

ORIGINAL ARTICLE

# Endurance exercises versus treadmill training in improving muscle strength and functional activities in hemiparetic cerebral palsy

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## KEYWORDS

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Muscle weakness;  
Treadmill training;  
Balance

**Abstract** Weakness of the sound side in hemiparetic cerebral palsy is one of the serious complications which affect these children. Many children with hemiparetic cerebral palsy have diminished muscle power in the neglected sound side, and the application of strengthening exercises aim to improve the muscle strength and function activities and so may be helpful in the management of such cases. In this study, endurance exercises and treadmill training was conducted to investigate its effect on increasing the strength of the quadriceps femoris and hamstring muscles of the sound side in spastic diaplegic cerebral palsy in comparison to the effect of an endurance exercise program. Thirty spastic hemiparetic children were the sample of this work. There were divided randomly into two equal groups. The ratio of peak torque of quadriceps femoris muscle and the hamstring muscle and balance were measured before and after six months of the application of the treatment program. Group A received the physiotherapy program and treadmill training, while group B received endurance exercise in the form of DeLorme resistance exercise in addition to the same physiotherapy program given to group A. Significant improvement were observed in all measuring variables when comparing the post-treatment results in both groups.

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*Conclusion:* Walking training may be considered as one of the most helpful methods in management of muscle weakness in the sound side and balance in spastic hemiparetic cerebral palsied children.

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## 1. Introduction

Cerebral palsy (CP) describes a group of disorders of posture and movement that occur as a result of a non-progressive disturbance in the developing fetal or infant brain. The neurological disturbance associated with CP is non-progressive, secondary musculoskeletal impairments, pain, and physical fatigue are thought to contribute to changes in motor function in adolescents and adults with CP that may include a decline in walking [1]. Cerebral palsy is the most common cause of disability in childhood and may affect the child on several health dimensions; the motor signs include primary neuromuscular deficits, such as spasticity, muscle weakness and decreased selective motor control, and secondary musculoskeletal problems, such as bony malformations and contractures. Cerebral palsy is often accompanied by disturbances of perception, cognition, communication, and behavior [2]. Cerebral palsied children are characterized by abnormal muscle tone, posture reflexes, or motor development and coordination. There are also bone deformities and contractures. The classical symptoms are spasticity, involuntary movements, unsteady gait, and problems with balance [3]. Hemiplegic cerebral palsy is the most common form of cerebral palsy, affecting up to one person per thousand of live births [4]. Spastic hemiplegia accounts for more than a third of all cases of CP, and the resulting impairments to extremities affect functional independence and quality of life [5]. The term hemiplegic cerebral palsy comprises pathological entities that results in limb weakness on one side of the body. Also in premature infants, the most common cause is periventricular hemorrhagic infarction. In term infant, the underlying causes are often cerebral malformations, cerebral infarction, and intracerebral hemorrhage, the usual concern that brings infants with hemiplegia from birth for a neurological evaluation is delayed crawling or walking [6]. Spastic hemiplegia is characterized by spasticity in the arm and leg on one side of the body and most walk independently but there is wide variation in the function of the affected arm and hand [7].

Children with hemiplegic cerebral palsy compensate for those problems by developing compensatory movement patterns, which allowed to persist and often developed into orthopedic and functional problems, so the goal of physical therapy is to minimize development of these compensatory movement patterns. Therapy is directed towards improvement of the basic motor co-ordination and correction of physical problems commonly associated with this syndrome [8]. Treadmill training was used for children with cerebral palsy to help them to improve balance and build strength of their lower limbs so they could walk earlier and more efficiently than those children who did not receive treadmill training. Some studies showed that treadmill training helped children with cerebral palsy to walk about 101 days earlier than children who did not train by treadmill [9]. Isokinetics has been used in testing and performance enhancement for over 30 years. In 1967, some authors

