Title of the article

Relationship of trunk control, core muscles strength and balance confidence in community-dwelling patients with chronic stroke.

Authors

Suruliraj Karthikbabu and Geert Verheyden

Abstract

Background and objective: Impaired trunk control and core muscles weakness affect the balance capacity after stroke. The study objective was to examine the relationship of trunk control, core muscle strength and self-confidence on balance efficacy in community-dwelling chronic stroke survivors and also to find the trunk performance measures for the determinants of balance confidence.

Methods: Patients with a median post-stroke duration of 12 (IQR 7–18) months and independent walking ability participated in this cross-sectional study. Trunk control, core muscle strength and balance confidence were measured using trunk impairment scale 2.0 (TIS 2.0), handheld dynamometer and activity-specific balance confidence scale, respectively. Correlation among TIS 2.0, core muscles strength and balance confidence were tested by Pearson's correlation coefficient. Stepwise multivariate linear regression analysis was conducted to examine the most important trunk performance variables determining the balance confidence.

Results: Of 177 study participants, the median (IQR) score of TIS 2.0 was 10 (7–12) out of 16 and balance confidence was 41 (27–61) out of 100. Trunk control was highly correlated to overall core muscles strength (R=0.61–0.70) and balance confidence (R=0.66) with a statistical significance of $p<0.001$. The major determinants of the balance confidence were the TIS 2.0 total score (R^2=0.46) and selective trunk lateral flexion (R^2=0.46) in chronic stroke.

Conclusion: A significant and strong positive association existed among trunk control, core muscles strength and balance confidence in community-dwelling patients with chronic stroke, warranting further investigation of the effect of trunk rehabilitation strategies.

Keywords: Trunk control, core strength, balance confidence, stroke

Introduction

Trunk control in sitting is clinically measured using Trunk Impairment Scale 2.0 (TIS 2.0)[1] and the trunk performance is related to balance capacity, walking and physical function in people after stroke.[2] Trunk post-stroke has widely been studied in the past decade and recent systematic reviews concluded that trunk exercise regimes practiced either on a stable or an unstable support surface are beneficial in improving trunk control, functional balance, and mobility in patients with stroke.[3,4] Trunk exercise regimes in chronic stroke showed favorable changes in trunk control, balance, physical function, and community participation compared to standard rehabilitation care.[5] From the ideas of published literature, treating trunk post-stroke is one of the possible ways of addressing functional performance and community participation. However, the benefits of trunk exercise program on core muscles strength and balance confidence are not clearly understood in scientific literature.

It is well recognized that the core muscles strength is poor post-stroke. The weakness of trunk flexors, extensors, lateral flexors and rotators in both sub-acute and chronic stage stroke recovery was confirmed by isokinetic[6,7] and handheld dynamometer muscle strength testing.[8,9] Trunk muscle weakness is believed to affect balance and daily functional tasks after stroke,[10] and was related to inadequate sit to stand performance measured using motion analysis system.[11] Patients having a good trunk performance post-stroke, particularly in dynamic sitting balance showed better functional status in late-stage stroke recovery.[12] Balance and mobility issues are common in patients who experienced a previous history of recurrent falls.[13] Additionally, stroke survivors residing in the community might experience fear of fall due to less confidence level of losing balance or becoming unsteady while performing daily functional and mobility tasks.[14] A cross-sectional study reported that balance capacity and self-confidence on balance efficacy in patients with chronic stroke positively affect their physical functioning[15] and satisfaction with community reintegration.[16]

The fact that the trunk muscles primarily contribute to stabilizing the torso and pelvis, optimal core strength is conditional for the selective trunk movements, and also for the coordinated movements between trunk and extremities during many daily activities. Poor selective movement of trunk lateral flexion and rotation in chronic stroke was shown to affect the pelvic stability in standing and was related to lower limb motor recovery.[17] The dissociated movement between upper and lower trunk and core muscles strength is of great importance in chronic stroke survivors for having confidence in not losing balance whilst meeting daily functional needs. To date, it is not clear about the extent of trunk control deficits on core muscles strength and balance confidence in patients with chronic stroke. To the best of our efforts, we couldn't retrieve information on whether the selective voluntary control of trunk movements or core muscles strength were the major determinants of the balance self-efficacy in community dwelling chronic stroke survivors. Hence this study was designed to examine the relationship among trunk control, core muscles strength and self-confidence on balance efficacy in community-dwelling patients with chronic stroke, and also to find the major determinants of balance confidence whilst doing daily activities.

