on compensatory positions [2,5,6,20]. A weak antigravitational potential in upright position, together with insufficiently concave position of ribs, reduces the mechanics of chest in sagittal and lateral planes. An insufficient tonus of the internal intercostals muscles and oblique abdominal muscles, the fibres of diaphragm's sterna part, which stabilise chest, lowers the sternum AT inspiration. This, in turn, together with insufficient chest decompression, flattenes breathing and increases the breathing rate. That mechanism reduces ventilatory capacity and structural chest development [8,10,19]. Those observations are confirmed by speech therapist, who noted a weaker fonation interrupted by breathing and shorter duration of sounds in diparethic children who assumed upright position [13,20]. This explains low values of ventilation observed in tis study.

The fact, that no significant between-group difference in VO_2max was observed, may indicate that this variable was not the principal one reflecting work capacity and adaptation to physical exercise, especially that it was associated with low oxygen utilisation in spastic boys.

The presented results indicated a low mechanical performance of boys with diplegic cerebral palsy subjected to leg exercise, as their men relative work output was by 52.5% lower than that of their healthy mates. This could have been due to a reduced blood flow in lower extremities [11], a high energetic cost of exercise [1], etc. It should be pointed out that lower work output in relation to oxygen uptake recorded for spastic subjects, as compared with their healthy mates, was due rather to factors like spasticity, than to differences in relative muscle mass, as confirmed by earlier reports of other authors [11,12,18,21].

One of the main factors responsible for an efficient energy supply is adequate circulation. Maximal heart rate, which reflects adaptive responses to work loads, was by about 10% lower than in healthy subjects, like reported by other authors [3,4]. Also, in our earlier study on youths with spastic paresis of lower extremities [16], no significant difference in HR max was found between upper or lower extremity exercises (179 and 177 bpm, respectively).

The laboratory exercise applied in this study induced a fairly high disturbance of acid-base equilibrium, which were shown to depend on the level of work capacity. Greatest differences between spastic and healthy subjects were found in work output, maximal ventilation and generation of lactate. The observed low level of work capacity of boys with diplegic cerebral palsy calls for introducing capacity-shaping exercises to the rehabilitation programmes implemented in vocational training of those subjects, especially that the importance of capacity-shaping exercises is being often neglected.

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