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Effectiveness of neuromuscular electrical stimulation in improving mobility in children with cerebral palsy: A systematic review and meta-analysis of randomized controlled trials

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Abstract

Objective: To investigate whether neuromuscular electrical stimulation improves mobility in children with spastic cerebral palsy.

Methods: PubMed, Cochrane, EMBASE, and Scopus were searched for randomized controlled trials studying the effects of NMES on the lower limbs in children with spastic CP. Randomized controlled trials comparing the effect of neuromuscular electrical stimulation with that of placebo or conventional therapy on mobility in children with cerebral palsy were eligible for inclusion. Two reviewers independently screened studies, extracted data, and examined the risk of bias and quality of evidence by using the revised Cochrane Risk-of-Bias Tool for Randomized Trials (RoB 2.0) and the Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) method. The final search was conducted on May 23, 2022.

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Results: A total of 14 randomized controlled trials (2 crossover studies and 12 parallel studies including 421 patients) were included in this meta-analysis. Compared with the control group (conventional physical therapy), the treatment group exhibited greater improvement in walking speed (standardized mean difference = 0.29; 95% confidence interval = 0.02–0.57) and the standing, walking, running, and jumping dimension of the Gross Motor Function Measure (standardized mean difference = 1.24; 95% confidence interval = 0.64–1.83).
Conclusion: Neuromuscular electrical stimulation improved mobility in children with spastic cerebral palsy, particularly in standing, running, and jumping function, and it is safe for children with spastic cerebral palsy.

Keywords
cerebral palsy, electrical stimulation, child, lower extremity, systematic review, meta-analysis

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Introduction

Cerebral palsy is a group of non-progressive motor disorders; it commonly appears in early childhood and affects muscle tone, posture, and movement.[1] Due to abnormal brain development or damage to the developing brain, cerebral palsy contributes to equinus when walking and results in the recruitment of compensatory strategies as well as trips and falls.[2] These factors may impair gross motor function of the extremities, which is necessary for exercise and physical activity.

Neuromuscular electrical stimulation is defined as the non-invasive application of electrical stimulation to produce skeletal muscular contractions through the percutaneous stimulation of peripheral nerves.[3] In 1975, Leyendecker first reported the use of neuromuscular electrical stimulation to improve extremity motor function in children with cerebral palsy.[4] Neuromuscular electrical stimulation is reported to decrease spasticity, activate weakened muscles, and improve gait in individuals with various neurological conditions including cerebral palsy.[5–8] Moreover, an increasing number of randomized controlled trials have indicated that the outcomes of neuromuscular electrical stimulation are more favorable than those of conventional treatments. Recently, two systematic reviews on this topic have been published.[1,9] Of those, one review did not involve a meta-analysis.[9] The other review involved a meta-analysis with a limited quality of evidence, and it reported that neuromuscular electrical stimulation may improve gross motor function in children with spastic cerebral palsy. However, this review did not examine whether neuromuscular electrical stimulation improves mobility in children with cerebral palsy.[1]

Whether neuromuscular electrical stimulation is an effective alternative to conventional treatment remains unclear. We conducted this systematic review and meta-analysis to verify and update the latest evidence on the effectiveness of neuromuscular electrical stimulation in improving mobility in children with cerebral palsy.

Materials and methods

This systematic review and meta-analysis was conducted in accordance with updated Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines[10] (Supplementary Appendix A). The systematic review protocol is registered in PROSPERO, the online international prospective register of systematic reviews of the National Institutes for Health Research (registration no. CRD42021271639), and the databases were last searched from their inception until May 23, 2022.

We included randomized controlled trials, including crossover designs. The PICO (patients, intervention, comparison, and outcomes) question of this study was as follows: compared with the

placebo or conventional therapy (C), does neuromuscular electrical stimulation (I) improve mobility (O) in children with cerebral palsy (P)? Papers were excluded if they were protocols, non-peer-reviewed articles, conference papers, and letters to the editor. In addition, we excluded papers describing studies in which the leads of a neuromuscular stimulator were not placed on the legs. No restrictions were applied with respect to the language or journal type.

We searched for relevant studies published in PubMed, Cochrane Library, Scopus, and EMBASE databases. The search was conducted using the following keywords and synonyms: "cerebral palsy" (or cerebral palsy [MESH]), "electrical AND stimulation," "electric AND stimulation" (or electric stimulation [MESH]), "electrostimulation" (or electrical stimulation therapy [MESH]), "ES," "FES," "NMES," and "random*." These keywords were used in the PubMed filter, and only randomized controlled trials were selected. The search terms were adapted for use in other electronic databases, if available (search strategies are presented in the Supplementary Appendix B). Series or duplicate publications in the same or different journals were counted only once. In addition, the reference lists of retrieved meta-analyses and reviews were manually searched to identify additional relevant articles.

