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EFFECT OF ARM CYCLING CROSS TRAINING AND VISUAL FEEDBACK ON MODULATION OF LOWER LIMB SPASTICITY IN DIAPLEGIC CEREBRAL PALSY CHILDREN

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Abstract

Spastic diaplegia is characterized by motor inco-ordination primarily in the lower extremities, that impairs many functional abilities, most notably ambulation. This study was conducted to determine the effect of arm cycling and visual feedback on controlling spasticity of the lower limbs, in spastic diaplegic cerebral palsied children. Thirty spastic diaplegic cerebral palsied children from both sexes, ranging in age from six to eight years represented the sample of the study. All subjects were ambulant with an abnormal gait pattern characterized by hip and knee flexion and ankle planter flexion. The subjects were divided randomly into two groups of equal number (A and B). Group A (control) received a designed physical therapy program in addition to arm pedaling using a reciprocate bicycle with an unloaded cycling for thirty ramps / minute for five minutes, repeated three times with five minutes rest in between. Group B (study) received the same program given to group A with applying the arm pedaling in front of a large mirror to produce visual feedback. Evaluation using 3D Motion Analysis was conducted to determine hip, knee and ankle joints' angles before and after three months of treatment. The results revealed significant improvement in all measuring variables of the two groups, when comparing their pre and post treatment mean values. Highly significant improvement was observed in favor of group B when comparing the post treatment results of the two groups. Improvement observed in the lower limbs joints' angles may be due to enhancement of the effect of cross education training using arm cycling via visual feedback, amelioration of motor learning which led to controlling spasticity of the lower limbs, in the diaplegic cerebral palsied children.
Key Words: Arm Cycling, Cross Training, Visual Feedback, Diaplegic Cerebral Palsy.

Introduction

Cerebral palsy (CP) is a number of non-progressive syndromes of disability which results from various insults to different areas within the developing nervous system[1]. Impairment in CP may include malalignment, contractures, deformities, insufficient force generation, abnormal muscle tone, abnormal tissue extensibility, exaggerated or hyperactive reflexes, poor selective control and regulation of activity of muscle groups, abnormal timing and decreased ability to learn unique movement[2].

Spastic diaplegia is the most prevalent form of cerebral palsy, with an incidence as high as 70% to 80% of the premature infants with CP [3].The term diaplegia is used when the legs are more affected than the arms. The severity and extent to which the arms are affected may vary from mild to moderate affections [4]. Spastic diaplegia is characterized by motor impairment, inco-ordination, primarily in the lower extremities that impairs many functional abilities, most notably ambulation [5]. It is clinically characterized by varying degrees of spasticity and /or inco-ordination in the lower extremities [3]. Lesion associated with spastic diaplegia may produce any or all of the following symptoms; increase muscle tone, loss of selective muscle control, deficient equilibrium reactions, and imbalance of muscle force across the joints, particularly in the lower extremities. Imbalance of muscle function in those children result in abnormal gait pattern described as crouch gait [6].

For those patients whose motor skill may be absent, impaired, insufficient or abnormal, motor skill learning is considered one of the important aspects to be included in their rehabilitation program. Several attempts have been conducted to find out the conditions and variables of practice that may be used to facilitate, enhance and promote motor learning [7]. Practice is essential for motor learning and development of motor programs[8]. Well organized structured practice in related movement skill may improve performance in other desired skills[9]. Practice of one part of the body in performing a skilled act may increase performance of the same act in other part of the body. This phenomenon is called cross education or intermanual transfer [10], bilateral transfer [8], contra-lateral transfer of training [11] .

A number of case reports and series reported benefits of mirror therapy in hemiparesis [12,13,14].

Although the majority of diaplegic children are able to ambulate, the acquisition of this skill is delayed and differs qualitatively from normal pediatric gait [6]. This compromises major problems that hinder such children from practicing most of their daily living activities.

This study was conducted to determine the efficacy of facilitation of alternative upper limb movement, in addition to visual feedback, on improving lower limbs joints' angles during initial contact of gait in spastic diaplegic children.

