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Photo Bio-stimulation on Acupuncture Points: Impact on Selected Measures in Children with Spastic Cerebral Palsy

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ABSTRACT

This study aims to investigate the effect of adding photo bio-stimulation to standard physical therapy on spasticity, ankle active range of motion (ROM), gross motor function, plantar surface area (PSA), hind foot peak pressure, and quality of life (QoL) in children with spastic cerebral palsy (CP). Fifty-one children with spastic CP were randomly assigned to the laser therapy group (LG) and received regular physical therapy plus laser acupuncture over three acupuncture points (GB34, LR3, LIV3), and the control group received regular physical therapy three times per week for 4 weeks. Muscle tone using the modified Ashworth scale, ankle active ROM using goniometry, PSA and the peak pressure on the hind foot (PPHF) by E-Med system, motor function by Gross Motor Function Measure (88 items), and pediatric QoL questionnaire were assessed before and after intervention and after 3 months. Posttreatment values of ankle plantar flexion (AP), ankle dorsiflexion (AD), and PPHF demonstrated statistically significant differences and medium to high effect size in favor of LG ($P = 0.005$ and $d = 0.73$, $P = 0.02$ and $d = 0.57$, $P = 0.01$ and $d = 0.61$, respectively). At the 3-month follow-up analysis, the same outcomes (AD, AP, and PPHF) demonstrated statistically significant differences and medium to high effect size ($P = 0.000$ and $d = 1.46$, $P = 0.02$ and $d = 0.86$, $P = 0.01$ and $d = 0.75$, respectively) in favor of the LG. Adding laser acupuncture on GB34, LR3, and LIV3 to standard physical therapy can reduce spasticity, and improve ankle ROM, gross motor function, PSA, hind foot peak pressure, and QoL for children with spastic CP.

KEYWORDS

acupuncture, cerebral palsy, laser, spasticity, quality of life

INTRODUCTION

Cerebral palsy (CP) is a common childhood disability that occurs because of cerebral damage before, during, or after birth (Corrado et al., 2019). CP ranks third in basic living support needs and fifth among the causes of disability, which places a financial burden on individuals, families, and governments (Kwon and Kwon, 2021). Multiple physical disabilities including abnormal muscular tone, impaired coordination, and lack of balance are usually seen in patients with CP (Corrado et al., 2019).

Spasticity, which is characterized by increased muscle tone, is a common sign of CP and plays a major role in the development of various CP-related disabilities. One common manifestation of spasticity is the tightness in the ankle plantar flexors, which affects the ability of the subject to stand and walk (Hanssen et al., 2021). According to Ali et al., spasticity can interfere with children's daily activities and quality of life (QoL) such as clothing, eating, walking, and bathing. In addition, spasticity can lead to delayed development in sitting, standing, and walking (Ali et al., 2019).

Treating muscle spasticity in CP is difficult, However, various approaches such as surgery, medications (Hägglund et al., 2021), and physical therapy (Das and Ganesh, 2019) have been used to control muscle tone, reduce spasticity, and, hence, allow better development and more achievements in gross motor activities related to standing and walking. Physical therapy interventions for treating children with CP include different approaches such as exercises, positioning, splinting, and use of physical agents (Lee et al., 2019).

Low-level laser therapy (LLLT) is the application of light (with power ≤500 mW) to a biological system to accelerate tissue regeneration, decrease inflammation, and alleviate pain. Some laser devices are capable of producing light with wavelengths affecting muscular tissues at a depth of 3-5 cm. LLLT has the advantages of being painless and has minimal risk of thermal or ablative injuries so it is safe for use in the treatment of children with CP (Putri et al., 2020). Additionally, it has been approved by the Food and Drug Administration and was performed in a previous study (Farivar et al., 2014). Laser mediates its therapeutic effect *via* its influences on light-sensitive biological structures such as the mitochondria resulting in the modulation of their activities, promoting anti-inflammatory effects and enhancing the repair and normalization of skeletal muscles. It also enhances blood flow which helps in the removal of toxins and inflammatory cells, as well as the delivery of necessary nutrients required for the restoration of function (Buravlev et al., 2014; Souza et al., 2014).

