Accepted Article

J Musculoskelet Neuronal Interact 2024

Journal of Musculoskeletal and Neuronal Interactions JMNI

Original Article

Effect of Universal Exercise Unit Versus Functional Electrical Stimulation on Genu Recurvatum in Diplegic Cerebral Palsy Children

Mahmoud R. Elsharkawy[1], Abd Elaziz A. Sherif[2], Engi E. Sarhan[3], Osama A. El-Agamy[4], Sara Y. Elsebahy[5]

[1]Department of Physical Therapy for Pediatrics, Alsalam University, Egypt;
[2]Faculty of Physical Therapy, Rashid University, Egypt;
[3]Department of Physiotherapy for Neurology and its Surgery, Faculty of Physical Therapy, Kafrelsheikh University, Egypt;
[4]Department of Pediatrics, Faculty of Medicine, Kafr El-Sheikh University, Egypt;
[5]Department of Physical Therapy for Pediatrics, Kafr El-Sheikh University, Egypt

Abstract

Objective: This study evaluated the effects of the Universal Exercise Unit (UEU) versus Functional Electrical Stimulation (FES) on genu recurvatum in children with diplegic cerebral palsy (CP). **Method:** Thirty children (8 males, 22 females) aged 4-8 years with diplegic CP and genu recurvatum were randomly assigned to two groups (n=15 each). Study group I received UEU therapy and an exercise program for three weeks for 12 weeks. Study group II received FES applied to the hamstring and tibialis anterior muscles during walking, with the same exercise program and frequency. Genu recurvatum and muscle strength were assessed pre- and post-treatment using a digital goniometer and Lafayette muscle tester. **Results**: Both groups improved significantly in all variables post-treatment, with Study Group I (UEU) showing greater improvements in reducing genu recurvatum and increasing muscle strength ($p<0.05$). **Conclusion**: UEU and FES were effective in treating genu recurvatum in children with diplegic CP, but UEU provided superior results. ClinicalTrials.gov ID: NCT06332729

Keywords: Diplegic Cerebral Palsy, Functional Electrical Stimulation, Genu Recurvatum, Universal Exercise Unit

Introduction

The most prevalent impairment in childhood is cerebral palsy (CP), a permanent neurological condition that presents obstacles throughout life, including spastic paralysis, chronic pain, walking difficulties, intellectual disabilities, and behavioral issues, with no known cure[1]. CP can be caused by a variety of reasons, such as stroke, newborn hypoxia, and infection of the central nervous system[2]. Early diagnosis of cerebral palsy involves taking a detailed medical history and conducting neuroimaging and standardized assessments that reveal characteristic abnormal findings. Clinicians must prioritize timely referrals to early interventions tailored to the diagnosis, as this enhances infant motor and cognitive development, prevents secondary complications, and supports caregiver well-being[3].

CP is associated with a lot of comorbidities, including eating disorders, musculoskeletal problems, epilepsy, intellectual disability, abnormalities in vision and hearing, and communication difficulties[4]. There are various classifications of CP, mostly based on motor type and topography. One such classification is diplegic CP, in which patients have toe walking due to a foot dorsiflexion issue and an expansion in the lower leg's tone. In certain instances, the lower extremity is more severely impacted than the upper extremity. In severe cases, the elbows, knees, and hips flex. The child's lower extremities are typically articulated when held upward, and tight adductor muscles in the lower legs are the cause of scissoring of the lower limbs[5]. Managing knee hyperextension in children with

The authors have no conflict of interest.

Corresponding author: Mahmoud R. Elsharkawy, Demonstrator of Physical Therapy, Department of Physical Therapy for Pediatrics, Alsalam University, Gharbia, Egypt
E-mail: Mahmoud.elsharakawy1994@gmail.com

Edited by: G. Lyritis
Accepted 31 October 2024

diplegic CP can be difficult. In cases of genu recurvatum (GR), the knee tends to hyperextend during the stance phase, often due to contracture or stiffness in the calf muscles. We predict less knee hyperextension from surgically treating the calf contracture[6]. GR is characterized by an abnormality in the tibiofibular joint, where the range of motion (ROM) extends beyond zero degrees of extension. Another reason for generalized retraction GR is weakness in the hamstring muscles, which regulate knee flexion during the stance phase. This is particularly true when there is stiffness in the extensor muscles of the knee[7]. The components of a universal exercise unit (UEU) are elastic cords, belts for support, suspensions, and pulley systems. The foundation of UEU is the idea of moving the body's weaker parts and emptying the body against gravity. The therapist can freely offer the patient the necessary assistance during their workout regimen if needed[8]. UEU offers therapy sessions that last between three and four hours, and it can be utilized by both adults and children with neurological disorders. Metal spider cages can be seen in either the pediatric or adult population. Elastic resistance of the cords is utilized to improve muscle strength[9]. A strength training program demonstrates beneficial effects on functional outcomes such as muscle strength, balance, gait speed, and gross motor function in children and adolescents with cerebral palsy classified as levels I, II, and III on the Gross Motor Function Classification System. Importantly, these improvements occur without an increase in spasticity, contingent upon the application of adequate dosage and adherence to specific training principles[10]. FES involves applying electrical impulses to muscles with impaired motor control to induce contractions and generate functionally beneficial movements[11]. This study aims to evaluate the effects of UEU versus FES on GR in children with diplegic CP.

