EFFECT OF PELVIC AND TRUNK CONTROL EXERCISES ON FUNCTIONAL OUTCOME OF AFFECTED UPPER EXTREMITY IN STROKE PATIENTS

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Abstract

Background: There is evidence that pelvic and trunk control exercises are one of the contributing factors that enhance the upper extremity functional outcome in stroke patients.

Aim: The study aimed to provide an insight into how pelvic and trunk control exercises together impacted the affected upper extremity functional outcomes for stroke patients.

Methods: The study's sample comprised of forty male stroke patients. They were between 45 and 60 years old. The patients were split into two groups equal in number: the control group (GA) received a selected physiotherapy program for thirty minutes, while the study group (GB) received the similar treatment program plus pelvic and trunk control exercises for forty minutes. Both groups received 3 sessions weekly on alternate days for 6 weeks. The Biodex System Pro Isokinetic and Fugel Meyer scale (FMA) were used to measure the functional outcomes of the affected upper extremity.

Results: In contrast to the control group, the post-treatment mean values of the study group of the elbow flexors isometric contraction, isokinetic contraction of elbow flexors and extensors, isometric contraction of shoulder abductors peak torque, and FMA scores all revealed a significant increase ($p<0.05$).

Conclusion: The impaired upper extremity functional outcomes of stroke patients are significantly impacted by pelvic and trunk control exercises.

Keywords: Pelvic control exercises**.** Trunk control exercises**.** Isokinetic biodex system**.** Fugel Meyer Scale**.** Stroke**.** Functional outcome.

Introduction

Due to motor cortical damage, stroke is a widespread disease that has a high rate of mortality and disability [1]. Based on available data, the annual number of new stroke patients globally is estimated to be around 13.68 million, and over 70% of survivors experienced varying degrees of dysfunction related to upper limb and hand motions [2]. An individual's ability to actively participate in society is impacted by this dysfunction. It was discovered that the degree of independence in daily living activities had an impact on returning to work following a stroke [3].

Pelvic stability refers to the capability to regulate the muscular contraction between the hip and the lower trunk muscles to enable effective lower extremity movement and proximal stabilization during functional balance and mobility activities [4].

The pelvis is the main structure that carries the weight of the body and transmits it to the lower extremities, connecting the trunk to the lower extremities. Additionally, when a person is seated, it is a part of their lower trunk; yet, when they are standing and walking, it becomes a functional part of their lower limb [5].

Upper-limb functions depend on pelvic stability. An important relationship between pelvic position, trunk control, and upper-extremity motor recovery has been documented in earlier research [6]. Because the lower trunk and pelvis have impaired dynamic stability after a stroke, the pelvis may move initially while reaching for an objective that was initiated by the upper body. Stroke patients typically move their pelvis first, then their trunk and head, when reaching. As opposed to this, healthy individuals start motions from the head and then move through the torso and pelvis [7,8].

In stroke patients, pelvic stability training helps to improve hip muscle strength, gait velocity, and trunk and lower limb motor recovery, as well as routine activities [5].

One of the main reasons of diminished trunk movement and related activities is stroke with long-term disability. Stroke often results in diminished strength and delayed trunk muscle activation. It causes difficulties with the patient's ability to walk, balance when sitting, as well as the sense of position. The symmetry and function of the trunk are strongly linked to balance [9].

The prognosis of stroke patients is largely influenced by trunk function. Static and dynamic stability is a significant prognostic indicator for stroke recovery because head control and extremities motions greatly affect routine activities [10].

Thus, trunk exercises may enhance functional recovery and stability. Research indicates that performing trunk exercises while sitting or lying supine, comprising core strength, weight transfer exercises, and proprioceptive neuromuscular facilitation, may enhance trunk steadiness, seated and standing stability, and locomotion in individuals in the sub-acute phase of stroke [9,11].

Reaching, gripping, and handling objects are examples of upper extremity tasks that depend on the shoulder girdle's dynamic stability in a stable trunk [12]. The movement and activation of the trunk muscles are strongly reliant on the pelvic alignment; hence, any mechanical abnormalities in the pelvis may prevent the activation of these muscles [13].

The study aimed to provide insight into how pelvic and trunk control exercises together impacted the affected upper extremity functional outcomes for stroke patients.

