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Transcutaneous electrical nerve stimulation in the management of calf muscle spasticity in cerebral palsy: A pilot study

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A R T I C L E I N F O

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A B S T R A C T

This study sets out to evaluate the effectiveness of transcutaneous electrical nerve stimulation (TENS) in the management of calf muscle spasticity in children with cerebral palsy. The study follows a one group pre-test–-post-test design involving fifteen children with spastic cerebral palsy, presenting with calf muscle spasticity. Spasticity was assessed before and after a 30 min application of TENS to the bilateral calf muscles. The H-reflex (electromyography) of the calf muscles and Modified Ashworth Scale (MAS) served as a measure of spasticity. A goniometer was used to measure the range of motion (ROM) angles for ankle dorsiflexion. We report here no significant difference ($p > 0.05$) between the left and right H-reflex responses, MAS scores, and ROM scores recorded at baseline (pre-test). Correlation analysis show no correlation ($p > 0.05$) between the pre-test HA Max (maximum H-reflex amplitude)/MA Max (maximum M-Wave Amplitude) ratio and MAS scores of both the left and right calf muscles. However, TENS significantly reduced ($p < 0.05$) the HA of the left calf muscle and MAS scores of the left and right calf muscles. Additionally, TENS significantly increased the ROM scores of the left and right calf muscles. Our findings lend support to existing evidence that TENS is effective in reducing spasticity. The potential mechanism underlying this effect is a reduction in neuron excitability.

1. Introduction

Cerebral palsy describes 'a group of permanent disorders that affect the development of movement and posture, causing limitation in activity. It is attributed to non-progressive disturbances in the developing foetal or infant brain' (Rosenbaum et al., 2007). There are four major classifications of cerebral palsy based on the neuromuscular presentation including spastic, dyskinetic (athetoid and dystonic), ataxic, and mixed cerebral palsy (Sankar and Mundkur, 2005). Globally, spastic cerebral palsy is the most common type, accounting for 70–80% of all cerebral palsy cases (Sankar and Mundkur, 2005; Wolting, 2018). In Africa and in Ghana, spastic cerebral palsy may account for more than 60% of all cerebral palsy cases (Adei-Atiemo et al., 2015; Abas et al., 2017).

Spasticity is an impairment that distorts motor function after a brain injury (Boyd and Ada, 2008; Alabdulwahab and Al-Gabbani, 2010). In spasticity, a velocity-dependent increase in resistance to passive movement, presenting as hypertonia and muscle tightness, is observed (Rethlefsen et al., 2010). Calf muscle spasticity affects a child's ability to stand, ambulate, and perform activities of daily living (Lin et al., 2016). Furthermore, it limits the range of motion (ROM) available at the ankle joint (Sheean, 2008). Spasticity can be assessed subjectively using the Modified Ashworth Scale (MAS), which is a spasticity grading scale, and objectively by electromyography (EMG), as an electrophysiological reference. EMG is a standard tool for the assessment of the integrity of the peripheral nervous system. This is achieved via nerve conduction studies, muscle activity recordings, and reflex responses such as the F waves, H waves, or blink reflexes elicited by a single or repetitive stimuli and recorded using a needle or surface electrode (Katirji, 2016). The H-reflex and F wave have been identified as a reliable measure of spasticity, with H-reflex being effective in assessing spasticity in children with cerebral palsy (Tekgul et al., 2013; Katirji, 2016). Tekgul et al. (2013) reported a strong correlation between MAS and the H-reflex in assessing spasticity.