introduced the concept of isokinetic exercise training and rehabilitation. Now, isokinetic testing is a commonly utilized tool for assessment of muscular strength in the orthopedic and sports medicine setting. Isokinetics are frequently chosen because of their inherent patient safety, objectivity, and reproducibility in testing measures. Objective isokinetic testing provides testing the entire lower extremity kinetic chain or performs isolated isokinetic testing [10]. Isokinetic represents a match between mechanically imposed velocity and the subject movement that contacts against a controlled angular velocity. There for, through accommodating resistance the muscle contracts at its maximal capability at all points throughout the range of motion [11]. Endurance exercises are considered as exercises that are done in a time limit of a person's ability to maintain either a specific force or power involving muscular contractions [12]. Several studies have found out that endurance exercises can greatly increase strength in the muscles by adding specific weight training to their programs [13]. Strength development through endurance training is important for the prevention and rehabilitation of injuries and for improving sport performance [14]. Strength is also important for maintenance of functional capacity; with aging or injury, there is catabolic breakdown of the muscle connective tissue, resistance training presents the only natural method to offset such wasting conditions [15]. Resistance exercise is a very common type of endurance training, which can improve the muscle strength and gives a good balance to our bodies [16]. Therefore, the goal of this study was to examine the potential of daily treadmill training in improving muscle strength of the sound side and so, improving function activities in hemiparetic cerebral palsied children.

## 2. Patients, instrumentation and procedures

### 2.1. Patients

Thirty hemiparetic cerebral palsied children (12 left and 8 right sides) represented the sample of this study. They were chosen from both sexes (12 males and 8 females), from EI-Nabawy El-Mohandas Institute of Poliomyelitis and Physical Medicine at the area of Imbaba, Giza, Egypt. Their ages ranged from 12 to 15 years ( $X'13.73 \pm 0.85\text{Yr.}$ ). They were able to understand any command given to them, with an IQ level within normal range. Children participated in the study were free from any associated disorders other than spasticity. The degree of spasticity was determined according to the modified Ashworth's scale [17] to be within the range of 1<sup>+</sup> and 2 grades. They were free from any structural changes in the joints of the lower limbs; however there were few degrees of soft tissue tightness. They were able to walk independently with an abnormal gait pattern. The study sample was divided randomly into two groups of equal number (A and B). Double blind evaluation was conducted for each child individually before and after six months of treatment. Group A received a daily designed exercise ther-

apy program and treadmill training while group B received daily endurance exercises in the form of DeLorme resistance exercise, in addition to the exercise therapy program given to group A.

## 2.2. Instrumentation

### 2.2.1. For evaluation

**2.2.1.1. Biodex dynamometer.** The ratio of peak torque of quadriceps femoris muscle and the hamstring muscle of both lower limbs were measured by the dynamometer (Biodex Medical System Inc. Shirely, New York). Biodex dynamometer is one of the recent computerized devices that were available for the current study in the Faculty of Physical Therapy, Cairo University. It is one of the most comprehensive computer device provided with attachments and isolation straps for every part of the body. Computer system is provided with a menu of programs which controlled through the control panel or the computer software programs and a testing chair for testing the subjects. The position of the dynamometer can be controlled, it can be rotated horizontally, tilted, and its height can be adjusted according to the test. The system requires all information to be entered through a typewriter style keyboard into its processor. It provides testing data, graph recording and printed results regarding advanced information in the area of torque, speed, time, motion, work, power, peak torque, ratio of peak torque to body weight, range of motion, and different ratios. The validity and accuracy of the Biodex isokinetic dynamometer has been investigated under static and dynamic conditions with satisfactory results [18].

**2.2.1.2. Functional scale.** Bruiniks–Oseretstity test of motor proficiency was chosen as a functional scale for evaluation. Balance evaluation: eight items ranging in difficulty from standing on one leg to stepping over on a balance beam [19].

### 2.2.2. For treatment

**2.2.2.1. Motorized treadmill.** Its model is a treadmill 770 (E.220V, 50HZ, 10A, and 2.2 kilowatts (KW), that allow person to exercise in a safe environment with adequate space, and with simple finger tip control of all important parameters; including speed; aiming for motor rehabilitation.