Materials and methods

A randomized controlled study was conducted at Cairo University's outpatient clinic for the Faculty of Physical Therapy between May 2023 and April 2024. Before their first evaluation, every patient received a detailed explanation of the goals, methods, and possible benefits of the study. The Faculty of Physical Therapy Ethical Committee at Cairo University accepted the study (P.T.REC/012/004391). Before the experiment started, each patient signed an informed consent form to ensure their acceptance.

Study population

Forty stroke male patients represented the sample of this study. A neurologist provided the diagnosis, which was then supported by an MRI or CT scan. Participants were considered eligible for this study based on these criteria. The patients' age were between 45 and 60 years; 2) They had either a single ischemic or hemorrhagic stroke;3) Their illness lasted between 6 and 18 months; and 4) Their muscle tone grade, on the modified Ashworth scale, varied from 1 to 1+. The patients could stand with or with no assisted device and were in a stable medical condition.

Patients with the following conditions were not accepted to participate: 1) perceptual or cognitive dysfunctions; 2) other neurological or musculoskeletal disorders that could impair upper or lower limb functions; 3) recurrent stroke; 4) severe spasticity; 5) upper limb or shoulder injuries that could impair recovery; and 6) BMI > 30 kg/m^2.

Randomization

Using a sealed envelope method, patients were distributed at random into study or control groups, with 20 patients in each group. The s physiotherapy program was administered alone to the control group, while the study group additionally performed pelvic and trunk control exercises.

Assessment

For all patients in both groups, the evaluations were completed both prior to and subsequent to treatment.

Assessment of muscle strength and upper limb function: The Biodex System 3 Pro Isokinetic (Biodex Medical Inc., Shirley, New York, NY, USA) was utilized to evaluate each patient's upper limb function and muscle strength objectively both before and after treatment. Measurements were made of isokinetic arm strength (elbow extension/flexion) and isometric arm strength (shoulder abduction and elbow flexion). When a patient has a persistent stroke and has mild to moderate arm paresis, these muscle groups are good indicators of upper extremity function [14]. The evaluative procedure was conducted in a quiet, separate room on the same day time. To ensure measurement consistency and prevent participant fatigue, the following order of measurements was followed: isometric shoulder abductors strength, isokinetic elbow flexors and extensors strength, and isometric elbow flexors strength. The participants were not permitted to view the computer display throughout the measurements, but they were directed by regular verbal commands and encouragement [14].

Assessment of upper limb motor recovery: An impairment-based tool called the Fugel Meyer Assessment Scale (FMA) [15] was created to assess motor recovery following a stroke. It is reliable, precise, and adaptable. Joint range of motion, balance, motor and sensory functions, and joint pain are its five FMA domains. The motor domain is the most frequently utilized and is primarily useful for evaluating a stroke patient motor recovery.

It took up to 30 minutes to administer and needed the following items: a chair, bedside table, pencil, reflex hammer, tiny slice of paper or card, small can, tennis ball, and stopwatch. When the patient was at their most alerts, the evaluations were conducted in a calm setting. 33 items were used to assess the patients. All scores range from 0 to 2, where zero indicates no performance, 1 indicates partial performance, and 2 indicates full performance. Reflex activity, however, is only scored with two points; a score of zero or two indicates the absence or the existence of a reflex, respectively.

The following protocols were adhered to during the voluntary movement evaluation (flexor/extensor synergy, and motion integrating synergies, motion out of synergy, wrist, hand, and coordination/velocity).

They started with the non-affected extremity and completed each movement three times on the affected side before scoring the best performance. You did not need to repeat three times if a complete score was achieved on trials one or two. Only coordination and speed tests were conducted once.

Interventions

Every training session was supervised by the same physiotherapist. The patients were allocated to two equal groups, the control group (GA) and the study group (GB). General patient's characteristics as age, height, weight, BMI, and the duration of disease were matched between the two groups.

The control group (GA) received a selected physiotherapy program consisting of exercises that stretched the pectoralis major muscle and strengthened the shoulder musculature through active resistive shoulder abduction and external rotation, strengthening the upper trapezius muscle, strengthening the serratus anterior muscle, proprioceptive neuromuscular facilitation for the upper extremities, weight-bearing exercises, and local facilitatory techniques (extroceptors, muscle tapping, vibration, activated muscles (isometric, eccentric, and concentric contractions)). This was performed for 30 minutes, 3 sessions weekly, on alternate days for 6 weeks.