Methods

Participants

Thirty male and female diplegic CP children and between the ages of four and eight took part in the study. They were selected from the pediatric physical therapy clinic of Kafr Elshiekh University. Their lower limb spasticity was rated as 1 or 1+ on the Modified Ashworth Scale. Participants exhibited functional genu recurvatum, were classified at levels I and II on the Gross Motor Function Classification Scale (GMFCS), and could follow orders for assessment and treatment. Exclusion criteria were recent lower limb surgery, severe limb abnormalities, significant visual or perceptual impairments, or received botulinum toxin injections in spastic lower extremity muscles in the past 6 months.

Design and Randomization

The study was a randomized controlled trial conducted from February 2024 to June 2024, forty-two diplegic CP children were initially assessed for participation and ten did not meet the criteria for participation so they weren't included. The thirty-two children that remained were equally put into two groups at random.: Study Group I and Study Group II. Both groups underwent a tailored Physical therapy program, with Study Group I receiving Universal Exercise Unit (UEU) therapy to strengthen the hamstring and tibialis anterior muscles, while Study Group II received Functional Electrical Stimulation. Randomization was carried out using an Excel sheet, where patients' names were listed in one column, and random numbers were generated in a second column using the RAND formula. Each patient was then assigned to either Study Group I or II in a third column. Patients were ultimately sorted into their respective groups based on the ascending order of the random numbers.

Sample size

The estimated sample size before the study, using G-power statistical software (version 3.1.9.4) for a t-test study with an α level of 0.05, a confidence level of 80%, and an effect size of 1.1, indicated that 15 subjects per group were required with a ratio of N2/N1 = 1. Based on previous studies in a similar population[12], we added 2 participants to account for potential dropout (6.25%)

Procedures

A - Method of evaluation

In this study, the strength of the hamstring and tibialis anterior muscles and the range of motion of knee hyperextension were evaluated both before and after treatment, utilizing a Lafayette manual muscle tester and baseline digital goniometer (DG), respectively.

1. Assessment of knee hyperextension: The digital goniometer (model: 12-1027, White Plains, New York, USA) is an instrument designed for measuring joint angles and range of motion. It is both affordable and easy to operate, making it suitable for single or repeated measurements. This device has proven to be highly accurate in evaluating a patient's range of motion, particularly in children with CP[13].

Each child was lying supine, with their knees and hips in a neutral alignment. The lateral epicondyle of the femur served as the goniometer's pivot point, according to the therapist. The goniometer's movable arm was oriented toward the lateral malleolus, parallel to the long axis of the fibula, and its stationary arm was positioned concerning the greater trochanter, following the long axis of the femur. Two adhesive straps were utilized to secure each arm of the gadget to guarantee stability. The examiner next steadied the child's thigh and directed them to move their foot upwards, recording the degree of motion on the DG screen[14].

2. Assessment of muscular strength: The new ergonomic Lafayette manual muscle tester (MMT) (model: 01163, Parkway North, USA) has precision and accuracy and produces more precise, dependable, and no-biased results[15]. The high inter- and intra-instrument repeatability, manual or automatic data storage choices, and minimum measurement drift are all features of this handheld strength assessment

Table 1. General characteristic of both study group I & study group II.

Items	Study group I mean ± SD	Study group II mean ± SD	t-value	p-value	Significance
Age (years)	7 ± 1.2	6.47 ± 1.55	1.054	0.3	NS
Height (cm)	104.86 ± 12.89	103.13 ± 16.21	0.324	0.75	NS
Weight (kg)	26.33 ± 5.36	25.77 ± 4.76	0.299	0.77	NS
Sex (M: F)	(3: 12)	(5: 10)	-	0.41	NS
Degree of spasticity (1, 1+)	(6: 9)	(9: 6)	-	0.27	NS

SD: Standard deviation, p-value: probability value, t-value: t-test value,NS: Not significant. Also Using chi square test there is no significant statistical differences were found between both groups in the pre-evaluation of sex, and degree of spasticity as shown in tables from 2 – 3.

Table 2. Pre-evaluation results for sex in study group I & study group II.

	Sex		Total	p
	Male	Female		
Group				
Study group I	3	12	15	0.41
Study group II	5	10	15	
Total	8	22	30	

Table 3. Pre-evaluation results for degree of spasticity in study group I &study group II.

Group	Degree of spasticity		Total	p
	1	1+		
Study group I	6	9	15	0.27
Study group II	9	6	15	
Total	15	15	30	

device. It produces steady, accurate, and trustworthy assessments of muscle strength by recording peak force as well as time.

