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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 problem, i.e., ischemic brain, hypoxic brain. The cause of pathology can be prenatal, perinatal and postnatal. Electromyography (EMG) biofeedback is muscles training program using electrical stimulation modality to train specific weakness of the muscles or pathologic side. Feedback response to the patients by visual or evidence through supporting sound can enable the patient to train themselves specifically. However, few evidences support 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. EMG biofeedback group included 17 children who received EMG biofeedback training in back and hip muscles plus conventional exercise. 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 test 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 test (P = 0.04, 0.003, 0.03, 0.003, respectively). No statistical significance of mean difference was found in all outcomes 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 test. 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 problem, 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 of neurological problem in children. Most patients suffer from movement disorder and poor function, development, perception, communication, behavior and also musculoskeletal problems. [4] 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, toxin, metabolic and also trauma problems. Most common abnormal clinical findings present by muscles weakness, spasticity, movement disorder, limitation of range of motion, joint stiffness, poor perception, abnormal communication and also impaired or poor balance and coordination. Balance and coordination problems are 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, 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 treatment to improve function in cerebral palsy children [6] such as conventional physical therapy by training strength, endurance and balance and coordination, gait training, serial casting, electrical stimulation at defect muscles, neurodevelopmental therapy (NDT), constraint-induced movement therapy (CIMT) to improve pathological side and limit function of normal side, Electromyography (EMG) biofeedback, botulinum toxin A, phenol, alcohol injection in spastic muscles, orthopedic surgery. However, there are few evidences supporting efficacy of EMG biofeedback in 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 side. Feedback response to the patients by visual or evidence supporting 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 effect 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, spinal cord injuries.[19]

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

In 2003, Armagan O. *et al.*[26] studies EMG biofeedback treatment of weakness of hand muscles in 27 hemiparesis stroke patients. EMG biofeedback group had statistically significant improvement in range 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 by using EMG biofeedback and 15 cases with conventional physical therapy. The study showed more significant improvement regarding muscle strength of plantar flexion muscles, range of motion; and gait pattern in EMG biofeedback groups was better than conventional group.[27] In conclusion, rehabilitation by EMG biofeedback statistically significant improves effectiveness of musculoskeletal system including range of motion and strength of muscles.

EMG Biofeedback can improve the effectiveness of outcome of treatment in cerebral palsy children and also safe for the children. The children have limitation of intention to co-operate tasks or activities especially cerebral palsy children, therefore EMG biofeedback stimulation is one quite interesting technique to enable the children to complete more activities.

Recently, there are 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, the researchers have interest to study the effect of the back and hip muscles with EMG biofeedback training in diplegic cerebral palsy, whether or not it can improve the balance and gait better than the conventional training.

This study is 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 the 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] study by using two independent group CI = 95 % (α = 0.05), power 95% (β = 0.8) and drop out 10%. Calculated number is 17 cases per group. Total is 34 cases. By using two independent group 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 good and have no severe joint injury or non-function joint deformities of hip knee and ankle.

Exclusion criteria: all 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 pathological back, hip and/or lower extremities within a year, botulinum toxin therapy in 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 designs

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

Group I EMG biofeedback

The patients are trained by EMG biofeedback Rephagia Silverfit Netherland. The surface electrode is put at the movement muscles of back, hip and lower extremities muscles by the same physical therapist. Firstly, surface electrodes are applied at gluteus maximus muscles and the patient cooperated to do hip flexion and extension for 10 minutes; secondly, surface electrodes are applied at gluteus medius muscle and the patient cooperated to do hip abduction and adduction for 10 minutes.

Thirdly, surface electrodes are applied at Erector spinae muscle and the patient cooperated to do back flexion and extension for 10 minutes. The patients have to do three kinds of exercise and follow visual and EMG biofeedback. The patients have to do every kind of exercise: 10 minutes per exercise and do range of motion for 15 minutes. Total time was 45 minutes per day for 3 days per week for 4 weeks. Total session received is 12 sessions per person.

Group II Conventional therapy

In this group the patients are trained in 3 steps of exercise. Range of motion exercise, 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 are trained by expert physical therapists.

