COMPARATIVE EFFECTS OF KINESIOTAPING AND FUNCTIONAL ELECTRICAL STIMULATION ON MOTOR FUNCTION AND PSYCHOSOCIAL WELL-BEING IN CHILDREN WITH DIPLEGIC CEREBRAL PALSY

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Abstract

Background: Children with diplegic cerebral palsy (CP) frequently have equinus deformity, a gait abnormality that frequently results in decreased mobility and functional impairments. Non-invasive methods for enhancing ankle dorsiflexion and gait patterns include Kinesiotaping (KT) and functional electrical stimulation (FES).

Objective: The purpose of this study was to examine how well KT and FES worked to improve gait metrics, balance and lessen equinus deformity in kids with diplegic cerebral palsy.

Methods: forty children with spastic diplegic CP (ages 4–7) were randomly assigned into two groups. Group A received KT to the gastrocnemius-soleus, and Group B received FES to the tibialis anterior muscle. Both groups received a design physical therapy programme. Interventions were administered 3 times per week for 12 weeks. Outcome measures included the Gross Motor Function Measure (GMFM-66), Pediatric Balance Scale (PBS), walking speed, and step length, all of which were assessed both pre- and post-treatment.

Results: Both groups showed statistically significant improvements in all outcome measures ($p < 0.05$). However, the FES group demonstrated significantly greater gains in GMFM scores, PBS scores, walking speed, and step length compared to the KT group ($p < 0.01$).

Conclusion: While both KT and FES are effective in managing equinus deformity and improving functional outcomes in children with diplegic CP, FES provides superior benefits in enhancing gait performance, but KT provides greater improvement in the pediatric balance scale.

Keywords: Cerebral palsy, equinus deformity, Kinesiotaping, functional electrical stimulation

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Introduction

Non-progressive disturbances in the developing fetus or infant brain generate a group of long-term movement and postural abnormalities known as "cerebral palsy" (CP), which limit an individual's activities. (1)

Diplopia is a form of cerebral palsy characterized by motor impairments that primarily impact the legs instead of the arms. Increased muscle tone and stiffness in the lower limbs are common symptoms of these disorders. mostly impacts the lower limbs, frequently resulting in anomalies of gait such equinus deformity. In the more general category of spastic cerebral palsy (CP), muscle rigidity mainly affects both sides of the body (2).

Equinus gait is the most prevalent walking abnormality and deformity linked to children with spastic cerebral palsy (SCP) (30). First contact with the forefoot due to insufficient ankle dorsiflexion results in a disproportionate amount of weight being sustained under the metatarsal heads (4).

Increased lateral inclination of the upper body is associated with the equinus deformity, which can cause pelvic retraction [6]. Ankle equinus that is severe increases the loading on the toes and forefoot. As soon as feasible, the equinus gait needs to be corrected to promote plant grade walking and prevent the equinus deformity from worsening. Weak ankle plantar flexors, ankle dorsiflexors (including the anterior tibial muscle), or a combination of these might result in dropping a foot or true equines (7).

Children with spastic diplegic CP had greater ankle (more distal part) spasticity than knee spasticity. Ankle spasticity is linked to restricted ankle joint mobility (8). While there are various definitions of equines, we can simply say that it is the lack of ankle joint dorsiflexion necessary for normal gait, which results in illness, lower extremity compensation, or both (9).

Functional electrical stimulation (FES) is defined as "the electrical stimulation of muscles to create a contraction to produce a functionally beneficial movement in the presence of poor motor control." The effectiveness of FES in inducing muscular contraction, improving range of motion (ROM), and strengthening muscles has been shown in numerous studies. FES is the process of electrically stimulating muscles with inadequate motor control to generate a contraction and a useful movement (10).

For instance, FES can be used to directly provide an "orthotic" effect during gait by engaging the quadriceps to extend the knee during stance or the ankle dorsiflexion muscles to raise the foot during swing. Long-term "therapeutic" advantages of FES could include improved motor control and a reduced risk of muscle atrophy because of more efficient neural connections (11,12).

In recent years, Kinesio taping (KT) has gained popularity in pediatric rehabilitation. Kinesiology taping is a useful adjunct to physiotherapy treatment for children with cerebral palsy who perform better, according to recent systematic studies with moderate evidence (13).

Whereas FES uses electrical currents to promote muscle contractions during functional tasks, KT applies elastic therapeutic tape to the skin to either promote or inhibit muscle activity (14).