Thirty spastic diaplegic cerebral palsied children from both sexes, ranging in age from 6 to 8 years (χ7.60 ±0.39 years) represented the sample of the study.

They were selected from the outpatient clinic of the Faulty of Physical Therapy, Delta University for Science and Technology, according to the predetermined criteria as follows:

- All subjects were ambulant with an abnormal gait pattern (crouch gait), characterized by hip and knee flexion and ankle planter flexion.
- The upper limbs were almost free with a degree of spasticity of the lower limbs ranged between grade 4 and 3 according to the Oswestry scale[15].
- None of them had any fixed deformity or surgery of the lower extremities, however, few degrees of tightness was present in the Tendo-Achillis.
- They were able to understand and follow instructions given to them, with an IQ within normal average range.
- The subjects were divided randomly into two groups of equal number (A and B)

Instrumentation

For evaluation

Gait evaluation was done by using a clinical 3DMA 6.11 software version, video based gait assessment system (CLIMA) STT Systems Company, Spain which consists of

- 4 infrared cameras.
- Calibration tool
- Reflective Markers

- Large screen (24 inch)

For treatment

- Reciprocate unit:

An electronically braked bicycle ergometer, with its power read in watts till 50 pedal revolutions per minute. It is equipped with an electronic meter showing total pedal revolutions and time function.

- Mat, ball, roll wedge and tilting board.
- Table with adjustable height
- Chair with back support
- A large mirror placed in front of the child

Procedures

For evaluation

For capturing motion data in children some special modifications were made to the system configuration to improve visibility.

1. Camera System

The camera system was adapted to capture a much smaller person by lowering and moving it closer to the center of the capture volume.

The recommended measurements were:

-Camera height: 1.4 m.

-Length of the narrow side of the capture area: 3 m.

-Length of the wide side of the capture area: 3.6 m.

2. Calibration

-The calibration rod (8 point rod with 125 mm separation distance) was used.

3. Markers

These set contains 5 mm diameter reflective markers which were used for accurately detecting the child during the capture

1. Preparation

1- The first step before performing any capture, a calibration test was performed by placing a rod in vertical on the capture area (same where the motion was captured) and without any other markers but the rod ones; as the results of the test were “Correct” we moved to the next step; where each child was asked to wear an easy fit, skin tight leg wear, then tracking tools (a simplified reflective markers consisting of 15 markers) were placed- according to Helen Hayes for children protocol[16] - at the following points on the child‘s body:

Right and left anterior superior iliac spine, right and left lateral aspect of the thigh, right and left knee, right and left calf ,right and left ankle, right and left 2nd toe, 2nd sacral vertebra , right and left heel.

2. Measurement

The capture process was then done with the child being instructed to walk with a straight back without turning

For treatment:

Group A received physical therapy program, for 60 minutes, including;

Improving posture control and balance, facilitation of righting, equilibrium and protective reactions, sustained stretching for the spastic muscles (Iliopsoas, Hamstrings and calf muscles), closed and open loops gait training exercises using parallel bars, obstacles, wedges, rolls and wooden stairs, arm pedaling on bicycle with unloaded cycling for three times as warming up and then with an intensity of thirty ramps/minute, for five minutes, repeated for three times, with five minutes rest in between.

Group B received the same program given to group A with applying the program in front of a large mirror to produce visual feedback.

Results

The raw data of the joints’ angles of the affected lower limbs were statistically treated to determine the mean and standard deviation of each measuring variable, for the two groups, before and after three months of treatment, t-test was then applied to examine the significance of treatment conducted for each group.

The obtained results revealed no significant differences when comparing the pre-treatment mean values of the two groups. Significant improvement was observed in all the measuring variables of the two groups A and B, when comparing their pre and post treatment mean values. High significant improvement was observed in group B, when comparing its post treatment mean values with the post treatment mean values of group A.