Before the tests, each child was shown how the tests were conducted. After that, each child completed three accurate trials for each of the two tests; the analysis used the average of these trials[16].

For the hamstring muscle test: Every child was positioned on a chair with hands resting on the thighs and their hips and knees bent at a 90-degree angle. The examiner used straps to stabilize the trunk, pelvis, and non-tested limb to prevent compensatory movements. The Lafayette apparatus was held in one hand while the tested limb was stabilized above the knee with the other hand. The child was told to push their lower leg backward against the device, which was resting on the behind lower part of the leg being tested.

For the tibialis anterior muscle test: All the kids were lying down on the plinth, their knees and hips extended in a neutral rotation, and their feet lying with their heads relaxed. Using straps at the pelvis and slightly above the knees, the examiner restrained the kid. After that, the apparatus was positioned above the dorsal side of the foot under examination. The child was told to put resistance against the gadget by moving their foot in the direction of it.

B - Treatment procedures

All children included received treatment at Kafr Elsheikh University's Pediatric Physical Therapy Outpatient Clinic.

A-Study group I

Each child in Study Group I underwent a designed Physical

Therapy program and came to 3 sessions per week for 3 months without discontinuation. Each session lasted one hour, with half an hour dedicated to exercises aimed at improving gait, balance, motor function, and the remaining half hour focused on strengthening the hamstring and tibialis anterior muscles using a Universal Exercise Unit. The program used a chain exercise of both types closed and open. Exercises that enhance balance and standing include half-kneeling and kneeling, standing on step, standing on one limb, standing on a balance board, going from supine to standing, and abdominal exercise and trunk control using a wedge. These exercises should be performed 3 times a week for 3 months[17]. The duration of the session is a half hour for the tailored program and the other half for UEU. The Universal Exercise Unit (UEU) is utilized to strengthen the hamstring and tibialis anterior muscles. The one-repetition maximum(1-RM) method is used to calculate the training weight. The 1-RM is defined as the maximum weight that can be lifted through all ranges of motion (ROM). To assess the 1-RM, begin with a weight slightly below the child's maximum lifting capacity and gradually increase it with each attempt until the lifting capability reaches its maximum. The weight increments ranged from one to five kg, depending on the muscle group being evaluated. Rest periods of one to six minutes were allowed between attempts with heavier weights[18]. Children performed exercises with a mild to moderate load (approximately sixty percent of 1-RM), completing one to two sets of eight to fifteen repetitions[19].

For the hamstring muscle, each child within the spider cage lay prone on the plinth and stabilized with straps around the pelvis and unaffected limb. The other limb was secured at the level of the thigh, with the leg free. A rope connected to the leg band was attached to the top of the cage, with a weight at the end of the rope to provide resistance. Pulling their leg toward them against the weight, a child was encouraged to do one set of ten repetitions at first, then one or two sets of eight to fifteen repetitions[20].

For the tibialis anterior: the child lays supine within a cage and supported by a belt around the pelvis and unaffected limb. With the foot free to move, the other limb was supported with a belt at the thigh and leg. a band around the foot that is fastened by a rope at the side of the foot to the top of the cage. At the rope's terminus, a weight needed to be pulled. For 20 minutes, every child was told to execute one set of ten repetitions or up to two sets of eight to fifteen repetitions while drawing his foot to the side of his face.

B-Study group II

Every child in Study Group II received the designed PT program as Study Group I, plus FES. This stimulation was applied for 30 minutes to the hamstring and tibialis anterior muscles while walking on a treadmill. The parameters used were: a pulse frequency of 25-40 Hz, a pulse duration of 250 to 300 milliseconds, and an on-off time ratio of 1:2 for 20 minutes. Electrodes will be placed on the tibialis anterior muscle, positioned 5 centimeters below the fibular head, and on the peroneal muscle, located at the rear of the fibular head. These electrodes will be adjusted to induce ankle dorsiflexion while preventing inversion. Additionally, electrodes will stimulate the hamstring muscles, specifically the biceps femoris, semitendinosus, and semimembranosus, near their motor points, while avoiding any rotation[21].

Statistical Analysis

All statistical measures were performed through the Statistical Package for Social Studies (SPSS) version 27 for Windows. For the normality test of data, the Shapiro-Wilk test was performed. Descriptive statistics and unpaired t-tests were used to compare age, height, and weight between the two groups. The chi-square test was used to compare sex and degree of spasticity between the two groups. Descriptive statistics and unpaired t-tests were used to compare pretreatment and post-treatment measurements of Muscle strength for tibialis anterior (right & left), Muscle strength for hamstring (right & left), and Digital goniometer of genu recurvatum (right & left) between the two groups. A paired t-test was used to compare pre- and post-treatment measurements of Muscle strength for the tibialis anterior (right & left), Muscle strength for the hamstring (right & left), and Digital goniometer of genu recurvatum (right & left) for each group. The arithmetic means an average description of the central tendency of the results. The standard deviation is a mean of dispersion of the results. The level of significance for all statistical tests was set at p. value < 0.05.

