



Comparison of weight bearing exercises and non-weight bearing exercises versus weight bearing exercises alone to improve the lower limb motor function in stroke patients

Dr. Vijayaraj VEDIAPPAN¹, Jeevitha Vadivel², P Sanjay Ram², VS Prashitha³

¹ Professor and Principal, Department of Physiotherapy, Nehru College, The Tamilnadu Dr. MGR Medical University, Tamil Nadu, India

² Department of Physiotherapy, Nehru College, The Tamilnadu Dr. MGR Medical University, TamilNadu, India

³ Department of Chemical Engineering, KPR Institute of Engineering and Technology, Tamil Nadu, India

Abstract

A sample of 30 subjects were randomly divided into three equal groups and out of them group A and group B were considered as experimental group whereas the group C was considered as control group. Among the experimental groups, group A received combined weight-bearing and non-weight-bearing exercises in which each exercise consists of both weight-bearing and non-weight-bearing phase in a single repetition. The subjects of group B received weight-bearing exercises where each exercise consists of weight-bearing phase alone. The pre and post test values were obtained using three standard outcome measures namely STREAM scale, Tinetti scale and Timed Up and Go test. The pre-post values were statistically analyzed and the results showed that weight-bearing exercises were more beneficial than the combined weight-bearing and non-weight-bearing exercises.

Keywords: Stroke rehabilitation assessment of movement, tinetti scale, timed up and go test, stroke, exercises

Introduction

Stroke refers to the sudden death of some brain cells due to a lack of oxygen when the blood flow to the brain is impaired by blockage or rupture of an artery to the brain.

According to WHO Stroke is defined as 'a focal neurological (or at times global) impairment of sudden onset and lasting more than 24 hours (or leading to death) and of presumed vascular origin.

Like the definition proposed by WHO for Stroke by demarcating with Transient Ischaemic Attack (which lasts for less than 24 hours) the Journal of Clinical Epidemiology also defined Stroke as a syndrome characterized by "rapidly developing clinical signs of focal (or global) disturbance lasting 24 hours or longer or leading to death with no apparent cause other than of vascular origin".

Stroke may be manifested as Hemiplegia, which is the paralysis of muscles of one side of the body, contralateral to the side of the brain in which CVA occurred.

Clinically a variety of deficits are possible including the changes in the level of consciousness, impairments of sensory, motor, cognitive, perceptual and language functions. The location of lesion, the extent of lesion, the amount of collateral blood flow and early acute care management determine the severity of neurological deficits. The impairment resulted due to Stroke may resolve spontaneously with neurological recovery (Reversible Ischemic Neurological Deficit) generally within 3 weeks. Residual neurological impairments are those that persist longer than 3 weeks and may lead to permanent disability and dependence.

Risk Factors

Stroke is a multi factorial disease where many determinants have been described. These determinants or risk factors can be divided into modifiable and non-modifiable.

Non-modifiable risk factors

Age and Sex are examples of two well-known risk factors for Stroke; high age and male sex are in many populations associated with an increased risk. 2/3 of all Strokes occur in people older than the age of 65; and after 55, the risk of Stroke doubles every 10 years. Although they are of major importance in predicting the occurrence of Stroke in the community, they cannot be modified.

Modifiable Risk Factors

In contrast, reduction in the exposure to modifiable risk factors may lead to a lower occurrence of Stroke such as tobacco smoking, physical inactivity, diet or factors in the environment such as passive smoking and access to medical treatment.

The combination of these risk factors, which do not all have to be present, will over time influence the subject's likelihood of suffering a Stroke.

Need for The Study

In Stroke, locomotion is one of the commonest problems. The most often stated goal for Stroke patients is to improve walking. Muscle weakness leads to difficulty in generating the necessary force and sustaining force output for effective motor performance due to impairment in muscle activation and motor control. For the improvement of walking, good strength of the lower extremity muscles is essential irrespective of the presence of spasticity because there is growing evidence that muscle weakness rather than abnormal reflex activity is a major limiting factor in physical function particularly for locomotor tasks following Stroke

Many studies have insisted the Weight-bearing exercises for the lower limb whereas most of the functional activities require a combination of Weight-bearing and Non-Weight-

bearing components. So, this study intends to study the effect of Weight-bearing versus combined Weight-bearing and Non-Weight-bearing exercises among Stroke patients. Also, in a previous study the authors suggested future research should explore the specific factors such as the type of exercise, the frequency, intensity and time spent in strength training and retention of training.

