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Original article

Back and hip muscles with EMG biofeedback training in diplegic cerebral palsy to improve balance and gait: A randomized control trial

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Background: Cerebral palsy has pathology in immature brain problems, i.e., ischemic brain, and hypoxic brain. The cause of pathology can be prenatal, perinatal and postnatal. Electromyography (EMG) biofeedback is a muscle training program using electrical stimulation modality to train specific weakness of the muscles or pathologic side. A feedback response to the patients by visual or supporting sound can enable the patient to train themselves specifically. However, little evidences supports the efficacy of EMG biofeedback to train muscles in cerebral palsy, especially in balance and coordination.

Objective: To evaluate the efficacy of EMG biofeedback compared with conventional physiotherapy on gait and balance in children with cerebral palsy diplegia.

Methods: Thirty-four children with diplegic cerebral palsy were recruited into the study. The EMG biofeedback group included 17 children who received EMG biofeedback training in back and hip muscles plus conventional exercise. The control group included 17 children who received only conventional exercise. Gait analysis, pediatric balance scale, range of motion of hip extension, abduction and 6-minute walk tests were evaluated and compared.

Results: Both the EMG biofeedback and control groups displayed statistically significant improvement in pediatric balance scale (P <0.001 and P = 0.001, respectively). Only the EMG biofeedback group displayed statistically significant improvement in gait speed, range of motion of hip extension, abduction and 6-minute walk tests (P = 0.04, 0.003, 0.03, 0.003, respectively). No other statistically significant differences were found between the two groups.

Conclusion: The EMG biofeedback group displayed statistically significant improvement in gait speed, pediatric balance scale, range of motion of hip extension, abduction and 6-minute walk tests. The control group, however, displayed statistically significant improvement only in pediatric balance scale.

Keywords: Cerebral palsy, EMG biofeedback, back and hip, muscle training, gait analysis.

The pathology of cerebral palsy is generally caused by immature brain problems, the pathology of which includes prenatal, perinatal and postnatal causes.[1 - 3] The incidence of cerebral palsy is 1 - 2.3/1,000; so far it is the most common neurological problem in children. Most patients suffer from movement disorder and poor function, development, perception, communication, behavior and also musculoskeletal problems. [4] The most common problems (> 50%) are weakness and spasticity in both the upper and lower extremities that can affect the soft tissues around the joints, bone growth and development, leading to impairment and disability.[5] Cerebral palsy can be caused by hypoxic brain, infection, toxins, metabolic and also trauma problems. The most common abnormal clinical findings present as muscles weakness, spasticity, movement disorders, limitations of ranges of motion, joint stiffness, poor perception, abnormal communication and also impaired or poor balance and coordination. Balance and coordination problems are the most important in cerebral palsy that can cause further limitation, i.e., activities of daily living, eating, toileting, transferring, grooming, dressing and other activities, e.g. walking, watching television, studying, and playing sport. These problems can decrease the quality of life of these children.

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As for the present study, there are many techniques and treatments to improve function in cerebral palsy children, [6] such as conventional physical therapy by training strength, endurance, balance and coordination, gait training, serial casting, electrical stimulation at the defect muscles, neurodevelopmental therapy (NDT), constraint-induced movement therapy (CIMT) to improve pathological side and limit function of the normal side, electromyography (EMG) biofeedback, botulinum toxin A, phenol, alcohol injections in spastic muscles, and orthopedic surgery. However, there is little evidence supporting the efficacy of EMG biofeedback in the training of the muscles of the lower extremities and also balance and coordination in cerebral palsy. So far, no definite study has been proved to improve the function of cerebral palsy patients.[7]

EMG biofeedback is muscles training by using electrical stimulation modality to train specific weak muscles or pathologic sides. A feedback response to the patients by visual or sound can enable the patient to train themselves specifically. The patients can learn to adapt and practice by themselves to achieve their goals in improving their function, motor power and decrease spasticity.[8] The patients can learn to move specific muscles to improve their function by decreasing spasticity and increasing muscles relaxation.[9] There are many studies about the effects of EMG biofeedback in the patients who have weakness and spasticity in the upper [10 - 13] and lower extremities[14 - 16] in many groups of patients such as stroke[17, 18], traumatic brain injury, and spinal cord injuries.[19]