Results

General Characteristics

As shown in Tables 1, 2, and 3 there were no significant differences between the two groups in terms of age, height, weight, and sex distribution ($p > 0.05$). Study Group I had a mean age of 7 ± 1.2 years, while Study Group II had a mean age of 6.47 ± 1.55 years. The sex distribution was 80% females and 20% males in Study Group I, and 67% females and 33% males in Study Group II.

Muscle Strength

As shown in Table 4 and as illustrated in Figure 1.

Tibialis Anterior (Right)

The pre-treatment muscle strength of the right tibialis anterior was not significantly different between Study Group I (2.82 ± 1.16) and Study Group II (2.29 ± 0.87), with a mean difference of 0.53 ($p = 0.165$). Following 12 weeks of treatment, both groups demonstrated significant improvements. In Study Group I, the muscle strength improved by 35%, while in Study Group II, the improvement was 21%. The post-treatment mean difference was 1.03, indicating a significant difference between the groups in

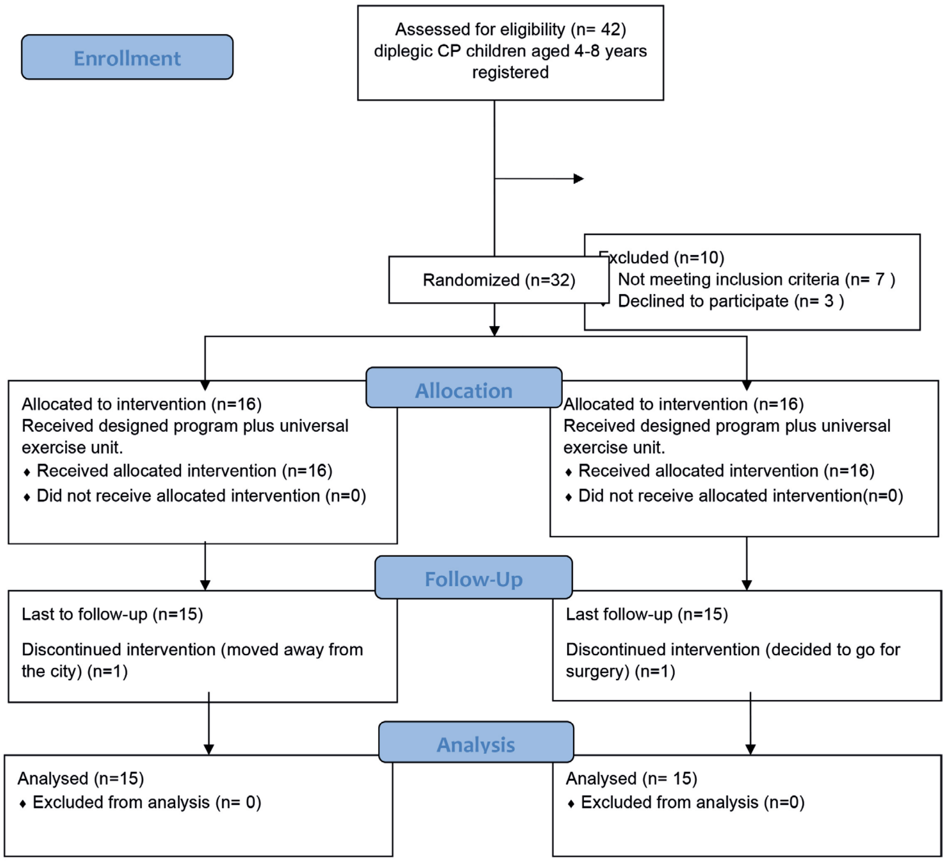

Figure 1. CONSORT Flow chart for patients in the study.

favor of Study Group I (p = 0.036).

Tibialis Anterior (Left)

Pre-treatment muscle strength for the left tibialis anterior was 3.07 ± 1.59 in Study Group I and 2.28 ± 0.82 in Study Group II, with no significant difference (p = 0.099). Post-treatment, there were significant improvements in both groups, with Study Group I showing a 32% improvement and Study Group II showing a 21% improvement ($p < 0.05$).

Hamstring (Right)

The pre-treatment muscle strength of the right hamstring was similar between the two groups, with mean values of 2.91 ± 0.35 in Study Group I and 2.84 ± 0.50 in Study Group II (p = 0.65). Both groups exhibited significant improvements after the intervention, with Study Group I showing a 32% increase and Study Group II showing a 20% increase ($p < 0.05$).

Hamstring (Left)

For the left hamstring, pre-treatment values were 2.91 ± 0.35 in Study Group I and 2.84 ± 0.50 in Study Group II, showing no significant difference (p = 0.674). Post-treatment, there was a significant improvement in both groups, with a 30% improvement in Study Group I and an 18% improvement in Study Group II (p = 0.032).