Methods

Participants

Community-dwelling chronic stroke survivors were contacted in out-patient physiotherapy units and tertiary rehabilitation centers. Through the convenience sampling method, the consecutive patients post-stroke visiting those centers were screened for study eligibility. They were informed about the objectives and procedures of the study and were requested to give written informed consent to volunteer in the study. Following study eligibility screening, patients with medical stability, first onset of supratentorial stroke, either gender aged between 30 and 75 years, scoring 20 or less out of 23 points on trunk impairment scale and independent walking capacity were included in the study. Patients having severe cognitive-perceptual dysfunction limiting their ability to follow simple verbal instructions, balance dysfunction due to other neurological disorders and diagnosed orthopedic conditions of lower limb in recent 4 months were excluded from the study. This cross-sectional study got its approval from institutional review committee of Manipal College of Health Professions, Manipal Academy of Higher Education and registered in the Clinical Trials Registry – India (CTRI/2017/08/009235).

Procedure

The patients meeting the eligibility criteria were assessed for their trunk control in a seated position by TIS 2.0. The TIS 2.0, a reliable clinical utility measurement has recently been validated with the original trunk impairment scale. Assessing dynamic sitting balance and trunk coordination is meaningful for stroke patients who had attained independent standing ability and walking capacity. So the subscale of static sitting balance was removed.[1] The dynamic sitting balance subscale of TIS 2.0 evaluated the selective movement of trunk lateral flexion initiated from the shoulder and pelvic girdle. The possible compensatory movement of torso and extremities were recorded. The coordination subscale of TIS 2.0 assessed the dissociated movement between upper and lower trunk against time.[1]

The strength of core muscles, namely trunk flexors, extensors, rotators towards most and least affected sides and bilateral trunk lateral flexors was examined using hand-held push-pull dynamometer (Fabricatio enterprises incorporation, New York). The isometric strength of core muscles was quantified using a break test. The test positions were standardized and proven to be reliable in measuring core muscles strength in people with chronic stroke.[18,19] The strength of trunk flexors and rotators muscles was tested whilst the patient was in supine position. To record the trunk flexors strength, the patient was asked to generate the maximum force against dynamometer placed at the sternum by clearing both the scapula from the plinth. The trunk rotators strength was recorded whilst asking the patient to lift the ipsilateral scapula by performing flexion-rotation of upper trunk and generating the optimal force against the dynamometer kept at the chest medial to shoulder joint. The strength of trunk rotator towards most and least affected sides was recorded. To measure the trunk extensor muscle strength in prone position, the patient was instructed to lift the upper body by generating a force against the dynamometer kept at fourth thoracic spine. The strength of bilateral trunk lateral flexors was recorded in sitting position. Against the dynamometer placed lateral to the chest wall and below the axilla, the patient had to side flex the upper trunk by attempting to move the elbow towards the plinth.[19]

Balance self-efficacy of stroke patients, a confidence capacity of not losing balance while doing day to day activities, was reported using activities specific balance confidence scale, an 11-point ordinal scale comprising of 16 daily functional activities. This questionnaire has good internal consistency, test-retest reliability and was moderately related to balance measures post-stroke. Patients scoring below 50 points in the activities specific balance confidence scale had low physical functioning status characteristics of home care clients. Patients who scored between 50 and 80 points in the said questionnaire had characteristics of chronic health conditions, classified under moderate physical functioning status. Stroke survivors scoring beyond 80 points in the balance confidence scale had high physical functioning status and they could actively participate in major community physical activities.[20,21] All the clinical measures were collected by three physical therapists who were earlier trained for skill acquisition of tool administration. Paper-chit technique was used to decide the order of clinical tests and adequate rest period was given between the measures.