The various management strategies for spasticity include stretches, strengthening, casting, nerve or muscle blocks, medications, tendon lengthening, dorsal rhizotomy, and therapeutic electrical stimulation (TENS, Neuromuscular Electrical Stimulation [NMES], and Functional

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Electrical Stimulation [FES]) (Ved and Shah, 2017). There is paucity of information on the available treatment options for spasticity in Ghana; however, in practice, it is managed pharmacologically (mostly with baclofen, a $GABA_B$ receptor activator), and/or non-pharmacologically (mostly by physiotherapy interventions). Recent studies have proven TENS to be effective in reducing spasticity in various conditions such as spastic cerebral palsy (Aydin et al., 2005; Sultan et al., 2005; Mills and Dossa, 2016). Although this stimulation is available in Ghana, it is used to manage other symptoms like pain and paresis, but not spasticity, in various physiotherapy centres. Exploring the use of TENS within the Ghanaian context may provide information on its effectiveness in spasticity management, considering its availability and ease of accessibility in various physiotherapy centres, where cerebral palsy is also managed. This study hypothesized that, TENS can cause a reduction in spasticity as measured by both objective (EMG) and subjective (MAS and ROM) parameters. Therefore, we aimed to evaluate the effectiveness of TENS in the management of spastic cerebral palsy.

2. Material and methods

2.1. Study design

A quasi-experimental one group pre-test–post-test design was used in this study. This study was conducted according to the ethical standards for the operation of the devices used, and it was approved by the ethical and protocol review committee of College of Health Sciences, University of Ghana.

2.2. Study site

This study was conducted at the neurophysiology unit of the Department of Medicine and Therapeutics, Korle-Bu Teaching Hospital.

2.3. Study participants

Fifteen children with spastic cerebral palsy attending the Korle-Bu Physiotherapy Unit who met the inclusion criteria were recruited for this study using purposive sampling. The research procedure was explained to all parents/guardians, and they all signed a written informed consent form. The children were not prevented from attending regular physiotherapy sessions prior to and after the study.

2.4. Inclusion and exclusion criteria

Inclusion criteria: Children from the ages of 1–11 years who had been diagnosed with spastic cerebral palsy.

Exclusion criteria: Children with a history of seizures, those who could not lie prone, and those who could not react to pain.

2.5. Procedure

Baseline assessment of the level of spasticity using the MAS and H-reflex responses (H-reflex amplitude [HA], H-reflex latency [HL], and H-reflex amplitude maximum/M-wave amplitude maximum [HA Max/MA Max ratios]) was performed on the bilateral calf muscles of the study participants by a licensed physiotherapist and neurologist, respectively.

MAS assessment was performed with children in the supine position on an assessment bed. The level of spasticity was assessed by passively dorsiflexing the ankle joint from a neutral position with the knee in extension. The resistance felt during the movement was graded and scored on the 6-point MAS with scores ranging from 0 to 5 (where 0 is no resistance and 5 is joint stiffness). The unexamined limb was kept stable by a non-examiner during the assessment. The investigator (licensed physiotherapist) performed the measurements twice for each lower limb, before and after the TENS.

H-reflex responses were obtained using a Cadwell Sierra II Wedge EMG system (CADWELL®, USA). Participants were positioned comfortably in the prone position over a pillow. The skin was cleaned, and a tape measure and pen were used to indicate eight equal divisions between the popliteal fossa and the medial malleolus. Two disposable surface electrodes (GS27 Pre-gelled Disposable sEMG Electrodes, Biomedical instruments, Inc., New Jersey-United States of America) were used for each stimulation. The active electrode was placed on the 6th division, and the reference electrode was placed on the last division (close to the Achilles tendon). A silver plate ground electrode was placed between the popliteal fossa and the active electrode (i.e., on the 3rd division). A bipolar electrode connected to a bipolar electrical stimulator of the EMG unit was placed in the popliteal fossa to stimulate the tibial nerve. The EMG system was set to deliver rectangular pulses with a width of 1 ms at a stimulation frequency of 0.1 Hz. The stimulation started at a low intensity of 9.5 mA and was increased in 0.5 mA increments until an intensity of 19.0 mA was attained (this corresponded to 20 stimulations). The sweep speed and sensitivity were set at 10 ms/D and 5 mV/D, respectively. H-reflex and M-wave responses triggered by each of the 20 stimulations were recorded. H-reflex and M-wave responses of the left and right calf muscles were assessed pre-TENS and post-TENS.

