Treadmill Training with Partial Body-Weight Support and Functional Electrical Stimulation in Muscle Power and Balance on Hemiparetic Cerebral Palsy Children

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ABSTRACT

Background and Purpose: *Treadmill training with harness support is a promising, task-oriented approach to restoring locomotor function in people with post stroke hemiparesis. The purpose of this study was to evaluate the effects of the combined use of functional electrical stimulation and treadmill training with body-weight support on walking functions and voluntary limb control in people with chronic hemiparesis.* ***Subjects:*** *Thirty hemparetic cerebral palsy children who were ambulatory after chronic stroke were evaluated.* ***Results:*** *The ratio of peak torque of quadriceps femoris muscle and the hamstring muscle and balance were measured before and after three months of the application of the treatment program.* ***Conclusions:*** *The combined use of functional electrical stimulation and treadmill training with body-weight support led to an improvement in motor recovery and seemed to improve the gait pattern of subjects with hemiparesis, indicating the utility of this combination method during gait rehabilitation.*
Key words: *Cerebral palsy, Hemiparesis, Gait, Treadmill.*

INTRODUCTION

Gait restoration is a major goal in poststroke neurological rehabilitation. For this reason, the recovery of independent walking is important in rehabilitation studies. Gait training on a treadmill with body-weight support (BWS) has received special attention. It consists of a suspension system to which a patient is connected so that weight shifting, balance, and stepping can be controlled; walking is facilitated by a treadmill[39]. Several studies[23,38,39] with promising outcomes have shown the feasibility of supported treadmill ambulation training in patients with stroke, but whether it is superior to other gait therapies is still under dispute[28]. According to Visintin and Barbeau[38], partial unloading of the lower extremities (40%) in subjects with hemiparesis results in a straighter trunk and knee alignment during the loading phase, a decrease in double-limb support time, and an increase in single-limb support time, stride length, and speed. On the basis of research with quadrupeds, indirect evidence suggests that this rehabilitation strategy apparently drives spinal motor programs through proprioceptive inputs and modulates spinal rhythm generators[13,17]. Furthermore, it may lead to an improvement in sensory inputs and better functional motor reorganization[14,37].

According to the specificity of learning hypothesis[33], optimal motor learning occurs when performance during practice is well matched to that required for retention or transference conditions. According to Schmidt and Lee[34], motor learning reflects a neural specificity of practice because it involves the integration of motor information and sensory information available during practice. The specificity of learning hypothesis is consistent with advances in neurorecovery and neuroplasticity, which have shown that task-specific activity results in changes in the nervous system that correlate with improvements in motor behavior. Animal and human work in locomotor recovery is particularly relevant to the neurophysiological rationale for step training on a treadmill, given that it specifically addresses how neuroplasticity is induced by repetitive locomotor activity that attempts to optimize the sensorimotor experience of walking at the spinal and supraspinal levels[12,15,22].

People with hemiparesis often display abnormal gait patterns, such as equinovarus (excessive plantar flexion and inversion) or foot drop (excessive plantar flexion), in which selective control impairments are particularly prominent in the feet. During walking, a person's big toe and outer foot margin rub against the ground, thus putting the person at risk of sustaining sprains and other ankle injuries[30]. To minimize these patterns, electrical stimulation to correct spastic foot drop in hemiplegia was first applied by Liberson and coworkers in 1961[27]. Surface electrodes were applied to the peroneal nerve at the fibular head, and a stimulator worn around the waist was controlled by a switch in the heel of the shoe worn on the affected limb. When a subject raised the heel to take a step, the stimulator was activated. Stimulation stopped when the heel came in contact with the ground again. This system, known as the peroneal stimulator, produces foot dorsiflexion and eversion during the swing phase of gait. Other studies[6,21] have shown that peroneal stimulation to prevent foot drop in people with stroke improves walking, because it can provide critical practice of close-to-normal movements by electrically inducing muscle contraction and coordinated movements not volitionally possible.

Functional electrical stimulation (FES), based on the concepts described by Liberson et al.,[27] uses electrical signals to activate peripheral nerves and control functional movements. This technique makes use of afferent feedback during contraction, a process that, with a patient's help, may maximize motor relearning during active repetitive movement training[7,35].

