Egyptian Journal of **Physical Therapy** (EJPT)

Egy. J. Phys. Ther. 2024; 20:57- 64

Original article

https://ejpt.journals.ekb.eg

Universal Exercise Unit versus Functional Resisted Training on Balance in Children with Diplegia

Islam Mohamed Elshahat Mahmoud[1*], Eman Ibrahim El Hadidy[2], Nahed Salah Eldin Ahmed[3], Rania Galal El Deen Abdou Hegazy[4]

[1]*Department of Physical Therapy for pediatrics and pediatric surgery, Faculty of Physical Therapy, Badr University in Cairo, Egypt.*
[2]*Professor of Physical Therapy for pediatrics, Faculty of Physical Therapy, Cairo University.*
[3]*Professor of Neurology, Faculty of Medicine, Ain Shams University.*
[4]*Lecturer of Physical Therapy for pediatrics, Faculty of Physical Therapy, Cairo University.*

***Correspondence to:**
Islam Mohamed Elshahat Mahmoud, 1Department of Physical Therapy for pediatrics and pediatric surgery, Faculty of Physical Therapy, Badr University in Cairo, Egypt.

Email:
eslamelshahat28@gmail.com

Telephone:
01150719680

Published online:
Dec 2024

Abstract

Purpose: To compare the effectiveness of adding a universal exercise unit to designed physical therapy versus functional resisted training with designed physical therapy on balance among diplegic children.
Methods: This study included 45 both–sexes CP children with spastic diplegia, between the ages of six to ten years old. They were randomly assigned to three equal–sized groups (control, study A, and study B). The control group was given only the designed physical therapy program; study group A was given a universal exercise unit program beside the same designed physical therapy program; and study group B was given functional resistance training beside the same physical therapy program as in the control group. All participants in the three groups were assessed for standing balance using the Biodex stability system pre and post–treatment program
Results: There were statistically significant improvements in standing balance score post–treatment in the three groups, with more improvement in study group A ($P<0.05$).
Conclusion: A universal exercise unit program showed more significantly improved balance in spastic diplegic children as compared to functional resisted training.
Key words: Balance, diplegia, functional resisted training, universal exercise unit.

1. Introduction:

Cerebral palsy (CP) is predominantly a neuromotor disorder that influences the development of both posture and movement. The prevalence of CP is 2–3 cases for 1,000 live births. Low birth weight along with premature birth is an important risk factor for CP. However, there are other factors, such as multiple gestational cysts and maternal infection that have also been associated with an increased risk of CP (1).

The motor disorders in CP are muscle tone abnormality, muscle weakness, deficiency in postural control, orthopedic problems, and abnormal movement

Pleas cite this article as follows: Islam Mohamed Elshahat Mahmoud, Eman Ibrahim El Hadidy, Nahed Salah Eldin Ahmed, Rania Galal El Deen Abdou Hegazy. Universal Exercise Unit versus Functional Resisted Training on Balance in Children with Diplegia. EJPT. EJPT. 2024; 20:57-64.

patterns ([2]). Children with spasticity may exhibit abnormal synergies of movement, including associated reactions and extensor or flexor patterns of movement, which lead to poor balance ([3]). Spastic diplegia refers to a specific form of spastic quadriparesis when the lower limbs are more impacted than the upper limbs. It comprises over half of the total CP population ([4]).

Universal exercise unit (UEU) therapy is a treatment technique that can be applied along with traditional physical therapy activities among children with CP ([5]). The UEU includes a system of pulleys, suspensions, support belts, and elastic cords. The pulley system is useful for muscle strengthening, improving function and endurance, increasing range of motion, and preventing muscle atrophy ([6]).

Functional resisted training is a crucial component of the rehabilitation protocol for children suffering from CP. The therapeutic philosophy has evolved from traditional to goal–oriented approaches. Experienced therapists accurately bring out the importance of practicing tasks. It is not new for training children with CP ([7]). Studies have demonstrated that functional resistance training has a direct impact on improving static and dynamic balance, regardless of age. Additionally, it has been found to enhance walking endurance ([8]).