According to Stamborowski et al. (2021), photo bio-stimulation, in other words, LLLT, can be effective in the treatment of multiple musculoskeletal conditions while Putri et al. (2020) suggested LLLT can be beneficial in reducing spasticity in CP children.

Few studies applied LLLT using power <0.500 mW on spastic muscles (Tsuchiya et al., 2008; Dabbous et al., 2016; Santos et al., 2016). These studies are quite heterogeneous because of the variation in the laser source, parameters, sample size, participants' age, and diagnosis. For example, Dabbous et al. (2016) applied infra-red LLLT on spastic muscles of young infants (1-4 years old) diagnosed with hemiplegia. The application was conducted on selected acupuncture points using a power of 250 mW for 3 months (Dabbous et al., 2016). Similarly, Putri et al., applied LLLT over acupuncture points to assess the impact on muscular spasticity. A 50 mW laser was applied 12 times through 1 month of intervention (Putri et al., 2020).

Another study applied a gallium–aluminum–arsenide laser with power equal to 60 mW on the obturator nerve for 10 sessions (1/week). Dabbous et al. (2016) were interested in measuring the hip adductor spasticity before and after treatment. In a third study, gallium–aluminum–arsenide LLLT with 120 mW was applied on the masseter muscle of children with spastic CP. Range of motion (ROM), muscle thickness, and QoL were assessed before and after 6 weeks of intervention during which six sessions of LLLT were applied (Santos et al., 2016).

This heterogeneity might affect the evidence of the effectiveness of LLLT in treating spasticity. Additionally, important outcomes such as QoL that might be affected by the status of spasticity have not been adequately investigated in previous literature.

The current study aims to investigate the effect of adding photo bio-stimulation (LLLT) to standard physical therapy on spasticity, ROM, gross motor function (GMF), plantar surface area (PSA), peak pressure on the hind foot (PPHF), and QoL in CP children with spastic calf muscle.

MATERIAL AND METHODS

Design

Double-blinded randomized controlled trial was used.

Participants

This study was conducted at the College of Applied Medical Sciences at a local university, and a private center for daily care of CP children in Saudi Arabia. This study was conducted between September 2023 and January 2024. All procedures were per the Declaration of Helsinki and the reporting guidelines for randomized controlled trials were adopted. All participants and/or their parents consented to participation after a full explanation of their rights and the purpose of the study. The protocol of the current study was prospectively registered at clinicaltrials.gov (NCT05912959).

Subjects were included according to the following criteria: (i) age between 8 and 14 years, (ii) diagnosed with spastic CP by a pediatrician, (iii) have 1-4 spasticity score on calf muscle according to modified Ashworth scale (MAS), (iv) ability to stand alone or with assistance, and (v) acceptance and approval of parents *via* the consent form for participation. The exclusion criteria were as follows: (i) children with an anatomical disorder or deformity in the lower limb; (ii) children who received a botulinum toxin injection in the calf muscle during the last 6 months; (iii) surgery in the lower extremity during the previous year; (iv) severe uncontrolled neurological diseases such as epilepsy, mental retardation, and loss of hearing or vision; and (v) poor nutritional status.

Interventions

Standard intervention

All children received the usual physical therapy care according to their level of lesion, abilities, and disability. This care included multiple activities such as strengthening, stretching, facilitation or inhibitory techniques, splinting, developmental techniques, gait, balance, and advice to parents. The duration of each session was 1 h and was repeated three times per week for 4 weeks.

Experimental interventions

A laser device (Vectra Genisys, Intellect Legend XT, Chattanooga, TN, USA) was used to apply LLLT for the children in the laser therapy group (LG) only. The laser was administered using a probe technique over the selected acupuncture points that could affect muscle tone (Dabbous et al., 2016). These points were GB34, LR3, and LIV 3 (Dabbous et al., 2016; Sahar et al., 2021). Procedures for determining the site of each point are explained in Table 1. The following laser parameters were used: power output: 300 mV, wavelength: 820 nm, contact area: 0.495 cm, power density: 0.606 mW/cm^2, treatment time per point: 13 seconds, and number of points: three (Dabbous et al., 2016). Three sessions per week of laser in addition to usual physical therapy were conducted for 4 weeks.