Statistical Analysis

We used SPSS software (version-16.0) for analyzing the data. Demographic characteristics of study participants were reported as descriptive statistics. The descriptive variables of trunk control, core muscles strength and balance confidence were reported into median (interquartile range 25-

75) and range. Pearson correlation coefficient (R) was used to test the strength of association among TIS 2.0, core muscles strength and balance self-efficacy. For subgroup analysis, we stratified the stroke patients according to the side of brain lesions and their physical functioning status. The 'R' value was classified as very low (<0.20), low (0.20–0.39), moderate (0.40–0.59), high (0.60–0.79) and very high (0.80–1.00). The p-value of <0.001 was considered highly significant. The variables were not retained for further analysis if the correlation coefficient was p>0.10. We conducted multivariate regression analysis (R^2) to examine the determinants of trunk performance and core muscles strength for balance self-efficacy, and the determinant models were developed.

Results

Among 209 chronic stroke survivors screened for study eligibility, 177 of them were included in this study. Thirty-two patients were excluded from the study due to the following reasons: Medically unstable–3; bilateral and multiple stroke–5; scoring ≥ 21 on trunk impairment scale–3; unable to walk beyond 10 meters–8; other brain lesion (tumor, head injury)–5; severe osteoarthritis and backache–4; and surgery of lower limb in past four months–4. There were 62% males (N=110) and 38% females (N=67) participated in the study. The median age of the patients was 57 (IQR 46–64, range 30–75) years. Median time since stroke was 12 (IQR 7–18, range 6–85) months. The majority of them (N=107) had left-sided stroke and 70 patients had stroke lesions on the right side. Fifty-seven percent of patients suffered from ischemic stroke (N=101) and 43% had haemorrhagic stroke (N=76). After excluding four patients in subgroup analysis, there were 106 patients scored > 50 in the balance confidence scale under low physical functioning category and 67 patients had a moderate physical functioning status (scored 50–80 points). The median (IQR) and range scores of trunk control, core muscles strength and balance confidence are shown in table 1.

Trunk control (TIS 2.0) showed a high correlation to all the core muscles strength (R=0.61–0.70, p<0.001) and self-confidence on balance efficacy (R=0.66, p<0.001). The trunk control of chronic stroke survivors was much involved in the right-sided stroke. The median score of TIS 2.0 was 10 (7–11) points in the right-sided cortical lesion compared to left-sided stroke lesion [11 (8–12) points], and it was highly correlated to core strength and balance confidence in both the sub-groups. Under the moderate physical functioning status, the trunk control was moderately correlated to balance confidence and all the core muscles strength except trunk extensors. The correlation coefficients among trunk control, core strength, and balance confidence are shown in table 2.

Stepwise multivariate linear regression analysis for variables determining the balance confidence is presented in table 3. When the TIS 2.0 or its subscales were used, the combined variables explained 46 % and 48 % of the variance of the balance confidence in patients with chronic stroke. The models 1 and 2 suggested that TIS 2.0 (R^2–0.431, p<0.001) and dynamic sitting balance subscale of TIS 2.0 (R^2–0.376, p<0.001), respectively were the most important determinants of balance confidence in chronic stroke survivors whilst doing daily activities. In model–3, the strength of trunk rotators towards the least affected side (R^2–0.042, p–0.039) explained additional 4% of the variance of the balance confidence when combined with TIS 2.0 (R^2–0.433, p<0.001).