Kassover M, *et al.* [20] showed that auditory biofeedback significantly increased the degree of ankle dorsiflexion in four spastic cerebral palsy diplegic patients. Flodmark A, *et al.* [21] showed that auditory biofeedback improved gait patterns in cerebral palsy diplegia and hemiplegia but no in athetoid cerebral palsy and also attention deficit children. James R, *et al.* [22] showed that EMG biofeedback muscle training exercise improved head, neck, trunk, sitting balance, spasticity, weight bearing walking, eye-hand and leg-head co-ordinations, and decreased drooling in cerebral palsy, diplegia and quadriplegia. Bolek JE, *et al.* [23] showed that two cases of cerebral palsy spastic hemiplegia improved and could clear up, e.g., the swing phase in the gait patterns. In 1998, Moreland JD, *et al* [24] concluded 12 meta-analysis EMG biofeedback training studies and/or with or without conventional therapy (randomized controlled trials) to measure the lower extremities function, and improvement of motor power (strength and endurance, range of motion). The results showed that EMG biofeedback significantly improved the strength of ankle, dorsiflexion muscles strength when compared with the conventional group. [24] In 1998, a study by Toner LV, *et al.*[25] regarding. EMG biofeedback treatment in five cerebral palsy children and a case of tip-toe walking, found that there was significant improvement in muscle strength and active ranges of motion of the joints. [25]

In 2003, Armagan O. *et al.*[26] studied EMG biofeedback treatment of weakness of hand muscles in 27 hemiparesis stroke patients. The EMG biofeedback group had statistically significant improvements in ranges of motion of the wrist joint and also the strength of wrist extensor and finger extensor muscles when compared with placebo EMG biofeedback.[26] In 2004, Erbil D, *et al* [27] studied 36 cerebral palsy patients; 21 cases for gait training using EMG biofeedback and 15 cases with conventional physical therapy. The study showed more significant improvement regarding muscle strength of plantar flexion muscles, and ranges of motion; gait patterns in the EMG biofeedback group was better than the conventional group.[27] In conclusion, rehabilitation by EMG biofeedback significantly improves the effectiveness of the musculoskeletal system including ranges of motion and strength of muscles.

EMG Biofeedback can improve the effectiveness of treatments in cerebral palsy children and also is safe for the children.Children have limited intention to co-operate in tasks or activities, especially cerebral palsy children. Therefore, EMG biofeedback stimulation is a quite interesting technique to enable children to complete more activities.

Recently, there have been few studies on EMG biofeedback training in the trunk and muscles around the hip which are very important factors of gait, walking and also balance and co-ordination that affects activities and quality of life in cerebral palsy children.

From the above reasons, we were interested in studying the effects of the back and hip muscles with EMG biofeedback training in diplegic cerebral palsy, and whether or not it can improve the balance and gait better than conventional training.

This study aimed to evaluate the effectiveness of EMG biofeedback training to the back and hip muscles in diplegic cerebral palsy to improve balance and gait compared with conventional therapy.

Materials and methods

Participants

Cerebral palsy children aged 5 - 13 years old were recruited in the present study. The sample size was calculated according to Erbil D. *et al.*[27] by using two independent groups CI = 95 % (α = 0.05), power 95% (β = 0.8) and drop out of 10%. The calculated number is 17 cases per group. The total is 34 cases. By using two independent groups 95 % CI (α = 0.05), 80% power (β = 0.8)

$N/group = 2(Z\alpha/2 + Z\beta)^2\sigma^2/(X1 - X2)^2$

$= 2(1.96 + 0.84)^2 (0.08) / (0.73 - 0.46)^2 = 17.2$

$\sigma^2 = (n1 - 1) SD1^2 + (n2 - 1) SD2^2 / n1 + n2 - 2$

$= (21-1) (0.283)^2+(11-1) (0.278)^2/21+ 11 -2 = 0.08$

Inclusion criteria all children with cerebral palsy with respect to gross motor function classification system (GMFCS) classification in group I - IV. The participants can understand well and also have good perception in hearing and vision with or without glasses. They can follow at least one step command well and have no severe joint injury or non-function joint deformities of the hip, knee and ankle.

