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Indicators of sitting balance ability and its association with fall risk in early stroke patients

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Abstract

Background & Objectives: There is insufficient data establishing correlates of sitting balance performance and its association with fall risk in patients with stroke (PwS). The primary aim of this study was to examine the indicators of sitting balance in early stroke. The secondary aim was to investigate the association between sitting balance and fall risk. *Methods:* Thirty-three healthy subjects and 52 PwS in early stage (acute and subacute) were included. Trunk muscle strengths, trunk repositioning error, and the presence of core stabilization were recorded in both groups. Stroke patients were additionally assessed with Motricity Index (MI), Trunk Impairment Scale (TIS), and Stroke Assessment of Fall Risk (SAFR). *Results:* In the stroke group, all trunk muscle groups' strength and the ratio of presence of core stabilization were statistically lower than healthy participants' ($p<0.001$), whereas trunk repositioning error was found higher ($p<0.001$). Age (β:-0.301, $p=0.01$), core stabilization (β:-0.291, $p=0.017$), proprioception (β:-0.236, $p=0.036$) and MI (β:0.371, $p=0.003$) were found to be indicators of TIS. There was a significant association between TIS and SAFR (β:-0,713; $p<0,001$). The strength of trunk lateral flexors ($p=0,049$) and extremities on the impaired side ($p=0.012$) were moderators of this association.
Conclusion: The trunk control in sitting was linked to core stabilization and proprioception of the trunk in PwS. The strength of trunk lateral flexors and extremities on the impaired side were moderators of the association between sitting balance and fall risk. The roles and importance of these factors in designing rehabilitation interventions need to be investigated in future studies.

Keywords: Accidental falls, stroke, postural balance, effect modifier, proprioception.

INTRODUCTION

Balance dysfunction is seen commonly after stroke.[1] Stroke survivors may have difficulties to maintain both sitting and standing balance due to impaired trunk control.[2] Trunk control is defined as the ability of the body to remain upright position and to respond to the new situation based on the changes in the center of gravity by adjusting weight shift in any plan.[3,4] Trunk control in sitting position has found to be an early predictor of independent mobility in patients with stroke (PwS).[5-7] Furthermore, sitting balance ability was found to be associated with falls in chronic phase of stroke.[8] As trunk control in sitting position has been found to be as an important part of functional recovery after stroke, the studies in the literature generally have focused on the effect of the additional trunk exercise to regain the trunk function.[9] However, it is necessary to determine the factors affecting trunk control in order to design these exercise programs more effectively.[10]

Fukata *et al*. reported that age and severity of stroke may affect the sitting ability early after stroke.[11] In the other studies, it was found that trunk control was correlated with core muscle strength, balance confidence, and functional independence in PwS.[12,13] However, postural control can only be achieved through the complex

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integration of motor and sensorial processes.[14] Sensory information should be regulated by the central nervous system to produce an adequate motor response to maintain postural control.[15] As stroke can result in sensory impairment as well as muscle weakness on one side of the body, the sensorimotor system should be holistically and simultaneously evaluated and their contribution to trunk control in sitting position should be well-understood.

Falls are common among stroke survivors and it has been found to be associated with many stroke-specific factors such as reduced balance, impaired mobility, and low cognitive level.[16-18] In a recent review, it has been suggested that specific impairments related to the lesion side such as visuospatial neglect or impulsivity should be screened to determine fall risk after stroke.[19] There are some tools that can be used to detect fall risk with a comprehensive view. One of them is Stroke Assessment of Fall Risk (SAFR) which assesses both impairments and functional limitations. But it still isn't known if there is an association between sitting balance ability and fall risk in early and subacute terms of stroke.

Establishing the possible factors affecting the trunk control in a sitting position and evaluating the association between sitting balance and risk of falling may lead to clinicians forming effective rehabilitation protocols to improve trunk control and to decrease the risk of falling in PwS.

Thus, the primary aim of this study was to examine the indicators of sitting balance in early stroke. With this aim firstly the differences in terms of trunk muscle strength, trunk reposition errors, and the presence of core stabilization between healthy subjects and PwS were examined. Then, the factors affecting the sitting balance of PwS were determined. The secondary aim was to investigate the association between sitting balance and fall risk.

METHODS

Study design

This was a single centered, prospective and definitive study conducted in a neurology service of a training and research hospital between June 2017-November 2019. A control group comprising healthy individuals was recruited among caregivers and other volunteers. The participants were informed about the study and the testing procedure by the assessor. The assessments of each participant were conducted in a single session after receiving the oral and written consent. All procedures were approved by the local ethics committee of a training and research hospital (process no. 2016/567).