The same program was administered to the study group (GB) along with 40 minutes of pelvic and trunk control exercises, which comprised pelvic tilting and pelvic stability exercises from various positions, abdominal drawing in technique for contraction of transversus abdominis, anterior/posterior, and lateral pelvic tilt, as well as pelvic rotation on a therapeutic ball. Exercises for pelvic stability included quadruped exercises, ball bridging, half-bridging, clamshells from supine and side lying, weight transfer on the impaired limb from standing via forward and diagonal reaching out, and rhythmic stabilization exercises. Every exercise was performed twice for a total of ten repetitions, with ten seconds of rest in between.

Sample size calculations

The G*POWER statistical software (version 3.1.9.2; Franz Faul, Universitat Kiel, Germany) carried out the sample size calculation utilizing data from the Biodex System 3 Pro Isokinetic pilot study, which involved five subjects per group. The results indicated that this study required eighteen subjects per group. The calculations utilized α = 0.05, power = 80%, and effect size = 0.96. Each group comprised a total of 20 subjects to accommodate a 10% dropout rate.

Data analysis

The unpaired t-test was utilized to differentiate the characteristics of the subjects between the groups, and the Chi-squared test was employed to compare the distribution of spasticity grades and the affected side. The data was tested for normal distribution utilizing the Shapiro-Wilk test. To evaluate the homogeneity across groups, Levene's test for homogeneity of variances was used. To examine treatment effects within and between groups on isometric shoulder abductors peak torque, isokinetic elbow flexors and extensors peak torque, and FMA, a two-way mixed MANOVA was used. Bonferroni corrections were done for subsequent multiple comparisons. All statistical tests were conducted with a significance level of $p < 0.05$. The statistical software for social sciences (SPSS) version 25 for Windows (IBM SPSS, Chicago, IL, USA) was utilized for all statistical tests.

Results

Subject characteristics

The subject characteristics of the two groups are illustrated in Table (1). Age, height, weight, BMI, duration of disease, affected side, and distribution of spasticity grades did not significantly differ across the groups ($p > 0.05$) (Table 1).

Impact of intervention on isometric elbow flexors peak torque, isokinetic elbow flexors and extensors peak torque, isometric shoulder abductors peak torque and FMA:

A two-way mixed MANOVA revealed a significant interaction between treatment and time (F = 31.22, p = 0.001). Time had a significant main effect (F = 86.97, p = 0.001). The main effect of treatment was significant (F = 2.50, p = 0.04).

Within group comparison

There was a significant increase in the peak torque of elbow and shoulder muscles of both groups after treatment compared with before treatment ($p < 0.001$). The percentage of change of in isometric elbow flexors, isokinetic elbow flexors and extensors and isometric shoulder abductors peak torque of control group was 22.2, 18.3, 21.7 and 12.9% respectively, and that of study group was 61.5, 68, 43.4 and 43.3% respectively.

There was a significant increase in FMA of both groups after treatment compared with before treatment ($p < 0.001$). The percentage of change of in FMA of control group was 6.7 % and that of study group was 27.8%. (Table 2-3).

Between group comparison

Before intervention, no significant change between both groups was reported ($p > 0.05$). Following intervention, there was a significant change ($p < 0.05$) in the study group's isometric elbow flexors, isokinetic elbow flexors and extensors, and isometric shoulder abductors peak torque and FMA compared to that of the control group (Table 2-3).

Discussion

This study was carried out to investigate the impact of pelvic and trunk control exercises on the affected upper extremity functional outcomes in stroke patients. Forty stroke male patients represented the sample of the study. Functional outcomes of affected upper extremity were measured by Biodex

Table 1. Subject characteristics of both groups.

	Control group	Study group	p-value
	Mean ± SD	**Mean ± SD**	
Age (years)	54.35 ± 5.82	55.45± 4.87	0.24
Weight (kg)	81.50 ± 4.02	82.20 ± 5.35	0.69
Height (cm)	171.20 ± 5.39	172.05 ± 4.77	0.41
BMI (kg/m²)	27.86 ± 1.78	27.79 ± 1.85	0.94
Duration of illness (month)	13.25 ± 2.94	12.80 ± 3.34	0.65
Affected side, n (%)			
Dominant side	6 (30%)	8 (40%)	0.51
Non-dominant side	14 (70%)	12 (60%)	
Spasticity grades, n (%)			
Grade I	15 (75%)	13 (65%)	0.49
Grade I+	5 (25%)	7 (35%)	

SD, Standard deviation; p value, Level of significance

Table 2. Mean isometric elbow flexors peak torque, isokinetic elbow flexors and extensors peak torque and isometric shoulder abductors peak torque before and after treatment of control and study groups.