Two authors independently screened the titles and abstracts of the retrieved studies. The full texts were reviewed as necessary. Trials were determined to be eligible for inclusion in this study according to the inclusion and exclusion criteria. Disagreements were resolved by a third review author.

The two authors independently evaluated the quality of included studies by using the revised Cochrane risk-of-bias tool for randomized trials (RoB 2.0).[11] This tool is used to evaluate the risks of bias in the following domains: (1) randomization process, (2) deviations from intended interventions, (3) missing outcome data, (4) measurement of outcomes, (5) selection of reported results, and (6) overall bias.. Two reviewers independently conducted this assessment in accordance with the *Cochrane Handbook for Systematic Reviews of Interventions*.[12] Disagreements were resolved through discussion with a third researcher, in which the outcome was decided based on the consensus of two-thirds of all authors.

For each included study, data were extracted independently by two authors using extraction forms. Differences in the quality appraisal and extracted data were resolved through discussion with a third reviewer. For each included trial, the following details were extracted: the publication year, group setting, participant demographics and baseline characteristics, details of the intervention plan (location of electrode, session frequency, session duration, and protocol duration), the parameters of the stimulator (intensity, duration, frequency, pulse width, and on/off time), and study outcomes. Outcomes were only included in the meta-analysis if they provided a point estimate and a measure of variability (e.g. mean $\pm$ standard deviation) and were reported in more than three randomized controlled trials. Discrepancies were identified and resolved through discussion with a third review author. Missing or unclear data were requested from the study authors by email.

The meta-analysis was conducted using RevMan 5.3 software (The Cochrane Collaboration, London, United Kingdom). All relevant data measured using different scales were converted to a single scale. All data are expressed as standardized mean differences and 95% confidence intervals, which were pooled using a RevMan 5.3 software program for calculation. The pooled data were analyzed using the random-effects model because of the expectations for various study methods in each randomized control trials. Effect sizes were based on thresholds defined by Cohen,[13] and categorized as follows: no clinical meaningfulness (standardized mean difference less than 0.2), small effect sizes (standardized mean difference between 0.2 and 0.5), medium effect size (standardized mean difference between 0.5 and 0.8), and large effect size (standardized mean difference greater than 0.8).[14,15] Statistical heterogeneity, calculated using the I^2 test, was considered high if the I^2 value exceeded 70%. In the case of high heterogeneity, a sensitivity analysis was conducted to confirm its effect after adjustment of the included data Results are presented according to both their statistical significance (p value less than

0.05) and probable clinical meaningfulness (standardized mean difference greater than 0.2).

The certainty in evidence was examined using the Grading of Recommendations, Assessment, Development and Evaluation (GRADE) approach.[16] The certainty of the included randomized controlled trials was determined on the basis of their study design, risk of bias, inconsistency, imprecision, indirectness, publication bias, and effect sizes and their trends.[16]

Results

Figure 1 presents the flowchart for trial selection. Among the studies retrieved from the aforementioned databases and independently reviewed by the two reviewers, 14 randomized controlled trials (2 crossover studies and 12 parallel studies including a total of 421 patients) comparing the effects of neuromuscular electrical stimulation with those of control treatment on mobility in children with spastic cerebral palsy met the eligibility criteria and were included in the meta-analysis. Seven studies,[17–23] which included a total of 213 patients, reported outcomes associated with walking speed. Nine studies,[19,21,24–30] which included a total of 302 patients, reported outcomes associated with the standing dimension (dimension D) and the walking, running, and jumping dimension (dimension E) of the Gross Motor Function Measure (GMFM). In all of the included studies, the lead of the electrical stimulator was placed on the legs of the patients. In particular, in most of the studies, the lead was placed on the ankle dorsiflexor muscles, such as the tibialis anterior. Furthermore, of the 14 included studies, in 10, the intensity of the electrical stimulator was adjusted to elicit muscle contractions. In 3, the intensity was maintained between 10 and 70 mA, and 2 studies did not report the intensity of stimulation used on the patients. Table 1 lists the characteristics of the selected trials, and Table 2 lists the characteristics of interventions and stimulator parameters.