Subjects

The inclusion criteria for PwS were as follows: a) being diagnosed with ischemic or hemorrhagic stroke in the last 6 months, b) being age ≥18 years old, c) scoring 20 or less on the Trunk Impairment Scale (TIS), d) having cognitive ability to follow simple commands during assessments. Participants were excluded based on the following criteria: a) prior stroke history, b) not having an adequate vision and hearing to understand the testing procedures, c) having an orthopedic or neurologic impairment before stroke such as lower extremity related pain or Parkinson's disease, which may limit the ambulation. The inclusion criteria for the healthy control group were as follows: (a) being age ≥18 years old (b) having an adequate vision and hearing to understand the testing procedures, and (c) not having a disease such as neurological problems, orthopedic conditions, etc. which might interfere with trunk function, extremity muscle strength and ambulation.

Materials and procedures

A form including socio-demographics and clinical characteristics such as 'age, gender, body mass index, comorbidities, disease duration, lesion type, localization, and lateralization was filled out for each patient by the investigators from the medical files of the patients. For each healthy subject, age, gender, and body mass index were recorded. While trunk muscle strengths, trunk repositioning error, and the presence of core stabilization were evaluated in the healthy group; stroke patients were additionally assessed with the Motricity Index, Trunk Impairment Scale, and The Stroke Assessment of Fall Risk.

The strength of flexor, extensor, bilateral lateral flexor, and rotator muscles in the trunk was measured with a hand-held dynamometer (Lafayette® Manual Muscle Tester, Model 01165).[20,21] Specific protocols were followed for the assessment of different muscle groups. The participant was seated on a backless chair for the measurement of all trunk muscle groups. In each direction, the measurements were performed 3 times and the average score was calculated. The dynamometer was placed over the sternum for the assessment of flexor muscle strength. Then, participants were asked to perform isometric trunk flexion for 5 seconds (make test) and the results were recorded. The placement of the device was T1 level, inferior to acromion and coracoid process of scapulae for extensors, lateral flexors, and rotators, respectively. The testing protocol, namely the testing position and the steps of the measurement protocol, were similar to the flexor muscle measurement as described above.

An inclinometer (Acumar Digital Inclinometer, ACU002) was used for the assessment of trunk proprioception.[22,23] The participants were seated on a bed to perform the test. The assessor placed the probes of the inclinometer on the spinous processes of T1 and S1 vertebrae to assess proprioception of the trunk flexion. Firstly, the participant performed 30^{o} trunk flexion with eyes open and closed. Then, he/she was asked to find a 30^{o} trunk flexion position three times and the deviations from the correct position were recorded. An average deviation score was calculated.

The core stabilization was measured with a sphygmomanometer.[24] The test was performed while the patient was in a supine hook-lying position. A blood pressure cuff was placed in the lumbar region of the participant and inflated to 40 Mm-Hg. The participant was asked to perform transversus abdominis selectively using an abdominal drawing-in maneuver and then to extend the knee (without lifting the foot from the bed) on the intact side, maintaining a steady pressure under the spine. If the stroke patients were unable to stabilize the knee on the impaired side, the extremity was stabilized by the therapist. More than a 5 Mm-Hg decrease in cuff pressure indicated the loss of stabilization.[24,25]

Motricity Index (MI) was used to assess the muscle strength of the impaired side extremities. MI is a validated measure of muscle strength assessing pinch grip, elbow flexion, shoulder abduction, ankle dorsiflexion, knee extension, and hip flexion.[26] It is a popular and widely used index for stroke patients.[27]

The ability of trunk control was measured by using the Trunk Impairment Scale (TIS).[28] It includes 17 items that evaluate static and dynamic sitting balance and trunk coordination. The static subscale investigates the ability to maintain an upright posture with different lower limb positions, while the dynamic subscale evaluates the unilateral motions of the trunk and hip in the frontal plane. Coordination investigates the ability to selectively rotate the upper and lower portions of the trunk. For each item, a 2- or 3-point ordinal scale is used. Total score ranges are between 0-and 23 points. Higher scores indicate better performance.

The Stroke Assessment of Fall Risk assesses 7 stroke-specific risk factors in the acute phase.[29] These factors contain 4 impairments (impulsivity, hemineglect, static, and dynamic sitting balance) and 3 functional limitations from the Functional Independence Measure subscales (transfers, problem-solving, and memory). Impulsivity and hemineglect are scored dichotomously (0: absent; 7: present). The remaining items are scored using a 7-point ordinal scale similar to the Functional Independence Measure, but with 0 indicating no impairment, and 7 indicating the most severe impairment.