The goniometer is commonly used to assess ROM limitation in spasticity (Soucie et al., 2011). A 360° head–12-in. arm universal goniometer (BASELINE® Plastic Goniometers, New York) was used to assess ROM by measuring the passive dorsiflexion angle at the ankle joints. The children were positioned comfortably in the supine position on the assessment bed with both lower limbs maintained in extension by a non-examiner. The centre of the goniometer was placed over the lateral malleolus of the fibula, with the stationary arm parallel to the lateral side of the fibula and the movement arm parallel to the lateral side of the 5th metatarsal. The ankle was moved passively to obtain maximum dorsiflexion. The movement arm was then aligned parallel to the lateral side of the 5th metatarsal bone. The angle observed on the goniometer was recorded for the left and right ankles. ROM measurements were performed twice for each measurement at baseline (pre--TENS) and post intervention (post-TENS) by the investigator for intrarater reliability.

After the baseline assessments, TENS 3000 Analog Unit (ROSCOE MEDICAL, Strongsville-Ohio) was used to deliver an asymmetrical biphasic square pulse via a non-invasive portable two-channel electrode connected to disposable self-adhesive electrode pads (FITOP TENS pads, EUROBYTECH, Macon-France). Prior to electrode placement, the skin was cleaned with an alcohol-based cleaning towel. The electrodes were placed three fingers apart (the negative electrode was placed proximally, and the positive electrode was placed distally) over the belly of the calf muscle. Stimulations were delivered to each calf muscle at a low intensity setting of 2, which served as a suprathreshold stimulation capable of inducing mild tingling sensations (intensity ranged from 0 to 5, where 0 is the least intensity, and 5 is the maximum intensity). This was performed with children comfortably positioned in prone on the assessment bed.

All children received 30 min of conventional TENS (continuous stimulation with all parameters constant) with a frequency of 100 Hz and a pulse width of 200 μs. Subsequently, the calf muscles were reassessed for spasticity using the H-reflex and MAS, and the angle of ankle dorsiflexion was assessed using the universal goniometer. The children were allowed at least a 10-minute rest upon arrival at the neurophysiology unit before the procedures begun.

2.6. Statistical analysis

Statistical analyses were computed using version 23 of the SPSS software (BM, Armonk, NY, USA). Both descriptive and inferential statistics were used to summarise and present the data.

For the descriptive statistics, mean ± standard deviation was used to present age distribution and heights of the children. The most preferred position at home, the gender, and children's routine medications were recorded and presented as frequencies.

For the inferential statistics, non-parametric tests were used to analyse the data because the data was not normally distributed. Mann–Whitney *U* test was used to analyse median differences between left and right EMG, MAS, and ROM scores. A correlation analysis was performed to assess the correlation between MAS and HA Max/MA Max ratios. Wilcoxon signed rank test was used to analyse median differences between pre-TENS and post-TENS EMG measures, MAS scores, and ROM angles. The confidence and significance levels were set at 95% and $p < 0.05$, respectively. Unless otherwise stated, the data are presented as median (IQR).

3. Results

Participants (10 males and 5 females) were aged from 1 to 10 years (mean age: 5.10 ± 2.93 years) with heights ranging from 67.0 to 112.5 cm (mean height: 91.47 ± 14.60 cm). The children's characteristic details are presented in Table 1.

3.1. Baseline characteristics of calf muscle spasticity as measured by Electromyography (EMG) and Modified Ashworth Scale (MAS)

Prior to TENS application, there was a need to assess baseline characteristics of both calf muscles using the three measures namely EMG, MAS, and ROM. The following three EMG parameters were recorded: HA (left: 0.228 mV; right: 0.181 mV; p = 0.775), HL (left: 61.8 ms; right: 58.0 ms; p = 0.744), and HA Max/MA Max ratios (left: 0.039; right: 0.043; p = 0.935). There was no significant difference in the three baseline EMG measures between the left and right calf muscles ($p > 0.05$; Table 2).