## 2.3. Procedures

### 2.3.1. For evaluation

**2.3.1.1. Isokinetic (Biodex dynamometer).** All tests were performed at the same time of day for each subject to reduce the effect of any variations. Age of each subject was recorded; also height and weight were measured by scale associated with the Biodex system. The dominant quadriceps femoris and hamstrings muscles were determined by the subjects' leg preference in kicking [20]. Position of the subject: Each subject was allowed five minutes of warming up before the evaluation. Then the subject was placed in the position seat with his hip and knee flexed at 110 degrees and 90 degrees, respectively. As inferred that the most appropriate position for isokinetic knee testing is sitting position with hip and knee flexed at 110 and 90 degrees respectively [21]. The subject was attached in position after adjustment of depth of the seat, the height of the dynamometer and the length of the support lever that allowing the axis

rotation of the dynamometer to be aligned to the most inferior aspect of the lateral femoral epicondyle and lower leg attached to the dynamometer lever arm above the medial malleolus by inches. Wide strap was placed diagonally on the subject chest. Thigh strap attach to the seat was used to stabilize the thigh [22]. With each subject identical positioning of the seat, back rest, dynamometer head, and lower arm length were used before and after training [23]. The subject data were entered to the computer program data base, test protocol was set from the soft ware program; concentric bilateral protocol with the extension and flexion of the knee range of motion was set from (90 degrees–0 and 0–90 degrees) with angular velocities 60 degrees per second and 180 degrees per second. The limb was weighed before testing by the Biodex's automatic limb weighing system to correct for the gravitational effect on torque value. Each subject was asked to hold in two sides of the chair with both hands during the testing procedures. The subject was allowed to do two trials before actual test, and then was instructed to give maximum voluntary concentric torque via verbal command to kick as hard and fast as he/she can, then relax. This test procedure composed of three sets each set of one maximum concentric contraction of quadriceps femoris and hamstring muscles, with rest of 30 s between each set. The mean ratio of peak torque to body weight of the three tests was taken.

**2.3.1.2. Bruininks–Oseretsity test for motor proficiency (balance test).** General directions:

1. The subjects were required to wear crepe-soled shoes.
2. Prepare the target (big colored circle) and a walking line.
  - a. Fasten the target to the wall with masking tape so that the lowest point on the circumference is at the subject's eye level.
  - b. Make a walking line by taping an 8-foot (2.4 m) piece of masking tape to the floor in front of the target, about 3 m from the wall. The walking line should be as straight as possible.
3. For all items, therapist must stand next to the subject to observe performance most efficiently.
4. For all items, administer a second trail only if the subject does not achieve a maximum score on the first trial. When a second trial is necessary, the subject's errors should be pointed out before the second trial is administered.

Item (1): Standing on preferred leg on floor:

Each subject was asked to stand on preferred leg on the walking line, looking at the target with hands on hips, and with other leg bent so that it is parallel to the floor. The subject must maintain the position for 10 s to achieve a maximum score.

Item (2): Standing on preferred leg on a balance beam:

Each subject was asked to stand on preferred leg on the balance beam, looking at the target with hands on hips, and with other leg bent so that it is parallel to the floor. The subject must maintain the position for 10 s to achieve a maximum score.

Item (3): Standing on preferred leg on a balance beam-eye closed:

Each subject was asked to stand on preferred leg on the balance beam, with eyes closed, hands on hips, and with other leg bent so that it is parallel to the floor. The subject must maintain the position for 10 s to achieve a maximum score.

Item (4): Walking forward on walking line:

Each subject was asked to walk forward on the walking line in a normal walking stride with hands on hips. The subject must walk forward six steps to achieve a maximum score.

Item (5): Walking forward on balance beam:

Each subject was asked to walk forward on the balance beam in a normal walking stride with hands on hips. The subject must walk forward six steps to achieve a maximum score.

Item (6): Walking forward heel-to-toe on walking line:

Each subject was asked to walk forward on the walking line heel-to-toe, with hands on hips. The subject must make six consecutive steps correctly to achieve a maximum score.

Item (7): Walking forward heel-to-toe on balance beam:

Each subject was asked to walk forward on a balance beam heel-to-toe, with hands on hips. The subject must make six consecutive steps correctly to achieve a maximum score.

Item (8): Stepping over response speed stick on balance beam:

Each subject was asked to walk forward on the balance beam stepping over the response speed stick held at the middle of the beam by the examiner. The subject walks in a normal walking stride with hands on hips. The score is recorded as a pass or a fail.