Knee Range of Motion (Genu Recurvatum)

Right Knee

The pre-treatment digital goniometer values for genu recurvatum in the right knee were 8.34 ± 1.27 in Study Group I and 8.2 ± 1.12 in Study Group II, with no significant difference (p = 0.75). After treatment, significant improvements were observed in both groups. Study Group I demonstrated a 30% improvement, while Study Group II showed a 20% improvement ($p < 0.05$).

Table 4. Mean ± SD, t, and p value of Muscle strength for tibialis anterior (right & left), Muscle strength for hamstring (right & left), and Digital goniometer of genu recurvatum (right & left) pre and post treatments for both groups (I & II).

Variables	mean ± SD		Mean difference	% of improvement	t-value	p-value
	Pre test	post test				
Muscle strength for tibialis anterior right						
Study group I (n = 15)	2.82 ± 1.16	3.8 ± 1.51	0.98	35 %	10.292	6.5 E -8
Study group II (n = 15)	2.29 ± 0.87	2.77 ± 0.99	0.48	21 %	13.392	2.3 E -9
Mean difference	0.53	1.03				
t-value	1.424	2.203				
p-value	0.165	0.036				
Muscle strength for tibialis anterior left						
Study group I	3.07 ± 1.59	4.05 ± 2.05	0.98	32 %	8.124	1.1 E -6
Study group II	2.28 ± 0.82	2.75 ± 1.02	0.47	21 %	8.931	3.7 E-7
Mean difference	0.79	1.3				
t-value	1.705	2.212				
p-value	0.099	0.035				
Muscle strength for hamstring right						
Study group I	2.91 ± 0.35	3.84 ± 0.46	0.93	32 %	32.562	1.4 E-14
Study group II	2.84 ± 0.5	3.41 ± 0.6	0.57	20 %	22.302	2.4 E-12
Mean difference	0.07	0.43				
t-value	0.459	2.233				
p-value	0.65	0.034				
Muscle strength for hamstring left						
Study group I	2.91 ± 0.35	3.78 ± 0.46	0.87	30 %	30.813	2.9 E-14
Study group II	2.84 ± 0.5	3.35 ± 0.59	0.51	18 %	23.114	1.5 E-12
Mean difference	0.07	0.43				
t-value	0.425	2.26				
p-value	0.674	0.032				
Digital goniometer of genu recurvatum right						
Study group I	8.34 ± 1.27	5.85 ± 0.89	2.49	30 %	25.889	3.2 E-13
Study group II	8.2 ± 1.12	6.57 ± 0.9	1.63	20 %	29.742	4.7 E-14
Mean difference	0.14	0.72				
t-value	0.321	2.171				
p-value	0.75	0.039				
Digital goniometer of genu recurvatum left						
Study group I	8.34 ± 1.27	5.95 ± 0.97	2.39	29 %	27.864	1.2 E-13
Study group II	8.2 ± 1.12	6.67 ± 0.9	1.53	19%	27.921	1.1 E-13
Mean difference	0.14	0.72				
t-value	0.321	2.108				
p-value	0.75	0.044				

Left Knee

Pre-treatment goniometer readings for the left knee were 8.34 ± 1.27 in Study Group I and 8.2 ± 1.12 in Study Group II, with no significant difference (p = 0.75). Post-treatment, both groups exhibited significant improvements. Study Group I improved by 29%, and Study Group II improved by 19% (p = 0.044).

Muscle Strength

Muscle strength of the right and left tibialis anterior increased by 35% and 32%, respectively, while muscle strength of the right and left hamstring increased by 32% and 30%, respectively, and the degree of digital goniometer decreased in the right and left knee by30% and 29 %, respectively. In study group II there were also significant differences between pre- and post-treatment values of all outcome measures. Muscle strength of the right and left tibialis anterior increased by 21% in both, while muscle strength of the right and left hamstring increased by 20% and 18%, respectively, and the degree of digital goniometer decreased in right and left knee by20% and 19 %, respectively.

Discussion

Our study was designed to compare the effects of the Universal Exercise Unit (UEU) and Functional Electrical Stimulation (FES) on genu recurvatum (GR) in children with diplegic cerebral palsy (CP). To the best of our knowledge, this is the first study to examine the impact of these interventions on GR in this population.

Our findings revealed a statistically significant improvement in muscle strength and knee joint alignment, as measured by a digital goniometer, following UEU and FES. However, UEU demonstrated superior outcomes compared to FES.

The participant age group (4 to 8 years) was chosen based on the assumption that children within this range can participate in strength training exercises. This is consistent with the findings of Fry et al.[22], who reported that children between the ages of 3 and 7 can engage in and benefit from strength training.

The choice of UEU plus a designed physical program in treating GR is agreed with Hoglund et al.[23] who mentioned that Treatment for GR includes a range of exercises focused on muscle control, gait training, and proprioceptive improvement. UEU therapy is a novel approach designed to strengthen weak muscles and enhance motor function without exacerbating spasticity[24]. According to Koscielny, the pulley system within the UEU enables therapists to target specific muscle groups in isolation from other parts of the body. This isolation allows the focused muscles to work independently, reducing compensatory movements and promoting the development of functional skills. Additionally, the pulley system can be used to improve endurance, increase range of motion, and enhance flexibility[25].

