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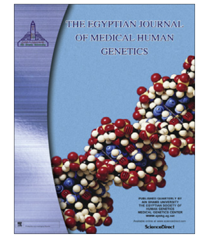

ORIGINAL ARTICLE

Effect of arm cycling on gait of children with hemiplegic cerebral palsy

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KEYWORDS

Gait;
Hemiplegia;
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Abstract *Background:* Arm swing during gait is usually neglected, as it is not an essential component of walking that it spontaneously occurs, so there are doubts if it affects gait or not. The upper limb in hemiplegic cerebral palsy is more involved than the lower limb. The aim of this study was to enhance swinging of arm by using arm cycling and assess its impact on both upper and lower limb joints' angular displacements during gait cycle of children with hemiplegic cerebral palsy.

Methods: Forty-eight hemiplegic cerebral palsy children participated in this study (18 boys, 30 girls) with an average age of 5.1 ± 0.87 years. Children were randomly assigned to two groups, study group (A) and control group (B). The study group received arm cycling in addition to gait training exercise, while the control group received gait training exercises only. Three dimensional (3D) motion analysis was used before and after the training program to evaluate the angular displacements of shoulder, elbow, hip, knee, and ankle joints during gait sub phases.

Results: Results showed a significant improvement ($p < 0.05$) in arm swing. Improvement was manifested by decreasing flexion angular displacements of shoulder and elbow joints. Also there was a significant increase ($p < 0.05$) in flexion angular displacements of the hip and ankle joints during gait cycle.

Conclusion: Using arm cycling exercise is an effective method for improving both arm swing and leg angular displacements during gait of hemiplegic children.

1. Introduction

Arm swing in human bipedal walking is a pendulum-like motion of arms in which each arm swings with the motion of the opposing leg. There are debates whether arm swing is arising actively or passively. Arm swing is efficient in human locomotion as it may minimize energy consumption, optimize both stability and neural performance [1].

Arm swing may minimize energy consumption and decrease vertical ground reaction moment during gait, since a smaller ground reaction moment needs to be generated by the leg

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muscles [2]. Still swinging the arms would cost more energy than the reduced energy demands of the legs. Later studies [3] however, confirmed that arm swing decreased angular momentum about the vertical.

In hemiplegic cerebral palsy (CP) children the impaired arm usually swings with decreased amplitude on the involved side whereas the arm swing amplitude of the non-hemiplegic arm exceeds that of healthy participants [4]. This increase in non hemiplegic arm swing was found to counteract an increased angular momentum generated by the legs suggesting it is aimed to control total body angular momentum, so arm swing is utilized in order to balance the rotational motion of the body [3]. Asymmetry in arm swing behavior contributes to reduction in bilateral arm coordination [5].

During gait, the affected upper extremity posture in children with hemiplegia typically includes an abducted, internally rotated shoulder, elbow flexion, wrist flexion, and thumb adduction the so called 'guard position' [6]. The role of arm movements in children with hemiplegic CP is to maintain stability in walking. Guard positions in children with CP have been suggested to be a compensatory strategy to maintain balance. Such a guard position is useful when preparing for a fall and in regaining balance after a perturbation [7].

The aim of this study was to enhance arm swing of children with hemiplegic cerebral palsy by using arm cycling and to assess its impact on angular displacements during gait cycle.

2. Subjects and methods

Forty-eight hemiplegic cerebral palsy children (18 boys, 30 girls) participated in the study, with mean age of 5.1 ± 0.87 years. They were selected from the outpatient clinic of the Faculty of Physical Therapy, Cairo University with 1 and 1+ degree of spasticity according to the modified

Table 1 Demographic data of the two groups.

	Groups		*P* value
	Study (*n* = 24)	Control (*n* = 24)	
Age (yrs.)			
Mean value ± SD	5.12 ± 0.75	5.25 ± 0.72	0.56
Sex			
(F/M)	(16/8) (67%/33%)	(14/10) (42%/58%)	0.766

Table 2 Pre treatment mean values of joint angular displacement (in degrees) for both groups.

