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Partial Body Weight-Supported Treadmill Training Versus Isokinetic Training on Muscle Strength and Balance in Children with Hemiparetic Cerebral Palsy: A randomized Controlled trial

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Abstract--*Muscle weakness in children with hemiparetic cerebral palsy is one of the serious complications which affect their performance. Isokinetic is one method to Strength weak muscles in children with hemiplegia and also one of the new applications of decreased weight to achieve muscle strength and function is partial body weight supported treadmill training. To compare between the effect of partial body weight-supported treadmill training and isokinetic training on muscle strength and balance in children with hemiparetic cerebral palsy. Thirty children with hemiparetic cerebral palsy participaed in this study. They aged from 10 to 14 years old. Children were randomly assigned to group A or group B. Children in both groups received the same designed physical therapy program. In addition, group A received partial body weight-supported treadmill training while group B received strength training program for the knee flexor muscle group three sessions per week for 12 successive weeks. Muscle strength and balance were assessed before and after treatment by using the Biodex isokinetic system and Bruininks–Oseretsky Test of Motor Proficiency respectively. The post treatment results revealed significant difference in all measured variables (peak torque and balance) as compared with its pre-treatment results. Post-treatment values measured variables, between the two groups, revealed significant difference in favor of group B. According to current results isokinetic strength training program is likely more effective than partial body weight-supported treadmill training on improving muscle strength and balance in children with hemiparetic cerebral palsy.*

Key words--*Balance, Cerebral palsy, Hemiparesis, Isokinetic training, Muscle strength, Partial body weight-supported treadmill training*

I. INTRODUCTION

Cerebral palsy (CP) is a term includes many disorders in which there is an injury to the developing brain that causes physical disability as the first or the prominent problem (1). CP is the most common cause of disability in childhood and may affect the child in various health dimensions (2). Children with CP who have mild disabilities demonstrate substantial weakness compared with age-related peers. Low level of physical activity is a primary contributor to muscle weakness in addition to decreased central input to the muscle due to the pyramidal

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tract insult, changes in the muscle's elastic properties, aberrations in the reciprocal inhibition pathways in pairs of agonist-antagonist muscles, and increased stretch responses or spasticiy[(3)].

Hemiplegic CP is the most common form of CP affecting up to one person per thousands of live births [(4)]. Although most of hemiparetic CP children get walk independently, they continue to have deficits in balance, co-ordination, and gait throughout childhood and adulthood [(5)]. Putting direct load on the muscle through specific exercises, activities is the only direct way to increase muscle strength in children with CP, and may be particularly useful in increasing or maximizing the function [(6)].

Strength training by isokinetic machine expresses a harmony between mechanically controlled velocity and the movement of the subject that comes against a controlled angular velocity. So, during accommodating resistance the muscle contracts at its maximum ability at all angles throughout the range of motion [(7)]. Strengthening muscles in CP children should be a major treatment choice. Treadmill training was used for children with CP to help them to improve balance and build strength of their lower limbs so they can walk earlier and more efficiently than those children who did not take treadmill training. It helped children with CP to walk about 101 days earlier than children who did not train by treadmill [(8)]. Partial body weight-supported treadmill training (PBWSTT) involves using an overhead harness to carry a percentage of body weight during walking. It is a way that is used successfully to improve gait in people suffering from motor function problems [(9)]. Its advantages are to give task-oriented training; to allow several repetitions of a supervised gait pattern with an almost null fall risk; to enable an increasing need of effort and requirements of postural control.

The previous literature provides evidence, although it is limited, that strength training programs may provide positive strength benefits for children and young adults with cerebral palsy [(10)].Here the current work aimed to compare between the effect of intensive body weight-supported treadmill training versus isokinetic training on muscle strength and balance in children with hemiparetic cerebral palsy.

II. MATERIALS AND METHODS

Study design

A randomized –controlled trail was conducted in accordance with the Code of Ethics of the World, Medical Association (Declaration of Helsinki). Participants, parents/ legal guardians provided written informed consent before the study was conducted.