Discussion

This study showed that trunk control had a high correlation to core muscles strength and balance confidence in people with chronic stroke living in the community. After stroke, the muscular forces acting upon the lower trunk and pelvis are critical for the optimal alignment of torso up against gravity, allowing for the upper trunk to move in different directions and planes during functional movements. Likewise, the upper trunk dynamic stability resulting from the coactivity and strength of upper abdominal muscles is required to permit the coordinated lower trunk initiated functional movement tasks. Due to poor dynamic stability of lower trunk and pelvis, patients with chronic stroke habitually sit in kypho-scoliotic posture and passively stabilize their trunk by posteriorly tilting the pelvis with asymmetrical weight-bearing between buttocks.[22] Over a period of time, the muscles around the torso might undergo weakness due to disuse of related trunk muscles. Due to poor muscular activity and weakness of lower abdominals and hip extensors in the seated position, they tend to flex their upper torso excessively against posteriorly tilted pelvis during forward arm reaching functional tasks.[23]

Along with soft tissue adaptation setting in spine after stroke, trunk muscles can not generate sufficient force either in a shortened or in a lengthened position. The relative weakness and stiffness of core muscles particularly in chronic stage stroke might further limit the dynamic balance control and movement coordination between upper and lower trunk movement. Compensatory movement recovery of either excessive trunk flexion or hyperextension of torso would restrict the physiological range of thoracic rotation mobility, allowing weakness of trunk rotators on both sides. Since the bilateral oblique abdominal muscles are connected through fascia, the imbalanced muscular forces acting on linea-alba might affect the trunk rotation towards the most and least affected sides following unilateral stroke lesion.[24] It was reported that poor trunk control and core muscles weakness are positively correlated to balance and daily functioning in patients with chronic stroke.[25,26] So it is clear that optimal trunk control and strength after stroke are vital for balance confidence during functional mobility. Previous studies demonstrated that community dwelling stroke survivors having poor balance capacity and mobility problems, experience less balance confidence, exhibit perception of becoming unsteady and fear of falling during daily activities.[13,14]

Due to fear of fall and less self-confidence on balance capacity during functional mobility tasks, the chronic stroke survivors usually stiffen the axio-scapular muscles excessively by retracting the shoulder girdle, thus extension-rotation of upper trunk on the most involved side as one of the compensory balance strategies. Such soft tissue restrictions of trunk in chronic stage stroke recovery would further affect the trunk rotators strength towards the least involved side, vice vera.[19] Our findings support that the weakness of trunk rotators was much involved contral lateral to lesion side [29 (21 – 37) lbs.] compared to ipsilateral side [32 (24 – 39) lbs]. We believed that the the trunk rotators i.e. tonic muscular system is conditional for proximal dynamic stability of the torso whilst doing most of functional daily activities, so that it helps the phasic muscular system for dissociated movements of trunk and distal extremities. The determinant model-3 of the current work supports our view that the strength of trunk rotators towards the least affected side explained additional 4% of the variance of the balance confidence when combined with 43% variance of TIS 2.0.

From the findings of the stepwise multivariate linear regression analysis, the strongest determinants of balance confidence were the overall trunk performance, particularly the dynamic sitting balance in chronic stroke survivors residing in the community. This could be further explained by the fact that lower trunk lateral flexion (lifting of pelvis towards rib cage) required to have an appropriate weight transfer towards opposite side by concentric contraction of ipsilateral lateral flexors and eccentric elongation of trunk lateral flexors on the weight-bearing side. While asked to selectively lateral flex the torso from upper trunk, people post-stroke usually tend to compensate by excessively flexing and lateral bending the spine resulting from poor lower trunk dynamic stability and bilateral trunk lateral flexor weakness. In an ideal situation, the upper trunk initiated side bending movement towards gravity involves eccentric lengthening of contralateral trunk lateral flexors.[27]

Biomechanically, the pelvis is considered to be the part of the trunk in sitting, but it plays a role as an element of lower limb while in standing and walking.[28] Lower trunk and pelvis not only remain unstable in seated position following stroke, but also critical for standing balance and many daily functional mobility tasks. The contribution of hip abductor muscles controlling the lateral postural stability of trunk movement is absent in seated position as the gluteus medius muscle is actively insufficient when the hips are being flexed.[29] The sideways weight shifts of trunk and lateral reach outs of arm movement in a seated position are entirely controlled by the quadratus lumborum muscle.[29] During sideways arm reach outs, an optimal movement control of trunk lateral flexors is required for maintaining the pelvis stable and shifting the bodyweight within the limits of balance stability. Whereas people with chronic stroke habitually lateral flex the trunk and consecutively the pelvis raises up on the non-weight bearing side due to medial-lateral postural instability.[30] Previous work on trunk regimes in chronic stroke showed a practice benefits of trunk performance and its carry-over effects on balance and physical functioning. We understood from the published stroke literature that the trunk performance mainly the dynamic sitting balance post-stroke was shown to be the strongest predictor of functional status, stressing the selective movement control of trunk lateral flexion is prerequisite for better confidence of not losing balance while performing daily physical functional tasks. Our views are supported by Kim et al.[15] who reported a positive association between balance capacity and self-efficacy of efficacy balance confidence in community-dwelling stroke survivors.