Outcomes

Initial, posttreatment, and follow-up assessments were conducted by an experienced pediatric physical therapist. At the

Table 1: The location of each acupuncture point used for laser therapy.

Number	Name	Site
Point 1	GB34	On the lateral aspect of the leg, anterior and inferior to the head of the fibula in the great depression
Point 2	LR3	On the dorsum of the foot, in the depression distal to the junction of the first and second metatarsal bones
Point 3	LIV3	On the dorsal aspect of the foot, 2 Tsun proximal to the web margin between the first and second metatarsals

initial visit, an interview with parents will be conducted to describe the purpose of the study and answer any questions. Further assessments will be conducted after obtaining their consent to participate.

Modified Ashworth scale (MAS) for muscle tone

For clinical assessment of spasticity, the MAS will be used to assess the level of calf muscle spasticity. The assessor will apply passive ankle dorsiflexion (AD) on the affected side and determine the appropriate grade of spasticity (Emara et al., 2022).

MAS grades have been described as 0 if there is no increase in muscle tone, 1 with minimal increase in tone (catch and release or minimal resistance at the end of the range, 1þ which is described as a minimal increase in tone manifested by a catch followed by low resistance throughout less than half of the range), 2 indicates a marked increase in muscle tone through most of the range, but the affected part can move easily, 3 means a considerable increase in the muscle where passive movement will be difficult, and 4 if the affected part is rigid in flexion or extension. The minimal clinically important difference will be considered if at least 1-grade change occurs in MAS compared to the baseline (Wang et al., 2016).

Active range of motion active (ROM)

Active ROM of the AD and plantar flexion joint on the affected side was assessed using a traditional goniometer using standard goniometry principles. Goniometry has been used previously for assessing ROM (Abu El Kasem et al., 2020). Its validity and reliability were documented (Venturini et al., 2006).

Plantar Surface area (PSA)

A foot scan plantar pressure detection system was used to determine the plantar support area and plantar pressure (E-Med). This device was used for the same purpose in a previous study (Lin et al., 2018). This device consists of a force plate (FAS system 1.0 ACP Light, Buratto Advanced Technology, Treviso, Italy), with an active surface (47.5 × 43.0 cm^2) equipped with 2544 optical sensors distributed along the perimetrical border.

The child was asked to assume a standing position (mild assistance was allowed if needed), with arms hanging down, looking at a fixed point, for a period of 14 s. Quantitative analysis of pedo barometric evaluation included the entire PSA (expressed in cm^2), and the peak pressure values at the forefoot and hind foot (expressed in kPa).

Gross motor function

Gross Motor Function Measure (88 items) is a tool used to assess changes in GMF in CP patients. It is considered one of the best evaluative tools of motor function designed for quantifying change in the gross motor abilities of children with CP.

The pediatric quality of life

Cerebral palsy QoL (CP-QoL) covers the age ranges of 4-12 (i.e. CP-QoL-Child) and 13-18 (i.e. CP-QoL-Teen). Both CP-QoL-Child and CP-QoL-Teen were reported to be validated tools with strong psychometric properties and clinical utility. The translated Arabic version of the CP-QoL questionnaire (caregiver form) is valid and reliable (Elweshahi et al., 2017).

The parent proxy form (parents of children aged 4-12 years) comprises 66 items and the child self-report form (9-12 years) comprises 52 items. Both the child's and the parent proxy's forms have demonstrated good psychometric properties including internal consistency, test–retest reliability, and construct validity. The higher the score, the better the QoL is represented (Davis et al., 2013).

Sample size

The sample size was calculated using the MAS as the outcome of interest, using G*Power software (3.1.9.7; Heinrich-Heine-Universität Dusseldorf, Dusseldorf, Germany). Calculations based on effect size = 0.341, significant level = 0.05, and power = 80%. Furthermore, the estimated desired total sample size for the study was 42 children (21 per group), the minimum acceptable number to be included in the study. A total of 58 were recruited to compensate for potential dropouts.

Randomization and concealment

Following the baseline assessment, children were randomly assigned to LG, where they received LLLT plus regular physical therapy, and the control group (CG) who received regular physical therapy. Before the data collection phase, randomization was conducted using a computer-generated table with randomized numbers. A unique identification code number was assigned for each child. These code numbers were randomized into two groups. Each child or parent was asked to pick an envelope randomly, and consequently, assigned accordingly to the appropriate group. The code number interpretations were with the senior author who was involved neither in assessment nor treatment procedures.