Participants

A convenient sample of thirty children with CP was recruited from the Outpatient Clinic, Faculty of Physical Therapy, Cairo University. They have been screened and included if they were:1) diagnosed as hemiparetic CP, 2) degree of spasticity ranged between grade1 and +1 according to the Modified Ashworth Scale [(11)] , 3) aged from 10 to 14years, 4) had no surgical procedures to the lower extremities in the preceding 12 months, 5) able to actively extend the knee without simultaneous hip extension, 6) able to fit anatomically on the isokinetic device,7) Level I and II on GMFCS, 8) height one meter or more. Participants excluded if they had any of the following; 1) history of musculoskeletal disorder of the knee joint, 2) Stiffness of knee joint, 3) surgical interventions in the lower limb and 3) severe spasticity.

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Randomization

After the baseline measurements, a randomization process was performed for 30 children using the method of sealed opaque envelopes. The researcher made 30 closed envelopes and each envelope containing a labeled card with either A or B. Each child/legal guardian was asked to draw a closed envelope that determined whether he/she was allocated to group A (N=15, 6 boys and 9 girls) or group B (N=15, 7 boys and 8 girls). No subjects dropped out of the study after randomization process. Refer to participant's flow chart (Figure 1). Group A received designed physical therapy program in addition to partial body weight-supported treadmill training for 30 minutes twice daily, while group B received the same designed physical therapy program in addition to isokinetic strength training program for the knee flexor group three sessions per week both for 12 successive weeks.

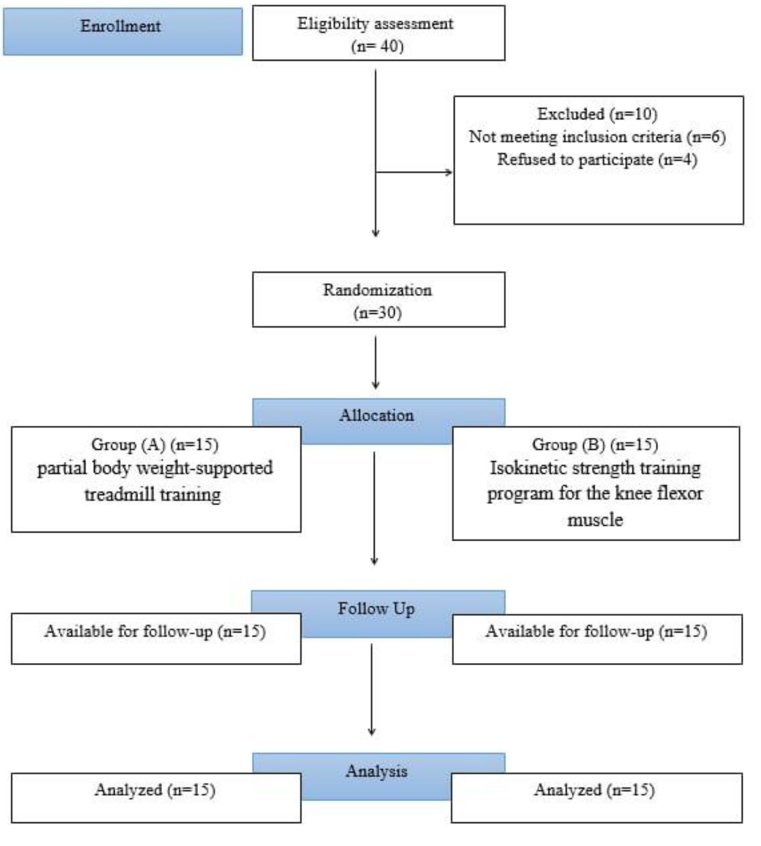

Figure 1: Flow chart of the study participants.

Procedures

Modified Ashworth scale:

It was used for grading spasticity at the time of child's selection. The child was asked to relax during the procedure.