Phase	Groups	Joints (mean value ± SD)				
		Shoulder	Elbow	Hip	Knee	Ankle
IC	Pre study	9.04 ± 5.72	24.37 ± 11.97	16.31 ± 6.58	6.77 ± 2.98	−12.39 ± 5.67
	Pre control	8.71 ± 6.05	24.63 ± 12.26	16.73 ± 6.44	6.18 ± 4.12	−13.34 ± 5.04
	p	0.84	0.94	0.82	0.57	0.54
LR	Pre study	4.59 ± 3.54	29.90 ± 13.58	16.60 ± 7.35	4.63 ± 4.55	−14.14 ± 5.3
	Pre control	4.12 ± 3.7	28.38 ± 12.79	6.13 ± 6.05	4.7 ± 4.36	−14.08 ± 5.32
	p	0.9	0.69	0.81	0.89	0.97
MS	Pre study	19.17 ± 6.91	49.36 ± 19.13	14.69 ± 8.42	4.56 ± 4.44	−9.41 ± 6.07
	Pre control	18 ± 6.8	49.63 ± 19.01	13.09 ± 7	4.69 ± 4	−10.53 ± 5.14
	p	0.55	0.96	0.47	0.67	0.49
TS	Pre study	16.05 ± 6.12	43.68 ± 20.88	−13.77 ± 8.68	5.66 ± 4.78	−16.09 ± 7.36
	Pre control	16.49 ± 6.17	42.36 ± 20.52	−15.66 ± 6.51	4.91 ± 3.82	−16.26 ± 7.66
	p	0.8	0.82	0.39	0.55	0.93
PS	Pre study	14.10 ± 6.23	49.82 ± 20.57	9.17 ± 5.74	18.18 ± 8.2	−24.15 ± 10.76
	Pre control	14.28 ± 6.03	50.63 ± 21.23	10.94 ± 4.69	16.47 ± 7.17	−23.22 ± 10.14
	p	0.91	0.89	0.24	0.44	0.75
IS	Pre study	12.34 ± 5.10	36.85 ± 19.74	21.53 ± 8.20	25.53 ± 9.96	−21.36 ± 12.48
	Pre control	10.94 ± 6.27	37.10 ± 19.54	23.43 ± 7.61	23.86 ± 9.37	−21.82 ± 11.98
	p	0.39	0.96	0.4	0.55	0.89
MS	Pre study	11.65 ± 4.33	34.17 ± 17.84	16.38 ± 6.65	18.82 ± 7.91	−19.64 ± 11.56
	Pre control	11.93 ± 5.26	34.29 ± 16.83	17.4 ± 6.86	18.12 ± 7.29	−21.36 ± 10.6
	p	0.84	0.98	0.6	0.75	0.59
TS	Pre study	13.34 ± 4.34	13.04 ± 10.90	19.77 ± 9.38	15.44 ± 6.86	−16.46 ± 9.19
	Pre control	12.91 ± 4.48	22.53 ± 11.38	17.81 ± 9.45	19.55 ± 6.98	−19.51 ± 9.93
	p	0.74	0.05	0.47	0.04*	0.27

IC: initial contact; LR: loading response; MS: midstance; PS: preswing; TS: terminal stance; IS: initial swing; MS: midswing; TS: terminal swing; x: mean; SD: standard deviation. Significant differences are denoted by "*".

Ashworth scale. The children's motor abilities and limitation were compatible to level II of the Growth Motor Function Classification Scale (GMFCS). Children were excluded if they had (1) visual or auditory problems that would prevent them from carrying out the testing tasks, (2) severe spasticity (Modified Ashworth score of $\geqslant 3$), (3) still enrolled in any form of physical rehabilitation program, (4) cognitive impairments and (5) lower limb contractures.