Methodology

Research Design

A Pre-post experimental study consisting of 30 Stroke patients were undertaken to investigate the voluntary control of affected lower limb, gait velocity and balance of the Stroke patients. There are two experimental groups and a control group.

Population

Stroke patients who were between the age of 40-60 years considered as population

Inclusion criteria

- Patient with either Middle Cerebral Artery or Anterior Cerebral Artery involved Stroke.
- Patient within 1 year of Post Stroke
- Both sexes.
- Age group between 40-60 years.
- Patient who can stand independently without any assistive devices at least for a minute.
- Patient’s willingness to participate in the study.

Exclusion criteria

- Patient with other musculoskeletal disorders
- Patient using ambulatory aids
- Cognitive impairment (score less than 24 out of 30 in Mini Mental State Examination)
- Medically unstable (Uncontrolled Hypertension, Arrhythmia Congestive Cardiac Failure)
- Unresolved Sub arachnoid hemorrhage.
- Patient who have had multiple Stroke.
- Patients who have impaired proprioception.

Sample Size and Sampling

Purposive Sampling of thirty samples was adopted in this study. A group of 30 subjects who had satisfied the inclusion criteria and exclusion criteria were selected and they were purposively divided into three groups.

Duration of The Study

It was an experimental study with the duration of 2 months of treatment per subject and all the subjects have to do the 5 specific exercises for 10 repetitions per set for the total of three sets per day.

Outcome measures

The Outcome measures were STREAM scale (lower limb and basic mobility components), Tinetti Balance and gait scale and Timed up and go test.

Procedure

The subjects were informed about the purpose, procedure, and effects of the study. The patients were assessed to ensure about the inclusion and exclusion criteria. Then the informed consent will be obtained. The selected subjects were divided into three equal groups by simple purposive sampling method. The selected sample will complete a data Proforma.


Pre Est





The subjects were assessed on the first day before the intervention with the three standard outcome measures. The subject’s voluntary activities of lower limb and basic mobility were assessed by 10 item each using STREAM scale. Balance is assessed by Tinetti Balance and Gait scale. The functional speed of walking was assessed by using Timed Up and Go Test which was assessed by asking the subject who is sitting in a chair to stand and walk for 3-meter distance and come back and sit on the chair. The time taken for completing the test is used to assess the velocity of the gait.

Intervention



Intervention was implemented according to the group to which the subjects belong. The subjects of experimental groups received regular physiotherapy in addition to experimental exercises. The subjects belong to group A were trained with Combined Weight-bearing and non-weight-bearing exercises and regular physiotherapy. The subjects belong to group B were trained with weight-bearing exercises and regular physiotherapy. The subject belong to group C were trained with conventional therapy and regular physiotherapy.




Exercises for Experimental Group A: (Combined Weight-bearing and non-weight-bearing exercises)

<p>(1) Stepping forward: Position: Standing in front of the foot stool. Instruction: Put the sound leg on the step forward followed by affected side leg crossing over the sound leg.</p>	
--	---

<p align="center">(2) Stepping over the foot stool: Position: Standing in front of the foot stool. Instruction: Lift the affected side leg and put it across the foot stool and bear some weight on it and bring it back to the starting position.</p>	
<p align="center">(3) Stepping across the foot stool: Position: Standing in front of the foot stool. Instruction: Lift the affected side leg and put it across the foot stool followed by sound leg across the foot stool.</p>	
<p align="center">(4) Ball pressing: Position: Chair sitting with both feet on the floor. Instruction: Lift your affected side leg and place it on the ball. Press the ball with your foot as force as possible. Bring the foot to the starting position. Note: The ball may be stabilized by the therapist.</p>	
<p align="center">(5) Stepping sideways: Position: Standing aside the foot stool. Instruction: Lift your affected side leg and place it on the foot stool. Shift your body weight towards the affected side. Bring back yourself to the erect position.</p>	