Isokinetic peak torque of knee flexors:

Knee flexor was measured by isokinetic dynamometer Biodex System 3 [Biodex Medical Systems, Inc, New York, USA] at 60 $°.s^{-1}$. After warm-up, subjects were familiarized with all testing procedures and equipment with submaximal effort before data collection. The knee flexor of the affected leg was tested. The test was given in sitting position. Inclination angle for the seat was 90 degrees from horizontal position. Subjects were

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secured to the dynamometer seat with straps across the chest and thighs. The center of the knee joint (lateral epicondyle of femur) was aligned with the center of the dynamometer's power shaft. The resistance pad was placed on the distal two third of the tibia. Range of motion was set between 10-90 degrees of knee flexion. The gravity correction was performed by the dynamometer. They were asked to perform one sets contains 5 repetitions of maximal effort at selected speed of (60 °/sec.). Each child had a practice trial included three submaximal knee extension-flexion combinations and three maximal efforts before recording the data to permit the child to achieve best performance. During the test protocol, Childs were provided with visual feedback for torque and encouraged to maintain the maximal torque. Peak torque (PT) values were recorded by the Biodex software and the highest torques value of the data set was used in the statistical analysis (12).

Bruininks–Oseretsity test of motor proficiency

Bruininks – Oseretsky Test of Motor Proficiency - Second Edition (BOT-2) was designed to evaluate a wide array of gross and fine motor skills in children and youth. It is based on normative data on individuals between the ages of 4 through 21. It included eight subtest areas involved into the BOTMP-2: four of them measuring gross motor skills (i.e., Bilateral Coordination, Balance, Running Speed and Agility, Strength), and the other four measuring fine motor skills (i.e., Fine-Motor Precision, Fine-Motor Integration, Manual Dexterity, and Upper Limb Coordination). It can be administrated in four different ways: The Complete Form, Short Form, select composites, or select subtests [(13)]. In this study the balance subtest was used to evaluate the motor proficiency of those children. Each task included in the subtest were illustrated and clarified to each child in a one testing session. For all the tasks, children were allowed to complete a practice trial before starting the scored trails. Child's performance was recorded for each trial. Only the best valid attempt was included in the analysis. After performing the test, the result of each task (examinee's raw score) was recorded and then converted into a point score which was recorded on the right of the scale using the available scale. For each item we selected the best performance. At the end of the test, total item point scores recorded for the subtest and converted to Scale Scores using the appropriate tables provided in the manual, considering both the gender and age [(13)].

Intervention:

All children in both groups received 3 sessions per week for twelve consecutive weeks.

Group A:

Children in this group received designed physical therapy program based on the neurodevelopmental treatment approach. Training of righting and equilibrium reactions with several exercises on medical ball and roll from different positions which used to improve the postural mechanism, Training of protective reactions was used to prevent the child from falling over when balance was disturbed severely, gait training was applied as forward, backward and sideways walking between parallel bars and in front of large mirror and by placing different obstacles across the track of walking (rolls of different diameters and wedges of different heights, stretching exercise for tight muscles) in addition to gait training on treadmill with partial body weight support for ten minutes (30% relief of total body weight) at 0.36 m/s as partial body weight support of > 30% was not recommended as it causes significant reduction of activity of muscles in the affected lower limbs of hemiparetic subjects. Whenever it is necessary, modification of gait, such as position of the foot, was done by a physiotherapist during walking on the treadmill. Weight bearing support was applied mechanically in a modified parachute harness supported centrally by a set of pulleys connected to a flexible spring. We start with 10 min

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walking with a speed of, 36m/s as warming up then 15 minutes with more speed at ,8 m/s then 5 minutes cooling down with a speed of ,36m/s. During the PBWSTT, each participant attended the 30-min treadmill training. [14].

Group B:

Children in this group received the same program as group A in addition to strength training three days per week for 12 successive weeks involved knee flexion movement on Biodex isokinetic machine that controls the velocity of concentric muscle action. Children were seated as illustrated (in strength evaluation section) and were asked to perform five sets with each set contains 5 repetitions of maximal effort at selected speed of (60 º/sec.) Two minutes' rest interval between each set was considered a preventive measure for fatigue. Starting from a full extended position of the knee, Childs were instructed to flex their knee as rapidly and as far as possible. The end positions set on the machine were the child's maximum joint range of motion for knee flexion and extension. While exercising we used both visual feedback and verbal encouragement to get the best results. The exercises were directed towards only the affected knee flexor muscles to specify the results at the end of the exercises, stretching exercises done as a cool-down procedure.