Numerous fields, including sports injuries, rheumatology, traumatology, neurology, and urogynecology, have found success with the tape.[15] Many interventions have evaluated the effectiveness of Kinesio tapes in comparison to either traditional rehabilitation or any other interventions because the tape mediates sensory feedback and has the ability to regulate muscle tone, both of which are necessary for maintaining posture and balance, which ultimately affect the patients' gait pattern (16,17).

This study aims to compare the efficacy of KT and FES in managing equinus deformity in children with spastic diplegic CP.

Materials and Methods

Study Design and Participants

An RCT design was used in this investigation, and it was filed on ClinicalTrials.gov with registration number NCT06953284. Males and females with spastic diplegic cerebral palsy (4–10 years old) were selected from Kafr El-Sheikh University's Pediatric Physical Therapy Clinic. Two equal groups of 20 participants each were randomly assigned to the groups.

Participants had to be categorized as level I or II of the Gross Motor Function Classification System (GMFCS) and have a lower limb spasticity grade of 1 or 1+ according to the Modified Ashworth Scale (MAS) to be eligible. This was done to ensure that the children could stand and walk independently.

For both treatment and evaluation methods, participants also needed to be able to follow verbal instructions with adequate cognitive and communication skills. Children who (1) had recently had lower limb orthopaedic surgery; (2) had severe visual, auditory, or perceptual impairments; (3) had received lower limb injections of botulinum toxin within the last six months; or (4) had a history of epileptic seizures were not included in the study. This was done because some of these conditions can make it difficult for the child to move their lower limbs, while others can affect their communication and cognitive abilities.

Using Cochran's method, the sample size was determined with a 95% confidence level ($Z = 1.96$), estimated proportion ($p = 0.35$), and margin of error ($e = 0.148$). It was found that 40 participants were the minimal sample size needed, with 20 kids assigned to each group.

Study Design and Randomization

A randomized controlled trial (RCT) was used to carry out this investigation from April to June of 2025. Microsoft Excel was used to perform the randomization. One column lists the names of the patients, while the second column uses the RAND function to create random numbers. The research and control groups were randomly assigned to the participants based on the ascending order of these random numbers.

Outcome Measures

Pediatric Balance Scale (PBS)

The PBS, which is a modified version of the Berg balancing Scale, comprises of 14 functional balancing tests with a total score of 56. Each activity is scored from 0 to 4. It has been shown to have great face and content validity in children with spastic cerebral palsy [18], as well as strong inter-rater and test-retest reliability [19]. It is especially made for kids with mild to moderate motor limitations.

Kinovea Motion Analysis Software

Kinovea is a 2D open-source software used to assess joint angles and motion during gait (Kinovea version 0.9.5; https://www.kinovea.org/). Gait parameters, including step length (SL) and walking speed (WS). Kinovea has been validated for use in gait and movement analysis, showing strong intra- and inter-rater reliability [20].

To get a good lateral view of the subject's lower limbs, position a camera about 2.5 meters away and perpendicular to the walking route. Three coloured markers were placed on the greater trochanter, lateral femoral condyle, and lateral malleolus. Bring the video up: In Kinovea, open the recorded video.

Draw Calibration Line: Over the video's known-length object, draw using the line tool. To set the real-world length, right-click the line, choose "Calibrate Measure," and then enter the measure (for example, 0.16 m). This establishes the scale for all measures that follow.

- **Measuring Step Length (SL)**

Find frames in the video where the same foot touches the ground in consecutive steps to identify heel strikes. Measure Distance: Draw a line between the two heel striking positions using the line tool. The step length is indicated by the length of this line. Repeat Measurements: Measure several steps and determine the average step length for accuracy.

- **Calculating Walking Speed (WS)**

Identify the beginning and ending frames of the walking sequence to determine the walking duration, which is the amount of time needed to walk a known distance.

Compute the speed: Use the following formula to use

Walking Speed (WS)= Distance /Time

Gross Motor Function Measure (GMFM

It was assessed using the GMFM-88 with an emphasis on the standing dimension (Dimension D). Children had up to three tries on each item, which is rated on a four-point ordinal scale. No additional tries were necessary if the task was completed satisfactorily on the first try. On the basis of the cumulative score for that dimension, the overall score is given as a percentage [21].