Exclusion criteria: any not correlated healthy problems with cerebral palsy at can involve the participants functional ability, such as cardiopulmonary problems, uncontrolled seizure or epilepsy, severe spasticity (modified Ashworth scale > = 3), previous surgery in the pathological back, hip and/or lower extremities within a year, botulinum toxin therapy in the pathological back, hip and/or lower extremities within 6 months, adjusted dose of any oral antispastic medications during study period, or deny to continue.

Study design

Single-blind, controlled trial, block of 4 randomization was divided into 2 groups.

Group I EMG biofeedback

The patients are trained with EMG biofeedback (Rephagia Silverfit Netherland). The surface electrode was put at the movement muscles of the back, hip and lower extremities muscles by the same physical therapist. Firstly, surface electrodes are applied at the gluteus maximus muscles and the patient cooperated to do hip flexions and extensions for 10 minutes; secondly, the surface electrodes were applied at the gluteus medius muscle and the patient cooperated to do hip abductions and adductions for 10 minutes.

Thirdly, the surface electrodes were applied at erector spinae muscle and the patient cooperated to do back flexions and extensions for 10 minutes. The patients had to do three kinds of exercises and follow visual and EMG biofeedback. The patients had to do every kind of exercise: 10 minutes per exercise and ranges of motion for 15 minutes. The total time was 45 minutes per day for 3 days per week for 4 weeks. The total sessions received were 12 sessions per person.

Group II Conventional therapy

In this group the patients were trained in 3 steps of exercise. Range of motion exercises, strengthening, balance coordination and walking exercise 15 minutes per exercise, 45 minutes per day, 3 days per week for 4 weeks. In total, each subject received 12 sessions. Both groups were trained by expert physical therapists.

All subjects were examined by a single blinded evaluator, regarding: age, gender, back, hip and/or lower extremities, history of healthy conditions, epilepsy or seizure treatment, vision problems, history of surgery in the previous one year and/or history of botulinum toxin A injections at the back, hip and/or lower extremities lesion side in the previous 6 months. They were evaluated pre-training and post training at 4^{th} and 8^{th} weeks.

Outcome measurement

Gait and motion analysis (Neurocom Balance master by Natusm, USA) at week 0 and week 4 was used for recording gait speed, stride length and cadence and examination by a physician used for pediatric balance scale at week 0, 2, 4 and 8. (Balance scores were evaluated from the child's ability: score 0, score 4, minimum score is 0 and maximum score is 54), 6-minute walk tests, 10-meter walk tests, modified time up-and-go tests, hip range of motion, spasticity, modified Ashworth scale (MAS), GMFCS, level I - V, and satisfaction scores (score 1 - 10). The main principal outcomes were gait parameter, gait speed, stride length, and cadence at week 2, 4, and 8; and secondary outcomes were: 6-minute walk test, 10-meter walk test, modified time up-and-go test, hip ranges of motion, spasticity, modified Ashworth scale (MAS), GMFCS, level I - V, and satisfaction score (score 1 - 10).

Statistical Analysis

Data were analyzed by SPSS (Cities version 22.0). Data analysis was blinded. Basic data were analyzed to compare between the two groups. Age, gait speed, stride length, cadence, and pediatric balance scales were analyzed by unpaired *t* - test, sex; classification of cerebral palsy and GMFCS were analyzed by Chi-square test. Pre and post training in gait speed, stride length and cadence were analyzed by paired *t* - tests. Pediatric balance scale, 6-minute walk test, 10-meter walk test, modified time up-and-go test and hip ranges of motion were analyzed by repeated measured analysis of variance (ANOVA) and a modified Ashworth scale. GMFCS were analyzed by Wilcoxon signed rank test.

Gait speed, stride length, cadence and satisfaction score by unpaired *t* - tests to compare between groups. Pediatric balance scale, 6-minute walk test, 10-meter walk test, modified time up and go test and hip ranges of motion were compared by repeated measured ANOVA. Modified ashworth scales (MAS) and GMFCS were analyzed by Mann-Witney U-tests.

Results

Basic data from both the biofeedback and conventional groups include: age, gender, GMFCS classification, gait speed, stride length, cadence and pediatric balance scales. There was no significant difference in the basic data of both groups. (Table 1)

From 61 cerebral palsy cases, there were 34 cases that fit the inclusion criteria in this study. Thirty-four cases were divided into two groups and all of them succeeded and finished the research without any drop out.