Statistical Analysis

Descriptive and t-test were conducted for comparison of subject characteristics between both groups. Normal distribution of data was checked using the Shapiro-Wilk test for all variables. Levene's test for homogeneity of variances was conducted to test the homogeneity between groups. 2x2 Mixed MANOVA was performed to compare within and between groups effects on peak torque of knee flexors, Bruininks–Oseretsky Test of Motor Proficiency. Post-hoc tests using the Bonferroni correction were carried out for subsequent multiple comparison. The level of significance for all statistical tests was set at $p < 0.05$. All statistical analysis was conducted through the statistical package for social studies (SPSS) version 25 for windows (IBM SPSS, Chicago, IL, USA).

III. RESULTS

Participant's characteristics:

Table (1) showed the participants characteristics of both groups. There was no significant difference between both groups in the mean age and BMI ($p < 0.05$).

Table (1): Comparison of the mean age and BMI between both groups.

	Group A	Group B	
	x̄±SD	**x̄±SD**	**value**
Age (years)	10.6 ± 2.5	10.5 ± 3.1	0.793
BMI (kg/m²)	16.8 ±1.2	17.1 ± 3.1	0.873

$\bar{x}\bar{x}$, Mean; SD, Standard deviation; MD, mean difference; p-value, Level of significance;

Effect of treatment on peak torque of knee flexors, Bruininks–Oseretsky Test of Motor Proficiency:

Mixed MANOVA revealed a significant main effect of treatment (Wilks' Lambda = 0.513; F = 12.349, p = 0.001, η^2 = 0.487). There was a significant main effect of time (Wilks' Lambda =0.018 ; = 696.825,

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p = 0.001, η^2 = 0.982). There was significant interaction of treatment and time (Wilks' Lambda = 0.406; F = 19.026, p = 0.001, η^2 = 0.594). Table 2 showed descriptive statistics of peak torque of knee flexors, Bruininks–Oseretsky Test of Motor Proficiency and the significant level of comparison between groups as well as significant level of comparison between before and after treatment in each group.

Within and between group comparison

There was a significant increase in the peak torque of knee flexors, Bruininks–Oseretsky Test of Motor Proficiency after treatment compared with that before treatment within studied groups (p < 0.05). There was no significant difference between groups (A) and (B) in both dependent variables before treatment (p > 0.05). A significant increase was found in peak torque of knee flexors, Bruininks–Oseretsky Test of Motor Proficiency of group (B) after treatment compared with that of group (A) (p < 0.05) (table 2).

Table 2: Mean value of peak torque of knee flexors, Bruininks–Oseretsky Test of Motor Proficiency pre and post treatment in both groups.

	Before treatment			**After treatment**			**Before vs After**	
	Group A	Group B		Group A	Group B		Group A	Group B
	x̄± SD	x̄±SD	P value	x̄±SD	x̄±SD	P value	P value	P value
Peak torque of Knee flexors	60.35 ±2	62.46 ± 8.33	0.401	73.42 ± 5.18	84.26 ± 5.22	0.001*	0.001**	0.001**
Bruininks–Oseretsky Test of Motor Proficiency	41.42 ±7	42.06 ± 3.01	0.589	68.5 ± 3.29	78.2 ± 5.49	0.001 *	0.001*	0.001*

x̄x̄: Mean; SD: Standard deviation; p-value: Probability-value; * Inter-group comparison; ** intra-group comparison of the results pre- and post-program.

IV. DISCUSSION

The purpose of this study was to compare between the effect of isokinetic training versus PBWST on muscle strength of knee flexors and balance in hemiparetic cerebral palsy children. Results revealed significant improvement in the mean values of all measuring variables after treatment in both groups but there was significant difference in favor of the group received isokinetic strength training. Comparing between pre and post treatment mean values of the balance and muscle strength parameters in the both groups showed significant improvement at the end of the treatment program. This improvement could be attributed to increasing in muscle strength and enhanced coordination between both sides of the body. The use of the affected limb of hemiparetic children in different activities is hindered due to motor and sensory impairments that affect the function [(15).] Hemiparetic children prefer using the less affected side in the different daily living activities which increase the disuse problem of the affected side [(16)]. Muscle strength and balance remain to be a problem for the children with age range between 10 and 14 years. Facilitation of motor skills explain the improvement in both groups after the