So, the purpose of this study was to compare the effects of a universal exercise unit and functional resisted training on balance among spastic diplegic CP children.

2. Subjects and methods:

2.1. Study design: The clinical trial was administered prospectively and randomized from November 2022 to December 2023.

2.2. Ethical consideration: The study was carried out following the approval of the ethical committee of the Faculty of Physical Therapy, NO: P.T.REC/012/003331, Cairo University. After explaining the experimental techniques, all participant parents obtained signed informed consent.

2.3. Sample size: The sample size calculation was conducted using the G*POWER statistical software (version 3.1.9.2; Franz Faul, Universitat Kiel, Germany), and it was determined that a minimum of 15 subjects per group was needed for this study. The calculations were conducted using an alpha level of 0.05, a power of 80%, and an effect size of 0.48.

Recruitment for 45 boy and girl children with spastic diplegia between the ages of 6 and 10 years old from the outpatient physical therapy clinic at Cairo University's Faculty of Physical Therapy and Wahet Nour Elhayat. The inclusion criteria of subjects were: Children with diplegic CP, with spasticity levels ranging from 1 to 1+ according to Modified Ashworth ([9]), level II in Gross Motor Function Classification System (GMFCS) ([10]), had heights not less than 1 meter, and had trouble maintaining their balance since the child has a history of frequent, repetitive falls, especially when accelerating or walking on an unsteady surface. Children with visual or auditory abnormalities, fixed abnormalities in one of the lower extremities, and sensory perception or cognitive impairments were excluded.

2.4. Randomization: Children were randomly assigned using basic randomization, closed envelope, to three matched equal groups (control group, study A, and study B). The control group included 15 children with diplegic CP who were given a specific program of physical therapy only; the Study group (A) received UEU strengthening exercises for both lower limbs and the similar specific program of physical therapy; and the Study group B received functional resisted training exercises (three exercises: squatting, sit to stand on block, and forward step–up) for both lower limbs and the similar specific program of physical therapy. The balances were evaluated pre and post–treatment program for all participating children using the Biodex stability system. The treatment was three times per week for three months.

2.5. Data collection and intervention:

2.5.1. Assessment tools and procedures:

- **Biodex stability system:**

(Biodex Medical Systems Inc., Shirley NY, USA, 11967–0702) was utilized for the purpose of assessing dynamic balance (anteroposterior stability index (APSI), mediolateral stability index (MLSI), and overall stability index (OASI)) for the children who participated in the study from a standing position before and after treatment ([11]).

Initially, each child was required to stand as straight as they could on the secured platform, and their data was recorded in detail (name, age, weight, height), and Level 5 was determined as the platform's stability ([12]). The platform is then unlocked by pressing (start), allowing foot placement to be determined, resulting in balanced platforms. The child looked at a screen positioned in front of them, which was divided into four portions forming a circular shape.

The child was directed to maintain focus on a location located at the center of the circle. Feet prints were gathered (1) at the angle of the 2nd metatarsal bone that ranged from 10° to 90° on the platform. (2) The letters A through H on the platform stand for the heel's center. (3) The last line may indicate that the heel is bearing weight, which is represented by the digits 1 through 9. After the platform's balance was unlocked, the testing procedure could begin by pressing (next screen). Subsequently, the child can readjust the platform and position the point precisely at the center of the shown circle. The test was conducted with eyes open and had a duration of 30 seconds. Finally, reaching the next screen displays the reported predicted value (% in quadrant, OASI, APSI, and MLSI). The test for each child was replicated three times, and then an overall average was calculated.

Pleas cite this article as follows: Islam Mohamed Elshahat Mahmoud, Eman Ibrahim El Hadidy, Nahed Salah Eldin Ahmed, Rania Galal El Deen Abdou Hegazy. Universal Exercise Unit versus Functional Resisted Training on Balance in Children with Diplegia. EJPT. EJPT. 2024; 20:57-64.