The quality of the included randomized control trials was independently evaluated by two independent reviewers,using Revised Cochrane risk of bias tool for randomized trials (RoB 2.0).[11] Of the 14 randomized controlled trials, 8 were associated with some concerns and 6 had a high risk or bias. Figure 2 illustrates results regarding the risk of bias.

All the results were statistically significant and clinically meaningful. In terms of outcome measurements, walking speed was reported in seven studies (with one crossover study),[18] which included 113 and 100 patients in the experimental and control groups, respectively. The experimental group exhibited significantly higher improvements in walking speed than did the conventional physical therapy group with a small effect size. Figure 3 presents the forest plot of the meta-analysis.

The standing dimension (dimension D) and walking, running, and jumping dimension (dimension E) of the Gross Motor Function Measure (GMFM) was reported in the nine randomized controlled trials (with one crossover study)[26] including 153 and 149 patients in the experimental and control groups, respectively. The experimental group exhibited significantly higher improvement than did the control group with a large effect size. Figure 4 presents the forest plot of the meta-analysis.

The studies comparing the improvement in walking speed between the neuromuscular electrical stimulation treatment group and the control group showed minimal heterogeneity ($I^2 = 0\%$). By contrast, studies comparing the improvement in gross motor function exhibited a high level of heterogeneity ($I^2 = 80\%$).[31] Therefore, a sensitivity analysis was performed.

After excluding the outlier randomized control trials,[28] the results showed reduced heterogeneity. Moreover, the findings continued to indicate a significantly more favorable outcome of neuromuscular electrical stimulation treatment with a large effect size (SMD, 0.98; 95% confidence interval, 0.53–1.43; n = 278; $I^2 = 64\%$; $P < .0001$).[13]

Regarding the safety of neuromuscular electrical stimulation treatment in children with cerebral palsy, five randomized controlled trials including 198 patients reported on the adverse effects of neuromuscular electrical stimulation.[19,21–23,27] No adverse event was reported for the 198 patients.

The Grading of Recommendations, Assessment, Development and Evaluation method revealed a