Before initial assessment, caregivers who had accepted participation of their children in the study signed an informed, written consent that had been approved by the Ethics Committee of Faculty of Physical Therapy Cairo University, in Egypt, where the study took place. The work has been carried out in accordance with the code of ethics of the world medical association (Declaration of Helsinki) for experiments involving humans.

Children were randomly assigned to two groups (study and control) as the children who came to clinic on Saturdays, on Mondays, or on Wednesdays were included in the control group, while children who came on other days were included in the study group.

2.1. Instruments and procedures

The 3D motion analysis lab in the Faculty of Physical Therapy, Cairo University was used to measure kinematic parameters of gait; Qualysis motion capture system model OR67; AMTI; USA; Qualysis Company, Sweden, 2001. Reflected dots were placed on bony prominence of lateral border of acromion, 7th cervical spinous process lateral epicondyle of elbow joint, lateral styloid process of wrist, anterior superior iliac spine, greater tochanter, lateral articulation of knee joint, head of the fibula, lateral malleolus, and base of 5th metatarsal joint.

For measurement of the angular displacement of the kinematic gait-cycle parameters, each child was asked to start walking from a position far enough from the measurement volume to enable him/her to reach a natural walking pattern. An entire gait cycle was captured within the measuring volume from the initial contact of one foot to the second toe-off of the other foot. Angular displacements of the shoulder, elbow, hip, knee, and ankle joints of every child were measured by 3D motion analysis from the sagittal plane; by measuring flexion and extension during a gait cycle for the involved side [8] before and after 6 months of treatment program.

2.2. Treatment procedures

Children of the study group received arm cycling exercises for 30 min and gait training exercises using parallel bars, obstacles, wedges, rolls and wooden stairs for 60 min. The control group received the same gait training program given to the study group only for about 60 min.

2.3. Arm cycling

It is a triangular cycle in shape that consists of two wheels connected by wheel track. The large wheel was connected to hand

Table 3 Post treatment mean values of joint angular displacement (in degrees) for both groups.

Phase	Groups	Joints (Mean value ± SD)				
		Shoulder	Elbow	Hip	Knee	Ankle
IC	Post study	3.76 ± 3.01	16.97 ± 9.56	26.02 ± 8.80	11.49 ± 5.07	−4.58 ± 2.04
	Post control	6.72 ± 4.51	23 ± 10.79	21.60 ± 7.78	8.73 ± 4.28	−5.43 ± 4.82
	p	0.003*	0.04*	0.07	0.04*	0.01*
LR	Post study	3.91 ± 1.58	19.10 ± 12.05	26.89 ± 8.80	11.54 ± 5.75	−6.32 ± 4.61
	Post control	4.58 ± 2.38	27.02 ± 12.02	22.01 ± 8.03	8.12 ± 6.06	−9.49 ± 3.94
	p	0.002*	0.02*	0.051*	0.051*	0.01*
MS	Post study	13.09 ± 6.01	35.56 ± 16.14	22.69 ± 10.30	11.21 ± 6.80	−4.49 ± 3.54
	Post control	16.55 ± 5.85	44.79 ± 16.60	17.66 ± 8.30	7.57 ± 6.11	−7.72 ± 4.71
	p	0.04*	0.057	0.06	0.057	0.01*
TS	Post study	11.49 ± 5.05	31.04 ± 16.79	−7.08 ± 6.23	11.22 ± 5.60	−9.68 ± 5.85
	Post control	15.14 ± 5.48	40.53 ± 15.43	−10.40 ± 6.83	7.91 ± 4.27	−12.91 ± 7
	p	0.02*	0.04*	0.08	0.02*	0.09
PS	Post study	7.09 ± 6.95	35.68 ± 19.76	4.43 ± 4.36	29.62 ± 10.48	−15.08 ± 7.32
	Post control	11.63 ± 7.16	47.87 ± 18.41	6.77 ± 3.66	22.73 ± 9.69	−18.99 ± 7.58
	p	0.03*	0.03*	0.05*	0.02*	0.07
IS	Post study	6.35 ± 4.4	26.31 ± 17.64	12.63 ± 9.96	34.38 ± 10.74	−12.29 ± 7.52
	Post control	8.77 ± 6.05	35.29 ± 14.61	18.74 ± 7.19	28.95 ± 9.95	−16.21 ± 7.26
	p	0.01*	0.06	0.01*	0.07	0.07
MS	Post study	5.43 ± 3.82	23.19 ± 16.60	26.04 ± 10.10	27.97 ± 10.14	−10.64 ± 7.77
	Post control	8.82 ± 5.53	32.87 ± 15	20.92 ± 7.27	22.70 ± 9.20	−15.38 ± 7.88
	p	0.01*	0.04*	0.05*	0.06	0.04*
TS	Post study	4.65 ± 4.16	23.38 ± 11.27	31.89 ± 9.15	22.16 ± 8.09	−9.83 ± 9.12
	Post control	11.13 ± 4.07	20.84 ± 13.26	25.20 ± 9.18	23. 01 ± 8.74	−15.20 ± 8.92
	p	0.0001*	0.47	0.01*	0.72	0.04*