Peak torque (Nm)	Pre treatment	Post treatment	MD	% of change	p value
	Mean ±SD	Mean ±SD			
Isometric elbow flexors					
Control group	14.98 ± 6.85	18.31 ± 8.94	-3.33	22.2	0.006
Study group	15.81 ± 4.13	25.53 ± 8.23	-9.72	61.5	0.001
MD	-0.83	-7.22			
	p = 0.65	p = 0.01			
Isokinetic elbow flexors					
Control group	8.82 ± 5.04	10.43 ± 4.93	-1.61	18.3	0.001
Study group	8.72 ± 4.22	14.65 ± 5.12	-5.93	68	0.001
MD	0.1	-4.22			
	p = 0.94	p = 0.01			
Isokinetic elbow extensors					
Study group	10.61 ± 5.59	12.91 ± 5.45	-2.3	21.7	0.001
Control group	11.98 ± 5.19	17.18 ± 6.42	-5.2	43.4	0.001
MD	-1.37	-4.27			
	p = 0.43	p = 0.02			
Isometric shoulder abductors					
Study group	15.46 ± 6.60	17.46 ± 7.24	-2	12.9	0.001
Control group	16.75 ± 8.14	24.01 ± 9.35	-7.26	43.3	0.001
MD	-1.29	-6.55			
	p = 0.59	p = 0.01			

SD, Standard deviation; MD, Mean difference; p value, Probability value

Table 3. Mean FMA before and after treatment of both groups.

	Pretreatment	Post treatment	MD	% of change	p value
	Mean ±SD	Mean ±SD			
FMA					
Control group	41.10 ± 10.21	43.85 ± 9.59	-2.75	6.7	0.001
Study group	40.25 ± 7.28	51.45 ± 8.22	-11.2	27.8	0.001
MD	0.85	-7.6			
	p = 0.76	p = 0.01			

SD, Standard deviation; MD, Mean difference; p value, Probability value

System 3 Pro Isokinetic and FMA.

Trunk and pelvic control exercises were reported to have a significant efficacy on isometric shoulder abductors (p <0.001). The shoulder abductors were only assessed isometrically in this study since elevating the arm above the horizontal plane increases the risk of impingement for many stroke survivors. To ensure a pain-free position, the contractions were carried out with the scapular plane slightly abducted (15°). These results supported the outcomes of Baby et al. [16] and Liao et al. [17] that core control and stability are closely linked to upper-limb function.

This could be explained by the fact that, when seated, the pelvis is a component of the lower trunk that provides dynamic postural stability during lateral and anterior weight transfers. A person has to have improved dynamic control of the lower trunk and pelvis in order to accomplish side bending and rotation of trunk motions when seated 6.

For patients with impaired upper extremity function, daily tasks including reaching and manipulating the arm, hand, and fingers of the paretic side present challenges [18]. Multifidus, rectus abdominis, abdominal oblique, and transversus abdominis muscles, are often activated before any limb motion during whole-body motions, indicating that motion control and stability develop in a core-to-extremities progress [19]. The stabilization of the shoulder girdle, spine, and pelvis in this instance is accomplished by the core muscles, which also offer an adequate foundation for limb motion.

Furthermore, a significant change (p<0.001) was reported between the two groups in isometric elbow flexion and isokinetic elbow flexion and extension. These findings corroborated the findings of Miyake et al. [12], who highlighted that shoulder stability improves elbow, wrist, and finger mobility, while trunk stability assures shoulder movement. Both isometric and isokinetic measurements were made of the elbow, which is a more stable joint than the shoulder. This could be explained by the fact that core stability is crucial for balance, motor task performance, and coordinated extremities movement [20]. Limb mobility is expected to increase with improved proximal stability [21]. Impaired upper and lower extremity functions are the result of compromised postural control and core stability in stroke survivors [22,23].

Neurological and musculoskeletal disorders hinder postural adjustments [24,25]. When performing a voluntary movement, muscles that regulate spinal stiffness and, hence, spinal stability, are used. These muscles serve both agonist and postural functions. Muscle activation makes the spine more rigid, which promotes stability and keeps the spine from buckling under load in stationary positions or during motion. It can be expected, synthetically, that the coordinated motion of both upper limbs necessitates the regulation of various types of restrictions involved in task as well as the activation of muscles with a postural role [26].