A high stability index score suggests a lot of movement during a test and less stability. Conversely, a lower stability index score suggests higher stability and is reflected as a better balance score (13).

2.5.2. Treatment tools and procedures:

a) A selected physical therapy program was set up for three groups consisting of stretching exercises for (the Achilles tendon, hamstring, hip flexor, and adductor for both lower extremities) (14), facilitation of righting and equilibrium reactions (15), facilitation of protective reactions (16), and facilitation of single limb support. A variety of positions were included in balance training, including kneeling, half kneeling, as well as standing, along with gait training involving sideways, forward, and backward movements using a stepper and balance board (3).

b) The universal exercise unit used for study group A:

Children of this group received UEU strengthening exercises for lower limb muscles and the same specific program of physical therapy as in the control group.

Children's posture for hip and knee extension training: The child was positioned in a supine posture on the table within the spider cage. They were secured with straps across the chest, pelvis, as well as the non–involved leg, while the other lower limb was free to move and exercise .

To extend the knee, bend the knee and fasten a strap around the foot to the upper portion of the UEU using a rope attached to the side of the head. At the rope's end, there was a weight that required pulling. The child was instructed to use his or her lower limb to push against a weight.

The child was lying supine with their knees extended and their hips flexed, and a band around their ankles was fastened by a rope to the head side of the UEU for hip extension. Weight was attached to the ends of the rope and needed to be pushed. The child was instructed to extend his leg and make contact with the plinth.

Each child in group (A) underwent an evaluation to determine their one repetition maximum (1–RM). This was done using the leg extension exercise, with the children in an upright seated position and both feet placed on the floor. Children were instructed to fully extend their knees, moving from a 90° angle of flexion to complete extension, prior to returning to the initial position. The highest amount of resistance that could be raised over the complete ROM was defined as the (1–RM) (17). Each child executed 8–15 repetitions in either one or two sets using a weight that was light to moderate (around 60% of their 1 RM) (18).

c) Functional resisted training used for study group B:

Children received three functional resisted training exercises (squatting, sit to stand on a block, and forward step–up) for both lower limbs in addition to the same program of physical therapy as in the control group.

The session began with a 3–minute warm–up exercise (ROM, mobilization, stretching), followed by 25 minutes of resistive exercise, and lastly a 2–minute cool–down exercise (ROM, mobilization, stretching (19).

1. **Squatting**: Standing with both legs completely extended is the starting point of the squat, then descends in a continuous action until the required squat depth is reached, then ascends in a continuous motion back to the upright position. (20).
2. **Sit to Stand:** Performing the exercise (A) The child sits on a stool. (B) The child slides forward as much as possible. (C) The child moves his feet back, so his heels are lined up with the front edge of the chair. (D) The child stands up using his buttocks and leg (20).
3. **Forward step up:** The child firmly planted his right foot on the bench. To stand on the bench, he presses his right heel on it and then brings his left foot to meet it . (20).

2.6 Statistical analysis :

The participant's characteristics were compared across different groups using an ANOVA test. Each group's sex distribution was compared using the chi–squared test. Each group's GMFM levels were compared using the Kruskal–Wallis test. The Shapiro–Wilk test was employed to check for the presence of a normal distribution in the data. Levene's test was employed to assess the homogeneity of variances among groups. A mixed ANOVA was employed to evaluate the impact of both within–group and between–group factors on stability indices. Post–hoc testing was conducted using the Tukey correction for multiple comparisons. The statistical tests conducted all had a significance threshold of $p < 0.05$. The statistical procedures were carried out using IBM SPSS's (Chicago, IL, USA) version 25 for Windows software.

3 .RESULTS

3.1 .Subject characteristics

(**Table 1**), statistically there was Nonsignificant difference between both groups related to age, and BMI ($P>0.05$).