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successive 12 weeks of training that was directed to enhance function. Trahan and Malouin [17] and Tsorlakis et al., [18] stated that when the repetition and time of treatment session increase that lead to significant and long-lasting changes in muscle strength, alignment of posture, muscle tone and gross motor skills but to gain full success this depends on commitment of the involved persons around the children and on the children themselves. The improvement in the group received PBWS could be attributed to the combined effect of a designed exercise program and sensory stimulation through PBWS or suspension therapy which worked at a multi-system level: the visual, proprioceptive, and vestibular inputs leading to muscle tone modulation that encouraged the appearance of normal motor response, improved the sensorimotor integrative process and enhanced the relationship between the sensory and motor system. The rehabilitation training of BWSTT is helpful in making changes of the muscle architecture which contributes to the potential of the force generation of the muscle [19]. BWSTT improved measures of endurance, functional gait and balance in a small sample of ambulatory school-aged children with CP who were in different diagnostic categories and age groups. There was a considerable improvement in the function of children diagnosed with hemiplegia and diplegia after undergoing intensive two-week BWSTT program which their initial scores were low[20]. In addition, the work of Holt et al. [21] added that, patients receiving treadmill training had increased walking endurance, gait stability, muscle function, aerobic fitness and balance which leaded to increasing their activity levels. The improvement in all measured variables after treatment recorded in favor of the group receiving isokinetic strength training program could be attributed to increase the mean peak torque output of skeletal muscle group after isokinetic training protocols. The good activation of the motor neuron pool and decrease fatigue of muscle (neural adaptations) is the cause of the significant improvement in strength after the isokinetic training protocol which causes significant increase in muscle performance [22]..This agreed with previous studies stated that the isokinetic training protocol evoked greater changes in thigh muscle strength compared with isotonic training protocol, which is reflected in greater changes in the ipsilateral concentric ratio [23]. Additionally, it resulted in trends of improvement in capacity for walking and balance. Also, this is supported by Fowler and Nwigwe [24] who mentioned that an appropriate motor response for postural balance control requires an intact neuromuscular system and adequate strength of the muscles to be able to adjust the center of mass within the base of support when balance is disturbed. Strength training protocol mechanism to improve the motor activity and balance is likely caused by neurophysiological adaptations and microscopic alternation of muscle properties of the targeted muscles as well as neuromuscular integration and improvement of muscle strength. This explanation is supported by the findings of Fowler et al., [25,26] who reported that, strength-training in individuals with CP results in neurophysiological changes such as increased co-activation of antagonist muscles, promote synergist muscles performance, enhancement of spinal cord connections and cross education bilateral effect. Those neural changes are believed to continue with training, helping to improve movement. Similarly, Shepherd et al., [27] mentioned that task specific strength training protocols enhances reorganization of the cortical areas in the brain during a specific task. In other words, it causes other benefits more than simply increasing the force-generation capacity of certain muscles. Alegre et al., [28] and Reeves et al., [29] have also illustrated that strength training for a period between 12 to14 weeks in young and older adults resulted in increases in cross section area and thickness (hypertrophy) of the muscles which reflected as increase in the cross section of muscle due to an increase in the number (hyperplasia), or the size (hypertrophy) of the muscle fibers. Additionally, Dos Santos et al., [30] and Taylor et al., [31] reported that progressive strength training is believed to affect the muscle metabolic capability and consequently, induced increase in muscle strength through morphological and metabolic acclimation. They suggested that this type of training enables the improvement of neural control commands as well as increases in in strength thus, improvements in functional

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activities. LeMura et al., [32] stated that limited active performance is a frequent problem in CP resulting in structural changes of the muscle in which type I muscle fibers (oxidative) change their structure to type II (Fast twitch). They added that, proper strength training causes changes in muscle structures as it leads to transformation and alternations in different types of muscle fibers. In different words, the oxidation of fast twitch muscle fibers increases with proper muscle training. Our results are consistent with Dodd et al., [33] who studied the effects of a home-based, six-week strength-training program on the strength of lower limb muscles and physical activity of young people with spastic diplegic CP. They concluded that, strength training can lead to long lasting changes in the strength of the key muscles of the lower-limbs that have an observed impact on the daily activities of young people with CP. Likewise, Kannabiran et al., [34] examined the effectiveness of functional resistance training in improving motor function in preschool children with spastic diplegia. Their results explained significant improvement in gross motor function particularly in standing, walking, running and jumping after 10 weeks of functional strength training program. Additionally, Blundell et al., [27] concluded that task-specific strength training for short time can improve both muscle strength and functional performance after examining the effect of short duration functional strength training in children with CP.