Furthermore, the study's results reported a significant effect of trunk and pelvic control exercises on FMA (p<0.001). These results supported the findings provided by Gillen [27] that stroke patients frequently assume a posterior pelvic tilt, which causes spinal flexion and subsequent muscular imbalance, with the extensors becoming elongated and the abdominals becoming shortened. The lack of natural lumbar spine lordosis and exaggerated thoracic spine kyphosis as a result of spinal flexion causes the scapula to become misaligned. Humeral internal rotation results from the scapula's tendency to spin downward. In these cases, this could be a factor in the upper extremity's delayed functional recovery.

Our study's findings, however, disagree with those of El-Nashar et al. [18]. This difference may be related to the moderate level of spasticity; this could account for the inadequate recovery of upper limb function, indicating that the appropriate motor deficiencies may not have been addressed by training. This could be the result of either spasticity in the biceps, which affects or impairs upper extremity function, or abnormal elbow flexor synergy patterns, which involve too much co-contraction between elbow flexors and extensors along with contraction of shoulder abductors, resulting in the joint torque included connection of shoulder abduction with elbow flexion.

Additionally, our study's findings contradict the findings of Sumi et al. [28], which was that the majority of motor and functional recovery occurs in the first three months following a stroke.

The study only included male stroke patients; therefore, additional research involving both gender is required to examine the impact of pelvic and trunk control exercises on the impaired upper extremity functional outcomes in stroke patients.

Conclusion

The study's findings revealed that for stroke patients, pelvic and trunk control exercises significantly affect the functional outcome of the impacted upper extremity.

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Conflict of interest

There was no conflict of interest among the authors.