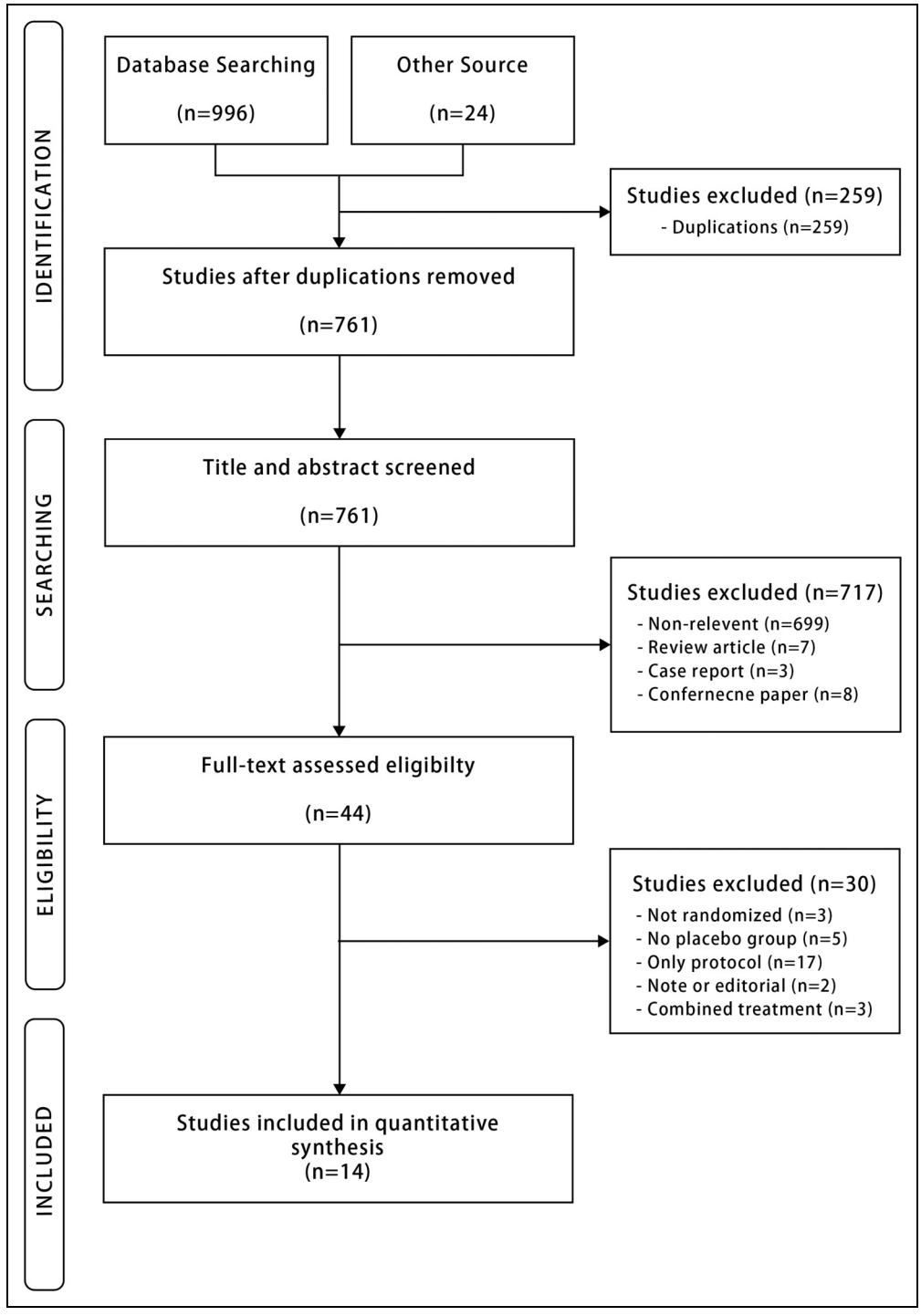

Figure 1. Flowchart for trials selection.

Table 1. Characteristics of selected trials.

Study	Group	Participants (M/F)	Diplegic/Hemiplegic/Quadriplegic	Age (Years)	GMFCS I/II/III	Outcomes included in meta-analysis
van der Linden (2003)[17]	NMES	11 (15/7)	6/4/1	8.5 ± 2.83	N/A	Walking speed
	Control	11	6/4/1	8.2 ± 2.91	N/A	
Chan (2004)[24]	NMES	6(4/2)	2/4/0	6.3 ± 1.03	N/A	GMFM D and E dimensions
	Control	6(5/1)	5/1/0	6.5 ± 2.74	N/A	
Ho (2006)[18] (Crossover study)	NMES	9(6/3)	5/4/0	7.6 ± 2.11	9/0/0	Walking speed
	Control	9(6/3)	5/4/0	7.6 ± 2.11	9/0/0	
Kerr (2006)[25]	NMES	18(12/6)	15/0/0/3*	11.12 ± 3.43	N/A	GMFM D and E dimensions
	Control	22(15/7)	20/1/1	10.6 ± 3.91	N/A	
Xu (2007)[19]	NMES	40(26/14)	25/15/0	3.8 ± 0.72	23/17/0	Walking speed / GMFM D and E dimensions
	Control	38(25/13)	24/14/0	3.7 ± 0.69	22/16/0	
van der Linden (2008)[20]	NMES	7(N/A)	3/3/0/1*	8.0± 3.07	N/A	Walking speed
	Control	7(N/A)	3/3/0/1*	8.1 ± 2.41	N/A	
Jiang (2008)[26] (Crossover study)	NMES	14(8/6)	N/A	5.54	N/A	GMFM D and E dimensions
	Control	14(8/6)	N/A	5.54	N/A	
Yang (2008)[21]	NMES	8(5/3)	6/2/0	6.1 ± 3.13	N/A	Walking speed / GMFM D and E dimensions
	Control	8(2/6)	6/2/0	6.8 ± 2.36	N/A	
Al-Abdulwahab (2009)[22]	NMES	21(N/A)	21/0/0	7.4 ± 2.04	N/A	Walking speed
	Control	10(N/A)	10/0/0	8.3 ± 2.10	N/A	
Zhang (2009)[27]	NMES	21(13/8)	21/0/0	3.31 ± 0.68	N/A	GMFM D and E dimensions
	Control	18(12/6)	18/0/0	3.29 ± 0.88	N/A	
Gao (2010)[28]	NMES	12(7/5)	12/0/0	3.9 ± 0.65	6/6/0	GMFM D and E dimensions
	Control	12(9/3)	12/0/0	4.0 ± 0.7	7/5/0	
Li (2013)[29]	NMES	14(5/9)	14/0/0	4.4 ± 1.02	6/5/3	GMFM D and E dimensions
	Control	11(8/3)	11/0/0	4.6 ± 0.94	7/2/2	
El-Shamy (2016)[23]	NMES	17(11/6)	0/17/0	10.6 ± 0.79	8/9/0	Walking speed
	Control	17(10/7)	0/17/0	10.4 ± 0.78	10/7/0	
Duymuz (2018)[30]	NMES	20(14/6)	0/20/0	8.2 ± 2.86	N/A	GMFM D and E dimensions
	Control	20(14/6)	0/20/0	8.4 ± 2.40	N/A	

Abbreviations: NMES: neuromuscular electrical stimulation, M/F: male/female, GMFM: gross motor function measure, GMFCS: Gross Motor Function Classification System, N/A: not applicable.
* Nonclassifiable cerebral palsy.