In the aspect of gait speed, the biofeedback group showed statistically significant difference compared with the conventional group at week 4 ($P = 0.004$), but no statistically significant difference in stride length and cadence.

In the aspect of gait, speed, stride length and cadence, the conventional group did not show a statistically significant difference at week 4. (Table 2)

Both the EMG biofeedback and the conventional groups had a statistically significant increase in pediatric balance scales at week 4 ($P = 0.001$) and week 8 ($P = 0.04$) when compared pre- and post-training (Table 3).

When comparing pre-training and post-training, the EMG Biofeedback group had a statistically significant improvement in 6-minute walk tests at week 2 and week 4 ($P = 0.002$, $P = 0.003$) (Table 4), and also in hip abduction and hip extension at week 4 ($P = 0.03$, $P = 0.003$) (Table 5). However, there were no statistically significant improvements in 10-meter walk tests, modified time up and go tests, modified Ashworth scale (MAS) and GMFCS at week 2, 4 and 8 (Table 5, 6).

Table 1. Demographic data and baseline characteristics.

	EMG biofeedback (Mean ± SE)	**Conventional (Mean ± SE)**	***P* - value**
Age (yr)	8.00 ± 2.45	7.00 ± 3.23	0.56*
Gender			0.08^
Male	5	6	
Female	12	11	
GMFCS			0.56^
III	3	3	
IV	2	4	
Gait parameter			
Speed (m/sec)	0.21 ± 0.17	0.23 ± 0.29	0.63*
Stride (m)	0.47 ± 0.35	0.63 ± 0.91	0.15*
Cadence (step/min)	56.04 ± 7.65	41.35 ± 8.56	0.23*
PBS	10.83 ± 2.26	5.33 ± 2.09	0.10*

*unpaired *t* - test, ^Chi-square test. GMFCS: Gross motor function classification system; PBS: Pediatric balance score.

Table 2. Gait speed, stride length, cadence pre and post training at week 4 and between group differences.

	EMG biofeedback (Mean ± SE)	Conventional (Mean ± SE)	*P* - value of between group mean difference*
Speed (m/sec)			
Pretreatment (I)	0.21 ± 0.17	0.23 ± 0.29	
4th week (II)	0.39 ± 0.05	0.25 ± 0.26	
I - II difference	0.18 ± 0.66	0.03 ± 0.16	0.08
P - value I - II difference^	0.04	0.53	
Stride length (m)			
Pretreatment (I)	0.47 ± 0.35	0.63 ± 0.91	
4th week (II)	0.54 ± 0.53	0.61 ± 0.19	
I - II difference	0.07 ± 0.06	-0.02 ± 0.10	0.48
P - value I - II difference^	0.31	0.87	
Cadence (step/min)			
Pretreatment (I)	56.04 ± 7.65	41.35 ± 8.56	
4th week (II)	78.48 ± 11.80	49.92 ± 7.30	
I - II difference	22.44 ± 18.88	8.57 ± .4.30	0.50
P - value I - II difference^	0.29	0.10	

**unpaired *t* - test, ^paired-T test

Table 3. Pediatric balance scale pre and post training at week 2, 4, 8 and between groups differences.

	EMG biofeedback (Mean ± SE)	Conventional (Mean ± SE)	*P* - value of between group mean difference*
Pretreatment (I)	10.83 ± 2.26	5.33 ± 2.09	
2nd week (II)	11.17 ± 2.24	5.50 ± 2.03	
4th week (III)	11.83 ± 2.25	6.00 ± 2.24	
8th week (IV)	11.50 ± 2.29	5.83 ± 2.30	
I - II difference	0.33 ± 0.21	0.17 ± 0.17	0.55
I - III difference	1.00 ± 0	0.67 ± 0.21	0.15
I - IV difference	0.67 ± 0.21	0.50 ± 0.27	0.60
P - value I - II difference*	0.11	0.40	
P - value I - III difference*	< 0.001	0.001	
P - value I - IV difference*	0.01	0.04	

*repeated measure ANOVA

Table 4. 6-minute walk test, 10-meter walk test, and modified time up and go tests pre and post training at week 2, 4, 8 and between groups differences.

