



Original Article

Immediate effects of short period lower limb ergometer exercise in adolescent and young adult patients with cerebral palsy and spastic diplegia

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Abstract. [Purpose] To determine the effects of lower limb ergometer exercise on the spasticity and joint range of motion of the lower extremity and gait function in patients with cerebral palsy and spastic paralysis. [Participants and Methods] This study included 8 participants with cerebral palsy and spastic paralysis (GMFCS levels I to IV) who received care at the outpatient clinic. After a 5-min rest, the lower limb ergometer exercises were performed for 10 min. We measured the participants' arterial blood pressure, pulse rate, passive range of knee joint extension, muscle tone using the Modified Ashworth scale (MAS) and Modified Tardieu scale (MTS), and 10-m walk test (10MWT). Measurements were collected three times (at baseline before exercise, immediately at the end of exercise, and 5 min after exercise during recovery). [Results] The 10-min lower limb ergometer exercise significantly improved the knee joint extension, MAS and MTS scores, and reduced lower extremity spasticity. Furthermore, it significantly increased the range of knee joint extension and decreased the 10MWT score. [Conclusion] The results showed that the 10-minute lower limb ergometer exercise is beneficial in reducing the spasticity of the lower limb muscles and in increasing the range of motion of knee extension in paraplegic patients with cerebral palsy, suggesting that its implementation in young children could prevent spasticity and enhance motor function.

Key words: Spasticity, Rehabilitation, Muscle tone

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INTRODUCTION

Cerebral palsy (CP) is the most common cause of upper motor neuron lesions in children, causing spasticity and muscle tendon contracture, leading to bone deformity, weakness, and loss of selective motor control¹⁾. In addition, 70 to 80% of the cerebral palsy pediatric cases are of the spastic type. Spasticity is a rate-dependent increased resistance against passive movements, related to the development of hyperactive reflexes following upper motor neuron lesions. Spasticity can also cause other problems, such as muscle pain or spasm, difficulty with body transfers, poor seating position, and impairment of standing and walking^{2, 3)}. Therefore, the main objectives of physical therapy of patients with spasticity are reduction of spasticity and maintenance of the range of joint movements in order to preserve physical mobility.

It was customary to avoid muscle strength training in children with CP because such programs were thought to increase the severity of spasticity and reduce the range of motion⁴⁾. However, a recent study has shown that physical therapy, such as long-term treadmill exercise, can lead to improvement in foot stiffness⁵⁾. It is therefore conceivable that a long-term proper exercise load can result in improvement of spasticity and expansion of the range of joint motion.

While treadmill exercises are difficult to perform as exercise therapy for patients with cerebral palsy and spastic diplegia,

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lower limb ergometer exercises are easy to perform and quantify the amount of load, making them suitable for lower extremity exercise programs. In addition, long-term bicycle ergometer exercise in people with cerebral palsy has been reported to improve motor function⁶). However, no studies have shown an immediate effect on lower extremity muscle spasticity or motor function in bicycle ergometer exercise. Identifying the effects of bicycle ergometer exercise on spasticity, joint range of motion, and motor function will lead to the development of an exercise therapy program for patients with cerebral palsy.

The aim of the present study was to define the relationship of lower limb ergometer exercise with spasticity and joint range of the lower limbs as well as gait function in patients with CP and spastic diplegia.