Other researchers were not aware of the randomization sequence.

Blinding

The senior author of this study performed the random allocation sequence and allocated the included children to the two groups. A single-blinded assessor with 20 years of experience in pediatric physical therapy collected all the data. Pediatric physical therapy specialists having 5 years of experience were responsible for conducting the interventions. The study statistician was also blind to the allocation; this blinding was conducted by giving the data of both groups specific codes after removing the names of the groups.

Statistical design

Statistical Package for the Social Sciences (SPSS) (version 23 for Windows) was used to analyze data. Mean ± standard deviation were used to express outcomes. An unpaired *t*-test was used to compare the basic characteristics of both groups. All outcome measures were not normally distributed; so, the Friedman test was used to assess significant differences between groups, and post hoc analyses using the Wilcoxon signed ranked test were performed to determine the source of difference after adequate adjustments of the *P* value. Cohen's *d* online calculator was used to determine the effect size for the between-group values. The significance level was granted at $P \leq 0.05$.

RESULTS

In the current study, 58 children were screened, and 54 (21 girls and 33 boys) joined the study. Of them, 39 were diagnosed by their pediatrician to have diplegia and 15 had hemiplegia. During the intervention stage, two children from the LG and one child from the CG withdrew from the study due to personal reasons leaving 25 children in the LG and 26 in the CG (Fig. 1). Age, weight, and height were comparable between both groups as shown in Table 2. The authors did not report any adverse effects during the study period.