The superior results of UEU may be attributed to its stronger impact on the hamstring and tibialis anterior muscles, which are crucial for knee control. Strengthening these muscles promotes foot dorsiflexion, which, in turn, facilitates knee flexion, thereby reducing GR during standing and walking. These improvements are expected to enhance the gait and overall mobility of the children, potentially reducing the duration of rehabilitation required to restore proper walking function after addressing the biomechanical challenges of the lower limbs.

Damiano et al.[26] stated that Numerous factors contribute to the increase in GR angle. However, their study focused specifically on the roles of hip and knee muscle strength. The findings indicate that the strength ratios between muscles hold greater significance than the weakness of individual muscles. Additionally, previous studies have reported positive outcomes from strengthening programs, such as improved stride length, reduced crouch posture, enhanced energy efficiency during walking, and higher Gross Motor Function Measure (GMFM) scores, particularly in ambulatory children with cerebral palsy.

The effect of UEU on muscle strengthening is further supported by Elnahas et al.[27], who demonstrated that UEU can be applied to children with spastic CP to enhance balance and strengthen the lower limb muscles. This is achieved by improving neural function, optimizing muscle architecture, and increasing the muscle's cross-sectional area, ultimately leading to better standing ability and balance in these children.

Similarly, Mohamed et al.[28] found that UEU serves as an effective adjunctive treatment for children with spastic CP, improving functional abilities, locomotion, and overall muscle strength.

The observed decrease in GR following treatment with UEU indicates that this intervention effectively addresses biomechanical issues in the knee. This finding is in line with research by Ahmed et al.[29], who found that strengthening the dorsiflexion through the application of weights around the ankle joint during locomotion significantly improves knee flexion and gait performance in children with spastic CP. Our results are also aligned with those of Mannan et al.[30], who reported improvements in muscle strength and reductions in lower limb spasticity following UEU use in children with CP. Additionally, Hamouda et al.[27] and Alabdulwahab et al.[31] similarly found that UEU enhances knee alignment and muscle strength in children with diplegic CP.

Afzal et al.[32] reported that strength training with the UEU can activate the vestibular system when a child is supported by elastic cords within the unit. This setup also enhances spatial awareness, aiding in skill acquisition. Additionally, the UEU can be used to improve spatial perception, and appropriate weight loading on the joints stimulates joint receptors, helping to stabilize and control joint movement.

The improvements observed with FES in correcting GR are consistent with the findings of Jang et al.[33], who also reported positive outcomes in children with CP treated with FES because the use of it led to a reduction of excessive ankle plantar flexion during the swing phase. FES enhanced active ankle dorsiflexion angle and strength; while also improving selective motor control, balance, and gait kinematics and this came with the result of Moll et al.[34].

The mechanism of reciprocal inhibition of the agonist muscle helps explain the benefits of FES in this study. Reciprocal inhibition refers to the relaxation of muscles on one side of a joint to allow contraction on the opposite side. In this case, the reciprocal inhibition of the gastrocnemius muscles, following stimulation of the tibialis anterior muscles, enhances ankle dorsiflexion during the swing phase and reduces heel rise during the stance phase[35].

Walking with FES was linked to significant improvements in peak ankle dorsiflexion during the swing phase, dorsiflexion angle at initial contact, and peak ankle dorsiflexion during stance, compared to walking barefoot or with an ankle-foot orthosis. The increase in the dorsiflexion angle following FES suggests that FES effectively addressed excessive plantar flexion by electrically stimulating the weak tibialis anterior muscle during the swing phase to induce dorsiflexion[36].

Springer et al.[37] It was suggested that FES should target not only the peroneal nerve but also the proximal muscles, such as the quadriceps femoris or hamstrings when aiming to correct GR during the stance phase. This approach would address proximal muscle weakness, rather than focusing solely on the distal muscles.

Sakullertphasuk et al.[38] their results validate the benefits of combining FES with treadmill gait training in children with spastic diplegia. The integration of FES into treadmill training resulted in increased maximal ankle dorsiflexion during the swing phase and reduced heel rise during the stance phase. Therefore, it is recommended that clinicians utilize FES to stimulate weak or inactive muscles in children with spastic diplegia during gait training.

Finally, UEU Despite its recognized benefits in treating CP, research on UEU remains limited. This lack of evidence hinders its broader integration into therapeutic practices, despite its potential to improve motor function and muscle strength. Expanding research in this area is crucial for supporting its clinical application.

Limitations

Some limitations of the current study include that it only looked at one type of CP and that the participants ranged in age from four to eight. Only level 1 or level 2 GMFCS were included in the chosen sample. Therefore, more research on different forms of cerebral palsy, neurological impairments, and age groups is required.