PARTICIPANTS AND METHODS

From the ambulatory patients with history of CP and spastic diplegia who visited the Outpatient Clinic at our Hospital between start of 2015 and end of 2019, we selected patients who fit the following criteria: 1) A modified Ashworth scale (MAS) of ≥ 1 , 2) ability to follow simple commands, 3) capacity to pedal independently on a static bicycle, 4) motor function scored as Level I to IV on the Gross Motor Function Classification System (GMFCS), 5) provision of a signed consent form from the patient/parents/guardians for participation in this research study, 6) no history of lower extremity surgery within the past 6 months, 7) no history of injection of botulinum toxin into the spastic muscles within the past 6 months, 8) suitability for participation in the study by the family physician. The above criteria fit 8 patients and all were enrolled in the present study. Their background is summarized in Table 1. Age ranged from 12 to 24 years (mean \pm SD, 16.3 ± 4.3). The GMFCS classification was I in 3, II in 1, III in 1 and IV in 3 cases. The walking ability profile was ability to walk unaided in 4, use of a cane in 1, and use of a walking aid in 3 patients. The study protocol was approved by the ethics committee of Aitoku Medical Welfare Center (approval number: 29-3) and adhered to the Declaration of Helsinki. The purpose and method of the research was explained to all participants, including their families, both in writing and verbally, before obtaining signed consent.

After the participant arrived to the laboratory, they rested for 5 minutes on a bed in the supine position, then stood up to undertake a 10-meter walk test (10-MWT), and again rested for another 5 minutes in the supine position. Blood pressure, pulse rate, range of joint movement, and muscle tone were measured at baseline. Next, the participant performed 10-min lower limb ergometer exercise under the physical therapist supervise. Immediately after the exercise, the above parameters were measured again and served as the post-exercise values. The participant was asked to rest after these measurements in the supine position for 5 minutes, and to have the recovery tests repeated before departing the laboratory. Two lower limb ergometers were used for exercise in this study, the recumbent ergometer (2100R, KONAMI Sports Life, Tokyo, Japan) or the Monark Ergometer (model No. 915E, Monark Exercise, Stockholm, Sweden). Patients who needed a backrest used a recumbent. The ergometer exercise was performed at 50 rpm for 10 min with a target of Borg scale ≥ 13 . The pulse rate was measured during exercise using SpO2 monitor (Lukla2800, Ubi-x, Tokyo, Japan).

Measured variables were arterial blood pressure and pulse rate during exercise and, modified Ashworth scale (MAS), modified Tardieu scale (MTS), passive range of knee joint extension and the time and steps in 10-Meter Walk Test (10M-WT) before and after the exercise. Arterial blood pressure and pulse rate were measured in the supine position using an automatic blood pressure monitor (KM-370 II, Meisei, Tokyo, Japan). The pulse rate was monitored during exercise using an SpO2 monitor. The mean blood pressure was calculated from the blood pressure measurements and used for statistical processing. MAS is used for clinical evaluation of spasticity and measures the grade of resistance during passive exercise of limb joints in six stages. The passive exercise of joint was performed in certain speed as move full joint range in one second. We measured the amount of resistance at knee joint extension (hip joint 90° flexion position with the knee joint in full extension) in supine position while the participant was on the bed. MTS is used clinically for evaluation of spasticity. In this test, the lower limb is moved passively and quickly, and the joint angle at which a catch occurs is measured. The knee joint extension (hip joint 90° flexion position to knee joint extension) angle was measured three times, and the average value was calculated. The hip joint and knee joint 90° flexion position was set as 0° reference line and the joint angle was measured at 5° intervals and recorded. The knee joint extension (hip joint 90° flexion position to knee joint extension) was measured passively in the supine position using a goniometer (CK -S4305-300, Takase, Japan). The hip joint and knee joint 90° flexion position was set as 0° reference line and the knee joint angle was measured at 5° interval and recorded. Walking at optimal speed and maximum speed was

Table 1. Participant characteristics

Total (n)	8
Age (years)	16.3 ± 4.0
Gender (male/female)	7/1
Height (cm)	155.7 ± 8.8
Weight (kg)	45.4 ± 13.1
BMI (kg/m ²)	18.4 ± 3.8
GMFCS (I/II/III/IV/V)	3/1/1/3/0

Data are mean \pm SD.

measured after rest and immediately after ergometer as well as after recovery. The maximum speed represented the fastest walking speed the participant could achieve without falling. In order to measure the walking speed and the number of steps taken, measurements were taken between 2 m before the start line and 2 m after the finish line. No assistance was given to the participants during the test; the participants walked aided or with a walker. We also counted the number of steps taken while walking the 10-m distance.