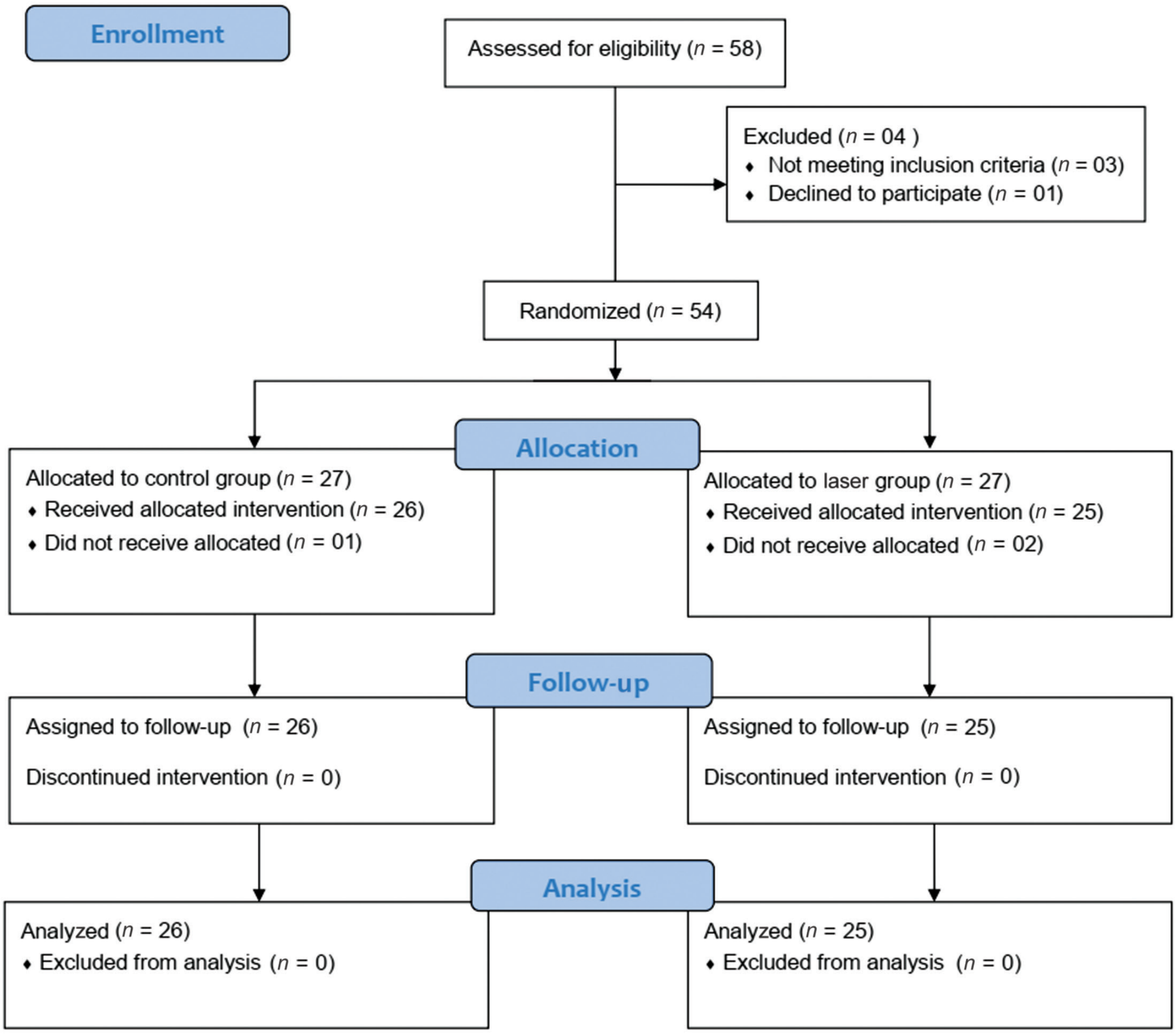

Figure 1: The flow diagram for recruitment procedures of participants.

Table 2: Basic characteristics of the participants.

Variable	LG (25 children)		CG (26 children)		*t*	*P*
	Mean	SD	Mean	SD		
Age	10.12	2.02	10.07	2.36	−0.07	0.74
Height	128.04	6.74	128.92	7.17	−0.12	0.65
Weight	30.99	5.17	31.19	6.03	−0.45	0.90

Abbreviations: LG, laser therapy group; CG, control group; SD, standard deviation; *t*, *t* value; *P*, significant level.

Between-group comparisons

The comparison between the LG and CG revealed that baseline values for all outcomes were similar (Table 3). Posttreatment values of AD, ankle plantar flexion (AP), and PPHF demonstrated statistically significant differences and medium to high effect size in favor of the LG ($P = 0.005$ and $d = 0.73$, $P = 0.02$ and $d = 0.57$, $P = 0.01$ and $d = 0.61$, respectively). At the 3-month follow-up analysis, the same outcome measures (AD, AP, and PPHF) demonstrated statistically significant differences and medium to high effect size ($P = 0.000$ and $d = 1.46$, $P = 0.02$ and $d = 0.86$, $P = 0.01$ and $d = 0.75$, respectively) in favor of the LG (Table 3).

Within-group comparisons in the LG

There were statistically significant differences in AD, AP, MAS, and PSA across the three points of measurement (before treatment, posttreatment, and at 3 months follow-up) where $P < 0.05$ in all analyses. Wilcoxon signed-rank tests were used for post hoc analysis with a Bonferroni correction applied, resulting in a significance level set at $P < 0.017$. According to the new P value, AD, AP, MAS, PSA, gross motor function standing category (GMF-D) and PPHF values were statistically significantly better posttreatment compared with baseline where P values = 0.000, 0.000, 0.000, 0.002, 0.006, and 0.000, respectively). The follow-up values of AD, AP, MAS, GMF-D, gross motor function walking category (GMF-E), PPHF, and QoL were statistically significantly better than those of the baseline ($P < 0.001$). Meanwhile, compared to the posttreatment, the follow-up values of AD, AP, GMF-D, GMF-E, PSA, PPHF, and QoL

Table 3: Within- and between-group comparisons at baseline, posttreatment, and follow-up.