IC: initial contact; LR: loading response; MS: midstance; PS: preswing; TS: terminal stance; IS: initial swing; MS: mid-swing; TS: terminal swing; x: mean; SD: standard deviation. Significant differences are denoted by "*".

rails, whereas the small one was connected to screw. The screw provides the required resistance to the movement in either clockwise or counterclockwise direction.

2.4. Statistical analysis

Data were normally distributed according to the test of normality. Results were expressed as mean ± standard deviation (SD) or number (%).

A comparison between the mean values of different parameters in the two groups was performed using unpaired Student's *t* test, while a comparison between pre- and post treatment within the same group was performed using paired Student's *t* test.

A comparison between categorical data was performed using Chi square test. SPSS computer program (version 19 windows) was used for data analysis. *p* value less than or equal to 0.05 was considered significant.

3. Results

Each group included 24 children with spastic hemiplegia. Mean age ± SD of both groups is shown in Table 1. There was no statistically significant difference between the mean value of age of both groups with p value = 0.56. Sex distribution within both groups was statistically comparable with a *p* value = 0.766.

Pre treatment comparisons revealed no statistically significant difference between the study and control groups as regards angular displacements of shoulder, elbow, hip, knee and ankle joints during gait sub phases (Table 2).

In post treatment comparison between the two groups regarding upper and lower limb angular displacements, significant improvement was reported in the majority of measuring variables with the exception of hip joint in the stance phase, knee joint in the initial swing and ankle joint at the end of the stance and initial swing (Table 3).

Pretreatment mean values of shoulder joint displacements in the study group ranged from 4.59 ± 3.54 to 19.17 ± 6.91 at the stance phase and from to 11.65 ± 4.33 to 13.34 ± 4.34 at the swing phase. Significant improvements of shoulder joint displacement were manifested by decreasing the flexion angular displacement from 3.91 ± 1.58 to 13.09 ± 6.01 at the stance phase and 6.35 ± 4.4 to 5.43 ± 3.82 at the swing phase on post treatment mean values respectively (Table 4).

Regarding elbow joint displacements; pretreatment mean values of displacements in the study group ranged from 24.37 ± 11.97 to 49.82 ± 20.57 at the stance phase and from 13.04 ± 10.90 to 36.85 ± 19.74 at the swing phase. Significant improvements of elbow joint displacement were manifested by decreasing the flexion angular displacement from 16.97 ± 9.56 to 35.68 ± 19.76 at the stance phase and 23.38 ± 11.27 to 26.31 ± 17.64 at the swing phase on post treatment mean values respectively (Table 4). There was also a statistically

Table 4 Pre and post treatment mean values of joint angular displacement (in degrees) for study group.

