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Motor Function Problems in Hemiparetic Patients and the Effectiveness of Functional, Balance and Strength Exercises Protocol in Treatment of These Impairments

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Abstract: This study aimed to determine motor function problems in hemiparetic patients and the effects of functional, balance and strengthening (FBS) exercises protocol in treatment of these impairments. In 2004, thirty-four hemiparetic patients secondary to stroke aging 49.05±6.19 years and 34.9±26.37 months since stroke were recruited in this randomized clinical trial from Kahrizak Charity Foundation. Patients were assigned randomly to either an experimental group or a control group and their motor function was assessed using a functional, balance and strength scale (FBSS) before and after 12 sessions of intervention. The experimental group received all exercises protocol. The control group received all protocol except strengthening exercises. In experimental group measure of motor function increased from 346.29±75.72 to 447.47±76.94 ($p<0.0001$) and in control group increased from 343.18±72.75 to 360.18±71.8 ($p<0.0001$). Significant improvement after treatment was seen in the experimental group in measures of motor function index compared to control group ($p<0.0001$). Independent-samples t-test also identified a significant difference between the experimental group and the control group with respect to mean difference of motor function variable scores ($p<0.0001$). The results of this study support the effectiveness of muscle strength training in improving motor function in the chronic stages of hemiparesis following stroke.

Key words: Motor function, strengthening exercises, hemiparesis, stroke

INTRODUCTION

Stroke is the most common cause of adult disability after heart disease and cancer (Anderson *et al*., 1993a, b). Stroke is defined as a sudden, focal neurological deficit resulting from ischaemic or haemorrhagic lesions in the brain, which lasts more than 24 hours (O'Sullivan, 1988). Thirty to forty percent of stroke survivors will have severe disability (Williams *et al*., 2001). The high prevalence (29.8%) of stroke and its high economic costs make the reduction of stroke- related activity limitation a national health care priority (Stineman and Granger, 1998). The impairment resulting from stroke is most commonly presented as hemiparesis (Sackley and Lincoln, 1997). Although the variety and severity of the impairment is dependent on the site and extent of the lesion, one of the most common problems resulting from stroke is motor function problems (De Quervain *et al*., 1996). Motor function has been described in terms of functional mobility, muscle strength, range of active motion, muscle tonicity, gait variables and patterns (Collen, 1995). Strength deficits, decreased velocity and control of movements affect 60 to 78% of persons suffering stroke and often result in decreased functional ability (Weiss *et al*., 2000).

There is still no agreement on the role of spastic hypertonicity in the loss of muscle strength (Katz and Rymer, 1989). Bobath (1979) suggests that Weakness of muscles may not be real, but relative to the opposition of spastic antagonist and have proposed that normalization of muscle tone should be a priority of treatment. Other studies have found evidence against this argument. Instead researchers are suggesting that inadequate recruitment of agonist motoneurons and not increased activity in the antagonist, is the primary basis for disorders of motor control following UMN lesions

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(Bohannon and Smith, 1987). Karimi (1996) reported the effectiveness of an isokinetic program in testing and training of weak muscles of hemiparetic subjects without increasing the spasticity. Weiss *et al.* (2000) showed that strength training is an appropriate intervention to improve the quality of physical function in stroke survivors. Teixeira-Salmela *et al.* (2001) evaluated the impact of a combined program of muscle strengthening and physical conditioning on gait performance in subjects with chronic stroke. This study showed that after training, subjects were able to generate higher levels of muscle power.

Most of the studies have focused on limited aspects of motor function problems and the attention in the assessment and treatment approach is concentrated on acute stages of the problem, however, the results show that motor function problems were seen in 50% of survivors (Inouye *et al.*, 2000). While conventional methods are not successful in treating these impairments, especially in chronic stages of the disease and controversy exists with regard to the appropriateness of muscle strength testing and training, determination of motor function index and appropriate recovery method of these impairments are necessary. Although weakness and spasticity are two different signs of upper motor neuron lesion, but lack of strength in this subjects was not attended. Thus, a combined physiotherapy program was designed consisting of functional, balance and strengthening exercises (FBS) for treatment of impairments on the basis of motor control, motor learning, postural control and principles of muscle strengthening. The aim of this study was two folded; first, to construct a motor function index and determine its interrater reliability in evaluating the results of two exercise protocols, FBS and functional and balance exercises (FB), in hemiparetic subjects one year after stroke. The second goal was to use this scale in evaluating the results of the two exercise protocols in treatment of the subjects.