Table 2. Characteristics of the intervention plans and parameters of stimulator.

Study	Intervention Plan				Parameters of Stimulator	
	Treatment	Location	Session Duration, Frequency	Protocol Duration	Frequency, Intensity, Pulse Width	Time On/Off
van der Linden (2003)[17]	NMES	Gluteus maximus	60 min, 6/w	8w	30 Hz, Muscle contraction, 100μs	5 s/15 s
Chan (2004)[24]	NMES + Treadmill	Triceps surae	15 min, 3/w	8w	30–35 Hz, Isometric contraction, N/A	N/A
Ho (2006)[18] (Crossover study)	NMES	Gastrocnemius	N/A, N/A	15 trials	32 Hz, 10-40 mA, 300 μs	N/A
Kerr (2006)[25]	NMES	Quadriceps	60 min, 5/w	16w	35 Hz, Muscle contraction, 300 μs	7 s/12 s
Xu (2007)[19]	NMES	Spastic musculotendinous & antagonist muscle in affected low limbs	20 min, 5/w	6w	1 Hz, Isometric contraction, 300 μs	N/A
van der Linden (2008)[20]	Cyclic ES + NMES	Ankle dorsiflexor/ quadriceps	Adjusted for each subject, Adjusted for each subject	8w	40 Hz, 20–70 mA, 3–350 μs	N/A
Jiang (2008)[26] (Crossover study)	NMES + Physiotherapy	Spastic musculotendinous & antagonist muscle in affected low limbs	20 min, 5/w	6w	N/A, Isometric contraction, 300 μs	N/A
Yang (2008)[21]	NMES	Quadriceps & hamstring & ankle dorsiflexors	20 min, 5/w	6w	40 Hz, Muscle contraction, 250 μs	N/A
Al-Abdulwahab (2009)[22]	NMES (3 stage management)	Gluteus medius	1_{st} 5 min, once 2_{nd} 15 min, 3/d 3_{rd} 5 min, once	once 7d once	20 Hz, Isometric contraction, 50 μs	N/A
Zhang (2009)[27]	NMES + Rehabilitation	Tibialis anterior	20 min, 5/w	6w	N/A, Isometric contraction, N/A	N/A
Gao (2010)[28]	NMES	Tibialis anterior	20 min, 6/w	12w	45–50 Hz, 25–38 mA, 200 μs	12 s/s
Li (2013)[29]	NMES	Gastrocnemius	30 min, 5/w	6w	1 Hz, Adjusted for each subject, N/A	N/A

(Continued)

Table 2. (Continued)

Study	Intervention Plan				Parameters of Stimulator	
	Treatment	Location	Session Duration, Frequency	Protocol Duration	Frequency, Intensity, Pulse Width	Time On/Off
El-Shamy (2016)[23]	NMES + Physical therapy	Tibialis anterior/Ankle dorsiflexors	120 min, 3/w	3m	33 Hz, Adjusted for each subject, 300 μs	N/A
Duymuz (2018)[30]	NMES + Neurodevelopmental therapy	Tibialis anterior/Ankle dorsiflexors	30 min, 3/w	12w	20 Hz, N/A, N/A	14 s/ 10 s

Abbreviations: d: day, ES: electrical stimulation, m: months, min: minutes, NMES: neuromuscular electrical stimulation, /s: per second, /w: per week, N/A: not applicable.