#### 2.4.1. For treatment

Group A received a designed exercise program which was conducted daily for six successive months, including: neurodevelopmental technique, proprioceptive training, facilitation of righting and equilibrium reactions, faradic stimulation on the antispastic muscles of the hemiparetic side, stretching exercise for the muscles liable to be tight, strengthening exercises for the antispastic muscles, and gait training in closed and open environment and treadmill training program as follows: Instructions at first and warming up for 5 min before starting the procedures. Children must be upright and so their feet were flat on the treadmill belt and the height of the hand rails were adjusted to suit every child. It is important to try to keep the child looking forward as much as possible to stimulate the conditions of independent walking. At first the child must hold the hand rails by two hands then by one hand till he/she gains the self confidence, and walked on treadmill without support. Cooling down for five minutes after ending the procedures. Special attention was also given to the unaffected side and to the trunk. In addition to the designed physical therapy program given to the control group, the group B received DeLorme resistance exercise technique; the children applied warming up for five minutes before starting procedure. Delorme technique is 10 Repetition Maximum (10 RM) in which the weight an individual could lift ten times through the full range [24]. In this system the 10 RM resistance was increased gradually over a limited series of repetitions (10 repetitions at 50% of the 10RM, 10 repetitions at 75% of the 10 RM and 10 repetitions at 100% of the 10 RM).

### 3. Measuring 10 RM

#### 3.1. For quadriceps femoris

Each subject sit on the edge of the plinth, fixation applied the Weight of the trunk, fixation on the thigh using belt above the knee joint to prevent the movement of the thigh, his hands are beside his trunk. The training weight (sand bag) was applied at the same position as the isokinetic test pad

to the limb (just above of the dominant leg). It would be equivalent to 80% of the peak torque. The measurement of the peak torque was obtained from the isokinetic testing, and then peak torque was divided by the movement arm of the testing machine to obtain the force measurement. This force value was multiplied by 0.8 [25]. The subject was asked to extend his knee to full extension. If the subject found this weight too difficult by not completing the 10 repetitions, or too easy by performing more than ten repetitions, the weight was adjusted to a true 10 RM by the examiner [26]. If the subject was able to complete 12 repetitions, add 5% to the weight but if the subject was unable to complete at least 8 repetitions, decreasing 5% of the weight [27]. The subjects performed all three bouts at each exercise session; the time of contraction was equal to the time of relaxation (6 s). This was arranged using stop watch, with the rest between each bout 1–2 min. The exercises procedure was repeated three times per week for 3 months [16].

#### 3.2. For Hamstring muscle

Subjects were lying in a prone position on a plinth with straight legs and 10 degrees of hip flexion. The hip stabilized or supported by a therapist hand. The resistance pad weight was resting on the lower leg about 10 cm above the Achilles tendon. The subject was asked to flex the knee joint to an angle of approximately 100 degrees and subsequently lowered the weight again. The hip joint angle was kept constant through out the entire range of motion. In all repetitions exercises, the range of motion was from full knee extension to a knee joint angle of approximately 100 degrees. The exercises procedure was repeated three times per week for 3 months [16]. Peak Torque (PT) of the quadriceps femoris and hamstring muscles for each subject were measured over two trials (around five times), and then the mean value was calculated.

### 4. Results

The raw data of isokinetic measured and balance test in spastic hemiplegic cerebral palsied children were statistically treated to determine the mean and standard deviation of the measuring variable, for the two groups before and after six months of treatment. Student *t*-test was then applied to examine the significance of treatment procedures conducted in each group. The obtained results in this study revealed no significant differences when comparing the pre-treatment mean values of the two groups. Significant improvement was observed in the measuring variable of the two groups (A and B), when comparing their pre and post-treatment mean values.

As revealed from Table 1 and Fig. 1 significant improvement was observed in the mean value of *isokinetic measured* in group (A) at the end of treatment as compared with the corresponding mean value before treatment ( $P < 0.01$ ).

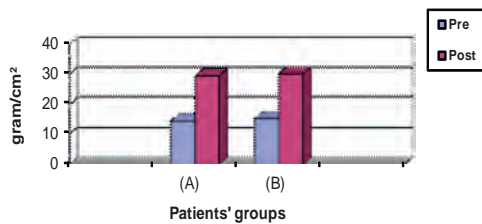
Also, Table 1 and Fig. 1, showed a significant improvement in the mean value of *isokinetic measured* in group (B) at the end of treatment as compared with the corresponding mean value before treatment ( $P < 0.01$ ).

As revealed from Table 2 and Fig. 2, significant improvement was observed in the mean value of *balance measured* in group (A) at the end of treatment as compared with the corresponding mean value before treatment ( $P < 0.01$ ).