Treatment Procedures

Every intervention took place over 12 weeks at King Abdulaziz Specialist Hospital in Taif Governorate. Three certified physical therapists took part in carrying out the intervention program. Standardized training was given to participants before to the study to guarantee uniformity in the way treatments were administered. Each therapist oversaw a subset of the subjects and, with the primary investigator's guidance, used the identical intervention techniques.

Participants in group A (KT)

The skin should be free of hair, skin blemishes, and any moisturizing lotions or oils that have been applied beforehand. Local asepsis was carried out using magnesium hydroxide to prevent skin irritation. In order to prevent any skin irritations, magnesium hydroxide was applied before the study location was applied to the study location because the youngsters involved in the study typically had weak skin. KT was administered bilaterally to the gastrocnemius and soleus muscles using the Y-strip inhibition method. For 12 weeks, a tension of 15–25% was applied when applying the tape, and it was changed every three to five days. (22) A structured physiotherapy program included the following elements: Exercises for equines correction include passive stretching, strengthening exercises for children with cerebral palsy, weight-bearing to reduce lower limb contracture through the use of tilting tables and standing frames through a prolonged stretch of the calf muscles21, and stretching exercises to increase the power of weak dorsiflexors and the corresponding spastic agonists. Ankle joint mobilization, particularly dorsiflexion, was also provided to all children three times a week. (23).

Participants in group B (FES)

The balanced, biphasic, current-regulated electrical pulses used for stimulation have amplitudes ranging from 8 to 50 mA (with an average of 15 to 30 mA); they also have widths of 250 s and frequencies of 40 Hz 24. It has been demonstrated that these factors provide a muscle response with the least degree of discomfort for the patients. It was expected that FES would cause a discernible muscular contraction that was painless. The patient's sensitivity was taken into consideration when choosing the intensity that was used during the sessions. Throughout therapy, the highest intensity range was between 28 and 44 mm. The child was wearing only heels that were in direct touch with the floor, sitting in a comfortable chair with his or her knees bent 90 degrees. ximal portion of the tibialis anterior, which is located 5 cm below the fibula's head. Another set of electrodes promoted plantar flexion by stimulating the lateral gastrocnemius valley (24). In addition to the identical physiotherapy regimen as the KT group.

Statistical Analysis

Descriptive statistics were calculated for all variables, and independent (unpaired) t-tests were used to compare baseline characteristics (gender, age, height, and weight) between the two groups. Inferential statistics were used to determine the within-group and between-group differences. Paired t-tests were used for intra-group comparisons, and independent t-tests were conducted to compare outcomes between groups. The statistical significance threshold was set at $p \leq 0.05$, and effect sizes were calculated using Cohen's d to evaluate the practical significance of the observed differences

Results

3.1. General Features The flow diagram for CONSORT is displayed in Figure 1. In the beginning, 50 kids were evaluated for eligibility. With two participants declining to participate and six not meeting the inclusion requirements, eight participants were eliminated, leaving 42 youngsters engaged in the study. The participants were divided into two groups (n = 21 each) at random. Group A had KT in addition to a structured program of physical therapy, whereas Group B had FES in addition to the same physical therapy programme. Of the 40 participants who finished the trial by the conclusion of the intervention period, two were lost to follow-up (Figure 1).

Descriptive statistics for age, height, and weight revealed no statistically significant differences between group A and group B at the baseline (Table 1). Some participants had a history of perinatal complications, including premature birth, anoxia (oxygen deprivation), and low birth weight. Others experienced caesarean delivery, labour involving suction procedures that resulted in cerebral cortex damage, prolonged stays in neonatal intensive care units following asphyxia, or severe neonatal jaundice (Table 1).

We can use the parametric mixed ANOVA test to compare the FES and KT in the targeted outcomes (PBS, SL, and WS), as shown in both (Table 2 & Table 3).

The mixed ANOVA results can also be explained. Pairwise comparisons between each two corresponding measurements, before mixing the design for the PBS, SL, and WS variables.

There is a statistically significant difference between the pre-measurement of

Table 1. General Characteristics of FES and KT Groups.

Items	FES group mean ± SD	KT group mean ± SD	t-value	p-value	Significance
Age (years)	7.37 ±1.35	7.33 ±1.17	0.100	0.92	NS
Height (cm)	123.97 ±12.38	123.01 ±11.22	0.257	0.799	NS
Weight (kg)	26.09 ±5.46	25.60 ±5.01	0.296	0.769	NS
BMI (KG/M²)	16.77 ±0.37	16.73 ±0.40	0.329	0.744	NS

SD: Standard deviation, p-value: probability value, t-value: t-test value ,NS: Not significant.