MATERIALS AND METHODS

Subjects: This study was performed in Kahrizak Charity Foundation in 2004. The pilot study performed on ten hemiparetic subjects and in two control and experimental groups determined that a total of 15 subjects were necessary for each group. Thirty-four subjects, suffering from hemipaersis secondary to stroke participated in this clinical trial through simple non-probability sampling. These patients were recruited through an approach to the consultant neurologist. Prior to commencement of the study, approvals were sought from the human ethic's Committee and the Research Council of Tarbiat Modarres University. The purpose of the study and testing protocol to be used were explained to the subjects and an informed and written consent document was obtained from all participants. None of these patients used of walking aids in the evaluation and treatment period. Patients were selected according to the following inclusion criteria: (1) at least one year after stroke, (2) age between 40 to 60 years, (3) hemiparesis secondary to stroke, (4) able to stand at least 30 sec with eyes open and separate feet, (5) able to understand instructions and follow simple directions, (6) no other physiotherapy program during this study. Patients with second stroke, bilateral involvements, lower limb arthritis, significant visual field deficit, severe perceptual aphasia and surgery of CNS and neuromuscular and other musculoskeletal disease of the lower limb were excluded. Patients were assigned randomly to either an experimental or a control group. The mean age of experimental group subjects' 49.3±7.1 years and their time post stroke was 34.5±26.37 months. The 7 female and 10 male, 8 right and 9 left hemiparesis participated in this group. The mean of motor function was 346.29±75.72 (ordinal scale), functional mobility 37.35±9.11 (ordinal scale), gait function 25.76±6.04 (ordinal scale), velocity 27.65 ±11.5 (m min^{-1}), stride length 67.9±28.24 (cm) and cadence 82.82±20.1 (step/min) in this group. The mean age of control group subjects 48.8±3 years and their time post stroke was 35.3±27.5 months. The 8 female and 9 male, 5 right and 12 left hemiparesis participated in this group. The mean of motor function was 343.18±72.75 (ordinal scale), functional mobility 37±6.08 (ordinal scale), gait function 24±4.69 (ordinal scale), velocity 26.5±9.05 (m min^{-1}), stride length 66.3±14.4 (cm) and cadence 71.57±34.1 (step/min) in this group.

Methods: Motor function of patients was assessed using motor function part of functional, balance and strength scale (FBSS). This is an ordinal assessment scale of functional mobility (12 tests; 7 items of Motor Assessment Scale, one item of Modified Motor Assessment Scale and 4 item of Berg Balance Scale) and gait patterns (17 tests; combination of Tinetti Scale, Functional ambulation category, Dynamic gait index and timed get up and go test). Muscle strength (kg) and ranges of motion (degree) were measured using hand-held dynamometer and goniometer, respectively. Gait velocity (m min^{-1}), cadence (step/min) and stride length (cm) were recorded. Gait velocity was measured in 15 m distance. Ten meters of this distance was marked. This procedure was performed for prevention of effects of acceleration and deceleration. Then, this distance was walked by subjects. Time is recorded with stopwatch and velocity obtained from divided of distance to time multiply by 60.

Step per minute also is numbered (Cadence). Also, stride length is obtained from divided of speed to cadence multiply 200 (2*100). FBSS is a combination of reliable and valid scales (Kevin and Means, 1996; Mahoney and Barthel, 1965; Tineti, 1986). Ordinal data obtained from the above measures using range of variations. Units of all variables were changed to ordinal unit. Then this data was collated into single number (Motor Function Index). For comparison of motor function we used this combination. However comparison between subgroup variables of motor function was performed using primary unit.