**Table 1** Post-treatment mean values of isokinetic measured (gram/cm<sup>2</sup>) for groups A and B in extension at 60 degrees.

	Group A		Group B	
	Pre	Post	Pre	Post
$\bar{X}$	14.055	29.5	15.321	30.145
$\pm$ SD	$\pm$ 1.934	$\pm$ 3.985	$\pm$ 1.783	$\pm$ 3.872
<i>t</i> -test	5.48		6.34	
<i>P</i> -value	0 < 0.01		< 0.01	
Sig.	Significant		Significant	

$\bar{X}$ : Mean, SD: Standard deviation, *P*-value: Level of significance, Sig.: Significance.

**Figure 1** Illustrating the pre and post-treatment mean values isokinetic measured (gram/cm<sup>2</sup>) for groups A and B.**Table 2** Post-treatment mean values of balance measured (points) for groups A and B.

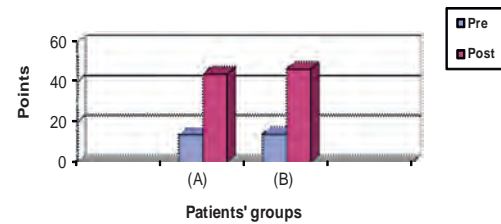
	Group A		Group B	
	Pre	Post	Pre	Post
$\bar{X}$	13.633	44.086	14.032	46.688
$\pm$ SD	$\pm$ 3.459	$\pm$ 40.055	$\pm$ 3.267	$\pm$ 4.345
<i>t</i> -test	4.98		5.01	
<i>P</i> -value	0 < 0.01		< 0.01	
Sig.	Significant		Significant	

$\bar{X}$ : Mean, SD: Standard deviation, *P*-value: Level of significance, Sig.: Significance.

Also, Table 2 and Fig. 2, showed a significant improvement in the mean value of *isokinetic measured* in group (B) at the end of treatment as compared with the corresponding mean value before treatment ( $P < 0.01$ ).

## 5. Discussion

The purpose of this study was to study the effect of treadmill training program on increasing the strength of the quadriceps femoris and hamstring muscles in hemiparetic cerebral palsy in comparison to the effect of an endurance exercise program. Thirty hemiparetic cerebral palsy children were randomly assigned into two groups of equal number; group A and group B. Group A received treadmill training program, and group II received endurance exercise in form of Delorme resistance exercise program. The results obtained from this study clearly demonstrated the effect of treadmill training in improving the muscle strength of the neglected sound side in hemiparetic cerebral palsy children, which attributed in increasing the bal-

**Figure 2** Illustrating the pre and post-treatment mean values balance measured (points) for groups A and B.

ance that played an important role in improving the children's function. In respect of the results of the present study, there was a significant improvement in the mean values of all measuring variables in the both groups A and B as compared with its pre-treatment results and the post-treatment results. Children with hemiparetic cerebral palsy have been viewed primary as paralysis of one side of the body rather than as motor delayed, they have not frequently been considered as candidates for physical therapy intervention [15]. Although most children of hemiparetic cerebral palsy eventually walk independently, they continue to evidence deficits in balance, co-ordination, and gait throughout childhood and adulthood [28]. Children with hemiparetic cerebral palsy perform poorly in measures of running speed, balance, visual motor control, strength, and overall gross and fine motor skills in comparison with the normal children of the corresponding age [29]. Clinical studies reported positive effects of treadmill training especially in patients with stroke. Although this training has not yet been widely used in clinical settings, several studies have demonstrated effects superior to those obtained by neurodevelopmental therapy intervention [30]. Strength of the quadriceps femoris and the hamstring muscles for sound side was done by using Biodex dynamometer (Isokinetic). It is one of the most objective methods used in muscle strength assessment. Concerning the superiority of treadmill training to regular intervention, two single case design studies showed that treadmill training was more effective than regular physical therapy program in increasing muscle strength and walking velocity for chronic hemiparetic subjects, treadmill training creates an environment that discourage the development of compensatory strategies compared with conventional gait training program [31]. Children with hemiparetic cerebral palsy learn to walk with their feet wide apart, knees stiff and feet turned in, weight is born on medial aspect of the feet, so the walking becomes painful and endurance decreased. Also they have poor balance, strength, visual motor control, shorter step length, stride length, high cadence, and slow velocity [32]. All these problems are due to hypertonia, and muscle weakness, so the purpose of this study is to try to minimize the effects of these abnormalities. This decrease muscle strength may be attributed to impairment of stability in hemiparetic cerebral palsy children, that affects the child's gait [33]. Children with hemiparetic cerebral palsy have predominance of primitive, spinally controlled muscle responses patterns over more centrally integrated and coordinated movement patterns that is because, poor myelination of the descending cerebral and brain stem neurons and also reduction in both number and connection of the neurons in higher nervous centers as motor cortex, basal ganglia, cerebellum and brain stem. [32]. After application of our exercise program, the mean values of the muscle peak torque after