The clinical characteristics of the participants were expressed as mean \pm standard deviation (SD). Differences among the results of a particular test conducted before and after lower limb ergometer and 5-min recovery were examined using the Friedman test for MAS followed by Wilcoxon test as the post-hoc test. Repeated ANOVA was used to assess the differences in mean blood pressure, pulse MTS, joint range of motion, walking time of the 10M-WT, number of steps, followed by the t-test as the post-hoc test. In addition, Bonferroni correction was carried out as required. All data analyses were performed using R software version 3.4.1. A p value <0.05 denoted the presence of a significant difference.

RESULTS

Relative to the baseline value measured at rest before the exercise, the mean blood pressure remained unchanged after the exercise and recovery. On the other hand, the pulse rate was significantly higher after exercise ($p<0.05$). However, the pulse rate was returned to the baseline level during the recovery phase (Table 2).

The score of the MAS for the both knee extension was significantly decreased both after exercise and recovery compared to baseline ($p<0.05$). This result implies an immediate and continuing effect of bicycle ergometer exercise on the reduction of spasticity in both lower limbs.

The score of the MTS for the both knee extension was significantly increased both after exercise and recovery compared to baseline (right knee extension: $p<0.01$, left knee extension: $p<0.01$, $p<0.05$). This result implies an immediate and continuing effect of bicycle ergometer exercise on the reduction of spasticity in both lower limbs.

No significant change was observed in the right knee joint extension angle after exercise, relative to the baseline, although that recorded at recovery was significantly higher ($p<0.05$). With regard to the left knee joint extension angle, exercise, but not recovery, value was significantly different from the baseline ($p<0.05$, Table 3).

This result implies an immediate and continuing effect of bicycle ergometer exercise on the increased of knee joint extension in both lower limbs.

There was a non-significant but decreasing trend in 10-m walking time at optimal and maximal speeds after exercise and recovery compared to rest. In addition, There was a non-significant but decreasing trend in the number of steps at optimal and maximal speeds, after exercise and recovery, compared to rest. These showed that bicycle ergometer exercise tended to improve walking speed and step count.

Table 2. Recorded values of mean arterial blood pressure (MBP) and pulse rate during the experiment

	Baseline	After exercise	Recovery
MBP (mmHg)	87.6 \pm 9.6	89.5 \pm 10.0	88.3 \pm 12.6
Pulse Rate (bpm)	76.5 \pm 12.1	108.6 \pm 22.6	79.8 \pm 14.2

Data are mean \pm SD. bpm: beats per minute.

Table 3. Changes in MAS score, MTS, P-ROM-T, 10MWT

	Baseline	After exercise	Recovery
MAS Right	1.4 \pm 0.2	1.0 \pm 0.0*	0.9 \pm 0.3*
MAS Left	1.5 \pm 0.3	1.06 \pm 0.2*	1.1 \pm 0.2*
MTS Right ($^{\circ}$)	10.8 \pm 8.3	22.6 \pm 11.7**	24.0 \pm 9.2**
MTS Left ($^{\circ}$)	10.0 \pm 8.2	17.9 \pm 9.1**	20.9 \pm 10.5*
P-ROM-T Right ($^{\circ}$)	21.9 \pm 8.3	28.2 \pm 11.2	31.9 \pm 6.1*
P-ROM-T Left ($^{\circ}$)	19.4 \pm 7.3	25.6 \pm 6.8*	26.3 \pm 8.6
10MWT walking time optimum speed (sec)	13.7 \pm 7.6	12.0 \pm 5.4	11.6 \pm 5.5
10MWT number of steps optimum speed (steps)	23.9 \pm 8.4	22.3 \pm 6.6	21.7 \pm 6.4
10MWT walking time maximum speed (sec)	12.7 \pm 8.1	10.9 \pm 5.7	10.5 \pm 4.8
10MWT number of steps maximum speed (steps)	23.1 \pm 8.8	21.2 \pm 6.9	21.3 \pm 6.1

Data are mean \pm SD. * $p<0.05$, ** $p<0.01$.