Participants' MAS scores ranged from 0 to 4, with a median value of 2 for the left and right calf muscles. Similar to the EMG measures, there was no statistically significant difference in the median MAS scores between the left and right calf muscles (p = 0.935, Fig. 1). Of the 15 participants, only one had a MAS score of 0 on both the left and right calf muscles although she had an observable lower limb spasticity, suggesting that the position in which the test was performed might have influenced the spastic presentation.

ROM was our third baseline measure performed prior to the TENS application. The results obtained showed no statistically significant difference in median dorsiflexion ROM angles between the left (10°) and right (12°) ankle joints (U = 107.5, p = 0.838).

In addition to establishing the baseline measures, we queried whether there was a relationship between HA Max/MA Max ratios and MAS. Such a correlation can be useful to clinicians in limited resource settings as it will help determine whether a MAS test can be used in place of an EMG test. There was no correlation between left pre-TENS MAS scores and HA Max/MA Max ratios (r = 0.307, n = 15, p = 0.133) and right pre-TENS MAS scores and HA Max/MA Max ratios (r = − 0.015, n = 15, p = 0.479).

Table 1
Demographic characteristics presenting data on gender, age, height, most preferred position, and medication categories description of participants.

		Number of participants *(%)*
GENDER	MALE	10 *(66.7)*
	FEMALE	5 *(33.3)*
MOST PREFERRED POSITION OF CHILDREN AT HOME	SUPINE	5 *(33.3)*
	SUPINE BUT CAN ROLL	3 *(20.0)*
	SIDE LYING AND PRONE	1 *(6.7)*
	SIDE-LYING ALONE	1 *(6.7)*
	ACTIVE	5 *(33.3)*
MEDICATION CATEGORIES	NO MEDICATION	6 *(40.4)*
	SPASTICITY MEDICATION	5 *(33.3)*
	SPASTICITY MEDICATION PLUS ANY OTHER MEDICATION	3 *(20.0)*
	OTHER MEDICATIONS	1 *(6.7)*
AGE (YEARS)	MEAN AGE ± SD	5.10 ± 2.93
	RANGE	1–10
	MEAN AGE (MALES)	5.90 ± 2.88
	MEAN AGE (FEMALES)	3.5 ± 2.55
HEIGHT (cm)	MEAN HEIGHT ± SD	91.47 ± 14.60
	RANGE	67.0– 112.5
	MEAN HEIGHT (MALE)	94.55 ± 13.67
	MEAN HEIGHT (FEMALES)	85.30 ± 15.95

Table 2
Differences in baseline EMG characteristics between the left and right calf muscles.

EMG measures	Left (IQR)	Right (IQR)	U value	*p-value*
HA (mv)	0.228 (0.182–0.318)	0.181 (0.138–0.461)	106	0.775
HA Max/MA Max	0.039 (0.032–0.068)	0.043 (0.030–0.052)	110	0.935
HL (ms)	61.800 (58.200–72.200)	58.000 (55.800–78.000)	104	0.744

EMG scores are presented in medians. Statistical significance: $p < 0.05$.
EMG, electromyography; *HA,* H-reflex amplitude; *HA MAX/MA MAX;* H-reflex amplitude maximum/M-wave amplitude maximum; *HL,* H-reflex latency; *IQR*, interquartile range.

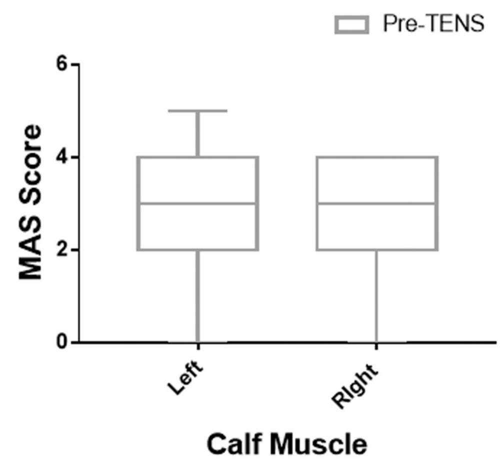

Fig. 1. MAS scores. Left and right MAS median scores of participants as recorded prior to TENS application. There was no significant difference in the MAS scores between the calf muscles (n = 15; U = 110, p = 0.935). *MAS,* Modified Ashworth Scale; *TENS,* transcutaneous electrical nerve stimulation.