application of the treatment program of group A and group B were increased, which means that there is a significant increase in this variable in both groups. Also in comparing the improvement of group A with that with group II after the application of treatment procedures, it was found that there was a significant difference between the two groups at  $P > 0.001$  in favor of group A. The result attributed to increase in muscle strength as a result of using specialized treadmill training program, this result come in agreement with some author [34] who reported that, the treadmill intervention offered repeated opportunities to improve the balance and build muscle strength in the lower limbs which are involved in the generation of more independent and mature walking. So the increase on the muscle strength enables the child with hemiparetic cerebral palsy to lift the swing limb into more flexion, so the hip flexion increases. In hemiparetic cerebral palsy children, the weakness of the hamstring muscle leads to loss of its counterbalancing action to GRFV extension movement, this leads to hyperextension of the knee joint (genu recurvatum). Moreover the weakness of the quadriceps leading to loss of its role which start from terminal swing and continue till initial contact this role at terminal swing is to extend the knee for creating a new step, so loss of this role makes the child forcibly extend the knee joint using the momentum leading to hyper extension of the knee joint. The quadriceps weakness diminishes the knee control and so the deficits in stance are most pronounced and compensations begin prior to weight acceptance at late swing and continue through the supporting activity of that limb. At terminal swing, the hip flexion leads to passive knee extension through the momentum transfer [35]. Furthermore the weakness of the quadriceps makes child leans by the trunk forward at initial contact, to increase the moment arm of the GRFV and so increase the extension moment created by it to compensate the loss of extension due to quadriceps weakness. The weak associated with hemiparetic cerebral palsy causes abnormal knee hyper extension throughout the gait cycle [36]. The results of the present study is supported by Carmeli et al. [37] who mentioned that, the knee flexion and extension isokinetic strength showed significant improvement after treadmill training, in elderly individual with hemiparetic cerebral palsy, also the dynamic balance performance was significantly improved by adapting suitable treadmill training program. Stepping in treadmill increases the strength of the lower limb muscles, so this intervention allowing for a more controlled leg action, and improvement in neuromuscular functioning and feedback loops [15]. Moreover the increase in balance may lead to proper knee position throughout the gait cycle, the hemiparetic cerebral palsy children lock their knees and widen their base of support to increase the balance, so when balance increased, this will lead to improvement in the knee position [38]. Increased exposure to the task developing muscle strength and improving balance may serve to enhance develop the motor program, so stepping in treadmill may enhance the motor control around the knee [39]. Decreased muscle control, body coordination, and postural reactions are areas known to be a problematic in hemiparetic cerebral palsy children, so enhancing the physical attributes of these children may contributing to improvement of kinesthetic awareness and motor control around the knee joint due to repetitive nature of the stepping over the treadmill [31]. Improvement in the knee position towards the normal position in the this sub phase (slight knee flexion), may be related to increase practice of the muscle interaction during training on treadmill, which would

heighten the sensory awareness of the knee joint and increase the muscle control around it, one of the treatment priorities to give greater emphasis on improving motor control, is to improve and promote muscle contraction [40]. Furthermore the significant improvement in the results of group A may be attributed to, improvement of the child ability to combine a pattern of stability and mobility because the treadmill provide postural stability with security so enable the child to improve balance and posture.

## 6. Conclusion

On the bases of the present data, it is possible to conclude that the combined application of the endurance exercise in the form of DeLorme resistance exercise and treadmill training is an effective therapeutic modality for improving muscle strength and functional activities of the unaffected part in hemiparetic cerebral palsy.

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