Conclusion

The Universal Exercise Unit (UEU) and Functional Electrical Stimulation (FES) are effective interventions for treating genu recurvatum in children with diplegic CP. However, UEU demonstrated superior outcomes, particularly in improving muscle strength and knee alignment. These findings suggest that UEU may offer a more comprehensive solution for addressing the biomechanical challenges associated with GR, ultimately leading to better gait and mobility in children with CP. Future research should aim to further explore the long-term benefits and optimize treatment protocols for this population.

Ethics approval

The study was approved by the Faculty of PT, Kafr Elshiekh University Ethical Committee (KFSIRB200-148).

Consent to participate

Informed consent was obtained from the parents or legal guardians of all participants included in the study.

Authors' contributions

MRE was responsible for the conceptualization and methodology of the study, carried out the investigation, managed data curation, performed formal analysis, and prepared the original draft. AAS contributed to the study's conceptualization, conducted formal analysis, and played a key role in both the review and editing of the manuscript, also providing final approval. EES and OAE were involved in the review and editing phases, provided supervision, and gave the final approval of the manuscript. SYE also contributed to the study's conceptualization, was involved in writing, and engaged in review and editing, ultimately providing final approval. All authors read and approved the final version of the manuscript.

Acknowledgment

The authors thank all participants for their cooperation in the study.

References

1. Jensen A. Cerebral palsy—brain repair with stem cells. Journal of Perinatal Medicine 2023;51(6):737-51.
2. Abd Elmagid DS, Magdy H. Evaluation of risk factors for cerebral palsy. The Egyptian Journal of Neurology, Psychiatry and Neurosurgery 2021;57:1-9.
3. Novak I, Morgan C, Adde L, Blackman J, Boyd RN, Brunstrom-Hernandez J, Cioni G, Damiano D, Darrah J, Eliasson AC, De Vries LS. Early, accurate diagnosis and early intervention in cerebral palsy: advances in diagnosis and treatment. JAMA Pediatrics 2017;171(9):897-907.
4. Sadowska M, Sarecka-Hujar B, Kopyta I. Cerebral palsy: current opinions on definition, epidemiology, risk factors, classification and treatment options. Neuropsychiatric disease and treatment 2020 12:1505-18.
5. Afnan Z, Malik AN, Jahan S, Ali A. Association of muscles length and strength with balance and functional status among children with diplegic spastic cerebral palsy. JPMA. The Journal of the Pakistan Medical Association 2023;73(2):253-7
6. Bauer J, Do KP, Feng J, Aiona M. Calf lengthening may improve knee recurvatum in specific children with spastic diplegic cerebral palsy. Journal of Children's Orthopaedics 2020;14(4):353-7.
7. Sutherland DH and Davids JR. Common gait abnormalities of the knee in cerebral palsy. Clin Orthop Relat Res 1993:288:139-147.
8. Olama KA, Elnahhas AM, Rajab SH. Effect of universal exercise unit on balance in children with spastic Diplegia.
9. Mohamed AS, Kamal HM, Elsied AO, Abd El-Gafar EM. Universal exercise unit versus functional resisted training effect on muscle strength in spastic diplegia. EXECUTIVE EDITOR 2020;11(04):181.
10. Merino-Andres J, Garcia de Mateos-Lopez A, Damiano DL, Sanchez-Sierra A. Effect of muscle strength training in children and adolescents with spastic cerebral palsy: A systematic review and meta-analysis. Clinical rehabilitation 2022;36(1):4-14.