3.2. Effect of TENS on EMG measures, MAS, and ROM

Having established the baseline parameters (EMG, MAS, and ROM), we applied the TENS and repeated the measures. TENS application did not have a significant effect on the HA of the right calf muscle (pre-TENS: 0.181 mV, post-TENS: 0.208 mV; Z = − 1.364; p = 0.08). However, TENS significantly decreased the median HA recorded on the left calf muscle from 0.228 mV to 0.168 mV (Z = 0.534; p = 0.011). This decrease was also expressed in the average left and right calf muscle median scores, which decreased from 0.24 mV to 0.204 mV (Z = − 2.530; p = 0.005, Fig. 2**A**). Individual participant values that make up this average decrease are presented in Table 3.

Despite the significant decrease in the HA of the left calf muscle, TENS did not affect the left HL (pre-TENS: 61.8 ms; post-TENS: 65 ms). The HL of the right calf muscle (pre-TENS: 58 ms; post-TENS: 58.6 ms) and the average HL of the left and right calf muscles (pre-TENS: 59.9 ms; post-TENS: 62 ms) were also unchanged (Fig. 2**B**).

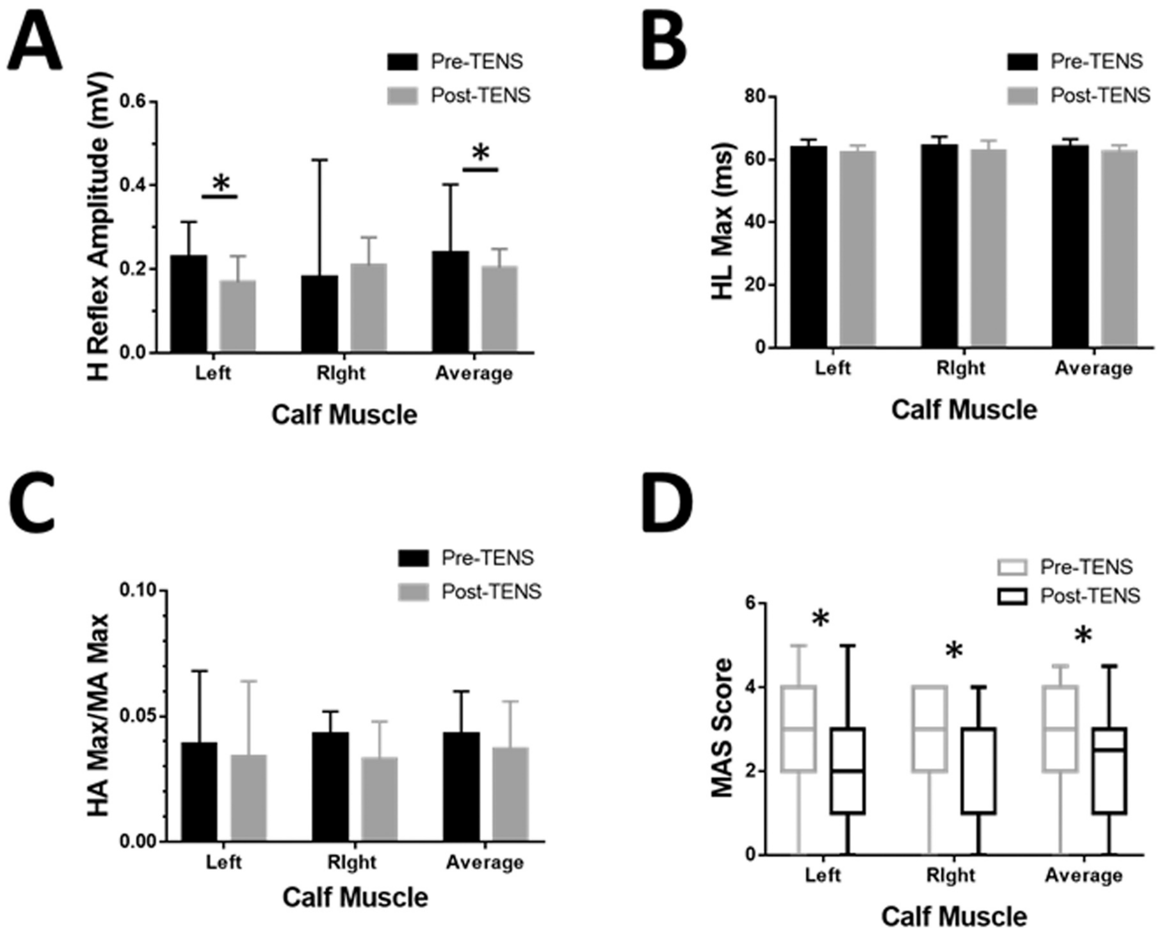

Fig. 2. Effect of TENS on EMG and MAS parameters. Differences in EMG and MAS scores before (light grey circles) and after (dark grey squares) TENS application were assessed for all participants (n = 15). **(A)** There was a significant decrease in the H-reflex amplitude of the left calf muscle (p = 0.011), which was not recorded for the right calf muscles (p = 0.08). Nonetheless, a significant decrease was observed when the H-reflex amplitude of both calf muscles was averaged per participant (p = 0.005). **(B)** TENS had no significant effect on the Maximum H-reflex latency recorded for the left calf muscle (p = 0.427), right calf muscle (p = 0.609) or the average of both calf muscles (p = 0.427). **(C)** HA Max/Ma Max ratios as calculated