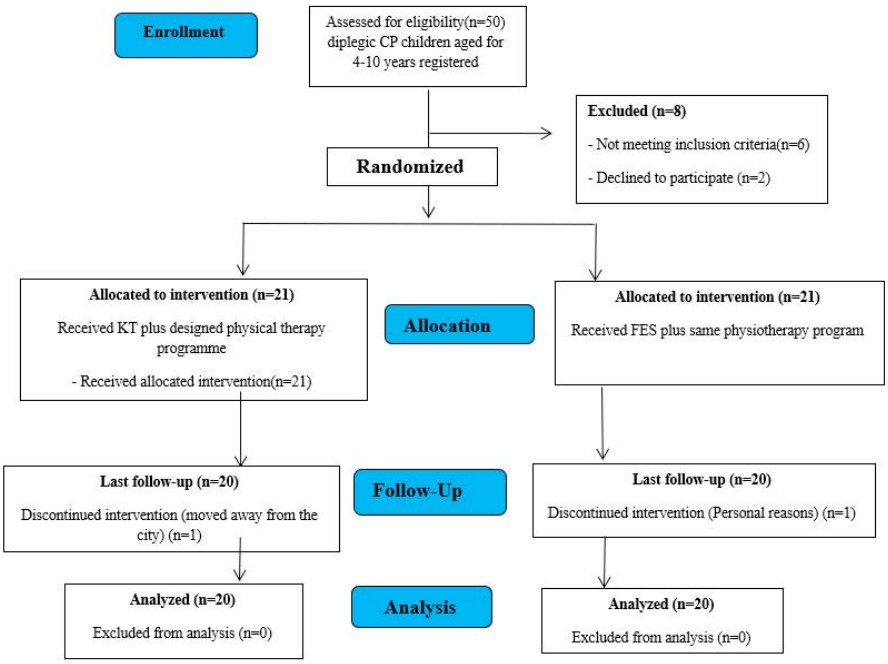

Figure 1. Consort flow chart for patients in the study.

Table 2. Pairwise comparisons between each two corresponding measurements, before mixing the design for the PBS, SL, and WS variables.

Variables		Group		Mean Difference	P=value Group × Time interaction
		Group A KT	Group B FES		
		Mean ± SD	Mean ± SD		
PBS	Pre-test	35.20±6.986	36.15±7.982	0.95	0.691
	Post-test	36.15±8.286	36.80±10.749	0.65	0.832
	Mean Difference	0.95	0.65		
	P=value	0.388	0.639		
SL	Pre-test	48.00±7.539	48.85±8.074	0.85	0.733
	Post-test	49.65±8.580	50.75±9.824	1.1	0.708
	Mean Difference	1.65	1.9		
	P=value	0.083	0.074		
WS	Pre-test	70.20±11.119	71.35±11.672	1.15	0.751
	Post-test	71.95±11.532	73.25±13.494	1.3	0.745
	Mean Difference	1.75	1.9		
	P=value	0.137	0.129		

Table 3. Comparison between FES and KT groups in PBS, SL, and WS, using mixed ANO.

Source	Measure	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
time	PBS	12.800	1	12.800	.849	.363	.022
	SL	63.013	1	63.013	6.917	.012	.154
	WS	66.612	1	66.612	4.927	.032	.115
time * Group	PBS	.450	1	.450	.030	.864	.001
	SL	.313	1	.313	.034	.854	.001
	WS	.113	1	.113	.008	.928	.000
Error(time)	PBS	572.750	38	15.072			
	SL	346.175	38	9.110			
	WS	513.775	38	13.520			

the GMFCS variable and the post-measurement $p<0.05$. By referring to Table 6, we find that this difference is in favour of the pre-measurement, because the mean of the pre-measurement = 1.9, but the mean of the post-measurement = 1.73.

As for the group effect, we find that it is not significant, $p>0.05$, which means that there are no differences between the FES and KT groups in the GMFCS variable. The same is true for the interaction effect between time and group, which is also not significant, $p>0.05$, which means that there are no differences among the pre-measurement of the FES group, the post-measurement of the FES group, the pre-measurement of the KT group, and the post-measurement of the KT group, in the GMFCS variable, because $p>0.05$ (Table 4), (Figure 2):

Discussion

This study was conducted to examine the comparative effects of Kinesio Taping (KT) and Functional Electrical Stimulation (FES) on equinus deformity in children diagnosed with diplegic cerebral palsy (CP). The findings demonstrate

Table. 4. Pairwise comparisons between each of the two corresponding measures, before mixing the design for the GMFCS variable.