Overall, trunk control was moderately correlated to strength and balance confidence in patients under the category of moderate physical functioning. On the other hand, chronic stroke survivors having a status of low physical functioning, characteristic of home care patients scoring > 50 in the activity-specific balance confidence scale showed a poor correlation between trunk control and balance confidence. Beyond trunk performance, we also believed that the lower limb motor recovery too might have majorly contributed in the self-confidence on balance efficacy of housebound clients. This assumption should be tested in future studies. People with poor trunk and lower limb motor recovery after stroke presented with unstable pelvis and asymmetrical weight-bearing between feet in standing.[17,31] They also showed limited weight transfer towards the most involved leg while moving the trunk forward and reaching out arm in standing.[32] Thus optimal activity of hip muscles along with core strength are essentials for stance stability of lower extremity during walking and daily tasks.[33]

Another interesting finding from the sub-group analysis was that patients with right-sided stroke lesions showed poor trunk control and core muscle weakness compared to those of left-sided cortical stroke. We are in line with previous studies demonstrating poor sitting postural control and greater trunk involvement in right-sided stroke lesions than left-sided stroke lesions.[34,35] Regardless of the side of cortical vascular lesion, we observed a strong correlation of trunk control with core muscles strength and balance confidence of community-dwelling chronic stroke survivors in both the sub-groups.

Study limitations and scope for future research

One needs to cautiously interpret the study findings. The study participants were young adults and their median age was 57 (IQR 46 – 64) years. We did not stratify the patients based on their walking ability with or without mobility aids. The isometric strength of all core muscles post-stroke was tested in supine and prone positions except lateral trunk flexors opposed to the trunk control measured in a seated position since the physiological muscular demand in the aforementioned two positions are different and unique. This should be explored and confirmed in future stroke studies. We chose the supine position in order to quantify the strength of trunk flexors and rotators from the selective upper trunk movement against the dynamic stability of the lower trunk. This is based on our clinical observations and views of experts working with people post-stroke, many community-dwelling stroke survivors invariably contract their rectus abdominal muscles as a whole by showing mass trunk flexion while getting up from supine to long sitting position in a bed, which is further reinforced by mass extensor synergy of affected lower limb muscles. Among 177 participants 59 patients were not able perform trunk extensors strength testing due to either difficulty in attaining prone position or shoulder pain. We also observed that the patients had more balance confidence whilst testing the isometric strength of trunk lateral flexors in sitting position as this movement was a part of close kinetic chain against the therapist's counter stabilizing force, whereas the selective trunk flexion initiated from shoulder girdle in the dynamic sitting balance subscale of TIS 2.0 is of open-kinetic chain. The selective trunk movements to be correlated with isokinetic strength of core muscles, trunk muscles recruitment and balance related outcomes in future studies. Analyzing the determinants of trunk performance combined with lower limb motor functioning measures for self-efficacy on balance might provide additional details to chronic stroke recovery in community-dwelling individuals.

Conclusion

There is a significant and strong positive association among trunk control, core muscles strength and balance confidence in community-dwelling patients with chronic stroke, warranting further investigation of the effect of trunk rehabilitation strategies. Overall trunk performance and dynamic sitting balance subscale of TIS 2.0 in chronic stroke survivors were the major determinants of balance confidence whilst doing daily activities.