Study limitation

The current study had several limitations. First, participants were delimited to children with hemiparesis and not all subtypes of CP make it difficult to generalize the findings to all children with CP. Second, the small sample size.

V. CONCLUSION

The results of the current study suggested that both isokinetic strength training program and partial body weight-supported treadmill training have the ability to make a significant improvement in muscle strength and balance in hemiparetic cerebral palsy children. Moreover, the partial body weight-supported treadmill training has been realized as being effective as but to less extent than isokinetic strength training program.

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Conflict of interest

The authors have no conflict of interest to declare

Authors' contributions

The authors testify that all persons designated as authors qualify for authorship. A.A. , A.A. and H.G. was involved in the study concept and design, interpretation of data, and writing of the initial and final drafts of the article. H.G. and H.A. were involved in data acquisition and analysis. All authors have critically reviewed and approved the final draft and are responsible for the content and similarity index of the manuscript.

REFERENCES

1. 1-Ayalon M, Ben-Sira D, Hutzler Y and Gilad T. Reliability of isokinetic strength measurements of the knee in children with CP. Dev Med Child Neurol., 2000,42: 398-402.
2. 2- Robert J, Steven E, Peter L and Beth T. Probability of walking, wheeled mobility, and assisted mobility in children and adolescents with cerebral palsy, Journal of development medicine& development; 2010, 52(1): 66-71.

DOI: 10.37200/IJPR/V24I8/PR280286
Received: 21 Jan 2020 | Revised: 08 Feb 2020 | Accepted: 14 Mar 2020