Exercises for Experimental group B (Weight-bearing exercises)

<p align="center">(1) Calf muscle stretching exercise: Position: Forward lean standing with affected leg behind. Instruction: Lean forward over the unaffected leg without raising the heel and without bending the affected leg and feel the stretch in the back of the leg. Hold the position for 20 seconds. L</p>	
<p align="center">(2) Sit to Stand and Sit-down exercise: Position: Patient sits on a firm surface. Feet flat on the floor. Instruction: Swing your shoulder forward and stand up. Instruction: Slowly sit down on the chair. Note: knee flexion can be assisted by moving the knees forward.</p>	

<p align="center">(3) Heel raising and lowering: Position: Forefoot on step; heels are free. Instruction: Lower your heels as far as possible and rise to plantigrade Note: Hips and knees are kept in extended position.</p>	
<p align="center">(4) Wall Squatting: Position: Wall standing. Instruction: Gradually lower your body as much as possible and stand up.</p>	
<p align="center">(5) Step up and Step down: Position: Paretic lower limb is placed on the foot stool. Instruction: Lift your sound leg and bring it forward by crossing over the paretic limb and bring it back.</p>	

Results

Study Design

An experimental study consisting of 30 patients with Ischaemia/ Haemorrhage are randomized in to three groups, 10 in Group A (Experimental 1-Combination exercises), 10 in Group B (Experimental 2-Weight-bearing) and 10 in Group C (Control) are undertaken to study the effect of differential treatment on STREAM, Tinetti and TU>.

Statistical Methods

Analysis of variance has been used to find the significance

of study parameters between three groups. Student t test (paired) has been used to find the significance of study parameters between pre-intervention and Post intervention for each group. Analysis of Variance has been used to find the significance of outcome of Study parameters between three groups. Tukey post-hoc test has been used to find the significance of pair wise comparisons of outcome measurement of study parameters.

Main Results

Table 1 and Fig 1: Comparison of Baseline Parameters between three groups and Presented in Mean

Baseline parameters	Group A	Group B	Group C
STREAM	30.60	32.80	30.80
TINETTI	20.20	21.20	20.60
TU>	19.30	16.70	20.20

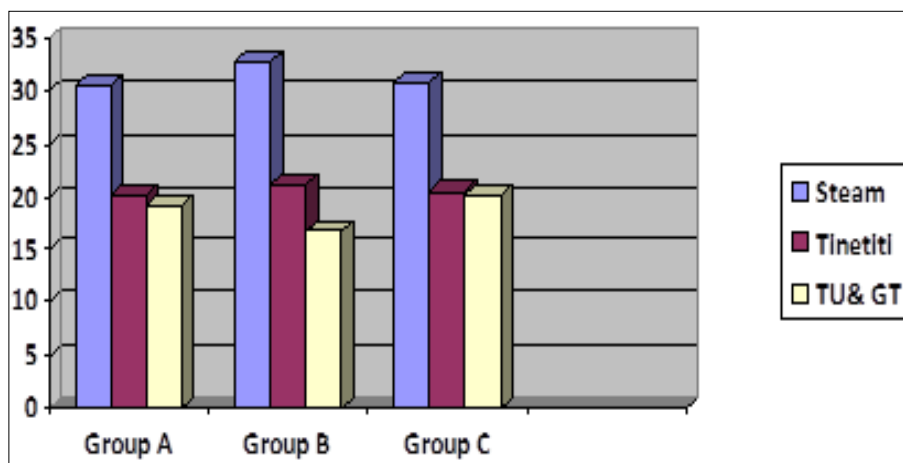


Table 2 and Figure 2: Comparison of Baseline STREAM, Tinetti and TU & GT between three groups

Study period	STREAM Groups			Tinetti Groups			Tinetti Groups		
	A	B	C	A	B	C	A	B	C
Pre-Intervention	30.60	32.80	30.80	20.20	21.20	20.60	19.30	16.70	20.20
Post-Intervention	35.30	40.00	34.30	22.80	25.00	22.70	16.60	13.50	17.80