MAS: Modified Ashworth scale; MTS: Modified Tardieu scale; P-ROM-T: Passive range of motion test; 10MWT: 10m-walk test; Right: Right knee joint extension; Left: Left knee joint extension.

DISCUSSION

The main finding of our study was that 10 min lower limb ergometer exercise improved lower limb muscle spasticity and the range of knee extension motion in CP patients with spastic diplegia.

One study involving hemiplegic post-stroke patients with spastic paralysis showed that 10-min unaffected arm ergometer exercise reduced the spasticity of the paralyzed upper limbs⁷⁾. Our finding was similar to study, showing that lower limb ergometer exercise reduced spasticity and increased the range of knee extension motion in patients with CP.

What is the mechanism(s) responsible for the observed improvement? It was considered the involvement of reciprocal inhibition, which enhances reduction of muscle tonus, to mediate the beneficial effects of lower limb ergometer exercise⁸⁾. Thus, in our study, repeated contraction of the quadriceps femoris muscle probably increased reciprocal inhibition of the antagonist hamstring muscles and led to reduction of spasticity of the knee joint extension.

One factor that can increase spasticity in CP is a general increase in muscle spindle sensitivity and imbalance in the descending inhibitory and facilitatory regulatory mechanisms acting on spinal stretch reflexes secondary to cortical disinhibition. It is possible that repeated pedaling exercise reduces the hypersensitivity of the muscle spindle, leading to decreased spasticity⁹⁾. Also, repeated pedaling exercise may activate upper motor neurons, leading to recovery of the balance between activation and inhibition of spinal reflexes.

The range of joint motion in patients with CP is affected by muscle stiffness. Increased stiffness of the muscles can have both neural and mechanical components¹⁰⁾. In this study, it is unlikely that the 10-min ergometer exercise affected the mechanical components of the exercising muscles, suggesting the likely involvement of neural mechanisms in the observed changes. This conclusion is in agreement with other study which suggested that the immediate stretch effect of exercise in children with CP was not mechanical changes in the muscles but rather neurally-based¹⁰⁾. On the other hand, soft tissue stretches can also be caused by continuous extension¹⁰⁾. Therefore, it is possible that the change in the range of joint motion is also influenced by the observed decrease in spasticity.

The 10MWT tended to improve immediately with bicycle ergometer exercise. Previous studies in patients with CP reported that the circumference of leg muscles¹¹⁾ and voluntary movements of the lower limb muscle correlate with gait function¹²⁾. These findings highlight the importance of improving not only lower limb muscle spasticity but also muscle strength by the exercise load and voluntary movements of lower limb muscles in order to improve the gait function. Long-term repetitive lower limb ergometer exercise⁶⁾ and persistent passive exercise over a 20-min period have been reported to improve gait function¹³⁾. Extended lower limb ergometer exercise may improve walking ability.

The present study has certain limitations. These include the large differences in the exercise capacity among the participating participants and the severity of spastic paralysis of lower limb muscles. These differences perhaps explain the variation in the extent of spasticity, range of joint motion, and gait function. Further studies of larger number of patients are needed to determine the true effects of exercise on muscle paralysis, extent of spasticity and exercise capacity. The average age of our participants was 16 years. It is possible that joint contractures have already occurred in these individuals due to the spastic paralysis. Therefore, it is important to compare our results with the effects of lower limb ergometer exercise in early childhood.

We have demonstrated in the present study that 10-min lower limb ergometer exercise reduced spasticity of lower limb muscles in paraplegic patients with CP. The results suggest that spontaneous exercise could be beneficial especially at young age in patients free of joint contracture, including prevention of joint contracture and improvement of motor function.

Conflict of interest

There is no conflict of interest to be disclosed in this research.

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