Two raters assessed all patients using FBSS after obtaining the history of the disease, characteristics of patients and testing visual field by confrontation test. Every test was performed once by researcher for showing correct movement and once by each patient for learning the movement and three times for scoring. Two raters recorded the highest score, independently. Two raters were blinded to the group allocation and to the results of the other rater. Isometric strength of hip flexors, knee flexors and extensors and ankle dorsiflexors and ROM of hip flexion, knee flexion and extension and ankle dorsiflexion was measured in sitting position and hip, knee and ankle joints in right angle, hip extensors strength and ROM of extension in side lying position, hip abductors strength and ROM of abduction in supine and plantarflexors strength and ROM of plantarflexion in prone position and knee and ankle joints in 90°. During the isometric testing the dynamometer was attached to distal end of the moving bone (Hislop and Motgomery, 1995). These methods have intrerater reliability. Treatment was started exactly after assessments and final assessments were completed exactly at the end of treatment.

Subjects were blinded to their group allocation and remained blinded. As well, the individuals were blinded to the aims and hypotheses of the study. Both groups received treatment for 12 sessions (4 weeks and 3 times a week) and approximately 3 h per session. All subjects tolerated the 3 h exercises protocol with brief resting during training. Any adverse effects were not seen in this study. All exercises were repeated ten times in one session for every group. The experimental group received FBS protocol that is a combination of three different parts. First part consists of 23 standing, 3 sitting balance, 58 functional mobility, 21 gait patterns and an aerobic fitness exercises. Second part consisted of 8 functional exercises on the basis of selective movements that included squatting, hiking, bridging, dropping, toe and heel walking, lower limb extension, alternating flexion and extension of lower limbs and tilting reaction. Third part of the protocol included strengthening of sagital and frontal plane muscles affected in gait. The one repetition maximum (1RM) was determined using dynamometer for strengthening of flexor, abductor and extensor muscle groups of hip, flexor and extensor groups of knee and dorsiflexor and plantarflexor groups of the ankles on the affected side. Concentric isotonic type of contraction was used for strengthening these muscles. Very weak muscles trained using synergism and motor imagery patterns. The control group received all FBSE protocol except for strengthening exercises. At the end of treatment all patients were assessed and results recorded by two raters.

Statistical analysis: Data were analyzed using SPSS9. Kolmogorov-Smirnov test for normality were performed for all outcome variables. For parametric data independent and paired t- tests were used for comparison between pre-treatment and post treatment test results between groups and within groups, respectively. For nonparametric data Mann-Whitney and Wilcoxon tests were used for comparison between pretreatment and post treatment test results between groups and within groups, respectively. Intraclass Correlation Coefficient (ICC's) was used to investigate the relationship between the scores of the two raters. The level of significance was set at $p<0.05$.

RESULTS

We first examined interrater reliability. Pretreatment scores from both raters were correlated (ICC = 1.000; 95% CI 0.99 to 1), as did post treatment scores (ICC = 1.000; 95% CI 0.99 to 1).

The comparisons were made within two groups to investigate the effects of both protocols. Then, mean difference between pre-treatment and post treatment test results in both groups were calculated. At the end, these mean differences between two groups were compared. Discussion and conclusion about each variable was performed only according to mean difference comparisons results.

Motor function: Intervention increased motor function index from 346.29±75.72 to 447.47±76.94 in experimental group ($p<0.0001$) and from 343.18±72.75 to 360.18±71.8 in control group ($p<0.0001$). Significant improvement after treatment was seen in the experimental group in measures of motor function index compared to control group ($p<0.0001$). The mean difference in experimental group compared to control group was 101 to 17 ($p<0.0001$).

Functional mobility: Treatment increased functional mobility from 37.35±9.11 to 47.29±8.64 in experimental group ($p<0.0001$) and from 37±6.08 to 40.35±6.46 in control group ($p<0.0001$). The mean difference in experimental group compared to control group was 10 to 3 ($p<0.0001$).