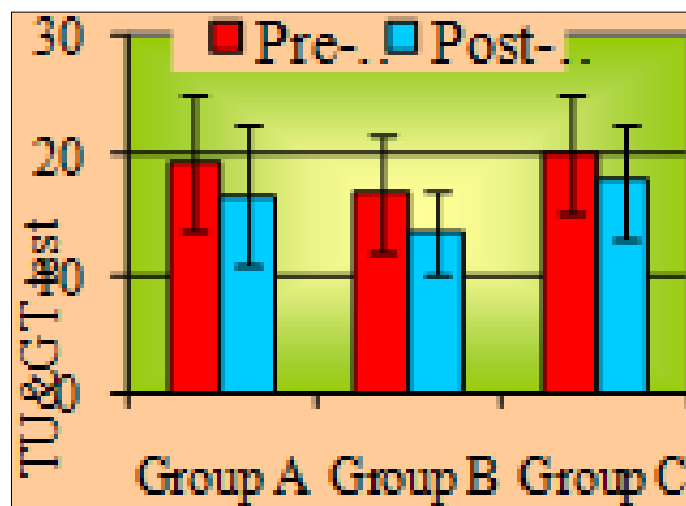
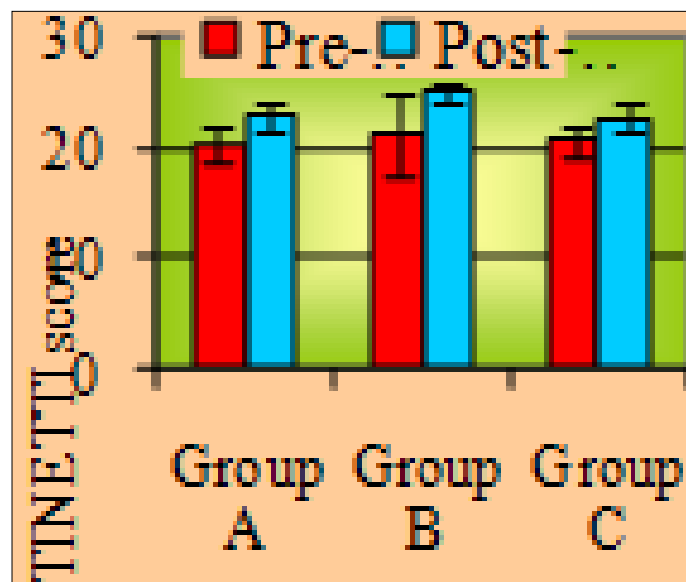
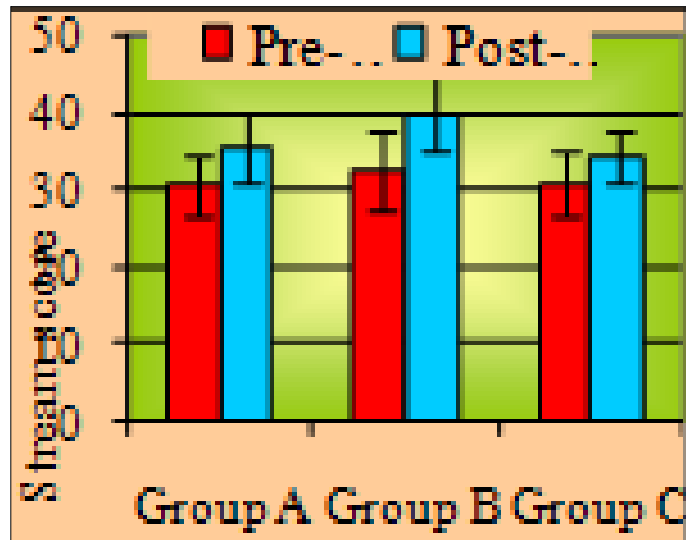
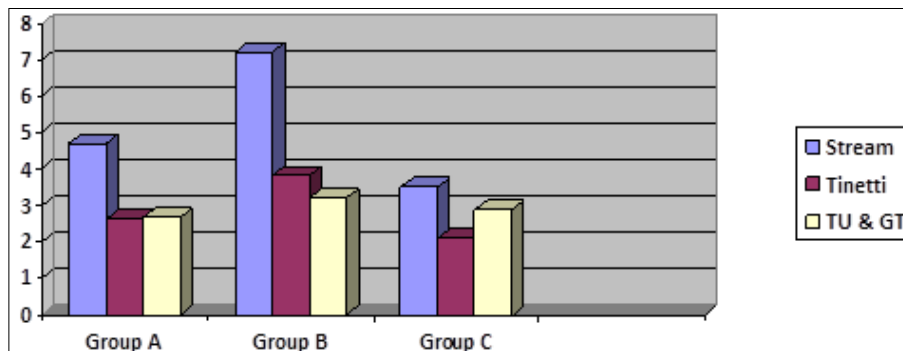