3.2. Effect of treatment on stability indices:

The results of the Mixed ANOVA indicated a substantial interaction between the treatment as well as time variables ($F = 12.56$, $p = 0.001$, Partial Eta Squared = 0.48). There was a substantial main effect of time ($F = 388.40$, $p = 0.001$, Partial Eta Squared = 0.96). There was a substantial main effect of treatment ($F = 4.35$, $p = 0.001$, Partial Eta Squared = 0.27).

- **Within–group comparison:**

The three groups revealed a significant decline in OASI, APSI, and MLSI post–treatment compared to pre–treatment ($p < 0.001$). The percentage of change in OASI, APSI, and MLSI in the control group was 27.15, 27.35, and 21.77%, respectively, while in study group A it was 55.16, 51.44, and 48.03%, and in study group B it was 35.05, 35.98, and 31.52%. **(Table 2).**

Pleas cite this article as follows: Islam Mohamed Elshahat Mahmoud, Eman Ibrahim El Hadidy, Nahed Salah Eldin Ahmed, Rania Galal El Deen Abdou Hegazy. Universal Exercise Unit versus Functional Resisted Training on Balance in Children with Diplegia. EJPT. EJPT. 2024; 20:57-64.

- **Between–group comparison:** Study group A had significantly lower OASI, APSI, and MLSI than the control group (p < 0.001) as well as study group B (p < 0.001), respectively. The study group B had significantly lower OASI, APSI, and MLSI than the control group (p < 0.05). (**Table 2).**

Table 1. Basic characteristics of participants.

Characteristics	Control group	Study group A	Study group B	p–value
Age, mean ± SD, years	7.86 ± 1.15	8.10 ± 1.31	8.06 ± 1.20	0.85
Weight, mean ± SD, kg	23.66 ± 3.65	24.06 ± 3.67	24.26 ± 3.95	0.90
Height, mean ± SD, cm	119.20 ± 8.20	119.66 ± 7.48	120.86 ± 7.60	0.83
GMFCS, median (IQR)	2 (2–2)	2 (2–2)	2 (2–2)	1
Sex, N (%)				
Girls	6 (40%)	5 (33%)	7 (47%)	0.75
Boys	9 (60%)	10 (67%)	8 (53%)	

SD, standard deviation; p–value, level of significance.

Table 2. Mean values of OASI, APSI, and MLSI pre– and post–treatment of the control group, study group A, and study group B.

	Control group	Study group A	Study group B	p–value		
	mean ± SD	mean ± SD	mean ± SD	Control vs study group A	Control vs study group B	Study group A vs study group B
OASI						
Pre treatment	3.02 ± 0.42	3.10 ± 0.25	3.11 ± 0.33	0.81	0.77	0.99
Post treatment	2.20 ± 0.16	1.39 ± 0.12	2.02 ± 0.21	0.001	0.01	0.001
MD (% of change)	0.82 (27.15%)	1.71 (55.16%)	1.09 (35.05%)			
	p = 0.001	***p = 0.001***	***p = 0.001***			
APSI						
Pre treatment	2.34 ± 0.33	2.43 ± 0.18	2.39 ± 0.23	0.62	0.87	0.90
Post treatment	1.70 ± 0.23	1.18 ± 0.16	1.53 ± 0.15	0.001	0.03	0.001
MD (% of change)	0.64 (27.35%)	1.25 (51.44%)	0.86 (35.98%)			
	p = 0.001	***p = 0.001***	***p = 0.001***			
MLSI						
Pre treatment	2.48 ± 0.34	2.54 ± 0.23	2.57 ± 0.46	0.91	0.78	0.96
Post treatment	1.94 ± 0.23	1.32 ± 0.13	1.76 ± 0.20	0.001	0.03	0.001
MD (% of change)	0.54 (21.77%)	1.22 (48.03%)	0.81 (31.52%)			
	p = 0.001	***p = 0.001***	***p = 0.001***			

SD, Standard deviation; MD, Mean difference; p–value, Level of significance
OASI, overall stability index; APSI, Anteroposterior stability Index, MLSI, Mediolateral stability Index