before (light grey circles, pre-TENS) and after (dark grey squares, post-TENS) TENS for all participants (n = 15). TENS application did not reveal a significant difference for the left calf muscle (p = 0.691), right calf muscle (p = 0.776) or the average of both calf muscles (p = 0.281). **(D)** TENS application significantly decreased MAS scores at the left calf muscle (Wilcoxon signed rank test; Z = − 2.598, p = 0.009), right calf muscle (Wilcoxon signed rank test; Z = − 2.889, p = 0.004) and average of both muscle responses (Wilcoxon signed rank test; Z = − 2.887, p = 0.004). *HL Max*, Maximum H-reflex latency; *HA Max/Ma Max*, H-reflex amplitude maximum/M-wave amplitude maximum; *MAS*, Modified Ashworth Scale; *TENS,* transcutaneous electrical nerve stimulation; *EMG,* electromyography.

We further compared the HA Max/MA Max ratios calculated pre- and post-TENS application of the left calf muscle (pre-TENS: 0.039; post-TENS: 0.034), right calf muscle (pre-TENS: 0.043; post-TENS: 0.033), and the average of both muscles (pre-TENS: 0.043; post-TENS: 0.037). There was no significant effect of TENS on the HA Max/MA Max ratios (Fig. 2**C**).

Having compared the EMG parameters, we investigated the effect of TENS on the MAS scores (Fig. 2**D**). The results indicate that TENS significantly decreased the MAS scores of the left calf muscle from 3.0 (IQR: 2.0–4.0) to 2.0 (IQR: 1.0–3.0) (p = 0.009). Although the median MAS score of the right calf muscle remained unchanged, a decrease in the range is reported due to a reduction in individual right calf muscle MAS scores and the small sample size (pre-TENS: 3.0 [IQR: 2.0–4.0]; post-TENS: 3.0 [IQR: 1.0–3.0]; p = 0.004). Overall, the average MAS scores of both calf muscles decreased from 3.0 (IQR: 1.75–4.0) to 2.5 (IQR: 1.0–3.0) after TENS application (p = 0.004).