Joint's angles during initial contact

For group A

As shown in table (1) and figure (1), the mean values of hip, knee and ankle joints' angles pre and post treatment were as follows:

Hip joints

The mean values of hip flexion angle pre and post treatment showed significant improvement. The mean value of right hip flexion angle pre -treatment was 42.79±3.39° and became 39.27±2.99° post treatment ($P< 0.01$). While the mean values of the left hip flexion angles pre and post treatment were 43.11±3.26° and 40±3.62° respectively ($P< 0.05$).

Knee joints

The mean values of knee joints flexion angle pre and post treatment showed significant improvement. The mean value of right knee joint flexion angle pre and post treatment were 35.02±3.21° and 32.3±3.07° respectively ($P< 0.05$). While the mean values of the left knee joint flexion angles pre and post treatment were 35.77±3.34° and 32±2.98° respectively ($P< 0.01$).

Ankle joints

The mean values of ankle joints planter flexion angle pre and post treatment showed significant improvement. The mean value of right ankle joints planter flexion angle pre and post treatment were 30.12±3.01° and 27.8±2.55° respectively ($P< 0.05$). While the mean values of the left ankle joints planter flexion angles pre and post treatment were 30.65±3.04° and 26.9±2.23° respectively ($P< 0.01$).

Table 1: Pre and post treatment mean values of lower limbs joints' angles (hip, knee and ankle) in degrees for group A

Joints	X± SD	t-test	P-value	Significance
Hip joints				
Rt. side Pre treatment Post treatment	42.79±3.39° 39.27±2.99°	3.016	< 0.01	Sig.
Lt. side Pre treatment Post treatment	43.11±3.26° 40±3.62°	2.47	< 0.05	Sig.
Knee joints				

Rt. side Pre treatment Post treatment	35.02±3.21° 32.3±3.07°	2.37	< 0.05	Sig.
Lt. side Pre treatment Post treatment	35.77±3.34° 32±2.98°	3.184	< 0.01	Sig.
Ankle joints				
Rt. side Pre treatment Post treatment	30.12±3.01° 27.8±2.55°	2.278	< 0.05	Sig.
Lt. side Pre treatment Post treatment	30.65±3.04° 26.9±2.23°	3.85	< 0.01	Sig.

For group B:

As shown in table (2), the mean values of hip, knee and ankle joints' angles pre and post treatment were as follows:

Hip joints:

The mean values of hip flexion angle pre and post treatment showed significant improvement. The mean value of right hip flexion angle pre- treatment was 43.62±3.05° and became 35.05±2.44° post treatment (P< 0.0001). While the mean values of the left hip flexion angles pre and post treatment were 43.32±3.01° and 36.09±2.88° respectively (P< 0.0001).

Knee joints:

The mean values of knee joints flexion angle pre and post treatment showed significant improvement. The mean value of right knee joint flexion angle pre and post treatment were 36.24±2.66° and 31.04±2.52° respectively (P< 0.0001). While the mean values of the left knee joint flexion angles pre and post treatment were 36.75±3.23° and 30.86±2.08° respectively (P< 0.0001).

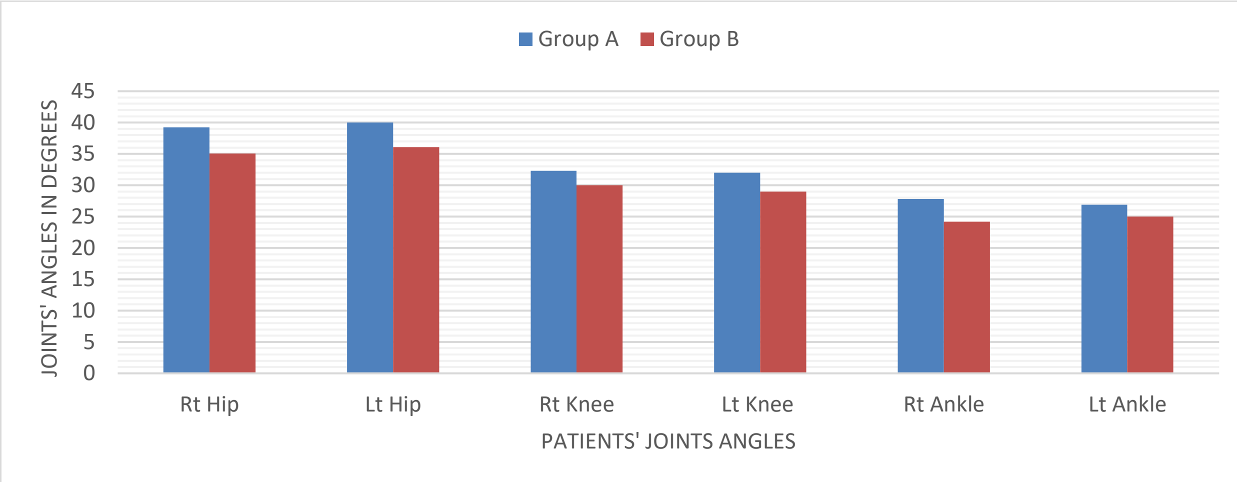
Ankle joints:

The mean values of ankle joints planter flexion angle pre and post treatment showed significant improvement. The mean value of right ankle joints planter flexion angle pre and post treatment were 29.75±3.22° and 24.17±2.87° respectively (P< 0.0001). While the mean values of the left ankle joints planter flexion angles pre and post treatment were 29.9±3.14° and 25.0±2.63° respectively (P< 0.0001).

Table 2: Pre and post treatment mean values of lower limbs joints' angles (hip, knee and ankle) in degrees for group B

Joints	X± SD	t-test	P-value	Significance
Hip joints				
Rt. side Pre treatment Post treatment	42.79±3.39° 39.27±2.99°	3.016	< 0.01	Sig.
Lt. side Pre treatment Post treatment	43.11±3.26° 40±3.62°	2.47	< 0.05	Sig.
Knee joints				
Rt. side Pre treatment Post treatment	35.02±3.21° 32.3±3.07°	2.37	< 0.05	Sig.
Lt. side Pre treatment Post treatment	35.77±3.34° 32±2.98°	3.184	< 0.01	Sig.
Ankle joints				
Rt. side Pre treatment Post treatment	30.12±3.01° 27.8±2.55°	2.278	< 0.05	Sig.
Lt. side Pre treatment Post treatment	30.65±3.04° 26.9±2.23°	3.85	< 0.01	Sig.

Comparing the post treatment mean values of lower limbs' joints angles (hips, knees and ankles) in degrees for groups A and B, revealed significant improvement in favor of group B



Post treatment mean values of lower limbs joints' angles for groups A and B

Discussion

The gait of children with spastic diaplegia is typically described as crouch gait, which is characterized by increased trunk flexion, hip flexion and ankle planter flexion[17]. In addition to the obvious cosmetic disadvantages to this gait pattern, there is potential risk of increasing hip and ankle flexion contractures, which may ultimately result in loss of independent ambulation[18]. Thus, physical therapy interventions concerned with learning of this skill is important for those children.

This study was conducted to determine the effect of arm cycling, in addition to visual feedback, on controlling spasticity of the lower limbs in spastic diaplegic children.

The results of the present study, after the suggested period of treatment revealed significant decrease in the range of measured angles in the two groups A and B, when comparing their pre and post treatment mean values.

High significant improvement was noticed in favor of group B, when comparing the post treatment mean values of the measuring variables of groups A and B. However, no significant differences were observed when comparing the pre-treatment mean values of the two groups.

The pre-treatment results confirm the findings of Galli et al.,[19] and Zhou et al.[20], who reported that at initial contact, in diaplegia, there is disturbance of the joints' angles, in the form of loss of dorsi- flexion of the ankle and generally reduced excursions.

O'Sullivan [8] stated that the abnormal gait pattern seen in spastic diaplegia results from the presence of spasticity and lack of practice. It may result from changes in the intrinsic properties of the muscle fibers themselves[21]. After the suggested period of treatment, it has been observed that the hip, knee flexion and also ankle planter flexion angles improved. This post treatment improvement may be due to the effect of bicycle ergometer, in addition to the exercise program which helped in the motor learning process and in turn helped in the acquisition of motor control.