4. Discussion:

The purpose of this study was to compare the impact of adding a universal exercise unit to designed physical therapy versus functional resisted training with designed physical therapy on balance among diplegic CP children. When comparing the three groups' mean values of measuring variables prior to and following treatment, a significant difference was discovered in the three groups. That provided evidence that physical therapy methods could help spastic diplegic children improve their dynamic balance. Upon comparing the post–treatment data of three groups, it was seen that the study group (A) exhibited a substantial improvement across the measured variables compared to both the control group as well as the study group (B).

Spastic diplegia is a particularly common form of CP, characterized by greater involvement of the lower limbs compared to the upper limbs. This condition significantly affects functional performance as well as gait (21). The current study focused on those who have spastic diplegic CP, which is a prominent subtype within the broader category of spastic CP, as defined by Jones et al. (22). The manifestations of spastic diplegia include irregular gait along with difficulties in balance, motor control, and spasticity in children (23). Motor functions, mobility, ADLs, and social participation were already severely impacted by CP's associated balance issues. Fall rates were also higher due to the balance difficulties (24).

For several reasons, the study's diplegic children were chosen to be between the ages of six and ten. First, children at this age can understand the instructions and procedures for evaluation and treatment. Wolff et al. (25) demonstrated that children with CP commonly experience delayed motor control and the initiation of gait, which can affect the development of postural control. Also, Westcott et al. (26) stated that children aged 7 to 10 can resolve a sensory conflict arising from contradictory information received by their somatosensory and visual receptors. In addition, they can proficiently utilize the vestibular system as a point of reference.

The selection of dynamic balance to be evaluated comes in agreement with Shumway–Cook et al. (27) who explained that evaluation of dynamic balance reflects the dynamic nature of locomotor tasks and it's reliable in identifying individuals at risk of falls. Also, Aydoğ et al. (28) stated that dynamic balance tests are more precise and can more accurately predict subjects likely to fall than static balance tests.

Using the Biodex stability system to measure APSI, MLSI, as well as OASI was consistent with Finn et al. (29) who noted that the Biodex Balance system has recently become more widely available as a method of accurately measuring balance. This system offers valid, reliable, as well as repeatable objective assessments of the patient's capacity to maintain balance on both stable and unstable surfaces, while also documenting their neuromuscular control in secure settings.

Regarding the results of the Biodex balance system, the pretreatment mean values for all participated children in three groups (control group, study group A, study group B) of APSI, MLSI, and OASI showed significant affection in their values, indicating that those children experienced significant problems with balancing.

There was a significant reduction in OASI, APSI, and MLSI in the three groups post–treatment compared with that pre–treatment ($p < 0.001$). The improvement in the post–treatment outcomes can be attributed to the impact of stretching exercises that were implemented to improve soft tissue flexibility, reduce stiffness of the muscles, enhance balance, and reduce the risk of falling.

This comes in agreement with Ganjwala (30), who recommended the use of stretching exercises, such as passive and active stretching, positioning, isokinetic stretching, as well as isotonic stretching, to alleviate spasticity. Tension applied to soft tissues, session duration, repetition, as well as frequency determine the effectiveness of stretching.

Fowler et al. (31) reported that there were no changes in spasticity after quadriceps muscle training among children with CP. Merino–Andrés et al. (32) indicated that a strength training program can have beneficial benefits on muscle strength, balance, gait speed, and gross motor function among children with CP; these positive effects can be achieved without increasing spasticity, as long as the program follows appropriate doses and specific principles.

Scianni et al. (33) and Rameckers et al. (34) reported no advantage to strengthening the muscles in the lower and upper extremities. However, Cho et al. (35) noted that strength training can enhance muscle strength among children having CP without causing any adverse effects on spasticity.

There was a significant reduction in OASI, APSI, and MLSI of study group A compared to the control group ($p < 0.001$) and study group B ($p < 0.001$).