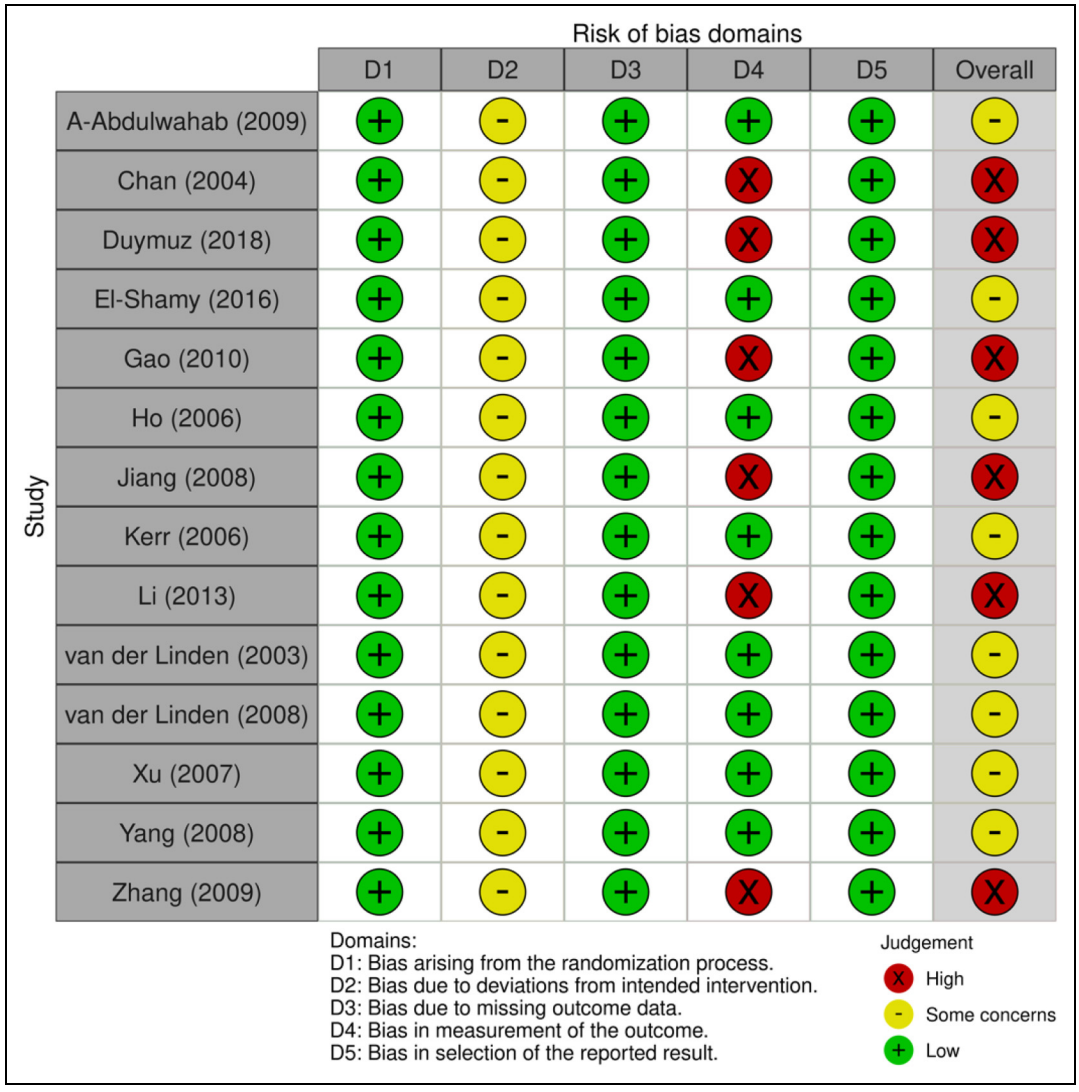

Figure 2. Chart representing the individual risk of bias assessment results according to Cochrane's Collaboration Tool (RoB2.0).

moderate quality of evidence for both the outcomes. Table 3 presents the evidence profile of it.

Discussion

The results of this study indicated that compared with control treatments, neuromuscular electrical stimulation resulted in higher improvements in mobility, particularly in standing, running, and jumping function in children with cerebral palsy. Moreover, the improvement in the Gross Motor Function Measure was clinically meaningful with a large effect size (standardized mean difference of 1.24) in the neuromuscular electrical stimulation group compared with the control group. Furthermore, the improvement in walking speed