Phase	Study groups	Joints (mean value ± SD)				
		Shoulder	Elbow	Hip	Knee	Ankle
IC	Pre	9.04 ± 5.72	24.37 ± 11.97	16.31 ± 6.58	6.77 ± 2.98	−12.39 ± 5.67
	Post	3.67 ± 3.01	16.97 ± 9.56	26.02 ± 8.8	11.49 ± 5.07	−4.58 ± 2.04
	p	.00*	0.0001*	0.0001*	0.0001*	0.0001*
LR	Pre	4.59 ± 3.54	29.90 ± 13.58	16.60 ± 7.35	4.63 ± 4.55	−14.14 ± 5.3
	Post	3.91 ± 1.58	19.10 ± 12.05	26.89 ± 8.8	11.54 ± 5.75	−6.32 ± 4.61
	p	.00*	0.0001*	0.0001*	0.0001*	0.0001*
MS	Pre	19.17 ± 6.91	49.36 ± 19.13	14.69 ± 8.42	4.56 ± 4.44	−9.41 ± 6.07
	Post	13.09 ± 6.01	35.56 ± 16.14	22.69 ± 10.3	11.21 ± 6.8	−4.49 ± 3.54
	p	.002*	0.001*	0.001*	0.0001*	0.0001*
TS	Pre	16.05 ± 6.12	43.68 ± 20.88	−13.77 ± 8.68	5.66 ± 4.78	−16.09 ± 7.36
	Post	11.49 ± 5.05	31.04 ± 16.79	−7.08 ± 6.23	11.22 ± 5.6	−9.68 ± 5.85
	p	.004*	0.01*	0.0001*	0.0001*	0.0001*
PS	Pre	14.10 ± 6.23	49.82 ± 20.57	9.17 ± 5.74	18.18 ± 8.2	−24.15 ± 10.76
	Post	7.09 ± 6.95	35.68 ± 19.76	4.43 ± 4.36	29.62 ± 10.48	−15.08 ± 7.32
	p	.001*	0.008*	0.002*	0.0001*	0.0001*
IS	Pre	12.34 ± 5.10	36.85 ± 19.74	21.53 ± 8.20	25.53 ± 9.96	−21.36 ± 12.48
	Post	6.35 ± 4.4	26.31 ± 17.64	12.63 ± 9.96	34.38 ± 10.74	−12.29 ± 7.52
	p	.00*	0.01*	0.0001*	0.001*	0.002*
MS	Pre	11.65 ± 4.33	34.17 ± 17.84	16.38 ± 6.65	18.82 ± 7.91	−19.64 ± 11.56
	Post	5.43 ± 3.82	23.19 ± 16.6	26.04 ± 10.10	27.97 ± 10.14	−10.64 ± 7.77
	p	.00*	0.02*	0.0001*	0.001*	0.0001*
TS	Pre	13.34 ± 4.34	13.04 ± 10.90	19.77 ± 9.38	15.44 ± 6.86	−16.46 ± 9.19
	Post	4.65 ± 4.16	23.38 ± 11.27	31.89 ± 9.15	22.16 ± 8.09	−9.83 ± 9.12
	p	.00*	0.0001*	0.0001*	0.0001*	0.004*

IC: initial contact; LR: loading response; MS: midstance; PS: preswing; TS: terminal stance; IS: initial swing; MS: mid-swing; TS: terminal swing; x: mean; SD: standard deviation. Significant differences are denoted by "*".

Table 5 Pre and post treatment mean values of joint angular displacement (in degrees) for control group.