References

1. Verheyden G, Kersten P. Investigating the internal validity of the Trunk Impairment Scale (TIS) using Rasch analysis: the TIS 2.0. Disabil Rehabil. 2010;32:2127–2137.
2. Verheyden G, Vereeck L, Truijen S et al. Trunk performance after stroke and the relationship with balance, gait and functional ability. Clin Rehabil. 2006;20(5):451–458.

3. Cabanas-Valdes R, Cuchib GU, Bagur-Calafat C. Trunk training exercises approaches for improving trunk performance and functional sitting balance in patients with stroke: A systematic review. NeuroRehabil. 2013;33:575–592.
4. Van Criekinge T, Saeys W, Vereeck L, De Hertogh W, Truijen S. Are unstable support surfaces superior to stable support surfaces during trunk rehabilitation after stroke? A systematic review. Disabil Rehabil. 2018;40(7):1981-1988.
5. Karthikbabu S, Chakrapani M, Ganesan S, Ellajosyula R, Solomon JM. Efficacy of trunk regimes on balance, mobility, physical function, and community reintegration in chronic stroke: A parallel-group randomized trial. J Stroke Cerebrovas Dis. 2018;27(4):1003-1011.
6. Tanaka S, Hachisuka K, Ogata H. Trunk rotatory muscle performance in post-stroke hemiplegic patients. Am J Physical Med Rehabil. 1997;76:366–369.
7. Tanaka S, Hachisuka K, Ogata H. Muscle strength of the trunk flexion-extension in post-stroke hemiplegic patients. Am J Phys Med Rehabil. 1998;77:288–290.
8. Bohannon RW. Lateral trunk flexion strength: impairment, measurement reliability and implications following unilateral brain lesion. Int J Rehabil Res. 1992;15:249–251.
9. Bohannon RW, Cassidy D, Walsh S. Trunk muscle strength is impaired multidirectionally after stroke. Clin Rehabil. 1995;9:47–51.
10. Karatas M, Cetin N, Bayramoglu M, Dilek A. Trunk muscle strength in relation to balance and functional disability in unihemispheric stroke patients. Am J Phys Med Rehabil. 2004;83:81–87.
11. Silva P, Franco J, Moura J, Teixeira Salmela L, Faria C. Trunk strength is associated with sit to stand performance in both stroke and healthy subjects. Eur J Phys Rehabil Med. 2015;51(6):717-724.

12. Verheyden G, Nieuwboer A, De Wit L, Feys H, Schuback B, Baert I, et al. Trunk performance after stroke: an eye catching predictor of functional outcome. J Neurol Neurosurg Psychiatry. 2007;78:694–698.
13. Mackintosh SFH, Goldie P, Hill K. Falls incidence and factors associated with falling in older, community-dwelling, chronic stroke survivors (1 year after stroke) and matched controls. Aging Clin Exp Res. 2005;17:74-81.
14. Botner E, Miller W, Eng J. Measurement properties of the Activities-specific balance confidence scale among individuals with stroke. Disabil Rehabil. 2005;27(4):156-163.
15. Kim J, Park E. Balance self-efficacy in relation to balance and activities of daily living in community residents with stroke. Disabil Rehabil. 2014;36(4):295–299.
16. Schmid AA, Puymbroeck MV, Altenburger PA, Dierks TA, Miller KK, Damush TM, et al. Balance and balance self-efficacy are associated with activity and participation after stroke: A cross-sectional study in people with chronic stroke. Arch Phys Med Rehabil. 2012;93:1101-1107.
17. Karthikbabu S, Chakrapani M, Ratnavalli E, Ganeshan S. Pelvic alignment in standing and its relationship with trunk control and motor recovery of lower limb after stroke. Neurol Clin Neurosci. 2017;5:22-28.
18. Burns SP, Spanier DE. Break- technique hand held dynamometry: relation between angular velocity and strength measurements. Arch Phys Med Rehabil. 2005;86:1420-26.
19. Karthikbabu S, Chakrapani M. Hand-held dynamometer is a reliable tool to measure trunk muscle strength in chronic Stroke. J Clin Diag Res. 2017;11(9):YC09-YC12.