3. 3- Berry E, Guiliani C and Damiano D. Intrasession and intersession reliability of hand-held dynamometry in children with CP. Phys Ther. , 2001, 81: 352-356.
4. 4- Jennifer B, Teresa O, Robert G. Supporting young adults with hemiplegia: services and costs. Health Social Care Commun J., 2001, 9(1):51–9.
5. 5- LeClair D, Pollock B, Elliott D. Movement preparation in adults with and without cerebral palsy. Am J Ment Retard, 1993, 97:628–33.
6. 6- Damiano D, Vaughan C and Abel M. Muscle response to heavy resistance in children with spastic CP. Dev Med Child Neurol., 1995, 37: 731-739.
7. 7-Brown L. Isokinetics in human performance. United States, Human Kinetics 2000, p. 3–21 and 301, 2.11- Damiano D., Abel M., Panunzio,M. and Roman, J.: Interrelationships of strength and gait after hamstrings lengthening. J Ped Orthop., 1999,19: 352-358.
8. 8- Dale B, Harrelson G, Leaver-Dunn D. Principles of Rehabilitation. In: Andrew J, Harrelson G, Wilk K, editors. Physical Rehabilitation of the Injured Athlete. Saunders; 2004:160–83.
9. 9 - Ganesan T, Sathyaprabha A, Gupta and Pal K. Effect of partial weight-supported treadmill gait training on balance in patients with Parkinson disease. The Journal of Injury, Function, and Rehabilitation, 2014, 6 (1): 22–33.
10. 10- Davis B, Bull R, Roscoe D. Physical Education and the Study of Sport. 4th ed. Mosby: Edinburgh; 2000, l30–150.
11. 11- Bohannon R and Smith M. Inter-Reliability of Modified Ashworth Scale of
12. Muscle Spasticity. J. Physical Therapy, 1987, 67 (2):206-208.
13. 12- Holland L and Mc Cubbin J. Reliability of concentric and eccentric muscle testing of adults with CP. Physical Activity Quarterly, 1994, 11: 261-274.
14. 13.Bruininks R and Buininks B. Bruinink-Oseretsky Test of Motor Proficiency Manual. 2nd edition, NCS Pearson Inc., Minneapolis, 2005.
15. 14- Damiano D, Martellotta T, Quinlivan J and Abel M. Deficits in eccentric versus concentric torque in spastic CP. Med Sci sports Exc.,2001, 33: 117-122.
16. 15- Brian J, Christine I, Hyam B and Leeanne C. Modified constraint-induced movement therapy or bimanual occupational therapy following injection of Botulinum toxin-A to improve bimanual performance in young children with hemiplegic cerebral palsy: a randomised controlled trial methods paper. BMC Neurol. 2010; 10: 58.
17. 16-Ehab M, Hebatallah M and Samah A. Effect of modified constrained induced movement therapy on improving arm function in children with obstetric brachial plexus injury. Egyptian Journal of Medical Human Genetics. 2013, 14: 299-305.
18. Trahan J and Malouin F. Intermittent intensive physiotherapy in children with cerebral palsy: a pilot study. Dev Med Child Neurol. 2002, 44:233-*9*.
19. Tsorlakis N, Evaggelinou C, Grouios G and Tsorbatzoudis C. Effect of intensive neurodevelopmental treatment in gross motor function of children with cerebral palsy. Dev Med Child Neurol. 2004, 46:740-5.
20. Thom J, Morse C, Birch K and Narici M. Influence of muscle architecture on the torque and power velocity characteristics of young and elderly men. European Journal of Applied Physiology.2007, 100: 613–619.
21. Fowler E and Nwigwe A. Intensive two-week BWSTT program on gait with CP. Dev Med Child Neurol; 2000, 42: 182-189.
22. Holt K, Butcher R and Fonseca S. Stability and balance of children with spastic hemiplegic CP. Ped Phys Ther; 2000, 12: 50-61.
23. Engsberg J, Ross S and Park T. Combined effect of a designed exercise program and sensory stimulation through PBWS or suspension therapy for spastic CP. Journal of Neurology.1999, 91: 727-732.
24. Engsberg J, Ross S and Olree K. Ankle spasticity and strength in children with spastic diplegic CP. Dev Med Child Neurol; 2000, 42: 42-47.
25. Fowler E and Nwigwe A. The effect of quadriceps femoris muscle strengthening exercises on spasticity in children with CP. Phys Ther., 2001, 81: 1215-1223.
26. Fowler E, Staudt L and Greenberg M. Lower-extremity selective voluntary motor control in patients with spastic cerebral palsy: increased distal motor impairment. Dev Med Child Neurol. 2010,52:264-9.
27. Fowler E, Staudt L, Greenberg M and Oppenheim W. Selective Control Assessment of the Lower Extremity (SCALE): development, validation, and inter rater reliability of a clinical tool for patients with cerebral palsy. Dev Med Child Neurol. 2009, 51:607-14.
28. Blundell S, Shepherd R, Dean C, Adams R. and Cahill B. Functional strength training in cerebral palsy: a pilot study of a group circuit training class for children aged 4-8 years. Clin Rehabil. 2003, 17:48-57.
29. Alegre L, Jimenez F, Gonzalo-Orden J, Martin-Acero R and Aguado X.: Effects of dynamic resistance training on fascicle length and isometric strength. J Sports Sci. 2006, 24:501-8.
30. Reeves N, Maganaris C, Longo S, and Narici M. Differential adaptations to eccentric versus conventional resistance training in older humans. Exp Physiol. 2009, 94:825-33.

DOI: 10.37200/IJPR/V24I8/PR280286
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31. Dos Santos A, da Costa C, Golineleo M and Rocha N. Functional strength training in child with cerebral palsy GMFCS IV: case report. Dev Neurorehabil. 2013, 16:308-14.
32. Taylor N, Dodd K and Damiano D. Progressive resistance exercise in physical therapy: a summary of systematic reviews. Phys Ther. 2005, 85:1208-23
33. LeMura L and von Duvillard S. Clinical Exercise Physiology. Application and Physiological Principles. Philadelphia: Lippincott Williams & Wilkins. 2004, 235-8.
34. Dodd K., Taylor N. and Graham H. A randomized clinical trial of strength training in young people with cerebral palsy. Dev Med Child Neurol. 2003, 45:652-7.
35. Kannabiran B, Nandhini K and Nagarani R. A Study to Analyze the Effectiveness of Functional Strength Training in Improving Gross Motor Function among the Children with Spastic Diplegic Cerebral Palsy. Int J Neurorehabilitation, 2016, 3:239.