Variable	Time	LG (*n* = 25) M ± SD	CG (*n* = 26) M ± SD	*U*	*P*
AD	Baseline	8.30 ± 4.91	8.76 ± 10.05	280.00	0.38
	Post	16.73 ± 6.35*	10.57 ± 10.03	178.00	**0.005**
	Follow-up	22.95 ± 5.72*¥	12.46 ± 8.35	105.00	**0.000**
AP	Baseline	44.04 ± 11.45	43.26 ± 12.99	292.50	0.53
	Post	55.78 ± 11.07*	49.07 ± 12.08*	209.00	**0.02**
	Follow-up	62.21 ± 11.43*¥	52.73 ± 10.59*	208.50	**0.02**
MAS	Baseline	2.43 ± 0.57	2.11 ± 0.64	240.00	0.07
	Post	1.39 ± 0.64*	1.57 ± 0.74*	283.50	0.38
	Follow-up	1.52 ± 0.65*	1.50 ± 0.79*	322.50	0.95
GMF-D	Pre	63.13 ± 11.80	64.11 ± 8.54	302.00	0.66
	Post	69.86 ± 11.10*	71.42 ± 8.80*	297.00	0.59
	Follow-up	76.60 ± 9.76*¥	71.88 ± 9.81*	248.00	0.14
GMF-E	Pre	64.86 ± 13.13	63.11 ± 10.59	318.50	0.90
	Post	67.91 ± 13.72*	64.57 ± 10.50	291.00	0.52
	Follow-up	79.08 ± 11.53*¥	74.15 ± 8.54*¥	242.50	0.11
PSA	Baseline	30.42 ± 10.37*	31.79 ± 14.83	325.00	0.94
	Post	38.70 ± 11.60*	37.19 ± 13.07	315.50	0.85
	Follow-up	52.45 ± 17.14¥	44.53 ± 13.27*¥	254.50	0.18
PPHF	Baseline	53.51 ± 13.01	53.27 ± 41.46	258.50	0.21
	Post	78.33 ± 20.78*	61.22 ± 33.04*	175.50	**0.01**
	Follow-up	92.24 ± 29.78*¥	70.48 ± 27.88*¥	189.00	**0.01**
QoL	Pre	69.86 ± 13.54	67.34 ± 7.67	286.00	0.46
	Post	70.17 ± 12.61	68.65 ± 9.08	311.00	0.79
	Follow-up	73.73 ± 12.51*¥	71.19 ± 9.86*¥	269.00	0.29

Abbreviations: AD, ankle dorsiflexion; AP, ankle plantar flexion; CG, control group; LG, laser therapy group; M, mean; MAS, modified Ashworth scale; GMF-D, gross motor function standing category; GMF-E, gross motor function walking category; PSA, plantar surface area; PPHF, peak pressure on the hind foot; QoL, quality of life; SD, standard deviation; *U*, Mann–Whitney value.
*Significant difference compared to baseline at $P \leq 0.017$.
¥Significant difference compared to posttreatment at $P \leq 0.017$.
The bold value means significant *P* values

Table 4: Clinical signs of improvement observed after applying laser.

Outcomes	Signs of clinical improvement
MAS	Calf muscle tone reduced by 1-2 categories
ROM	Improved AP more than dorsiflexion
GMF-D	Ease of standing, reduced need for assistance, increased standing time
GMF-E	Improved walking distance, improved balance, lower number of falling
PSA and peak pressure	Increased PSA, and increased weight acceptance in the mid and hind feet
QoL	Limited improvement was reported after the end of the study

Abbreviations: AP, ankle plantar flexion; MAS, modified Ashworth scale; GMF-D, gross motor function standing category; GMF-E, gross motor function walking category; PSA, plantar surface area; QoL, quality of life; ROM, range of motion.

were statistically significantly better where the *P* values were 0.000, 0.001, 0.000, 0.000, 0.000, 0.002, and 0.000, respectively.

Within-group comparisons in the CG

There were statistically significant differences in all outcome measures across the three-point measurement where *P* values were < 0.05. After post hoc analysis and Bonferroni correction, AP, MAS, GMF-D, and PPHF values were statistically significantly better posttreatment compared with those collected at baseline *P* = 0.008, 0.000, 0.000, and 0.007, respectively. AP, MAS, GMF-D, GMF-E, PSA, PPHF, and QoL values demonstrated significantly better results at follow-up when compared to baseline readings (*P* values = 0.001, 0.001, 0.001, 0.000, 0.000, 0.000, and 0.001, respectively). Meanwhile, GMF-E, PSA, PPHF, and QoL values were statistically significantly better when compared to the posttreatment readings where *P* values were 0.000, 0.002, 0.001, and 0.002, respectively (Table 3).