Gait indices: Gait patterns increased from 25±6.04 to 36±4.78 ($p<0.0001$) in experimental group and from 24±4.69 to 28±4.8 ($p<0.0001$) in control group. The mean difference in experimental group compared to control group was 11 to 4 ($p<0.0001$). Gait velocity in experimental group increased from 27±11.5 to 39±15.9 m min^{-1} ($p<0.0001$) and in control group increased from 26.5±9.1 to 27.5±9.3 m min^{-1} ($p = 0.002$). Comparison of after treatment results demonstrated significant improvement ($p<0.0001$) in the experimental group compared to control group. The mean difference in experimental group compared to control group was 12 to 1 m min^{-1} ($p<0.0001$). Stride length in experimental group increased from 67.9±28.24 to 90.09±29.8 cm ($p<0.0001$) and in control group increased from 66.3±14.4 to 69.3±16.4 cm ($p<0.0001$). The mean difference in experimental group compared to control group was 23 cm to 3 cm ($p<0.0001$). Significant improvement was not shown in cadence measures of gait after intervention in both groups. The mean difference test results of cadence between two groups were not significantly different ($p = 0.051$).

Muscle strength: Intervention increased total strength (summation of seven muscle groups strength) of affected lower limb from 30±16.33 to 57±12.9 kg in experimental group ($p<0.0001$) and from 29±14.6 to 33±15.8 kg in control group ($p<0.0001$). The mean difference in experimental group compared to control group was 27 to 4 kg ($p<0.0001$). All muscles' strength of unaffected lower extremity in the experimental group increased after intervention ($p<0.0001$). Intervention was not effective in control group except for hip and knee extensors ($p<0.0001$) and ankle dorsiflexors ($p = 0.008$). The mean difference of all muscles except for knee extensors ($p= 0.184$) increased in the experimental group compared to the control group. All muscles' strength of affected lower extremity in the experimental group increased after intervention ($p<0.0001$), but intervention was not effective in control group except for hip ($p = 0.003$) and knee ($p<0.0001$) extensor muscles. The mean difference of all muscles increased in the experimental group compared to the control group.

Range of motion: Intervention increased ROM of affected lower limb from 336 to 412 degree in experimental group ($p<0.0001$) and from 335 to 349 degree in control group ($p<0.0001$). The mean difference in experimental group compared to control group was 76 to 14 degree ($p<0.0001$).

DISCUSSION

The findings showed that both protocol in the chronic stages of stroke have improved motor function. Comparing of the mean difference and after treatment results showed a significant improvement in motor function of the experimental group compared to the control group. The major finding was that adding strengthening exercises to FB protocol resulted in significant improvement of motor function. Present findings also suggest that new combined FBSS had the capability of patient assessment in the chronic stages of stroke and its interrater reliability was good.

Positive effects of strengthening exercises were demonstrated on the subtasks of motor function. Effects of both protocols on the functional mobility improvement was significant, however the higher improvement seen in experimental group compared to the control group was due to the effects of muscles strengthening exercises.

Walking patterns and gait variables such as velocity and stride length improved in both groups, the improvement was higher in the FBS protocol group. Other studies have reported effects of increased muscle strength on the improvement of gait in hemiparetics patients and showed that resistance exercises could result in improvement of kinematic and kinetic gait variables (Teixeira-Salmela *et al*., 2001; Weiss *et al*., 2000).

In this study, particular muscles of affected lower extremity that are active in sagital and frontal plane were strengthened. The presumption was that training has the potential to drive brain reorganization and to optimize functional performance. Emphasis is on skill training, which will accompany an increase in strength and endurance. Use of biomechanical principles, skill learning and strength training has been recommended for above effects (Shepherd, 2001). It has been reported in the literature that the patterns of motion of the affected lower extremity had a stronger association with the severity of muscle weakness. Therefore, the goal of therapy should be to improve muscle strength on the affected side (De Quervain *et al*., 1996).