Phase	Control Groups	Joints (mean value ± SD)				
		Shoulder	Elbow	Hip	Knee	Ankle
IC	Pre	8.71 ± 6.05	24.63 ± 12.26	16.73 ± 6.44	6.18 ± 4.12	−13.34 ± 5.04
	Post	6.72 ± 4.51	23 ± 10.79	21.6 ± 7.78	8.73 ± 4.28	−5.43 ± 4.82
	p	0.06	0.53	0.03*	0.03*	0.0001*
LR	Pre	4.12 ± 3.7	28.38 ± 12.79	16.13 ± 6.05	4.7 ± 4.36	−14.08 ± 5.32
	Post	4.58 ± 2.38	27.02 ± 12.02	22.01 ± 8.03	8.12 ± 6.06	−9.49 ± 3.94
	p	0.72	0.63	0.002*	0.02*	0.0001*
MS	Pre	18 ± 6.8	49.63 ± 19.01	13.09 ± 7	4.69 ± 4.0	−10.53 ± 5.14
	Post	16.55 ± 5.85	44.79 ± 16.60	17.66 ± 8.3	7.57 ± 6.11	−7.72 ± 4.71
	p	0.55	0.33	0.02*	0.01*	0.006*
TS	Pre	16.49 ± 6.17	42.36 ± 20.52	−15.66 ± 6.51	4.91 ± 3.82	−16.26 ± 7.66
	Post	15.14 ± 5.48	40.53 ± 15.43	−10.4 ± 6.83	7.91 ± 4.27	−12.91 ± 7
	p	0.7	0.7	0.001*	0.01*	0.02*
PS	Pre	14.28 ± 6.03	50.63 ± 21.23	10.94 ± 4.69	16.47 ± 7.17	−23.22 ± 10.14
	Post	11.63 ± 7.16	47.87 ± 18.41	6.77 ± 3.66	22.73 ± 9.69	−18.99 ± 7.58
	p	0.57	0.54	0.0001*	0.01*	0.01*
IS	Pre	10.94 ± 6.27	37.10 ± 19.54	23.43 ± 7.61	23.86 ± 9.37	−21.82 ± 11.98
	Post	8.77 ± 6.05	35.29 ± 14.61	18.74 ± 7.19	28.95 ± 9.95	−16.21 ± 7.26
	p	0.61	0.68	0.01*	0.02*	0.02*
MS	Pre	11.93 ± 5.26	34.29 ± 16.83	17.4 ± 6.86	18.12 ± 7.29	−21.36 ± 10.6
	Post	8.82 ± 5.53	32.87 ± 15	20.92 ± 7.27	22.7 ± 9.2	−15.38 ± 7.88
	p	0.21	0.68	0.02*	0.01*	0.006*
TS	Pre	12.91 ± 4.48	22.53 ± 11.38	17.81 ± 9.45	19.55 ± 6.98	−19.51 ± 9.93
	Post	11.13 ± 4.07	20.84 ± 13.26	25.2 ± 9.18	23.01 ± 8.74	−15.2 ± 8.92
	p	0.47	0.48	0.006*	.005*	0.02*

IC: initial contact; LR: loading response; MS: midstance; PS: preswing; TS: terminal stance; IS: initial swing; MS: mid-swing; TS: terminal swing; x: mean; SD: standard deviation. Significant differences are denoted by "*".

significant difference in hip, knee, ankle angular displacement toward flexion in the study group (Table 4).

When comparing pre and post treatment mean values of angular displacement in the control group during gait sub phases, no significant difference in both shoulder and elbow ($p > 0.5$) was found, whereas there was a significant improvement in hip, knee and ankle angular displacements ($p < 0.5$) (Table 5).

4. Discussion

In hemiplegic children there are impairments in coordinative stability between the upper and lower limbs, the less stable coordination patterns originated from the hemiplegic arm (the more affected limb) [9]. This study aims to investigate the effect of arm cycling exercises on the arm swing of the hemiplegic arm by measuring the shoulder and elbow angular displacements during sub phases of gait cycle and assess its impact on angular displacements of hip, knee, and ankle joints of the hemiplegic side during sub phases of gait cycle in children with hemiplegic cerebral palsy.