20. Myers AM, Flecther PC, Myers AH, Sherk W. Discriminative and evaluative properties of the Activities-specific Balance Confidence (ABC) Scale. J Gerontol. Ser A-Biol Sci Med Sci 1998;53:287-294.
21. Botner EM, Miller WC, Eng JJ. Measurement properties of the Activities-specific balance confidence scale among individuals with stroke. Disabil Rehabil 2005;27:156-163.
22. 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):1483-1487.
23. Messier S, Bourbonnais D, Desrosiers J, Roy Y. Dynamic analysis of trunk flexion after stroke. Arch Phys Med Rehabil. 2004;85(10):1619–1624.
24. Davis PM. Problems associated with the loss of selective trunk activity in hemiplegia. In: Davis PM, editor. Right in the middle: Selective trunk activity in the treatment of adult hemiplegia. Heidelberg: Springer; 1990.pp 31-65.
25. Verheyden G, Vereeck L, Truijen S, Troch M, Herregodts I, Lafosse C, et al. Trunk performance after stroke and the relationship with balance, gait and functional ability. Clin Rehabil. 2006;20:451–485.
26. Karatas M, Cetin N, Bayramoglu M, Dilek A. Trunk muscle strength in relation to balance and functional disability in unihemispheric stroke patients. Am J Phys Med Rehabil. 2004;83:81–87.
27. Mohr JD. Management of the Trunk in Adult Hemiplegia: The Bobath Concept. Top Neurol. 1990. American physical therapy association in touch series.
28. Lee D, Hodges P: Principles of integrated model of function and its application to the lumbopelvic- hip region; in Lee D, Hodges P (eds): The Pelvic Girdle, ed 3. Churchill Livingstone, 2004, pp 41–54.

29. Van Nes JW, Nienhuis B, Latour H, Geurts AC. Posturographic assessment of sitting balance recovery in the subacute phase of stroke. Gait Posture. 2008;28:507–512.
30. Verheyden G, van Duijnhoven HJR, Burnett M, Littlewood J, Kunkel D, Ashburn AM, et al. Kinematic analysis of head, trunk, and pelvis movement when people early after stroke reach sideways. Neurorehabil Neural Repair. 2011;25(7):656–63.
31. Karthikbabu S, Chakrapani M, Ganesan S, Ellajosyula R. Relationship between pelvic alignment and weightbearing asymmetry in community-dwelling chronic stroke survivors. J Neurosci Rural Pract. 2016;7:S37-40.
32. Chern JS, Lo CY, Wu CY, Chen CL, Yang S, Tang FD. Dynamic postural control during trunk bending and reaching in healthy adults and stroke patients. Am J Phys Med Rehabil. 2010;89(3):186-197.
33. Dubey L, Karthikbabu 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;25:80–89.
34. Gjelsvik B, Strand LI, Naess H, Hofstad H, StureSkouen J, Eide G, et al. Trunk control and lesion locations according to Alberta stroke program early CT score in acute stroke: A cross-sectional study. Int J Phys Med Rehabil. 2014;S3:1-6.
35. Spinazzola L, Cubelli R, Della Sala S. Impairments of trunk movements following left or right hemisphere lesions: dissociation between apraxic errors and postural instability. Brain. 2003;126:2656-2666.

List of legends

Table 1. Descriptive characteristics of 177 chronic stroke survivors for measures of trunk control, core muscles strength and balance confidence.

Table 2. Pearson's correlation coefficients of trunk control measure with core muscles strength and balance confidence in chronic stroke.

Table 3. Stepwise multivariate linear regression analysis for variables determining the balance confidence in chronic stroke survivors.

Table 1. Descriptive characteristics of 177 stroke survivors for measures of trunk control, core muscles strength and balance confidence.