Present findings revealed that muscle-strengthening exercises not only did not result in increased tonicity but also decreased the tonicity. Other studies suggest that muscle weakness is, at least in part, the consequence of decreased force output by the agonist motor units (Bohannon and Smith, 1987). Present findings showed that strengthening exercises resulted in increased muscle strength, therefore, emphasize on dependence of agonist strength on the hypertonicity of the antagonist may not be substantiated. Other studies suggest that strengthening exercises did not cause any change in the level of spasticity (Karimi, 1996).

The strength of flexor, extensor and abductor muscle groups of hip, flexor and extensor muscle groups of knee, dorsiflexor and plantarflexor muscle groups of ankle in sound lower limb were compared. In control group hip, knee and ankle extensor muscles' strength increased after treatment. Higher improvement was seen in knee extensor muscles. Other muscles did not show any change. In experimental group strength of all muscle groups increased with higher increase in knee extensor groups. Significant strength improvement was seen in experimental group compared to control group. The comparison of mean difference in all muscle groups except for knee extensor groups revealed significant improvement in experimental group. To prevent collapse during the stance phase of gait, some of the muscles of the supporting lower limb contract to create an extensor moment. Although the stance phase extensor moment can be produced by any combination of hip, knee and ankle extensor muscles' activity, the knee extensor muscles normally make a major contribution to the total extensor moment (Bohannon, 1991a). The nature of FBE protocol is so, that some exercises included in the protocol can cause hypertrophy in addition to synchronization of motor units (Bohannon, 1991b). The role of strengthening exercises along with balance and functional exercises in improvement of muscle strength on the affected side of hemiparetic patients were investigated. In experimental group significant improvement of muscle strength was seen after treatment, however, in control group only increase in knee and hip extensor muscles' strength was significant. Higher improvement in experimental group was in hip flexors and in control group in knee extensors. The strength improvement in experimental group compared to control group was significant and this may be attributed to additional exercises.

The comparison of range of motion of flexion, extension and abduction of hip, flexion and extension of knee, dorsiflexion and plantarflexion of ankle revealed that both protocols were resulted in increase in range of motion of both lower limbs. The FBSE protocol was more successful in recovery of range of motion than FBE protocol.

Strength results from both, properties of muscle itself and the appropriate recruitment of motor units and the timing of their activation (Kisner and Colby, 1996; Smidt and Rogers, 1982). In prescribing exercise for hemiparetic patients above aspects should be considered. The effect of the present exercise protocol was on both the central set and the actuator. The muscle work is not dependent on the instant input, but is dependent on the previous works. The affected part in memorization of hysteresis is the force generator system, which is triggered by chemical, electrical and mechanical forces which, the muscles use this memory in next works. The central effects of exercises are due to motor learning (Shumway-Cook and Woollacott, 1995). Physiological plasticity associated with recovery of function is the same that is affected in learning. Thus, practice and experience can result in reorganization of central nervous system. Motor learning and consequent changes of synaptic connections are activity-dependent. These evidences suggest that our sensory and motor maps in the cortex are constantly changing in accordance with the amount to which they are activated by peripheral inputs. In addition, experience is very important in shaping cortical maps (Shumway-Cook and Woollacott, 1995). Other studies demonstrated that the development of skilled movement, but not increased strength, was associated with a reorganization of movements' representation within motor cortex (Remple, 2001). A third group of authors believe that passive movements in hemiparetic stroke patients elicit some of the brain activation patterns after substantial brain recovery. Others emphasized on the learning process (Hochstenbach and Mulder, 1999). Improvement of strength and coordination of muscles is effective on functional independence (Katz and Rymer, 1989). Although increases in strength are generally considered by muscle hypertrophy, adaptation within the central nervous system may also be affected. Whereas there is evidence for training induced changes in neural function within the spinal cord including increased motor unit recruitment and motoneuron excitability, other work has implicated supraspinal motor structures. Increased force production has been correlated with increased activity of motor cortex. Despite considerable evidence for the involvement of motor cortex in controlling movement force, a few studies have examined the enduring effects of strength training on the functional organization of this brain region (Shumway-Cook and Woollacott, 1995).

In conclusion, in spite of recovery of motor function, further research about type of strengthening exercises is necessary until motor function has been improved and residual disability has been decreased.

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