Statistical analysis

Analyses were performed using Statistical Package for Social Sciences (SPSS) Version 20 (IBM SPSS Statistics, New York, USA). The required sample size for effective comparison of trunk repositioning error degree between the patients and the control group was calculated by utilizing G*Power (Version 3.1.9.2) software. The effective minimum sample size was determined as 44 for the stroke group and 30 for the control group when the allocation ratio was set at 3:2.[30] The Shapiro-Wilk test was used to confirm the distribution of the data. To compare quantitative variables between the two groups, the Chi-square test was used for categorical data, and Student's t-test was used to compare continuous variables. Possible correlations were calculated by using Pearson's correlation in parametric variables and Spearman's correlation in non-parametric data. The association between TIS and possible factors affecting the trunk control was established by linear regression analysis. Independent factors were age, core stabilization, trunk proprioception, and MI, whereas TIS was a dependent factor.

The association between TIS and SAFR was analysed with linear regression. Moderators of this association were investigated using PROCESS v3.4.1 for SPSS. The moderators that were independently investigated were strengths of the trunk muscles and extremities of the impaired side as well as trunk proprioception. The statistical level of significance was set at $p<0,05$.

RESULTS

Fifty-two PwS and 33 healthy participants were included in the study. The demographic and clinical features of the groups are presented in Table 1. There was no statistically significant difference between the two groups in terms of age, sex, dominant side, and body mass index. In the stroke group, all trunk muscle groups' strength was statistically lower than healthy participants' (p<0.001). In the stroke group, trunk repositioning error was found higher (p<0.001), whereas the ratio of presence of core stabilization was lower compared to the healthy group (p<0.001).

The results of linear regression analysis to establish indicators of TIS are shown in Table-2 (Adjusted R2: 0.463, F: 11.359, p<0.0001). The regression model consisted of age, core stabilization, trunk proprioception, and MI-Extremities and it was found to be associated with TIS.

There was a significant association between TIS and SAFR (β: -0.713; p<0.001) based on linear regression analysis. The moderators of this association are shown in Table 3. The moderators were strengths of lateral flexor muscles on the trunk and the MI-Extremities.

DISCUSSION

This study showed that trunk muscle strength, trunk proprioception, and core stabilization were impaired in stroke patients compared to age-matched healthy participants. Besides the trunk

Table 1: Characteristics and outcome measure scores of the study population

Characteristics of study population	PwS (N=52) Mean (SD)	Healthy Subjects (N=33) Mean (SD)	p
Age (years)	61.1 (14.9)	60.09 (4.2)	0.701
Sex (Female/Male, N)	27/25	12/21	0.186
Body mass index (kg/m^2)	25.59 (3,9)	26.47 (3,3)	0.338
Dominant side (Right/Left, N)	49/3	30/3	0.673
Core stabilization (Present/Absent, N)	16/36	30/3	**<0.001***
Trunk repositioning error (degree)	5.9 (6.7)	2.1 (1.5)	**<0.001***
Trunk muscle strengths (kg)			
Flexors	7.4 (3.3)	19.87 (4.6)	**<0.001***
Extensors	9.3 (3.9)	25.75 (4.9)	**<0.001***
Right lateral flexors	6.8 (2.5)	20.7 (4.2)	**<0.001***
Left lateral flexors	7.1 (2.6)	21 (4.6)	**<0.001***
Right rotators	5.9 (2.0)	20.81(4.3)	**<0.001***
Left rotators	6.3 (2.0)	21.30 (3.4)	**<0.001***
Characteristics and outcome measures of stroke group			
Disease duration (day)	25.61(39.9)		
Impaired side (R/L)	38/14		
Hemorrhagic/ Ischemic (N)	12/40		
Modified Rankin Scale (Level)	1.63 (0.48)		
Trunk Muscle Strengths (kg)			
Impaired side lateral flexors	6.7 (2.6)		
Non- impaired side lateral flexors	7.3 (2.6)		
Impaired side rotators	6.0 (1.9)		
Non- impaired side rotators	6.3 (2.1)		
Trunk Impairment Scale	10.7 (6.0)		
Stroke Assessment of Fall Risk	15.6 (10.6)		
Motricity Index	52.1 (20.8)		

*Statistical significance at p < 0.05.