Variables		Group		Mean Difference	P=value Group × Time interaction
		Group A KT	Group B FES		
		Mean ± SD	Mean ± SD		
GMFCS	Pre-test	1.95±759	1.85±.813	-0.1	0.69
	Post-test	1.75±.716	1.70±.801	-0.05	0.836
	Mean Difference	-0.2	-0.15		
	P=value	0.042	0.186		

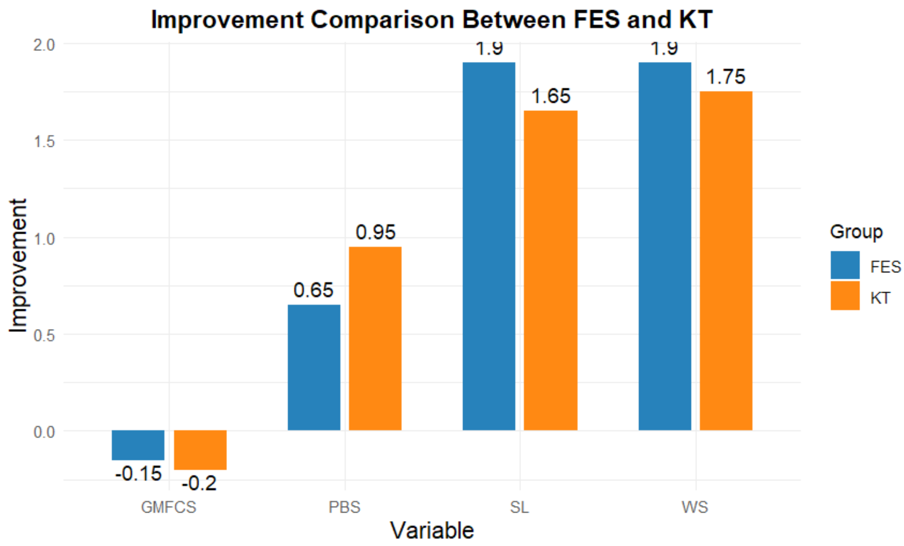

Figure 2. Comparison between FES and KT groups in PBS, SL, WS, and GMFCS.

that both interventions, when combined with a standardized physiotherapy program, contribute to significant improvements in motor performance and functional outcomes. However, the extent of improvement was greater among children who received FES.

Both KT and FES showed statistically significant improvements in gross motor function, gait metrics (step length, walking speed), and balance, according to our findings. However, the FES group demonstrated a larger improvement in the majority of the outcomes that were examined, indicating that they were more effective at correcting dynamic equinus and neuromuscular re-education. Children between the ages of 4 and 10 were chosen on the grounds that they are capable of engaging in strength-training activities, which are essential to programs aimed at improving core stability. According to Fry et al. [25], who documented the advantages of strength training for kids ages three to seven, this premise was validated.

Dietz et al.26 confirmed the significant improvement of both groups, pointing out that crouch gait development is a result of treating ankle equines with Achilles tendon lengthening exercises in an intolerable number of spastic diplegic and quadriplegic children. A comparison of the group (A.B) before and after treatment showed significant differences in all measured variables. They discovered that the gait of many mobile patients with spastic diplopia steadily declined over time.

Ozen et al.27, who documented that physiotherapy following treatment on the horse foot of diplegic CP youngsters, could corroborate the previously acquired findings. It preserves the musculoskeletal system's biomechanics and range of motion, enhances muscular endurance and strength, balances agonist and antagonist muscles, and offers proprioceptive training. were found, supporting the claim made by Moll et al.28 that FES lowers ankle joint muscle contraction by addressing defective reciprocal inhibition. FES causes the tibialis anterior muscle to contract, which inhibits the gastrocnemius muscle, allowing the foot to be properly prepositioned for the stance phase of gait. The observed improvements in the ankle joint's selective motor control may be attributed to this reciprocal inhibition in combination with the heightened awareness brought on by the stimulation.

When post-treatment mean values are compared between two groups (A and B), it is consistent with Chiu and Ada 's29 findings that FES is effective, meaning it is better than no FES intervention, but it is not more effective than activity training, meaning practicing the activity without FES will be just as effective. FES might be more effective; as the stimulation might draw attention to the muscle that requires attention, it might be beneficial for children with cognitive impairments who struggle with exercise regimens.