Higher improvement in study group A might be due to strengthening exercise by UEU to knee and hip extensors as hip extensors and knee extensors are relatively weaker than their antagonists in diplegic children. This is in accordance with Aye et al. (36) who proposed that implementing a strength–training regimen specifically targeting the hip and knee extensor muscles could potentially result in enhanced muscle strength among children diagnosed with spastic diplegic CP. Engaging in activities that target weak muscles, namely the knee extensors, is crucial for enhancing dynamic balance among children with spastic diplegic CP (37).

UEU is used to strengthen isolated muscles or muscle groups. In addition, Kamal et al. (38) reported that selecting the UEU training program for those with CP who are undergoing strength training is advantageous since it helps reduce the impact of gravity on spastic muscles. Additionally, it has a

Pleas cite this article as follows: Islam Mohamed Elshahat Mahmoud, Eman Ibrahim El Hadidy, Nahed Salah Eldin Ahmed, Rania Galal El Deen Abdou Hegazy. Universal Exercise Unit versus Functional Resisted Training on Balance in Children with Diplegia. EJPT. EJPT. 2024; 20:57-64.

beneficial impact on enhancing balance control among children diagnosed with spastic CP (39).

The UEU therapy is an innovative method employed to enhance the strength of weak muscles as well as enhance motor function without increasing spasticity. Furthermore, it has been observed that UEU therapy yields greater improvements in muscular strength compared to functional resistive training (20). Greater dynamic balance ability was found to be strongly linked with an increase in lower limb muscle strength (40).

The enhancement of study group A can be attributed to the pulley system that enables therapists to isolate and strengthen a specific muscle group, separate from the other parts of the body. This enables the targeted muscle group to function. In addition, UEU significantly enhances endurance as well as standing balance (41).

The enhancement observed in study group B due to the improvement of muscle strength is supported by Cho et al. (35) who revealed that functional progressive resistance exercise has a beneficial impact on enhancing lower extremity strength along with quadriceps muscle morphology, as well as enhancing dynamic balance and functional ability among children with spastic CP.

FST can be done with resistance, such as gravity, body weight, resistance bands, or free weights. Exercises are tailored to the specific muscle or muscle groups used throughout functional activities (20). Abd–Elmonem et al. (42) stated that FST is a highly successful approach for improving motor function, gait characteristics, and balance.

While there were significant improvements in all measuring variables, there were certain limitations to verifying these findings. Further studies utilizing longer study durations and follow–up are required.

Conclusion:

From the previously obtained findings of the current study, it could be concluded that UEU has significantly improved balance in children with spastic diplegic CP compared to functional resisted training. This improvement in balance may help those children to walk more efficiently without falling and improve their performance in their activities of daily living.

Declaration of interest:

The authors declare no conflict of interest.

Funding:

Self-funded.

Acknowledgements:

We are grateful to all participants for their assistance and for providing us with the time needed to perform this research.

Reference:

1) Patel DR, Neelakantan M, Pandher K, Merrick J. Cerebral palsy in children: a clinical overview. Translational pediatrics. 2020 Feb;9(Suppl 1): S125.
2) Günel MK, Türker D, Ozal C, Kara OK. Physical management of children with cerebral palsy. Cerebral Palsy: Challenges for the Future. 2014 Mar 19; 19:29.
3) Levitt S, Addison A. Treatment of cerebral palsy and motor delay. John Wiley & Sons; 2018 Nov 28.
4) Damiano DL, Martellotta TL, Sullivan DJ, Granata KP, Abel MF. Muscle force production and functional performance in spastic cerebral palsy: relationship of cocontraction. Archives of physical medicine and rehabilitation. 2000 Jul 1;81(7): 895–900.
5) Menz SM, Hatten K, Grant–Beuttler M. Strength training for a child with suspected developmental coordination disorder. Pediatric Physical Therapy. 2013 Jul 1;25(2): 214–23.
6) Koscielny R. Strength training and CP. Cerebral Palsy Magazine. 2004;2(1): 12–4.
7) Papavasiliou AS. Management of motor problems in cerebral palsy: a critical update for the clinician. european journal of paediatric neurology. 2009 Sep 1;13(5): 387–96.
8) Josephson MD, Williams JG. Functional–strengthening: A pilot study on balance control improvement in community–dwelling older adults. Montenegrin Journal of Sports Science and Medicine. 2017 Sep 1;6(2): 75.
9) Bohannon RW, Smith MB. Interrater reliability of a modified Ashworth scale of muscle spasticity. Physical therapy. 1987 Feb 1;67(2): 206–7.
10) McDowell B. The Gross Motor Function Classification System—expanded and revised. Dev Med Child Neurol. 2008 Oct;50(10): 725.
11) Cachupe WJ, Shifflett B, Kahanov L, Wughalter EH. Reliability of biodex balance system measures. Measurement in physical education and exercise science. 2001 Jun 1;5(2): 97–108.
12) Abd–Elmonem AM, Elhady HS. Effect of rebound exercises on balance in children with spastic diplegia. International Journal of Therapy and Rehabilitation. 2018 Sep 2;25(9): 467–74.
13) Marsden JF, Playford DE, Day BL. The vestibular control of balance after stroke. Journal of Neurology, Neurosurgery & Psychiatry. 2005 May 1;76(5): 670–9.