Table 2: Indicators of Trunk Impairment Scale based on linear regression analysis

Model	β	Confidence Interval (%95)	p value
Constant		12.520- 28.138	**<0.0001***
Age	-0.301	-0.212-(-0.03)	0.01
Core stabilization	-0.291	-6.866-(-0.698)	0.017
Proprioception	-0.236	-0.406-(-0.015)	0.036
MI-Extremities	0.371	0.04-0.174	0.003

Abbreviations: MI, Motricity Index. *Statistical significance at $p < 0.05$.

Table 3: The results of moderation analysis

Moderator	Outcome (SAFR)	Variable b	*p*-value	Overall Model R^2	F	*p*-value
Trunk flexor strength				0.512	16.465	**<0.001***
	Constant	15.939	<0.001			
	TIS	-1.236	<0.001			
	Moderator	0.021	0.950			
	Interaction	0.055	0.374			
Trunk extensor strength				0.519	16.922	**<0.001***
	Constant	15.969	<0.001			
	TIS	-1.228	<0.001			
	Moderator	0.163	0.573			
	Interaction	0.053	0.237			
Strength of impaired side lateral flexors				0.544	18.685	**<0.001***
	Constant	15.903	<0.001			
	TIS	-1.255	<0.001			
	Moderator	-0.004	0.991			
	Interaction	0.150	**0.049***			
Strength of impaired side rotators				0.508	16.172	**<0.001***
	Constant	15.727	<0.001			
	TIS	-1.238	<0.001			
	Moderator	-0.174	0.748			
	Interaction	0.054	0.556			
Proprioception				0.640	27.202	**<0.001***
	Constant	14.567	<0.001			
	TIS	-1.220	<0.001			
	Moderator	0.132	0.425			
	Interaction	-0.035	0.153			
MI - Extremities				0.581	22.154	**<0.001***
	Constant	14.568	<0.001			
	TIS	-1.286	<0.001			
	Moderator	-0.026	0.634			
	Interaction	0.021	**0.012***			

Abbreviations: TIS, Trunk Impairment Scale; MI, Motricity Index; SAFR, Stroke Assessment of Fall Risk.
*Statistical significance at $p < 0.05$.

proprioception and core stabilization, extremity muscle strength on the impaired side and age were also found as the indicators of sitting balance in early stage stroke patients. Finally, it was found that there was an association between trunk control in sitting and fall risk. This association was moderated by two factors; the muscle strengths of trunk lateral flexors and extremities on the impaired side.

In the past decade, the importance of trunk rehabilitation after stroke has been widely studied and recent systematic reviews concluded that trunk training improved trunk control, balance in sitting and standing, and mobility in PwS.[31,32] Interestingly, possible determinants of trunk control in sitting has been researched in a limited number of studies, especially in the acute and subacute stroke population.[10] On the other hand, it is necessary to determine indicators of trunk control for clinical reasoning and for establishing priorities in the early phases of rehabilitation. In the light of this information, we firstly examined if there had been differences in possible indicators of sitting balance such as trunk muscle strength, trunk repositioning error, and presence of core stabilization between stroke and healthy population. After finding significant impairment in those possible indicators in stroke participants compared to healthy subjects, we analysed for indicators of sitting balance in stroke participants by taking into account other possible demographic factors. Therefore, the factors that may possibly affect trunk control in PwS such as age, trunk proprioception, and core stabilization, were investigated simultaneously in the present study.

In a recent study, trunk control has been found to be linked to core muscle strength in community-dwelling patients with chronic stroke.[33] The authors have stated that the core muscle weakness and soft tissue adaptations around the spine may limit the dynamic balance and the coordination between the upper and lower portions of the trunk, which in turn leads to decreased trunk control. It has also been known that decreased trunk motor control following acute stroke is associated with increased trunk reposition.[10] Similarly to the findings of the literature, there was a statistically significant association between trunk control in sitting and core stabilization and trunk proprioception in our study populated with acute and subacute stroke patients.

The present study also showed that muscle strength of both upper and lower extremities on the impaired side was an indicator of trunk control in sitting. Current literature suggests that muscle strength of the lower extremities affects anterior-posterior control of the trunk.[32] Even though the effect of trunk control on upper extremity function is commonly investigated, there is only limited research studying the link between the muscle strength of extremities and trunk control. In one of these studies, there were significant associations between Fugl-Meyer upper and lower extremity scores and trunk control.[34] In another study, patients with moderate-severe upper and lower extremity paralysis had poor sitting balance.[11] Additionally, strength training for upper and lower extremity muscles has been shown to improve trunk control and balance.[35,36] Overall, our results were in line with the literature.