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

Outcome measurement

Gait and motion analysis (Neurocom Balance master by Natusm, USA) at week 0 and week 4 for recording gait speed, stride length and cadence and examination by physician for pediatric balance scale at week 0, 2nd, 4th and 8 th. (Balance score evaluated from the child's ability: score 0, score 4, minimum score is 0 and maximum score is 54), 6-minute walk test, 10-meter walk test, modified time up-and-go test, hip range of motion, spasticity, modified Ashworth scale (MAS), GMFCS, level I - V, and satisfaction score (score 1 - 10). Main principal outcomes were gait parameter, gait speed, stride length, cadence at week 2nd, 4th, and 8th; and secondary outcome were: 6-minute walk test, 10-meter walk test, modified time up-and-go test, hip range of motion, spasticity, modified Ashworth scale (MAS), GMFCS, level I - V, 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, pediatric balance scale analyzed by unpaired *t* - test, sex, classification of cerebral palsy GMFCS analyzed by Chi-square test. Analyzed pre and post training in gait speed, stride length and cadence by paired *t* - test. Pediatric balance scale, 6-minute walk test, 10-meter walk test, modified time up-and-go test and hip range of motion analyzed by repeated measured analysis of variance (ANOVA) and modified Ashworth scale. GMFCS analyzed by Wilcoxon signed rank test.

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

Results

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

From 61 cerebral palsy cases, there were 34 cases that fit in with 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 aspect of gait speed, biofeedback group shows statistically significant difference compared with conventional group at week 4^{th} (P = 0.004) but no statistically significant difference in stride length and cadence.

In aspect of gait, speed, stride length and cadence conventional group did not shows statistically significant difference at week 4^{th}. (Table 2)

Both EMG biofeedback and conventional group have statistically significant increase in pediatric balance scales at week 4^{th} (P = 0.001) and week 8^{th} (P = 0.04) when compared pre- and post-training (Table 3).

When compared pre training and post training EMG Biofeedback group had statistically significant improvement in 6-minute walk test at week 2^{nd} and week 4^{th} (P = 0.002, P = 0.003) (Table 4) and also in hip abduction and hip extension at week 4^{th} (P = 0.03, P = 0.003) (Table 5). However, there are no statistically significant improvement in 10-meter walk test, modified time up and go test, modified Ashworth scale (MAS) and GMFCS at week 2^{nd}, 4^{th} and 8^{th} (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 4th and between group difference.

	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 2nd, 4th, 8th and between groups difference.

	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, Modified time up and go test pre and post training at week 2nd, 4th, 8th and between groups difference.

	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, Modified time up and go test pre and post training at week 2nd, 4th, 8th and between groups difference.

	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 range of motion at pre and post training at week 2nd, 4th, 8th and between groups difference.

	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 2nd, 4th, 8th and between groups difference.

	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 statistically significant improvement in satisfaction score; that of the EMG biofeedback group is 8.83 out of 10 whereas 7.33 out of 10 in the conventional group ($P = 0.003$).

Discussion

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

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

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

Biofeedback group success to increase significantly in gait speed, pediatric balance scale, hip abduction, hip extension and also 6-minute walk test but conventional group has significant statistically increase only in pediatric balance scale.

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

We do not find any unsatisfied signs and symptoms in both EMG biofeedback and also conventional groups. EMG biofeedback machine is safe to use.

Biofeedback group success to increase significantly in gait speed, pediatric balance scale, hip abduction, hip extension and also 6-minute walk test at week 4th but not significant statistically at week 8th. This can be concluded that EMG biofeedback may be cannot effect in the long duration. So far long-time biofeedback training for long-duration effect should be considered in the future.

Conclusion

In aspect of gait speed, pediatric balance scale, hip abduction, hip extension and also 6-minute walk test EMG biofeedback group shows statistically significant difference in cerebral palsy diplegia. We can conclude that biofeedback muscles training technique is one of the most useful techniques to train cerebral palsy children to improve their gait pattern and balance to success 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 effect 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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