Lastly, we compared the dorsiflexion ROM angles recorded pre- and post-TENS. TENS increased the dorsiflexion ROM angles in the left ankle (from 10° [IQR: 0–20°] to 20° [IQR: 5–26°]; p = 0.02), right ankle (from 12° [IQR: 2–22°] to 18° [IQR: 10–28°]; p = 0.003), and average ROM angles for both ankle joints (from 11° [IQR: 1.5–20.5°] to 18° [IQR: 7.5–26.5°]; p = 0.038) (Table 4).

4. Discussion

Globally, cerebral palsy affects more males than females, and although we used a small sample size, this elevated male gender susceptibility is also reflected in our study (Cleves et al., 2011). Whether male or female, children with cerebral palsy exhibit preferences for specific resting positions. In particular, inactive children exhibited a preference for the supine position. This can be attributed to the discomfort that is often reported when children are in the prone position, which encourages a flexor pattern. Interestingly, the supine position has been found to be associated with an increased extensor pattern and can easily introduce a windswept position (Barnes, 1998).

Although we did not observe a bilateral difference in the MAS scores at baseline, the high MAS score on each side is an indication of muscle spasticity in both calf muscles and a bilateral brain pathology (Kohan et al., 2010). Additionally, we did not find a correlation between MAS scores and HA Max/MA Max ratios. Unlike the objective nature of EMG, the MAS is entirely based on the examiner's clinical judgement on the resistance produced by the muscle being assessed (Bakheit et al., 2003).

Table 3
Individual H-reflex amplitudes scores of the left and right calf muscles.

	Left pre-HA score	Left post-HA score	Status of left post-HA scores	Right pre-HA score	Right post-HA score	Status of right post-HA scores
Participant 1	0.171	0.146	Reduced	0.099	0.150	Increased
Participant 2	0.063	0.099	Increased	0.143	0.054	Reduced
Participant 3	0.109	0.044	Reduced	0.117	0.117	No change
Participant 4	0.251	0.066	Reduced	0.248	0.128	Reduced
Participant 5	0.113	0.130	Increased	0.705	0.225	Reduced
Participant 6	0.323	0.168	Reduced	0.264	0.129	Reduced
Participant 7	0.129	0.147	Increased	0.091	0.221	Increased
Participant 8	0.113	0.108	Reduced	0.121	0.108	Reduced
Participant 9	0.162	0.098	Reduced	0.097	0.338	Increased
Participant 10	0.187	0.070	Reduced	0.227	0.198	Reduced
Participant 11	0.687	0.117	Reduced	0.492	0.244	Reduced
Participant 12	0.248	0.184	Reduced	0.157	0.100	Reduced
Participant 13	0.128	0.653	Increased	0.072	0.277	Increased
Participant 14	0.220	0.123	Reduced	0.127	0.093	Reduced
Participant 15	0.574	0.427	Reduced	0.385	0.337	Reduced

Table 4
Median differences in ankle dorsiflexion range of motion angles between pre-test and post-test measurements.

Test limb	Pre-test (IQR)	Post-test (IQR)	Z score	P-value
Left (°)	10° (0–20°)	20° (5–26°)	-2.314	0.02*
Right (°)	12° (2–22°)	18° (10–28°)	-2.957	0.003*
Average (°)	11° (1.5–20.5°)	18° (7.5–26.5°)	-2.078	0.038*

Statistical significance: *$p < 0.05$. IQR: interquartile range.

Therefore, it is not surprising that there is no consensus on the relationship between MAS scores and HA Max/MA Max ratios. (Kohan et al., 2010; Tekgul et al., 2013; Arumugam et al., 2016). Nonetheless, the absence of a correlation could be due to anatomical and biomechanical factors that influence obtained when most ordinal scales are used in spasticity assessment (Mutlu et al., 2008; Flamand et al., 2013). MAS scores decreased after TENS, suggesting that in our study population, TENS was capable of decreasing spasticity.