DISCUSSION

This study aimed to investigate the effect of adding LLLT to regular physical therapy on muscular spasticity, ankle active ROM, gross motor function, plantar surface area (PSA), PPHF, and QoL in CP children with spastic calf muscle. The current findings can be summarized as follows: the majority of the outcome measures were better after treatment and at follow-up when compared to baseline; some of the outcomes demonstrated more improvement at follow-up when compared to posttreatment values; and the ankle ROM and peak pressure on the hind foot were better in the LG compared to CG posttreatment and at follow-up. A list of the clinical signs of improvement is listed in Table 4.

Previous studies that were concerned with the effect of laser on patients with CP are quite heterogeneous in favor of laser parameters, site of applications, and outcome measures (Asagai et al., 2004; Tsuchiya et al., 2008; Putri et al., 2020; Abdelhalim et al., 2023). Quite a few studies are comparable to the current one where similarities in patient age group and outcome measures were evident. On the other hand, outcomes such as PSA, PPHF, and QoL were not addressed in these studies, so the comparison was not applicable.

Muscle tone

The current findings were consistent with those reported in a previous study conducted by Putri et al. (2020). In the study by Putri et al. (2020), 60 CP patients aged between 2 and 10 years received either laser acupuncture on five acupuncture points or received placebo laser acupuncture. After 12 sessions, the upper and lower extremity muscular tone was assessed. Posttreatment, using MAS it was found that the group who received laser acupuncture was better. The findings of the current study and those reported by Putri et al. (2020) were further supported by the report of Asagai et al. (2004); they reported improvement in muscle tone and reduction in spasm after application of infra-red laser to acupuncture points, points of local injections, or where the muscle spasm is evident. According to Asagai et al. (2004), laser is a safe, reliable, and effective method of treatment for increased muscle tone associated with spasticity (Asagai et al., 2004).

Range of motion

In a study conducted by Tsuchiya et al. (2008), LLLT was applied to many severely handicapped patients who were diagnosed with CP. The focus of the laser application was on the obturator and tibial nerves. The immediate effect (following each session) and the posttreatment effect were recorded where the improvement in ROM, ranged from excellent to fair improvement in the majority of the participants (14 out of 20 patients).

Despite the limited knowledge about the influence of laser on muscle tone and neural function (Asagai et al., 2004), the observed effects in the current study could be attributed to different reasons; some authors argued that through stimulation of specific acupuncture points, alteration in the activities of the brain sensorimotor cortex occurred (Putri et al., 2020). Additionally, light therapy through the application of laser photobiomodulation over acupuncture points may affect the autonomic nervous system by inhibiting sympathetic nerve fibers and stimulating parasympathetic activity (Zhou et al., 2005). Moreover, previous research found that laser could affect motor neuron activity (Mukherjee and Chakravarty, 2010) in a way that reduces muscular tone and consequently the burden of spasticity on the patient. The laser was associated with increased levels of gamma-aminobutyric acid neurotransmitter, an inhibitory neurotransmitter, and consequently, reduction in muscle tone and spasticity occurs (Chan et al., 2004). According to previous research, low-level laser radiation may lead to local improvement in blood supply secondary to the activation of the parasympathetic nervous system, and consequently, reduce tonic spasm in muscles that are in a hypoxemic state (Dabbous et al., 2016).

The improvement in muscle tone is the cornerstone for the improvements seen in other outcome measures; for example, the reduced tone in calf muscle enables the child to assume more normal standing. Hence, the PSA will increase which reflects the improvement in the peak pressure exerted on the hind foot.

The current study highlights the beneficial effects that can be gained by adding the laser to the standard physical therapy treatment in children with spastic CP. Such modality could improve the outcomes when incorporated into physical therapy aiming to reduce spasticity in the calf muscle and consequently improve ankle ROM and weight distribution on the sole of the affected foot, which in turn can lead to improvement in standing and walking abilities and enhance the QoL.

The authors of the current study were interested in lower limb function; hence, no measures were taken related to the upper limb functions. The current results could not be generalized to spastic CP patients of older ages such as adults.

CONCLUSIONS

Adding laser acupuncture on GB34, LR3, and LIV3 to standard physical therapy care can reduce spasticity and improve ankle ROM, gross motor function, PSA, hind foot peak pressure, and QoL for children with spastic CP.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest in association with the present study.

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