Table 3 and Figure 3: Comparison of Outcome (difference of pre and post score) between three groups and results are presented in Mean

Study parameters	Outcome (Difference of Pre and Post)		
	Group A	Group B	Group C
STREAM	4.70	7.20	3.50
TINETTI	2.60	3.80	2.10
TU>	2.70	3.20	2.90



The subjects of group B have shown marked difference compared to group A and group C.

Discussion

The main purpose of the study is not only to find out the efficiency of either weight-bearing exercises or combined weight-bearing and non-weight-bearing exercises but also to find to which extent one type of exercises show its efficacy over another. Weight-bearing exercises consist of more eccentric training compared with combined activities. Weight-bearing exercises have been proved as beneficial compared to mere concentric training in improving even weight shifting thereby improving balance. As both the weight-bearing and non-weight-bearing phases are required to carry out the functional activities the need of the combined activities cannot be ignored. Moreover, the ability to initiate and control voluntary weight shifts toward either leg is a prerequisite for independent walking, learning to load and unload the affected leg while standing is an important step in balance and gait training of Stroke patients.

Post treatment comparison of voluntary control between three groups

Voluntary control assessed with STREAM scale has shown better results in subjects of group B who received weight-bearing exercises than subjects of group A who received combined weight-bearing and non-weight-bearing exercises. The subjects of group C who were considered as control group also showed significant change but not equal to the level of experimental groups which indicate the improvement in the control group may be due to the routine physical therapy treatment they received in addition to the spontaneous recovery to certain extent due to the neuronal plasticity. Marked difference (11 points) has been seen in a Group B subject before and after the intervention.

The voluntary control regaining is more achieved by group B subjects who received weight-bearing exercises which focuses more of eccentric activity rather than concentric. The improvement in the results coincides with the results of the studies done by Engardt and co workers who suggested that restraint of the antagonistic muscles in concentric movements increased after concentric training but not after eccentric training.

Post treatment comparison of balance and gait between three groups

Balance and gait assessed with Tinetti scale has shown better results for group B subjects who received weight-bearing exercises than group A and group C. A subject of group B showed peak difference before and after the intervention the percentage of the change between the group C and group A are not much varying as with that of group B though the subjects of group A received combined activities which reflect the similarity with the components of Tinetti scale.

Sit to Stand was one of the challenging tasks which was used as an exercise for the group B could be a reason for their higher performance of balance activities. Weight shifting capacity which provides unique information about balance recovery after Stroke. Though weight shifting capacity was focused more on group A has not performed better than group B it could be due to the factor of intensity of exercises rather than mode of exercises.

Post treatment comparison of functional gait speed between three groups

Gait velocity assessed with the Timed Up and Go Test also gave the better results

towards the group B than the group A and group C respectively. The marked difference of velocity between pre and post intervention was seen in a subject belongs to group B as well as no change has also been noted before and after the intervention in the same group.

Functional gait velocity improved maximally for group B and coincides with the results of the previous studies. It could be because of the determining factors such as strength of quadriceps muscle, isokinetic torque, non-paretic side strength, eccentric training which would result in even weight distribution. The subjects of group A also were also taken attention of non-paretic side and hence they might have resulted better than control group.

Further more repeated practice of Sit to Stand activity which was mentioned as toughest task are the beginning and finishing phase of the Timed Up and Go test might produce favorable result to group B.