A meta-analysis of RCTs showed that KT has moderate-to-large effects on children with CP in terms of improving their gross motor function, balance, and muscle tension. There is limited evidence of KT's beneficial effects on upper extremity function and substantial evidence of its beneficial effects on sitting posture.

There is not enough data to determine how KT affects other motor function outcomes as range of motion, balance, gross motor function, and gait pattern.30

KT® is often advised as a physical therapy treatment method (Unger & 2018; Abdel Ghafar & 2021) (31.32). The weakening and shortening of the spastic muscle of the spastic equinus foot results in a prolonged joint retraction that ultimately causes the surrounding tissues to become hypo mobile, keeping the joint in plantar-flexion.

(Zuardi & 2010) (33). When applied to the spastic antagonist musculature, KT® can help regulate spasticity in the equinus foot by balancing the reciprocal innervation mechanism.

GMFM scores improved for both the KT and FES groups, although the FES group's growth was noticeably larger. A validated instrument for evaluating functional mobility in children with cerebral palsy, particularly in areas like standing, walking, and running, is the GMFM. Improved dorsiflexion activation may be the cause of the gains seen in the FES group. This would increase gross motor performance by enhancing foot clearance during the swing phase and pushing off more effectively during stance.

These results are in line with those of Pool et al. (2015), who found that FES training enhances functional mobility as well as isolated muscle activation in kids with spastic cerebral palsy. The KT group also shown a moderate improvement in GMFM, which may have been brought about by greater voluntary motor control during task execution as well as increased proprioceptive feedback and decreased spasticity.

Both groups showed considerable improvements in balance, as measured by the Pediatric Balance Scale, but the KT group's improvement was more pronounced. The PBS is a valid instrument for measuring functional balance in children, and an improvement in it denotes improved dynamic stability and postural control.

By increasing ankle dorsiflexion during the stance and swing phases, FES probably helped people balance better by creating a more secure base of support. Additionally, improved sensory integration and anticipatory posture modifications can result from rhythmic muscle contractions brought on by FES. Even though KT isn't as dynamic as FES, it might have helped the central nervous system receive proprioceptive information, which enhanced joint awareness and allowed for minor postural adjustments that helped with balance.

Both groups showed considerable improvements in walking speed. A key factor in determining functional independence and community ambulation is walking speed. Participants in FES may have increased gait velocity due to improved foot clearance, more symmetrical gait patterns, and decreased toe drag, which enables quicker and more effective movement. By enhancing alignment and decreasing involuntary plantarflexion, KT, on the other hand, may increase walking speed; nevertheless, its passive nature restricts its effectiveness in comparison to the active facilitation offered by FES. According to earlier research, FES applied to the dorsiflexors increases walking cadence and speed in children with cerebral palsy (CP), as demonstrated by van der Linden et al. (2003).

Following the intervention, step length increased considerably in both groups, with FES once again exhibiting higher efficacy. Step length increases correspond to improvements in lower limb coordination and stride mechanics. FES lengthens the stride and enhances gait symmetry by activating the tibialis anterior during the swing phase, which permits regulated dorsiflexion and heel strike.

By improving joint alignment and reducing plantarflexion tone through mechanical correction and sensory stimulation, KT may also enable longer steps. KT's passive function in dynamic muscle re-education, however, may account for its comparatively smaller impact when contrasted with FES. These results corroborate those of Damiano and DeJong (2009), who emphasized how neuromuscular therapies like FES might enhance kinematic gait characteristics including cadence and step length (36).

Conclusion

For children with diplegic cerebral palsy, equinus deformity can be improved with both Kinesiotaping and functional electrical stimulation. FES, on the other hand, shows better results in improving gait metrics, especially walking speed and active dorsiflexion.

While KT continues to be a useful, affordable adjunct for managing spasticity and posture, FES may be more successful in clinical practice in producing functional gait improvements.

Limitation

The fact that the study only examined one form of cerebral palsy and that the participants' ages ranged from four to eight are among its shortcomings. The sample that was selected contained only level 1 or level 2 GMFCS. Thus, additional research is needed on age groups, neurological abnormalities, and other types of cerebral palsy.

Ethics approval

The study was approved by the Faculty of PT, Kafr Elsheikh University Ethical Committee (KFSIRB200-496). Consent to participate. Informed consent was obtained from the parents or legal guardians of all participants included in the study.\

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