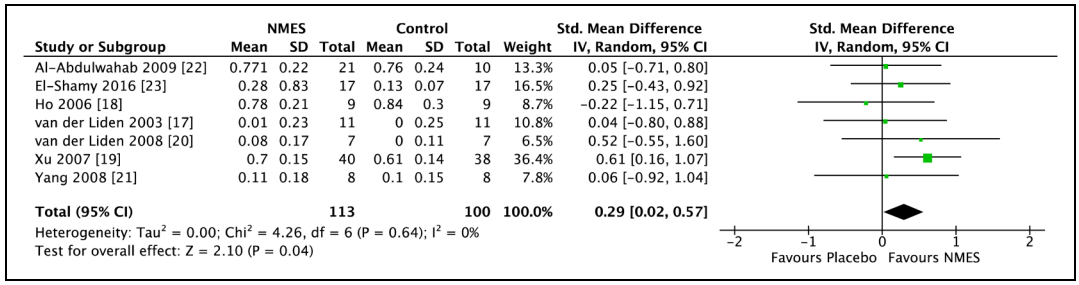

Figure 3. Effect of neuromuscular electrical stimulation on walking speed compared with conventional therapy in children with cerebral palsy. Abbreviations: NMES: Neuromuscular electrical stimulation.

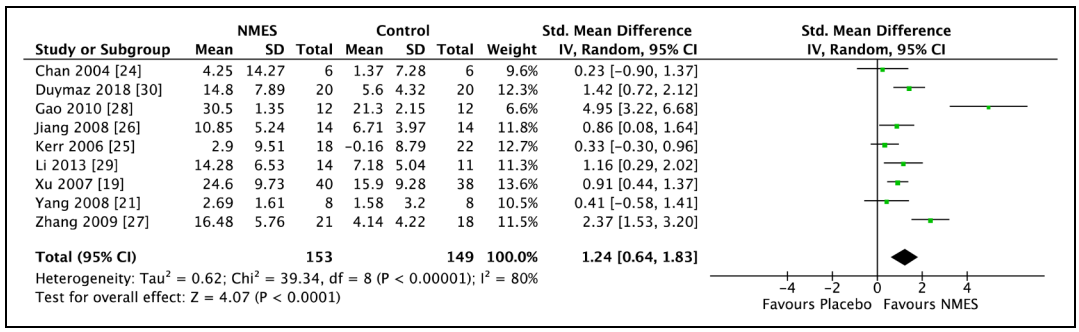

Figure 4. Effect of neuromuscular electrical stimulation on gross motor function (GMFM D and E dimensions) compared with conventional therapy in children with cerebral palsy. Abbreviations: NMES: Neuromuscular electrical stimulation.

was clinically meaningful with a small effect size in the neuromuscular electrical stimulation group compared with the control group.

Because of the high heterogeneity of improvement in the Gross Motor Function Measure, a sensitivity analysis was conducted. In the sensitivity analysis, we found that the heterogeneity of the Gross Motor Function Measure improvement was lower after the outlier was excluded.[28] Furthermore, we found that the patients in the outlier had a lower mean age (4 years old) than the patients in the other trials, and thus, we extracted the randomized controlled trials whose patients had a mean age of less than 4 years old.[19,27,28] The results showed that younger patients seemed to show greater improvement in Gross Motor Function Measure D and E scores after receiving neuromuscular electrical stimulation treatment compared with older patients. Age may be a crucial factor for the benefits of children with cerebral palsy receiving neuromuscular electrical stimulation. Younger children might benefit more from electrical stimulation treatment. There were several studies having a similar conclusion that younger children may show greater improvements than the older after receiving neuromuscular electrical stimulation.[17,18,32,33] Although we could not determine the reason for greater improvements in younger children, a previous case report[34] indicated that compared with older children, younger children respond more rapidly to neuromuscular electrical stimulation because biomechanical changes have not yet occurred in their muscles; this facilitates changes following treatment.

According to the studies by Gao et al.,[28] Duymaz et al.,[30] and Jiang et al.,[26] neuromuscular electrical stimulation treatment in children with

Table 3. Grading of recommendations, assessment, development and evaluation (GRADE) of studies with outcomes.

Question: Effects of neuromuscular electrical stimulation compared with conventional therapy on children with cerebral palsy.												
Certainty assessment							№ of patients		Effect			
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Speed	placebo	Relative (95% CI)	Absolute (95% CI)	Certainty	Importance
Walking speed												
7	randomised trials	serious[a,b]	not serious	not serious	not serious	none	113	100	—	SMD **0.29 higher** (0.02 higher to 0.57 higher)	⊕⊕⊕◯ Moderate	IMPORTANT
Gross Motor Function Measure (GMFM)												
9	randomised trials	serious[c,d]	very serious[e]	not serious	not serious	very strong association	153	149	—	SMD **1.24 higher** (0.64 higher to 1.83 higher)	⊕⊕⊕◯ Moderate	IMPORTANT