	EMG biofeedback (Mean ± SE)	Conventional (Mean ± SE)	*P* - value of between group mean difference*
6-minute walk test			
Pretreatment (I)	91.50 ± 17.63	60.85 ± 18.76	
2nd week (II)	112.83 ± 19.95	67.70 ± 20.76	
4th week (III)	116.00 ± 23.88	72.78 ± 20.31	
8th week (IV)	126.50 ± 24.58	102.30 ± 18.23	
I - II difference	21.33 ± 5.54	6.86 ± 4.53	0.07
I - III difference	24.50 ± 7.59	11.93 ± 4.30	0.18
I - IV difference	35.00 ± 11.03	41.49 ± 22.22	0.80
P - value I - II difference*	0.002	0.21	
P - value I - III difference*	0.003	0.08	
P - value I - IV difference*	0.07	0.07	

Table 4. (Con) 6-minute walk test, 10-meter walk test, and modified time up and go tests pre and post training at week 2, 4, 8 and between groups differences.

	EMG biofeedback (Mean ± SE)	Conventional (Mean ± SE)	*P* - value of between group mean difference*
10-meter walk test			
Pretreatment (I)	38.81 ± 4.85	30.88 ± 16.51	
2nd week (II)	30.03 ± 5.51	41.15 ± 27.98	
4th week (III)	29.65 ± 5.24	22.73 ± 10.89	
8th week (IV)	24.12 ± 3.48	12.90 ± 3.30	
I - II difference	2.78 ± 2.22	-10.28 ± 11.00	0.31
I - III difference	3.16 ± 3.48	8.15 ± 5.80	0.48
I - IV difference	8.69 ± 2.42	17.98 ± 13.85	0.52
P - value I - II difference*	0.75	0.26	
P - value I - III difference*	0.52	0.12	
P - value I - IV difference*	0.40	0.10	
Modified time up and go test			
Pretreatment (I)	9.68 ± 1.46	23.86 ± 9.94	
2nd week (II)	8.44 ± 1.38	18.85 ± 6.38	
4th week (III)	8.61 ± 1.53	13.34 ± 3.47	
8th week (IV)	6.90 ± 1.11	11.83 ± 3.91	
I - II difference	1.24 ± 0.21	5.02 ± 3.39	0.29
I - III difference	1.07 ± 0.93	10.53 ± 6.96	0.21
I - IV difference	2.78 ± 1.09	12.04 ± 8.03	0.28
P - value I - II difference*	0.61	0.06	
P - value I - III difference*	0.83	0.06	
P - value I - IV difference*	0.69	0.06	

* repeated measure ANOVA

Table 5. Hip extension and abduction ranges of motion at pre and post training at week 2, 4, 8 and between groups differences.

	EMG biofeedback (Mean ± SE)	Conventional (Mean ± SE)	*P* - value of between group mean difference*
ROM of hip extension			
Pretreatment (I)	17.50 ± 0.89	13.33 ± 5.67	
2nd week (II)	18.67 ± 0.42	13.33 ± 5.30	
4th week (III)	18.83 ± 0.54	14.00 ± 5.61	
8th week (IV)	18.50 ± 0.56	13.83 ± 5.39	
I - II difference	1.17 ± 0.79	0 ± 0.63	0.28
I - III difference	1.33 ± 0.42	0.67 ± 0.21	0.19
I - IV difference	1.00 ± 0.51	0.50 ± 0.43	0.47
P - value I - II difference*	0.14	1.00	
P - value I - III difference*	0.003	0.07	
P - value I - IV difference*	0.06	0.32	
ROM of hip abduction			
Pretreatment (I)	40.17 ± 2.73	42.00 ± 1.86	
2nd week (II)	40.50 ± 2.33	42.00 ± 1.86	
4th week (III)	41.67 ± 2.74	42.17 ± 2.06	
8th week (IV)	41.67 ± 2.36	42.67 ± 1.80	
I - II difference	0.33 ± 0.88	0 ± 0.63	0.77
I - III difference	1.50 ± 0.56	0.17 ± 0.65	0.15
I - IV difference	1.00 ± 0.58	0.67 ± 0.56	0.80
P - value I - II difference*	0.67	1.00	
P - value I - III difference*	0.03	0.79	
P - value I - IV difference*	0.11	0.27	

* repeated measure ANOVA. ROM : Range of motion.

Table 6. MAS, GMFCS pre and post training at week 2, 4, 8 and between groups differences.