The combined use of FES and partial BWS training was previously reported[10,11,18,24]. Hesse et al.,[24] investigated the use of multichannel electrical stimulation combined with treadmill training and partial BWS for subjects with hemiplegia. After the training program, improvements were seen in gait parameters such as speed, stride length, and cadence. That study had important implications for walking in subjects with hemiplegia and showed that the combined use of FES and partial BWS training improved their gait pattern. However, that study was carried out with subjects in both chronic and acute poststroke phases, when spontaneous functional recovery is to be expected[25]. In addition, FES was applied to the peroneal nerve and to the quadriceps femoris, biceps femoris, and pelvic stabilization muscles, according to the needs of each individual. The combined intervention with FES and partial BWS training was compared with conventional physical therapy (Bobath approach) as opposed to partial BWS training alone.

In a study of the combined use of FES and partial BWS training, Daly and Ruff[10] used intramuscular electrodes to stimulate lower-limb muscles, but no comparisons were made between combined therapies and one training method alone.

The aims of this study were: (1) to compare the effects of the combined use of FES and partial BWS training with the effects of partial BWS training alone on walking functions and voluntary limb control and (2) to investigate whether the use of FES in conjunction with partial BWS training provided any additional benefit to patients with chronic hemiparesis.

SUBJECT INSTRUMENTATIONS AND PROCEDURES

Subjects

Thirty hemiparetic cerebral palsied children (12 left and 18 right sides) represented the sample of this study. They were selected from both sexes (12 males and 18 females), from Faculty of Physical Therapy, Cairo University, Giza, Egypt. Their ages ranged from 12 to I5 years (XI3.73 ± 0.85Yr.). 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 (I + 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 three months of treatment.

Instrumentations

For evaluation:

Biodex dynamometer.

The ratio of peak torque of quadriceps femoris muscle and the hamstring muscle of both lower limbs were measured by the dynamometer. Biodcx dynamometer is computerized devices that was available for the current study in the Faculty of Physical Therapy, Cairo University. It is provided with attachments and isolation straps for every part of the body. 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.

Functional scale for balance evaluation

Balance evaluation: eight items ranging in difficulty from standing on one leg to stepping over on a balance beam[7].

For treatment

Motorized treadmill:

Its model is a treadmill 770 (E.220V, 50HZ, lOA, 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; in eluding speed; aiming for motor rehabilitation.

Procedures

Evaluation procedures

Isokinetic

(Biodex dynaniometet), All tests were performed at the same time of day for each subject to reduce the effect of any variations. Age, height and weight of each subject were recorded; measured by scale associated with the Biodex system. The dominant quadriceps femoris and hamstrings muscles were determined by the subjects' leg preference in kicking[24]. 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 isokineric knee testing is sitting position with hip and knee flexed at 110 and 90 degrees respectively[18]. The subject was attached in position after adjustment of depth of the scat, 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[10]. With each subject identical positioning of the seat, back rest, dynamometer head, and lower arm length were used before and after training[11]. 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 090 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 01'30 s between each set, The mean ratio of peak torque to body weight of the three tests was taken.

For treatment

Group A received a designed exercise program which was conducted daily for three successive months, including: neuro-developmental technique, proprioceptive training, facilitation of righting and equilibrium reactions. In addition to the designed physical therapy program given to the control group, the group B received 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 and treadmill training program as follows: Instructions at first and warming up for five 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 each 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.

Item (l): 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. 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. 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 scoreItem (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.

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 three months of treatment. 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 (1' < 0.0l).

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 (1' < 0.01).

Table (1): Comparison of Post–treatment mean values of isokinetic measured (gram/cm2) groups A and B in extension at 60 degrees.

	Group A		Group B	
	Pre	Post	Pre	Post
X	13.22	44.26	14.12	46.22
±SD	±3.9	±40.5	±3.7	±4.5
t-test	4.98		5.01	
p-value	0>0.01		0>0.01	

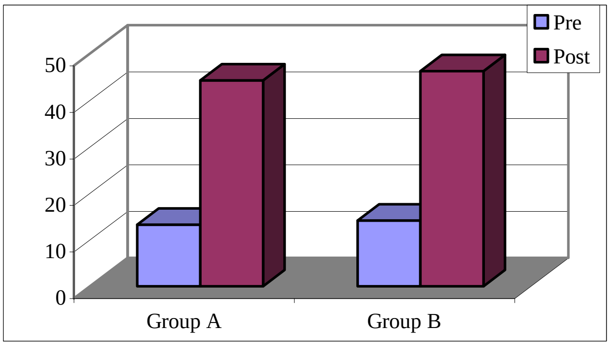

Fig. (1): Illustrating the pre and post treatment mean values isokinetic measured (gram/cm2) for groups A and B.