The second important finding of this study is that there was an association between sitting balance and fall risk in PwS. This association was moderated by the muscle strength of lateral flexors and extremities on the impaired side. Previous studies also reported that trunk control was a significant predictor of fall risk in chronic stroke.[36-39] An association between balance confidence and trunk control has been found.[13] However, the moderators of this association have not been reported in any of these studies. To the best of our knowledge, this is the first study to report moderators of the association between fall risk and trunk control in the early phases of stroke.

Global muscle weakness is a common impairment following stroke. It is one of the key reasons for loss of balance both in stroke patients[40,41] and healthy older adults.[42] Appropriate weight transfer can be performed by ipsilateral concentric contraction and contralateral eccentric elongation of trunk lateral flexors during the lower trunk lateral flexion in the sitting position. So optimal movement control of trunk lateral flexors is needed to stabilize the pelvis and to shift the bodyweight within the limits of balance stability. As insufficient trunk lateral flexor muscle strength negatively impacts the trunk control on the pelvis in sitting position, this may indirectly affect fall risk in early stroke.[13]

Additionally, Aguiar *et al*. reported that specifically the lateral flexor muscles of the trunk compensate for hip abductor weakness and control the lateral displacement of the trunk during gait.[20] It could also be associated with hip-hiking during gait for foot clearance.[2] Therefore, the weakness of trunk lateral flexors may negatively affect both sitting balance and gait, leading to increased fall risk.

To the best of our knowledge, there is no study that reports muscle strength on the impaired side as a moderator of the association between fall risk and trunk control in the early phases of stroke. Our findings are in line with a paper by Lee *et al*.[43] The authors reported that the degree of post-stroke neurological impairment presented with Fugl-Meyer Assessment of the upper and lower extremity has a proportional relationship with limits of stability deviation in sitting position among patients with acute stroke. Combining these data, it may be said that the muscle strength of the affected side extremities has an effect on the control of the trunk, and it plays a moderator role between trunk control and the risk of falling.

The interesting finding of our research is that trunk proprioception was not a moderator for the association between trunk control and fall risk. Ryerson *et al*. stated that lack of trunk proprioception was a predictor of balance impairments and trunk instability.[44] Similarly, trunk reposition error based on lack of proprioception sense was found to be increased in patients with acute stroke.[10] On the other hand, it was stated in a recent study that even though PwS had significantly impaired sense of trunk proprioception and hence, a trunk control, proprioception was not correlated with clinical parameters such as balance, and functionality, or dependence.[45] Therefore, it is conceivable to draw a conclusion that proprioception may not have a moderator effect on the association between trunk control and fall risk. It may directly affect trunk control, as revealed in the present study, which in turn may affect the risk of falling.

Another reason for this finding would be the characteristics of our patients. As indicated in Table-1, the mean score of SAFR was 15 points and the mean angular deviation (proprioception) was 5° in our patients. However, the cut-off point for identifying fall risk with SAFR is 27 which is almost twice as high compared to our population.[29] Even though we believe these scores (15,6 ± 10,6 and 5,9 ± 6,7, respectively) are enough to investigate an association or moderation, they may be still low/weak to indicate a strong relationship. Thus, we strongly recommend for future research to investigate the direct and indirect effect of proprioception on trunk control and fall risk in the early stages of stroke.

This study had some limitations. Firstly, we did not exclude or stratify participants according to trunk repositioning error level, as there is no grade in the literature considered to be a cut-off score for trunk repositioning error in the stroke population. Secondly, using a hand-held dynamometer and inclinometer for measuring the muscle strength of trunk muscles and trunk repositioning error might cause some measurement errors. Therefore, we suggest future studies to evaluate patients with isokinetic devices for more accurate results. On the other hand, we would like to emphasize the strength of this study as this is the first study to establish trunk-related factors affecting sitting balance and moderators of the association between fall risk and trunk control in sitting in acute and subacute phases of stroke.

In conclusion, muscle strength and proprioception of the trunk and core stabilization were impaired in stroke patients compared to healthy subjects. The sitting balance of PwS was affected by age, core stabilization, trunk proprioception, and strength of the muscles at the extremities. The risk of falling was associated with sitting balance and this association was moderated by muscle strength of the lateral flexors and extremities on the impaired side. The indicators and moderators that are presented in this study should be taken into careful consideration when evaluating the PwS in both clinical practice and research settings, as well as when planning the rehabilitation program. The roles and importance of these factors need to be investigated in future studies.

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