Post treatment comparison of three outcome measures between the groups

Among three outcome measures STREAM scores are strongly significant in all three groups than Tinetti scale and Timed Up and Go Test. It could be due to the influences of multiple impairments such as balance, motor power, fear of falling, anxiety influencing the performance of the Tinetti scale and TU> which are more functional than STREAM which focuses more on single impairment.

The improvement obtained as a result of weight-bearing exercises can be attributed to the following reasons

- All the weight-bearing activities are focusing more on eccentric muscle activity which has been proved as beneficial over the mere eccentric training.
- Weight-bearing is used to decrease the spasticity in the leg because movements of the trunk over the fixed extremity lengthen the tight muscles between the trunk and limbs.
- Joint approximation can modulate flexor afferent activity thus dampens the spastic muscle action.
- Joint compression that is in long axis of the body segments in a weight-bearing alignment gains co-contraction with greatest facilitation to one joint flexors of the lower limb and lengthening of antagonist extensors result in inhibition of spasticity.
- The entire body weight has to be borne through the weight-accepting limb almost during all the exercises. So, the patient gains balance and strength simultaneously.
- Though there is significant improvement seen in both the experimental groups there are some advantages and disadvantages in both type of exercises.
- High intensity activities including resistance training could form an important rehabilitation program for Stroke patients.
- Moreover, the mode of treatment was more functional which shows improvement due to the similarity between the natures of the assessment components, which are also, reflects the functional activities.

The improvement obtained as a result of combined weight-bearing and non-weight-bearing exercises can be attributed to the following reasons

- During each lift the patient regains the strength of the sound limb that is also weak to certain extent.
- Joint approximation can modulate flexor afferent activity thus dampens the spastic muscle action.
- Joint compression that is in long axis of the body segments in a weight-bearing alignment gains co-contraction with greatest facilitation to one joint flexors of the lower limb and lengthening of antagonist extensors result in inhibition of spasticity.
- Task specific training produces superior outcome.
- The patient might feel the exercises not as a strict drill but as a mean of direct regaining of functional performance.
- Making self-generated weight shifts in the frontal plane within the base of support seems an essential ability to train and monitor in Stroke patients.
- Moreover, the mode of treatment was more functional which shows improvement due to the similarity between the natures of the assessment components, which are also, reflects the functional activities.

Conclusion

Weakness is the most common and troublesome manifestation of Stroke leading to activity limitation, functional impairment. And also, Stroke is the major cause of postural imbalance in terms of static and dynamic control. Overcoming the weakness through the strengthening training will pave the way to improve the independence in ADL. Based on muscle work it would be of concentric training or eccentric training.

All type of strengthening training will biomechanically fall under either Closed Kinematic Chain (CKC) activities which are performed in weight-bearing position or Open Kinematic Chain (OKC) activities which are performed in non-weight-bearing position. By combining CKC&OKC activities, the patient's lower limb can be strengthened as well as trained functionally. So combined weight-bearing and non-weight-bearing activities as well as weight-bearing exercises were implemented to the patients though the beneficial effects of the later were proven. So, in this study, combined weight-bearing and non-weight-bearing exercises, and isolated weight-bearing exercises have employed to analyze the effect each of them in regaining functional performance.

The conclusion of this study is both weight-bearing and combined weight-bearing and non-weight-bearing exercises are beneficial in regaining the lower limb motor activity of the Stroke patients. The results of this study are consistent with the previous study done by Stensdotter and coworkers.⁵⁷ But weight-bearing exercises are more beneficial than combined activities. The Stroke patient's lower limb motor activity can be improved without focussing on the non-weight-bearing phases also. So, this study has intensified the concept of increased intensity of therapy leads to more significant functional outcome.

Summary

Weakness is the commonest complication after the Stroke. It appears to correspond to the severity of the Stroke and is a relatively consistent phenomenon.

Unless it is treated, it will cause undesirable effects which limits one's overall functional level thereby affects the patient's quality of life.