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

Table (2): Comparison of Post–treatment mean values of balance measured between both groups.

	Group A		Group B	
	Pre	Post	Pre	Post
X	14.055	29.5	15.321	30.145
±SD	±1.934	±3.985	±1.783	±3.872
t-test	5.48		6.34	
p-value	0>0.01		0>0.01	

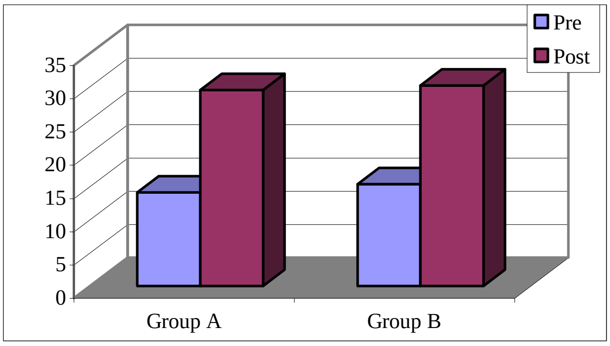

Fig. (2): Illustrating the pre and post treatment mean values balance measured (points) for groups A and B.

DISCUSSION

In this study, we showed that three months of treadmill training with BWS resulted in improvements in motor function and in gait variables in subjects with chronic hemiparetic stroke. However, three months of treadmill training with BWS combined with FES yielded better results with respect to isokinetic measure, and balance test. The improvement with BWS and FES was better than that obtained with BWS only.

Motor status is an important factor in gait quality and gait performance in hemiplegia and appears to be strongly dependent on the degree of motor recovery[5]. The STREAM results revealed considerable improvements in lower-limb motor function and in basic mobility. The items that changed, especially an improvement in walking ability during stimulation with FES, were related to gait restoration training. Although the upper extremities did not undergo specific training, gait is a full-body activity; that fact may account for the improved STREAM outcomes. Furthermore, hand control could have been influenced by the training, because the subjects were encouraged to hold onto the horizontal bars attached to the sides of the treadmill for stability; doing so could have influenced the test results (i.e., close hand from fully opened position and open hand from fully closed position.

The STREAM results indicated significant benefits for the subjects. Visintin et al.,[39] also reported change scores for the STREAM after 6 weeks of BWS training and after a three -month posttraining follow-up. According to Ahmed et al.,[1] the STREAM is preferred over other, related impairment or disability measures for monitoring recovery from stroke and focusing on the goals of immediate therapy. It can be used to monitor the reemergence of voluntary movement and basic mobility[1]. The subjects recruited for this study had significant gait disabilities, as profiled by the clinical measures of mobility, and all of them showed improvements not only in gait variables but also in specific components of basic mobility and voluntary limb movements. It is known that dynamic and static tasks are compromised after stroke, and the results of the present study suggest that training with partial BWS and FES could change motor activities in both types of tasks. Although the results of the present study are not conclusive in this regard, we hypothesize that training with partial BWS and FES also could improve the behavioral repertoire in everyday life, because the ability to perform functional activities is dependent on a person's motor ability[16,41].

Increasing evidence has suggested that treadmill training in older subjects with hemiparesis improves locomotor capabilities during over-ground walking[38] and motor relearning, because it provides task-oriented practice of walking and active repetitive movement training[7]. It has been suggested that through training, functional movements of locomotor patterns, sensory inputs, and therefore central neuronal circuits, become activated[14]. In addition, in experiments with spinalized cats and chronic locomotor training paradigms, it was hypothesized that proprioceptive and cutaneous impulses associated with repetitive movements may induce the activation of central pattern generators[17,38] and long-term potentiation of the motor cortex, which in turn modify the excitability of specific motor neurons and facilitate motor learning[2].