Similar to the MAS, there was no significant difference in the baseline ROM values between the left and right ankles. It is standard practise for a healthy joint to be used as reference when measuring the ROM of a pathological joint (Macedo and Magee, 2008). Since majority of the children in this study presented with spastic quadriplegic cerebral palsy, no meaningful difference in ROM between the left and right ankles was expected. However, we report here a bilateral increase in ROM after TENS application. This supports the MAS findings and lends support to our hypothesis that TENS has the beneficial effect of decreasing spasticity.

EMG measures were the only objective measures used in this study. A key indicator of muscle activity is the H-reflex, and it describes the motor neuron excitability (Lebiedowska and Fisk, 2003). At baseline, there was no significant difference in the H-reflex responses recorded between the left and right calf muscles.

After TENS, a decreased HA, which is evidence of a decrease in spasticity, was observed although this effect was restricted to the left calf muscle. It is accepted that younger age groups elicit lower H-reflex responses (Palmieri et al., 2004); however, there is conflicting evidence regarding differences in H-reflex scores between the left and right calf muscles (Tan, 1985; Jankus et al., 1994; Mezzrane and Kohn, 2002). Previous studies have reported that TENS is indeed capable of reducing the HA (Hui-Chan and Levin, 1993; Joodaki et al., 2001); however, not all studies have corroborated this potential benefit of TENS (Gürcan et al., 2015). To the best of our knowledge, our study is the only one to report an effect of TENS in one calf muscle but not in the other. Although the children had quadriplegic cerebral palsy, the baseline HA scores lean towards a potential asymmetry. This suggests that the pathology of cerebral palsy in some children may have been asymmetrical to begin with. Therefore, this result could explain the asymmetrical effect of TENS. Indeed, asymmetry in brain lesions, even in children with quadriplegic cerebral palsy, has previously been reported (Abdel-Hamid et al., 2018).

Despite the effect of TENS on HA, the HL and HA Max/MA Max ratio remained unchanged. There are reports both in support of (Hui-Chan and Levin, 1993; Gürcan et al., 2015; Garcia and Vargas, 2019) and against our findings (Joodaki et al., 2001; Ved and Shah, 2017). Therefore, it can be concluded that using EMG measures alone to assess the potential benefit of TENS in reducing spasticity cannot be conclusive. Underlying factors such as the position and psychological state of the children during data collection could influence study findings. Therefore, interpretation of the EMG results should be performed in light of other measures of spasticity such as MAS and ROM. In our study, TENS decreased the MAS and increased the ROM. Both changes are indicative of a reduction in spasticity (Seliem et al., 2007; Arati and Shraddha, 2014; Mills and Dossa, 2016). Indeed, mechanisms associated with TENS could lead to a corresponding reduction in spasticity by inhibiting muscle excitability (Mills and Dossa, 2016). The application of TENS over a spastic calf muscle will, therefore, result in relaxation of the calf muscles, which will in turn ease tension on the ankle joint and allow movement.

This study has some limitations that need to be considered. First, a large sample could not be recruited due to several factors including study site selection, unwilling participation by caregivers of the children, and project cost restraints, which reduced the number of electromyography test that could be performed per individual. Second, a single evaluator performed the MAS and ROM assessment. As these are subjective measures, they could have negatively influenced the reliability of our findings. To mitigate this, the measurements were conducted twice to reduce the risk of bias. Lastly, the study design and lack of a long-term follow-up on the effect of TENS limits the generalisability of the findings.

Further studies will focus on conducting a multi-centre study to obtain large samples as well as increase the duration and frequency of TENS application over a long-term period. This will not only increase the power and reliability of the study but also allow us to investigate the longevity of any observed benefits.

5. Conclusion

Challenges related to the management of spasticity among children with cerebral palsy require the use of evidence-based interventions. Spasticity often employs the use of pharmacological methods, non-pharmacological methods, and some physical modalities like TENS. TENS may be considered as an effective tool for managing spasticity in spastic cerebral palsy, considering its ability to reduce neuronal excitability.

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Conflicts of Interest

None. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Data used in this study is available upon request.

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