A sample of 30 subjects were randomly divided into three equal groups and out of them group A and group B were considered as experimental group whereas the group C was considered as control group. Among the experimental groups, group A received combined weight-bearing and non-weight-bearing exercises in which each exercise consists of both weight-bearing and non-weight-bearing phase in a single repetition. The subjects of group B received weight-bearing exercises where each exercise consists of weight-bearing phase alone. The pre and post test values were obtained using three standard outcome measures namely STREAM scale, Tinetti scale and Timed Up and Go test. The pre-post values were statistically analyzed and the results showed that weight-bearing exercises were more beneficial than the combined weight-bearing and non-weight-bearing exercises.

Reference

1. Patten C, Lexell J, Brown HE. Weakness and strength training in persons with post Stroke hemiplegia: Rationale, method, efficacy. *J Rehabil Res Dev*,2004;41(3):293-312.

2. Ingles JL, Eskes GA, Phillips SJ. Fatigue after Stroke. *Arch Phys Med Rehabil*,1999;80(2):173–8.
3. Gandevia SC. The perception of motor commands or effort during muscular paralysis. *Brain*,1982;105:151–59.
4. Berta Bobath, *Adult Hemiplegia, Evaluation a Treatment* 3rd Ed. s
5. *Neurological Rehabilitation*, 4th ed, Darcy Umphered, p742-743.
6. *Joint structure function*, 3rd Ed, Pamela K Levangie, Cynthia Norkin p75.
7. Zackowski KM, Dromerick AW, Sahrman SA, Thach WT, Bastian AJ. How do strength, sensation, spasticity and joint individuation relate to the reaching deficits of people with chronic hemiparesis? *Brain*,2004;127(5):1035–46.
8. Harris ML, Polkey MI, Bath PM, Moxham J. Quadriceps muscle weakness following acute hemiplegic Stroke. *Clinical Rehabil*,2001;15(3):274–81.
9. Hachisuka K, Umezu Y, Ogata H. Disuse muscle atrophy of lower limbs in hemiplegic patients. *Arch Phys Med Rehabil*,1997;78(1):13–8.
10. Hsu AL, Tang PF, Jan MH, Analysis of impairments influencing gait velocity and asymmetry of hemiplegic patients after mild to moderate Stroke. *Arch Phys Med Rehabil*,2003;84(8):1185–93.
11. Nadeau S, Gravel D, Arsenault AB, Bourbonnais D. Plantar flexor weakness as a limiting factor of gait speed in Stroke subjects and the compensating role of hip flexors. *Clinical Biomechanics Bristol, Avon*,1999;14(2):125–35.
12. Suzuki K, Nakamura R, Yamada Y, Handa T. Determinants of maximum walking speed in hemiparetic Stroke patients. *Tohoku J Exp Med*,1990;162(4):337–44.
13. Mizrahi J, Solzi P, Ring H, Nisell R. Postural stability in Stroke patients vectorial expression of asymmetry, sway activity relative sequence of reactive forces. *Med Biol Eng Compat*,1989;22(2):180–90.
14. Nakamura R, Hosokawa T, Tsuji I. Relationship of muscle strength for knee extension to walking capacity in patients with spastic hemiparesis. *Tohoku J Exp Med*.1985;145(3):335–340.
15. Morris SL, Dodd KJ, Morris ME, Outcomes of progressive resistance strength training following Stroke a systematic review. *Clinical Rehabil*,2004;18(1):27–39.
16. Badics E, Wittmann A, Rupp M, Stabauer B, Zifko UA, Systematic muscle building exercises in the rehabilitation of Stroke patients.
17. Weiss A, Suzuki T, Bean J, Fielding RA, High intensity strength functional performance after Stroke. *Am J Phys Med Rehabil*,2000;79(4):369–76.
18. Teixeira-Salmela LF, Olney SJ, Nadeau S, Brouwer B. Muscle strengthening physical conditioning to reduce impairment and disability in chronic Stroke survivors. *Arch Phys Med Rehabil*. 1999;80(10):1211–8.