CI: confidence interval; SMD: standardized mean difference.
Explanations:
[a]In 5 out of 7 allocation concealment unclear.
[b]No participants could be blinding because of the treatment characteristic.
[c]No studies provided information on allocation concealment.
[d]No studies could blind participants and assessors because of treatment characteristics.
[e]The heterogeneity is high ($I^2 = 80\%$).

spastic cerebral palsy can decrease muscle tone, resulting in improved range of passive motion and motor function of the legs. Furthermore, a study by Chan et al.[24] mentioned that the effects of neuromuscular electrical stimulation could persist for 2 weeks after the end of treatment. Nevertheless, some studies have disagreed. In a study by Ho et al.,[18] neuromuscular electrical stimulation was only effective for increasing impulses during walking; it did not decrease muscle stiffness. The mechanism through which neuromuscular electrical stimulation treatment results in functional improvement in the legs remain controversial, and further research and long-term follow-up are necessary.

The results of the present study indicated that neuromuscular electrical stimulation considerably improves mobility in children with spastic cerebral palsy, including walking speed and gross motor function. Similar findings were observed in a previous systematic review including only six randomized controlled trials,[1] which revealed that neuromuscular electrical stimulation resulted in improved Gross Motor Function Measure D scores; however, the quality of evidence for this study was limited.[1] By contrast, we included 14 randomized controlled trials with a total of 421 patients in our meta-analysis and identified improvements not only in Gross Motor Function Measure D scores but also Gross Motor Function Measure E scores.

In terms of the safety of neuromuscular electrical stimulation treatment, no adverse effects were reported in our included studies. However, some adverse effects, such as a prickling sensation and superficial burns, have been reported. In the study by Abu-Khaber et al.,[35] 15% of the participants described a prickling sensation, but this was not clinically significant. In a study by Rodriguez et al.,[36] there was a single case of a superficial burn due to the improper configuration of neuromuscular electrical stimulation parameters. In summary, neuromuscular electrical stimulation is considered safe when performed by trained professionals and by using appropriate parameters.[37]

All the randomized controlled trials included in our study had some risk of bias, which reduced the quality of evidence of this meta-analysis. Participants were not blinded in any of the studies, and therapists were not blinded in most of the studies. Successful therapist blinding was only achieved in one randomized controlled trial.[23] However, because of the nature of neuromuscular electrical stimulation, blinding patients and therapists is difficult. Moreover, the status of assessor blinding was not provided in most of the included studies. The risk of bias in the measurement of the outcome domain was higher in the studies that examined outcomes associated with the Gross Motor Function Measure but lower in the studies examining walking speed because the Gross Motor Function Measure might be affected by the awareness of assessors.[11] Although the included randomized controlled trials had some risk of bias, we observed a moderate quality of evidence for both the outcomes by using the Grading of Recommendations, Assessment, Development and Evaluation method.

There were several limitations of this study. First, the included randomized controlled trials varied in their parameters and location of the stimulator, which increased the risk of bias in the study. Second, as the duration of the follow-up ranged from 1 to 16 weeks, the long-term effects of neuromuscular electrical stimulation could not be discerned. Lastly, the results of the quality assessment revealed that there was potential bias in the included randomized controlled trials. However, this meta-analysis also had several strengths. A comprehensive search in several major databases was performed using rigorous criteria. In addition, our review was restricted to a high standard of evidence, as only randomized controlled trials were included. Moreover, our results not only indicated favorable outcomes of neuromuscular electrical stimulation but also showed large effect sizes for these positive effects, namely in improved Gross Motor Function Measure D and E scores.

In conclusion, our meta-analysis indicates that neuromuscular electrical stimulation results in clinically meaningful improvement in mobility in children with spastic cerebral palsy, particularly in standing, running and jumping function. Neuromuscular electrical stimulation is beneficial and safe for children with spastic cerebral palsy. However, the long-term effects of neuromuscular

electrical stimulation on the mobility could not be discerned from this meta-analysis. The presence of some bias in outcome measurement reduced the current level of evidence. Additional studies with high methodological quality and long-term follow-up should be conducted.

Clinical messages

- Neuromuscular electrical stimulation results in clinically meaningful improvements in mobility in children with spastic cerebral palsy, particularly in standing, running and jumping function.
- Neuromuscular electrical stimulation of the legs is safe for children with spastic cerebral palsy.
- The evidence is insufficient to support the long-term benefits of neuromuscular electrical stimulation, and the ideal location and parameters of stimulation remain unclear.

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Supplemental material

Supplemental material for this article is available online.

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