14) Levitt S, Addison A. Treatment of cerebral palsy and motor delay. John Wiley & Sons; 2018 Nov 28.
15) O'Neil ME, Fragala–Pinkham MA, Westcott SL, Martin K, Chiarello LA, Valvano J, Rose RU. Physical therapy clinical management recommendations for children with cerebral palsy–spastic diplegia: achieving functional mobility outcomes. Pediatric physical therapy. 2006 Apr 1;18(1): 49–72.
16) Jr ME. Treatment of neuromuscular and musculoskeletal problems in cerebral palsy. Pediatric rehabilitation. 2001 Jan 1;4(1): 5–16.
17) Faigenbaum AD, Milliken LA, Westcott WL. Maximal strength testing in healthy children. The Journal of Strength & Conditioning Research. 2003 Feb 1;17(1): 162–6.
18) Behm DG, Faigenbaum AD, Falk B, Klentrou P. Canadian Society for Exercise Physiology position paper: resistance training in children and adolescents. Applied physiology, nutrition, and metabolism. 2008 Jun;33(3): 547–61.
19) Soliman YM, Eltohamy AM, Ayad MN. Functional progressive resistance exercise versus eccentric muscle control in children with hemiplegia: A randomized controlled trial. Bulletin of Faculty of Physical Therapy. 2022 Dec;27(1): 32.
20) Mohamed AS, Kamal HM, Elsied AO, Abd El–Gafar EM. Universal exercise unit versus functional resisted training effect on muscle strength in spastic diaplegia. EXECUTIVE EDITOR. 2020 Apr;11(04): 181.
21) Sah AK, Balaji GK, Agrahara S. Effects of task–oriented activities based on neurodevelopmental therapy principles on trunk control, balance, and gross motor function in children with spastic diplegic cerebral palsy: A single–blinded randomized clinical trial. Journal of Pediatric Neurosciences. 2019 Jul 1;14(3): 120–6.
22) Jones MW, Morgan E, Shelton JE, Thorogood C. Cerebral palsy: introduction and diagnosis (part I). Journal of Pediatric Health Care. 2007 May 1;21(3): 146–52.
23) Allah NE, Kamal HM, El–Nabie WA. Association between pelvic inclination and balance in children with spastic diplegia. Bulletin of Faculty of Physical Therapy. 2023 Jan 6;28(1): 4.
24) Chen CL, Shen IH, Chen CY, Wu CY, Liu WY, Chung CY. Validity, responsiveness, minimal detectable change, and minimal clinically important change of Pediatric Balance Scale in children with cerebral palsy. Research in developmental disabilities. 2013 Mar 1;34(3): 916–22.
25) Wolff DR, Rose J, Jones VK, Bloch DA, Oehlert JW, Gamble JG. Postural balance measurements for children and adolescents. Journal of Orthopaedic Research. 1998 Mar;16(2): 271–5.
26) Westcott SL, Crowe TK, Deitz JC, Richardson PK. Test–retest reliability of the pediatric clinical test of sensory interaction for balance (P–CTSIB). Physical & Occupational Therapy in Pediatrics. 1994 Jan 1;14(1): 1–22.
27) Shumway–Cook A, Hutchinson S, Kartin D, Price R, Woollacott M. Effect of balance training on recovery of stability in children with cerebral palsy. Developmental medicine and child neurology. 2003 Sep;45(9): 591–602.
28) Aydoğ E, Bal A, Aydoğ ST, Çakci A. Evaluation of dynamic postural balance using the Biodex Stability System in rheumatoid arthritis patients. Clinical rheumatology. 2006 Jul;25: 462–7.
29) Finn JA, Alvarez MM, Jett RE, Axtell RS, Kemler DS. Stability performance assessment among subjects of disparate balancing abilities. Medicine & Science in Sports & Exercise. 1999 May 1;31(5): S252.
30) Ganjwala D. Multilevel orthopedic surgery for crouch gait in cerebral palsy: An evaluation using functional mobility and energy cost. Indian Journal of Orthopaedics. 2011 Aug;45(4): 314–9.
31) Fowler EG, Ho TW, Nwigwe AI, Dorey FJ. The effect of quadriceps femoris muscle strengthening exercises on spasticity in children with cerebral palsy. Physical therapy. 2001 Jun 1;81(6): 1215–23.
32) 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 Jan;36(1): 4–14.
33) Scianni A, Butler JM, Ada L, Teixeira–Salmela LF. Muscle strengthening is not effective in children and adolescents with cerebral palsy: a systematic review. Australian Journal of Physiotherapy. 2009 Jan 1;55(2): 81–7.
34) Rameckers EA, Janssen–Potten YJ, Essers IM, Smeets RJ. Efficacy of upper limb strengthening in children with cerebral palsy: a critical review. Research in developmental disabilities. 2015 Jan 1;36: 87–101.
35) Cho HJ, Lee BH. Effect of functional progressive resistance exercise on lower extremity structure, muscle tone, dynamic balance and functional ability in children with spastic cerebral palsy. Children. 2020 Jul 31;7(8): 85.
36) Aye T, Thein S, Hlaing T. Effects of strength training program on hip extensors and knee extensors strength of lower limb in children with

spastic diplegic cerebral palsy. Journal of physical therapy science. 2016;28(2): 671–6.

37) Emara HA. Effect of a new physical therapy concept on dynamic balance in children with spastic diplegic cerebral palsy. Egyptian Journal of Medical Human Genetics. 2015 Feb 3;16(1): 77–83.
38) Kamal HM, Sayed AO. Motor control and standing function following strength training in spastic diplegia children. Bull. Fac. Ph. Th. Cairo Univ. 2014 Jan;19(2).
39) Liaqat S, Butt MS, Javaid HM. Effects of universal exercise unit therapy on sitting balance in children with spastic and athetoid cerebral palsy: A quasi–experimental study. Khyber Medical University Journal. 2016;8(4): 177–.
40) Saquetto M, Carvalho V, Silva C, Conceição C, Gomes–Neto M. The effects of whole body vibration on mobility and balance in children with cerebral palsy: a systematic review with meta–analysis. Journal of musculoskeletal & neuronal interactions. 2015 Jun;15(2): 137.
41) 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 January 6(1), 85–88.
42) Abd–Elmonem AM, Abd El–nabie WA. Therapeutic outcomes of functional strength training versus conventional physical therapy in children with cerebral palsy: A comparative study. Physical Therapy and Rehabilitation. 2019;6(1): 7.