According to Yan et al.,[42] FES induces afferent-efferent stimulation, which results in limb movement plus cutaneou and proprioceptive inputs. The results of the present study revealed improvements in muscles power and balance. Therefore, training with FES could have activated the tibialis anterior muscle, leading to increased contraction of the paretic tibialis anterior muscle and negligible co-contraction of the antagonist spastic plantar-flexor muscles—movements that tend to occur in subjects with hemiparesis. This situation could have led to the significant improvements in gait parameters. Furthermore, training with FES could be important in reminding subjects how to perform a movement properly. Therefore, it is possible that FES applied to the peroneal nerve facilitated motor relearning and improved ankle dorsiflexion.

Previous studies with FES in subjects with chronic hemiparesis[24] and chronic spinal cord injury[19] showed that gait speed was improved after a training period. Pohl et al.,[31] and Sullivan et al.,[36] also showed that when trained at faster speeds, subjects with hemiparesis could effectively improve their over-ground walking speed.

Some researchers[31] have shown that speed training yields greater results when maximal, as opposed to submaximal, speeds are used. However, in the present study, we decided to preserve good gait patterns; this strategy may explain the results obtained during phase A_2. Better results might have been obtained if velocity and gait kinematics had been continually challenged during training.

The stance phase for both affected and unaffected limbs is greater in hemiparetic gait and represents a greater proportion of the gait cycle. Furthermore, the stance phase on the unaffected side is greater than that on the affected side, whereas the double-limb support phase on the affected side (the time spent in initial double-limb support on the affected side) is not greater than that on the unaffected side[29].

Our motor function, strength and balance outcomes are in agreement with the results of the study conducted by Hesse et al.,[24] in which multichannel electrical stimulation combined with a treadmill was applied to subjects with hemiparesis. However, the percentage of improvement in gait speed was very different from our data; this difference may be explained by the number of muscles stimulated by FES and by the contribution of spontaneous recovery, particularly in 6 of the 11 subjects in the study by Hesse et al., whose poststroke interval was less than 6 months.

After the gait training period, the subjects noted an improvement in their gait and balance and reported being more able to perform their activities in different environments. We identified 2 main advantages of using FES combined with treadmill training. The first advantage was that all of the subjects reported a preference for walking on the treadmill with BWS combined with FES. They reported that gait training during phase B was more comfortable because it was easier to place their foot during early stance. The other advantage was that training with FES decreased the participation of the physical therapists. Manual assistance was provided to help the subjects optimize gait quality during training, and the therapists noted a decrease in their work. It was easier to assist gait and paretic limb loading during phase B, but there was no change in the number of personnel involved in training with FES.

Despite these limitations, the present study provided important information about the influence of FES combined with partial BWS training in subjects with chronic hemiparesis and can help to optimize the physical therapeutic approach in stroke rehabilitation.

Conclusion

The results of the present study indicate that people with chronic hemiparetic stroke provided with training likely would benefit from a walking program combining partial BWS and FES. Besides the well-known effects of gait training with a treadmill and partial BWS in gait restoration after stroke, the combined use of FES applied to the common peroneal nerve and treadmill training with BWS may promote improvements in motor recovery. In addition, the use of FES during treadmill training was preferred by the subjects and facilitated the work of the physical therapists.