19. Richards CL, Malouin F, Wood-Dauphinee S, Williams JI, Bouchard JP, Brunet D. *et al* Task-specific physical therapy for optimization of gait recovery in acute Stroke patients *Arch Phys Med Rehabil*.1993;74(6):612–20.
20. Nakamura R, Watanabe S, Handa T, Morohashi I. The relationship between walking speed and muscle strength for knee extension in hemiparetic Stroke patients: a follow-up study. *Tohoku J Exp Med*,1988;154(2):111–3.
21. Viosca E, Lafuente R, Martinez JL, Almagro PL, Gracia A, Gonzalez C. *et al* Walking recovery after an acute Stroke: assessment with a new functional classification the Barthel Index. *Arch* 2005;86(6):1239–44.
22. De Haart M, Geurts AC, Dault MC, Nienhuis B, Duysens J. Restoration of weight-shifting capacity in patients with post acute Stroke: a rehabilitation cohort study. *Arch Phys Med Rehabil*.2005;86(4):755–62.
23. Lomaglio MJ, Eng JJ, Muscle strength weight-bearing symmetry relate to sit-to-stand performance in individuals with Stroke. *Gait Posture*,2005;22(2):126–31.
24. Stensdotter AK, Hodges PW, Mellor R, Sundelin G, Hager-Ross C. Quadriceps activation in closed in open kinetic chain exercise. *Medicine and Science in Sports and Exercise*,2003;35(12):2043–7.
25. Eng JJ, Chu KS. Reliability comparison of weight-bearing ability during standing tasks for individuals with chronic Stroke. *Archives of Physical Medicine Rehabilitation*,2002;83(8):1138–44.
26. Deschenes MR, Giles JA, McCoy RW, Volek JS, Gomez AL, Kraemer WJ, *et al* Neural factors account for strength decrements observed after short-term muscle unloading. *Am J Physiol Regul Integr Comp Physio*
27. Schulze K, Gallagher P, Trappe S. Resistance training preserves skeletal muscle function during unloading in humans. *Medicine and Science in Sports Exercise*,2002;34(2):303–13.
28. Janssen WG, Bussmann HB, Stam HJ. Determinants of the sit-to-stand movement a review. *Physical Therapy*,2002;82(9):866–79.
29. Alexander A, Aruin, Tim Hanke, Gouri Choudhuri, Richard Harvey, Noel Roe, *et al* Compelled weight-bearing in persons with hemiparesis following stroke: the effect of a lift inserts and goal-direct balance exercises. *Journal of Rehabilitation Research and Development*,2000;37(1).
30. Dean CM, Richards CL, Malouin F. Task-related circuit training improves performance of locomotor tasks in chronic stroke a randomized, controlled pilot trial. *Archives of Physical Medicine Rehabilitation*,2000;81(4):409–17.
31. Escamilla RF, Fleisig GS, Zheng N, Barrentine SW, Wilk KE, Biomechanics of the knee during closed kinetic chain open kinetic chain exercises. *Medicine and Science in Sports and Exercise*,1998;30(4):556–69.
32. Malouin F, Potvin M, Prevost J, Richards CL, Wood-Dauphinee S. Use of an intensive task-oriented gait-training program in a series of patients with acute cerebrovascular accidents. *Physical Therapy*,1992;72(11):781–9.
33. Pincivero DM, Lephart SM, Karunakara RG, Relation between open and closed kinematic chain assessment of knee strength and functional performance. *Clinical Journal of Sport Medicine*,1997;7(1):11–16.
34. Perennou D, Decavel P, Manckoundia P, Penven Y, Mourey F, Launay F. *et al* Evaluation of balance in

- neurologic and geriatric disorders. *Annales de Réadaptation et de Médecine Physique*,2005;48(6):317–35.
35. Ng SS, Hui-Chan CW, the timed up go test its reliability and association with lower-limb impairments and locomotor capacities in people with chronic stroke. *Archives of Physical Medicine Rehabilitation*,2005;86(8):1641–7.
 36. Hsueh IP, Wang CH, Sheu CF, Hsieh CL, Comparison of psychometric properties of three mobility measures for patients with stroke. *Stroke*,2003;34(7):1741–5.
 37. Brunnstrom S. Walking preparation for adult patients with hemiplegia. *Physical Therapy*,1965;45:17–29.