11. Moll I, Marcellis RG, Coenen ML, Fleuren SM, Willems PJ, Speth LA, Witlox MA, Meijer K, Vermeulen RJ. A randomized crossover study of functional electrical stimulation during walking in spastic cerebral palsy: the FES on participation (FESPa) trial. BMC Pediatrics 2022;22:1-5.
12. Olama KA, Elnahhas AM, Rajab SH. Effect of universal exercise unit on balance in children with spastic Diplegia. International Journal of Multidisciplinary Research and Development 2019;6(1):85-88.
13. Luedtke K, Schoettker-Königer T, Hall T, Reimer C, Grassold M, Hasselhoff-Styhler P, Neulinger C, Obrocki M, Przyhoda P, Schäfer A. Concurrent validity and reliability of measuring range of motion during the cervical flexion rotation test with a novel digital goniometer. BMC musculoskeletal disorders 2020;21:1-0.
14. Hancock GE, Hepworth T, Wembridge K. Accuracy and reliability of knee goniometry methods. J Exp Orthop 2018;5:46. doi:10.1186/s40634-.018-0161-5.
15. Mentiplay BF, Perraton L, Bower KJ and Adair B. Assessment of lower limb muscle strength and power using hand-held and fixed dynamometry 2015;10(10): e0140822.doi:10. 1371/journal. pone.0140822.
16. Soderberg GL, Knutson LM. Handheld dynamometry for muscle testing. Muscle and Sensory Testing-E-Book 2020;455.
17. Madbouly MM, Olama KA, Ayoub HS, and Hachem RH. Knee cage versus long ankle foot orthosis for genurecurvatum in children with spastic diplegia 2018. 22-23 March 2018.
18. Avery DF, Laurie AM, and Wayne LW. Maximal strength testing in Healthy Children Journal of Strength and Conditioning Research 2003;17(1):162-166.
19. David G, Avery DF, Falk B and Klentrou P. Canadian Society for Exercise Physiology position paper: resistance training in children and adolescents. Physiol Nutr Metab 2008;33:547-561
20. Elmalah HM, Elnagmy EH, Ali MS. Does Functional Electrical Stimulation Improve Power and Reduce Mild Equines in Children with Diplegia? NeuroQuantology 2022;20(15):71.
21. Bae DY, Shin JH, Kim JS. Effects of dorsiflexor functional electrical stimulation compared to an ankle/foot orthosis on stroke-related genu recurvatum gait. Journal of Physical Therapy Science. 2019;31(11):865-8.
22. Fry AC, Irwin CC, Nicoll JX, and Ferebee DE. Muscular strength and power in 3-to-7-year-old children. Pediatr Exerc Sci 2015;27(3): 345-54.
23. Hoglund LT, Wong AL, Rickards C. The impact of sagittal plane hip position on isometric force of hip external rotator and internal rotator muscles in healthy young adults. International Journal of Sports Physical Therapy. 2014 Feb;9(1):58.
24. Datorres ECS. Intensive therapy combined with strengthening exercises using the TheraSuit in a child with cerebral palsy: a case report. 2004.
25. Koscielny R. Strength training and CP. Cerebral Palsy Magazine 2004;2(1):12-4.
26. Damiano D, Kelly L, Vaughan C. Effects of quadriceps strengthening on crouch gait in children with spastic diplegia. Gait & Posture 1994;2(1):62.
27. Hamouda MM, Mohamed NE, W.A. Abd el-Nabie. Effect of Pulley Therapy on Genurecurvatum in Children with Unilateral Cerebral Palsy: Randomized Controlled Trial. Pakistan Journal of Medical & Health Sciences 2021;15(7):1994-1998.
28, Mohamed AS, Kamal HM, Elsied AO, and Abd El-Gafar EM. Universal Exercise Unit versus functional resisted training effect on muscle strength in spastic diplegia 2020. Indian Journal of Public Health Research & Development 11(4):1139-1144.
29. El-Negmy EH, Ahmed HI, Amina SH, Khaled AO. Effect of ankle weight during gait training on dorsiflexion strength in hemiparetic children. The Medical Journal of Cairo University 2019;87(September):3619-24.
30. Mannan I, Javed A, Afzal F, Ahmad B, Shah SN, Rana AA. Effects of Functional Strength Training Using Universal Exercise Unit on Spasticity of Lower Extremities Among Children with Cerebral Palsy; A Quasi-Experimental Study: Functional Strength Training in Cerebral Palsy. The Healer Journal of Physiotherapy and Rehabilitation Sciences 2023;3(8):756-61.
31. Al Abdulwahab, SS. Electrical stimulation improves gait in children with spastic diplegic cerebral palsy. NeuroRehabilitation 2011;29(1):37-43.
32. Afzal F, Manzoor S. Strength training by using universal exercise unit to improve the motor functions in cerebral palsy. Rawal Medical Journal 2018;43(1):120-.
33. Jang SJ, Kim BJ, Kim CW, Kang MJ, Kim BS. Effect of Plastic Ankle Foot Orthosis and Functional Electrical Stimulation on Hemiplegic Gait. Journal of the Korean Academy of Rehabilitation Medicine 1999;23(4):853-60.
34. Moll I, Vles JS, Soudant DL, Witlox AM, Staal HM, Speth LA, Janssen-Potten YJ, Coenen M, Koudijs SM, Vermeulen RJ. Functional electrical stimulation of the ankle dorsiflexion during walking in spastic cerebral palsy: a systematic review. Developmental Medicine & Child Neurology 2017;59(12):1230-6.
35. Sakullertphasuk W, Prasertsukdee S, Suwanasri C, Lertmanorat Z. Effect of functional electrical stimulation (FES) when combined with gait training on treadmill in children with spastic diplegia. InProceedings of the 5th International Conference on Rehabilitation Engineering & Assistive Technology 2011 Jul 21 (pp. 1-4).
36. Bae DY, Shin JH, Kim JS. Effects of dorsiflexor functional electrical stimulation compared to an ankle/foot orthosis on stroke-related genu recurvatum gait. Journal of Physical Therapy Science

2019;31(11):865-8.
37. Springer S, Vatine JJ, Lipson R, Wolf A, Laufer Y. Effects of Dual-Channel Functional Electrical Stimulation on Gait Performance in Patients with Hemiparesis. The Scientific World Journal 2012;2012(1):530906.
38. Sakullertphasuk W, Prasertsukdee S, Suwanasri C, Lertmanorat Z. Effect of functional electrical stimulation (FES) when combined with gait training on treadmill in children with spastic diplegia. InProceedings of the 5th International Conference on Rehabilitation Engineering & Assistive Technology 2011 Jul 21 (pp. 1-4).