References

1. Pan B, Huang Z, Jin T, Wu J, Zhang Z and Shen Y. Motor Function Assessment of Upper Limb in Stroke Patients. Journal of Healthcare Engineering 2021; 11
2. Johnson C. O. Global, regional, and national burden of stroke, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. The Lancet Neurology. 2019;18(5):439–458.
3. Enas Elsayed, Gehad Mohammed, Khaled Takey Ahmed, Amira H Mohammed, Nesma A Helmy, and Ahmed S Ali (2021). Factors affecting return of stroke patients to their job. Clin Schizophr Relat Psychoses 15 (S8): 1-4.
4. Jung, K. S., Jung, J. H., In, T. S., & Cho, H. Y. (2022). Effects of Pelvic Stabilization Training with Lateral and Posterior Tilt Taping on Pelvic Inclination, Muscle Strength, and Gait Function in Patients with Stroke: A Randomized Controlled Study. BioMed Research International, 2022: 9224668.
5. Dubey L, Karthikabu S, Mohan D. Effects of Pelvic Stability Training on Movement Control, Hip Muscles Strength, Walking Speed and Daily Activities after Stroke: A Randomized Controlled Trial. Ann Neurosci. 2018; 25(2):80–89.
6. Enas Elsayed, Amr Hassan, Heba khalifa, Rowida Elsayed. (2019). Relationship between pelvic alignment and motor recovery of the affected upper extremity in stroke patients. The Second International Conference on Scientific Research and Its Practical Applications in Physical Therapy. Cairo University, 28 November
7. Iyengar YR, Vijayakumar K, Abraham JM, Misri ZK, Suresh BV, Unnikrishnan B. Relationship between postural alignment in sitting by photogrammetry and seated postural control in post-stroke subjects. NeuroRehabil. 2014; 35(2):181–190.
8. Pathak S, Vijayakumar K, Nayak A, Kedambadi RC. The relationship between pelvic alignment and trunk control in stroke subjects: a cross-sectional study. Int. J. Res. Med. Sci. 2014; 2(4): 1483–1447.
9. Haruyama K, Kawakami M, Otsuka T. Effect of core stability training on trunk function, standing balance, and mobility in stroke patients: a randomized controlled trial. Neurorehabil Neural Repair. 2017;31(3):240–9.
10. Selves C, Stoquart G, Lejeune T. Gait rehabilitation after stroke: review of the evidence of predictors, clinical outcomes and timing for interventions. Acta Neurol Belg. 2020;120(4):783–90.
11. Yoon, H.S.; Cha, Y.J.; You, J.S.H. E_ects of dynamic core postural chain stabilization on diaphragm movement, abdominal muscle thickness, and postural control in patients with subacute stroke: A randomized control trial.NeuroRehabilitation 2020, 46, 381–389.
12. Miyake Y, Kobayashi R, Kelepecz D, Nakajima M. Core exercises elevate trunk stability to facilitate skilled motor behavior of the upper extremities. Journal of body work and movement therapies. 2013;17(2):, 259-265
13. Pathak S, Kumar V, Nayak A, Kedambadi RC. The relationship between pelvic alignment and trunk control in stroke subjects: a cross-sectional study. Int J Res Med Sci. 2017;2(4):1483–7.
14. Ekstrand E, Lexell J, Brogardh C. Grib strength is a representative measure of muscle weakness in the upper extremity after stroke. Topics in stroke rehabilitation. 2015, 23(6). 400-405
15. Fugl-Meyer AR, Jääskö L, Norlin V (1975): The post-stroke hemiplegic patient.II. Incidence, mortality, and vocational return in Göteborg, Sweden witha review of the literature. Scand J Rehabil Med, 7:73–83.
16. Baby L, Joy, A.; Ranjith, K.V. Relationship between trunk impairment and upper extremity function, and its impact on activities of daily living in chronic stroke survivors. Int. J. Sci. Healthc. Res. 2021, 6, 220–227.
17. Liao, C.F.; Liaw, L.J.; Wang, R.Y.; Su, F.C.; Hsu, A.T. Electromyography of symmetrical trunk movements and trunk position sense in chronic stroke patients. J. Phys. Ther. Sci. 2015, 27, 2675–2681.
18. El-Nashar, H.; ElWishy, A.; Helmy, H.; El-Rwainy, R. Do core stability exercises improve upper limb function in chronic stroke patients? Egypt. J. Neurol. Psychiatry Neurosurg. 2019, 55, 38.
19. Bacho Z , Khin N and Daud M. Effect of Core Exercises on Motor Function Recovery in Stroke Survivors with Very Severe Motor Impairment. J. Cardiovasc. Dev. Dis. 2023, 10, 50
20. Lee, K.; Lee, D.; Hong, S.; Shin, D.; Jeong, S.; Shin, H.; Choi,W.; An, S.; Lee, G. The relationship between sitting balance, trunk control and mobility with predictive for current mobility level in survivors of sub-acute stroke. PLoS ONE 2021, 16, e0251977.
21. Lazaro, R. Within-session effects of selected physical rehabilitation interventions for a dysfunctional arm post-stroke on arm movement and muscle firing patterns. Ann. Phys. Rehabil. Med. 2018, 61, e185.
22. Yang, S.H.; Chung, E.J.; Lee, J.; Lee, S.H.; Lee, B.H. The effect of trunk stability training based on visual feedback on trunk stability, balance, and upper limb function in stroke patients: A randomized control trial. Healthcare 2021, 9, 532.
23. Aguiar, L.T.; Camargo, L.B.A.; Estarlino, L.D.; Teixeira-Salmela, L.F.; de Morais Faria, C.D.C. Strength of the lower limb and trunk muscles is associated with gait speed in individuals with sub-acute stroke: A cross-sectional study. Braz. J. Phys. Ther. 2018, 22, 459–466.
24. Jacobs, J.V., Kasser, S.L.,. Balance impairment in people with multiple sclerosis: Preliminary evidence for the Balance Evaluation Systems Test. Gait Posture 2012 36, 414–418.
25. Keser, I., Kirdi, N., Meric, A., Tuncer Kurne, A, Karabudak, R. Comparing routine neurorehabilitation program with trunk exercises based on Bobath concept in multiple sclerosis: Pilot study. J. Rehabil. Res. Dev. 2013, 50, 133–140.
26. Tettamanti, A., Giordano, M., Gatti, R.,. Effects of coupled upper limbs movements on postural stabilisation. J. Electromyogr. Kinesiol. 2013, 23, 1222–1228
27. Gillen G. (2015): Stroke Rehabilitation A Function-Based Approach. 4th edition, Published; p 471.
28. Sumi, R.; Vasanthan, R. Effect of trunk strengthening exercise on functional outcome in post stroke patients. Int. J. Curr. Res. 2016, 8, 33658–33665.