On basis of the literature review, little information is available regarding the role of cross education between the upper and lower extremities in spastic diaplegic cerebral palsied children. However, most of the studies were conducted to determine the effects of unilateral side training on the contralateral side in hemiplegic children.

Significant improvement observed in group B come in agreement with Stephen and Duncan[22] who reported significant reduction in maximum force generated in ipsilateral and contralateral legs following continuous vibration at 30 Hz and 120Hz to the ipsilateral Quadriceps muscle. They attributed their findings to be due to the effect of activation of the central descending derived acting on the contralateral muscles. They established that cross education through inter limb transfer can be incorporated into treatment.

Accordingly, in diaplegic children, the uninvolved upper extremities can be engaged in practice to enhance the necessary motor programs, which can be used to control movements in the involved lower extremities.

The post treatment results agree with Farmer et al., [23] who investigated neurophysiological evidence for a reorganization of central motor pathways in hemiplegic children. They reported that the motoneuron pools of homologous left and right hand muscles receive common synaptic input from abnormally branched pre-synaptic axon.

Weir et al., [24] examined the effects of unilateral eccentric leg extension weight training and detraining on joint angle, cross education and bilateral deficit. The results indicated that, unilateral training resulted in increased bilateral strength, indicating cross training effect.

The results of the study agree with Wang et al., [25] who established that there was a great influence of isometric knee flexion of the non-involved side on activation of the Rectus Femoris and Tibialis anterior muscles of the paralytic leg in stroke patients.

Andree and Maitra[10] reported that an already learned task by one hand can positively influence learning and improve performance of the same task by the other hand, than activities comprising previously unlearned tasks.

The post treatment results confirm the findings of Helen and Daniel[26] who investigated neuromuscular recruitment during self-driven and externally driven lower limb motion. Healthy subjects exercised on a recumbent stepper using different combinations of upper and lower limb exertions. The recumbent stepper mechanically coupled the upper and lower limbs, allowing users to drive the stepping motion with upper and/or lower limbs. The subjects were instructed to step with: (1) active upper and lower limbs at an easy resistance level (active arms and legs), (2) active upper limbs and relaxed lower limbs at easy, medium and hard resistance levels (self-driven), (3) relaxed upper and lower limbs while another person drove the stepping motion. They recorded surface electromyography (EMG) from six lower limb muscles. The results revealed that self-driven EMG amplitudes were higher than externally driven EMG amplitudes. As resistance and upper limb exertion increased, self-driven EMG amplitudes also increased.

According to the results of this study and literature review, it can be stated that improvement observed in the study group may be due to:

*Active upper limb movement increased neuromuscular activation of lower limbs during cyclic motions and enhanced activity dependent plasticity.

*Using visual feedback during active upper limb movement in addition to the exercise program increased neuromuscular activation of lower limbs and enhanced activity dependent plasticity.

*Self-assistance i.e. using upper limbs to assist the lower limbs could be beneficial due to inherent inter-limb neural coupling, in reflex response.
*Effect of activation of motor cortex during inter-limb movement and visual feedback.
*Interneuron connection between the upper and lower limbs and reorganization of motor output in the non-affected brain centers.
*Development of control over the tonic reflexes that are responsible about the distribution of muscle tone all over the body, through diffusion of motor impulses from practiced to unpracticed body parts through irradiation.
*The motor learning effect in skill acquisition and performance which is enhanced through practice and visual feedback.
*Modulation of abnormal muscle tone through improvement of sensory and motor awareness, enhancement of postural readjustment and motor learning process.
*Disruption of abnormal ratio between excitatory and inhibitory impulses from the afferent nerves in spastic cerebral palsy.
*The motor cortex sends its efferent corticospinal tracts that project ipsi- laterally as well as contra laterally.
Conclusion:
Cross education through inter limb transfer and Visual Feedback via mirroring can be incorporated into the physical therapy program to improve functional recovery (gait) through modulation of lower limb spasticity in Diaplegic Cerebral Palsy Children

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