Measures (Possible score)	Median (IQR 25 – 75)	Range
Trunk Impairment Scale 2.0 (0 - 16)	10 (7 – 12)	2 – 16
Dynamic sitting balance (0 – 10)	7 (5 – 8)	2 – 10
Coordination (0 – 6)	3 (2 – 4)	0 – 6
Trunk muscles strength (lb.) [a] Flexors (0 – 60)	32 (25 – 40)	12 – 60
Extensor [b] (0 – 60)	37 (30 – 44)	18 – 60
Rotators towards most affected side (0 – 60)	32 (24 – 39)	12 – 60
Rotators towards least affected side (0 – 60)	29 (21 – 37)	0 – 60
Lateral flexors – most affected side (0 – 55)	32 (24 – 36)	14 – 54
Lateral flexors – least affected side (0 – 55)	32 (27 – 38)	14 – 54
Activity specific balance confidence scale [c] (0 – 100)	41 (27 – 61)	3 – 95

[a] The possible trunk muscle strength (lb.) is reported from 50 age-matched healthy adults; [b] N = 118 & [c] N = 163.

Table 2. Pearson's correlation coefficients of trunk control measure with core muscles strength and balance confidence in chronic stroke.

Variable	TIS 2.0 (N = 177) R (p value)	Trunk Impairment Scale 2.0* Low physical function status (N=106) R (p value)	Moderate physical function status (N=67) R (p value)	Left sided stroke lesion (N=107) R (p value)	Right sided stroke lesion (N=70) R (p value)
Core strength Trunk flexors	0.65 (< 0.001)	0.48 (< 0.001)	0.50 (< 0.001)	0.64 (< 0.001)	0.65 (< 0.001)
Trunk extensors	0.70 (< 0.001)	0.57 (< 0.001)	0.61 (< 0.001)	0.70 (< 0.001)	0.70 (< 0.001)
Trunk rotators – most affected side	0.69 (< 0.001)	0.51 (< 0.001)	0.59 (< 0.001)	0.70 (< 0.001)	0.67 (< 0.001)
Trunk rotators – least affected side	0.70 (< 0.001)	0.56 (< 0.001)	0.59 (< 0.001)	0.68 (< 0.001)	0.69 (< 0.001)
Lateral flexors – most affected side	0.62 (< 0.001)	0.49 (< 0.001)	0.48 (< 0.001)	0.62 (< 0.001)	0.61 (< 0.001)
Lateral flexors – least affected side	0.61 (< 0.001)	0.49 (< 0.001)	0.45 (< 0.001)	0.65 (< 0.001)	0.60 (< 0.001)
ABC scale	0.66 (< 0.001)	0.38 (< 0.001)	0.53 (< 0.001)	0.61 (< 0.001)	0.68 (< 0.001)

*TIS 2.0 – Trunk Impairment Scale 2.0; ABC scale – Activity Specific Balance Confidence Scale; Correlation matrix is highly significant at the 0.001 level (2 tailed) and it's interpreted as very low <0.20; low 0.20-0.39; moderate 0.40-0.59; high 0.60-0.79 and very high >0.80. * Subgroup analysis - Coefficients of TIS 2.0 with core strength and ABC scale are presented under the physical functioning status and side of stroke lesion.*

Table 3. Stepwise multivariate linear regression analysis for variables determining the balance confidence in chronic stroke survivors.

Model	Model 1 TIS 2.0 total score			Model 2 TIS 2.0 subscales DSB/COO			Model 3 Core muscles strength		
	Variable [a]	R^2	p value	Variable [a]	R^2	p value	Variable [a]	R^2	p value
Balance Confidence[b]	TIS 2.0	0.431	<0.001	DSB	0.376	<0.001	TIS 2.0	0.433	<0.001
	Age	0.032	0.002	COO	0.072	0.001	Rot-LA	0.042	0.039
				Age	0.033	0.003			
Model R^2		0.463			0.481			0.475	

[a] Variables reported are Trunk Impairment Scale 2.0 (TIS 2.0), dynamic sitting balance (DSB) and coordination (COO) subscales of TIS 2.0 and muscle strength of trunk rotators towards the least affected side (Rot-LA) and age at stroke onset time (Age). [b] Activity specific balance confidence scale. The trunk performance measure for the determinant of balance confidence models was TIS 2.0 total score (model 1) or TIS 2.0 subscales (model 2) or trunk strength (model 3) when combined with other variables.