Pre-treatment findings revealed that both groups of children keep their shoulder and elbow flexed during walking, this might be attributed to the fact that hemiplegic children hold their arm in front of their body in elevation and backwardly rotation with the presence of elbow flexion compared to the non involved one [7,10].

Improvement in the study group regarding shoulder and elbow joint angular displacement could be attributed to usage of arm cycling, which might improve coordinated movements between the two sides, as arm cycle provides bimanual motor performance (flexion on the one side and extension on the other side) which may reduce the associated reactions. The associated reactions are involuntary changes in muscle tone that arise from excessive effort needed for a voluntary mirror movement, that is due to unintended symmetrical irradiations of motor activity to the contralateral side during a unimanual motor performance, such reactions are found in children with hemiplegic CP [11,12].

There was a significant improvement of the hip joint angular displacement manifested by increasing flexion in the swing phase in the study group. Also, there was a non-significant difference in the stance phase which might be due to increasing uncontrolled extension, as the child uses exaggerated trunk extension as substitution.

In a pre to post comparison there was significant improvement ($p < 0.05$) in angular displacements of hip, knee and ankle joints in the study group that was associated with a concomitant improvement of the arm swing which can be explained by inter limb coordination, as coordinated upper limb exercise by using arm cycling may improve coordination between upper and lower limbs [9]. Meyns et al. [4] reported that upper and lower limb movements influence each other during locomotor-like tasks. From this point of view, including arm movements in the rehabilitation of gait has been proposed to be beneficial for several central neurological pathologies (e.g. stroke, spinal cord injury, cerebral palsy) [13,14]. In particular, it has been suggested that normalizing inter limb coordination could improve gait in patients with CP [15].

Improvement in the lower limb angular displacement in the study group might be due to the usage of arm cycling, as arm cycling exercises may allow children to reciprocally swing the arms while walking at a faster speed than they were normally able to achieve [16,17], as Huang et al. [17] found that upper limb movement influences the recruitment of lower limb motor neurons during locomotors-like rhythmic activity on a recumbent stepper.

There is some evidence that passive flexion/extension movement at the elbow joint, rhythmic arm swinging and static positioning of the arms influences the amplitude of the human soleus H (Hoffman) reflexes in normal subjects. It was found that soleus H (Hoffman) reflexes were reduced (10%) during arm swing but only when the shoulder was extended beyond the midaxillary line; it was proposed that this modulation was due to lengthening of the anterior deltoid (AD) during the backward swing and the onset of the forward swing. With arm cycling, there was also a reduction (9%) of H-reflexes during shoulder extension, but H-reflexes were also significantly depressed (22%) during shoulder flexion [16,18].

Improvement in flexion angular displacement of the lower limb of the study group could be attributed to minimizing energy consumption of legs during gait, as arm cycling exercises given to the study group facilitated arm swing which may reduce energy consumption. This comes in agreement with the finding of Meyns et al. [9] and Umberger et al. [19] who reported that arm swing decreases the angular momentum about the vertical which leads to a reduction in the vertical ground reaction moment. Reduction in the vertical ground reaction moment is likely to be accompanied by a decrease of energy consumption of legs.

Significant improvement in the swing phase of both study and control groups manifested by an increase in knee flexion, might be due to same gait training program given to both groups, as gait training might improve muscle strength around the knee joint. Such an increase in muscle strength enables a child with hemiparetic cerebral palsy to lift the swing limb into more flexion, so that the knee flexion increases [20]. Also gait training might stimulate sensorimotor system toward regaining normal function by facilitating weight-bearing to improve limb alignment [21].

5. Conclusion

In conclusion, this study suggests that the arm cycling exercises may have significant improvements in the involved upper extremity angular displacements of hemiplegic children. From the obtained results arm cycling could also have a positive impact on leg angular displacements in these patients.

Funding resources

None.

Conflict of interest

The authors declare no conflict of interest.

There is no financial and personal relationship with other people or organization that could inappropriately influence this work.

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