REFERENCES

1- Ahmed, S., Mayo, N.E. and Higgins, J.: The Stroke Rehabilitation Assessment of Movement (STREAM): a comparison with other measures used to evaluate effects of stroke and rehabilitation. Phys Ther.; 83: 617-630, 2003.
2- Asanuma, H. and Keller, A.: Neuronal mechanisms of motor learning in mammals. Neuroreport.; 2: 217-224, 1991.
3- Barbeau, H., Wainberg, W. and Finch, L.: Description and application of a system for locomotor rehabilitation. Med Biol Eng Comp.; 25: 341-344, 1987.
4- Bohannon, R.W. and Smith, M.B.: Interrater reliability of a modified Ashworth Scale of muscle spasticity. Phys Ther.; 7: 206-207, 1987.
5- Brandstater, E.B., De Bruin, H., Gowland, C. and Clark, B.M.: Hemiplegic gait: analysis of temporal variables. Arch Phys Med Rehabil.; 64: 583-587, 1983.
6- Burridge, J.H., Taylor, P.N. and Hagan, S.A.: The effect of common peroneal stimulation on the effort and speed of walking: a randomized controlled trial with chronic hemiplegic patients. Clin Rehabil.; 11: 201-210, 1997.
7- Chae, J. and Yu, D.: A critical review of neuromuscular electrical stimulation for treatment of motor dysfunction in hemiplegia. Assist Technol.; 12: 33-49, 2000.
8- Cross, J. and Tyson, S.F.: The effect of a slider shoe on hemiparetic gait. Clin Rehabil.; 17: 817-824, 2003.
9- Daley, K., Maki, B.E. and Danys, I.: The Stroke Rehabilitation Assessment of Movement (STREAM): refining and validating the content. Physiother Can.; 9: 269-278, 1997.
10- Daly, J.J. and Ruff, R.L.: Feasibility of combining multi-channel functional neuromuscular stimulation with weight-supported treadmill training. J Neurol Sci.; 255: 105-115, 2004.
11- Daly, J.J., Roenigk, K.L. and Butler, K.M.: Response of sagittal plane gait kinematics to weight-supported treadmill training and functional neuromuscular stimulation following stroke. J Rehabil Res Dev.; 41: 807-820, 2004.
12- de Leon, R.D., Hodgson, J.A., Roy, R.R. and Edgerton, V.R.: Locomotor capacity attributable to step training versus spontaneous recovery after spinalization in adult cats. J Neurophysiol.; 79: 1329-1340, 1998.
13- Dietz, V., Colombo, G., Jensen, L. and Baumgartner, L.: Locomotor capacity of spinal cord paraplegic subjects. Ann Neurol.; 37: 574-582, 1995.
14- Dietz, V.: Spinal cord pattern generators for locomotion. Clin Neurophysiol.; 114: 1379-1389, 2003.
15- Dobkin, B.H., Davis, B. and Bookheimer, S.: Functional magnetic resonance imaging assesses plasticity in locomotor networks [abstract]. Neurology.; 54(suppl 3): A8, 2000.
16- Duncan, P.W., Goldstein, L.B. and Matchar, D.: Measurement of motor recovery after stroke: outcome assessment and sample size requirements. Stroke.; 23: 1084-1089, 1992.
17- Edgerton, V.R., Tillakaratne, N.J.K. and Bigbee, A.J.: Plasticity of the spinal neural circuitry after injury. Annu Rev Neurosci.; 27: 145-167, 2004.
18- Field-Fote, E.: Combined use of body weight support, functional electric stimulation, and treadmill training to improve walking ability in individuals with chronic incomplete spinal cord injury. Arch Phys Med Rehabil.; 82: 818–824, 2001.
19- Field-Fote, E.C. and Tepavac, D.: Improved intralimb coordination in people with incomplete spinal cord injury following training with body weight support and

electrical stimulation. Phys Ther.; 82: 707-715, 2002.

20- Figueroa, P.J., Leite, N.J. and Barros, R.M.: Flexible software for tracking of markers used in human motion analysis. Comput Methods Programs Biomed.; 72: 155-165, 2003.

21- Granat, M.H., Maxwell, D.J. and Ferguson, A.C.B.: Peroneal stimulator: evaluation for the correction of spastic drop foot in hemiplegia.Arch Phys Med Rehabil.; 77: 19-24, 1996.

22- Harkema, S.J., Hurley, S.L. and Patel, U.K.: Human lumbosacral spinal cord interprets loading during stepping. J Neurophysiol.; 77: 797-811, 1997.

23- Hesse, S., Bertelt, C. and Jahnke, M.T.: Treadmill training with partial body weight support compared with physiotherapy in nonambulatory hemiparetic subjects. Stroke.; 26: 976-981, 1995.

24- Hesse, S., Malezic, M., Schaffrin, A. and Mauritz, K.H.: Restoration of gait by combined treadmill training and multichannel electrical stimulation in non-ambulatory hemiparetic subjects. Scand J Rehabil Med.; 27: 199-204, 1995.

25- Jorgensen, H.S., Nakayama, H. and Raaschou, H.O.: Outcome and time course of recovery in stroke, part II: time of recovery. The Copenhagen Stroke Study. Arch Phys Med Rehabil.; 76: 406-412, 1995.

26- Knox, V. and Evans, A.L.: Evaluation of the effects of a course of Bobath therapy in children with cerebral palsy: a preliminary study. Dev Med Child Neurol.; 44: 447-460, 2002.

27- Liberson, W.T., Holmquest, H.J., Scott, D. and Dow, M.: Functional electrotherapy: stimulation of the peroneal nerve synchronized with the swing phase of the gait of hemiplegic patients. Arch Phys Med Rehabil.; 42: 101-105, 1961.