	EMG biofeedback (Mean ± SE)	Conventional (Mean ± SE)	*P* - value of between group mean difference*
MAS of hip adductor			
Pretreatment (I)	0.58 ± 0.66	0.75 ± 0.88	
2nd week (II)	0.58 ± 0.66	0.67 ± 0.82	
4th week (III)	0.50 ± 0.55	0.67 ± 0.82	
8th week (IV)	0.50 ± 0.55	0.75 ± 0.88	
I - II difference	0	0.08 ± 0.20	0.7
I - III difference	0.83 ± 0.20	0.08 ± 0.20	1
I - IV difference	0.83 ± 0.20	0	0.7
P - value I - II difference^	1	0.31	
P - value I - III difference^	0.31	0.31	
P - value I - IV difference^	0.31	1	
GMFCS			
Pretreatment (I)	3.50 ± 0.55	3.67 ± 0.52	
2nd week (II)	3.50 ± 0.55	3.67 ± 0.52	
4th week (III)	3.50 ± 0.55	3.67 ± 0.52	
8th week (IV)	3.50 ± 0.55	3.67 ± 0.52	
I - II difference	0	0	1
I - III difference	0	0	1
I - IV difference	0	0	1
P - value I - II difference^	1	1	
P - value I - III difference^	1	1	
P - value I - IV difference^	1	1	

*Mann-Whitney U test, ^Wilcoxon signed-rank test. MAS : Modified ashworth scale; GMFCS: Gross motor function classification system.

Between the EMG biofeedback and conventional groups, there was no statistically significant change in all primary and secondary outcomes except a statistically significant improvement in satisfaction scores; that of the EMG biofeedback group was 8.83 out of 10, whereas it was 7.33 out of 10 in the conventional group ($P = 0.003$).

Discussion

From a previous study, in 1998, Toner LV, *et al.*[25] who studied the effectiveness of EMG biofeedback in cerebral palsy and concluded that the biofeedback machine gave statistically significant help to the degree of active ranges of motion of joints, and also increased the ankle dorsiflexion muscles group. [22]

In 2004, Erbil D, *et al.* studied the effectiveness of EMG biofeedback and found statistically significant improvement in the strength of the ankle plantar flexion group, degree of active ranges of motion of the ankle joint and developed gait patterns better than the convention group. In 2010, Rosemary B, *et al.*[28] found that biofeedback helped improve the functions of upper extremities.[26] Our previous report showed that EMG biofeedback training could significantly improve the upper extremities and hand functions in male cerebral palsy children. [29]

Between EMG biofeedback and conventional groups, there are no statistically significant change in all primary and secondary outcomes except a statistically significant improvement in satisfaction scores.

The biofeedback group increased significantly in gait speed, pediatric balance scale, hip abduction, hip extension and also 6-minute walk tests, but the conventional group had a statistically significant increase only in pediatric balance scale.

Also from this study, the EMG Biofeedback group has more statistically significant improvements within the group pre and post training than the conventional group, but there is no statistically significant difference between the groups.

We did not find any unsatisfied signs and symptoms in either the EMG biofeedback or conventional groups. The EMG biofeedback machine is safe to use.

The biofeedback group increased significantly in gait speed, pediatric balance scale, hip abduction, hip extension and also 6-minute walk tests at week 4 but not significant at week 8. It can be concluded that EMG biofeedback may not be effective in the long-term. So long-term biofeedback training for long-duration effects should be considered in the future.

Conclusion

In gait speed, pediatric balance scale, hip abduction, hip extension and also 6-minute walk tests, the EMG biofeedback group show a statistically significant difference in cerebral palsy diplegia. We concluded that the biofeedback muscles training technique is one of the most useful techniques to train cerebral palsy children to improve their gait pattern and balance to improve their independent activities with low-cost technology.

What is already known on this topic?

EMG biofeedback can increase strength and decrease spasticity in stroke and cerebral palsy patients.

What does this study add?

EMG Biofeedback rarely has side effects in children and can increase strength, endurance, balance and coordination and gait improvement and function in cerebral palsy diplegic patients. It, therefore, can be further used in disability or gait training, and lower extremities muscles to increase their functions and their activities.

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Conflict of interest

None of the authors has any potential conflict of interest to disclose.

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