28- Moseley, A.M., Stark, A., Cameron, I.D. and Pollock, A.: Treadmill training and body weight support for walking after stroke. Cochrane Database Syst. Rev.; (4): CD002840, 2005.

29- Olney, S.J. and Richards, C.L.: Hemiparetic gait following stroke, part II: recovery and physical therapy. Gait Posture.; 4: 149-162, 1996.

30- Perry, J.: Gait Analysis: Normal and Pathological Function. New York, NY: McGraw-Hill; 1992.

31- Pohl, M., Mehrholz, P.T., Ritschel, C. and Ruckriem, M.A.: Speed-dependent treadmill training in ambulatory hemiparetic stroke subjects: a randomized controlled trial. Stroke.; 33: 553-558, 2002.

32- Remme, W.J. and Swedberg, K.: Guidelines for the diagnosis and treatment of chronic heart failure. Eur Heart J.; 22: 1527-1560, 2001.

33- Richards, C.T., Malouin, F. and Wood-Dauphine, S.: Task-specific physical therapy for optimization of gait recovery in acute stroke patients. Arch Phys Med Rehabil.; 74: 612-620, 1993.

34- Schmidt, R.A. and Lee, T.D.: Motor Control and Learning: A Behavioural Emphasis. 3rd ed. Champaign, Ill: Human Kinetics; 1998.

35- Soetanto, D., Kuo, C. and Babic, D.: Stabilization of human standing posture using functional neuromuscular stimulation. J Biomech.; 34: 1590-1597, 2001.

36- Sullivan, K.J., Knowlton, B.J. and Dobkin, B.H.: Step training with body weight support: effect of treadmill speed and practice paradigms on poststroke locomotor recovery. Arch Phys Med Rehabil.; 83: 683-691, 2002.

37- Van de Crommert, H.W., Mulder, T. and Duysens, J.: Neural control of locomotion: sensory control of the central pattern generator and its relation to treadmill training. Gait Posture.; 7: 251-263, 1998.

38- Visintin, M. and Barbeau, H.: The effects of body weight support on locomotor pattern of spastic paretic subjects. Can J Neurol Sci.; 16: 315-325, 1989.

39- Visintin, M., Barbeau, H., Korner-Bitensky, N. and Mayo, N.E.: A new approach to retrain gait in stroke subjects through body weight support and treadmill stimulation. Stroke.; 29: 1122–1128, 1998.

40- Wade, D.T.: Measurement in Neurological Rehabilitation. New York, NY: Oxford University Press; 1992.

41- Wood-Dauphinée, S.L., Williams, J.L. and Shapiro, S.H.: Examining outcome measures in a clinical study of stroke. Stroke.; 21: 731-739, 1990.

42- Yan, T., Hui-Chan, C.W.Y. and Li, L.S.W.: Functional electrical stimulation improves motor recovery of the lower extremity and walking ability of subjects with first acute stroke: a randomized placebo-controlled trial. Stroke.; 36: 80-85, 2005.

الملخص العربي

دراسة تأثير التنبيه الكهربائي مع سير المشي المتحرك مع تحميل جزئي للجسم على زيادة القوة العضلية والتوازن وذلك للأطفال المصابين بالشلل النصفي التشنجي

الخلفية والهدف : ممارسة المشي على الماشية الكهربائية أثناء السير على المشاية الكهربائية مع تحميل جزئي للجسم وذلك للأطفال المصابين بالشلل النصفي التشنجي على زيادة القوة العضلية والتوازن . **الدراسة :** اهتمت الدراسة على ثلاثون طفل مصاب بشلل نصفي تشجني وتم تقسيمهم إلى مجموعتين متساويتين مجموعة ضابطة (15) طفل ومجموعة الدراسة (15) طفل تتراوح أعمارهم ما بين 12- 15 سنة . **النتائج :** أظهرت النتائج تحسن ملحوظ في تلك المجموعتين مع تفوق واضح في مجموعة الدراسة التي تلقت تنبيه كهربائي مع المشي على سير المشي المتحرك . **التوصيات :** إضافة برنامج تنبيه كهربائي أثناء المشي على سير المشي المتحرك وذلك لتحسين المشي عند الأطفال المصابين بالشلل النصفي التشنجي .