Altered Trunk Position Sense and Its Relation to Balance Functions in People Post-Stroke

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Objective: To determine whether trunk position sense is impaired in people with poststroke hemiparesis.

Background: Good trunk stability is essential for balance and extremity use during daily functional activities and higher level tasks. Dynamic stability of the trunk requires adequate flexibility, muscle strength, neural control, and proprioception. While deficits of trunk muscle strength have been identified in people post-stroke, it is not clear whether they have adequate postural control and proprioception to ensure a stable foundation of balance to enable skilled extremity use. Trunk position sense is an essential element of trunk postural control. Even a small impairment in trunk position sense may contribute to trunk instability. However, a specific impairment of trunk position sense has not been reported in people post-stroke.

Subjects: Twenty subjects with chronic stroke and 21 nonneurologically impaired subjects participated in the study.

Main outcome measures: Trunk repositioning error during sitting forward flexion movements was assessed using an electromagnetic movement analysis system, Flock of Birds. Subjects post-stroke were also evaluated with clinical measures of balance (Berg Balance Scale), postural control (Postural Assessment Scale for Stroke), and extremity motor impairment severity (Fugl-Meyer Assessment-Motor Score).

Results: There were significant differences in absolute trunk repositioning error between stroke and control groups in both the sagittal ($P = 0.0001$) and transverse ($P = 0.0012$) planes. Mean sagittal plane error: post-stroke: 6.9 ± 3.1 degrees, control: 3.2 ± 1.8 degrees; mean transverse plane error: post-stroke 2.1 ± 1.3 degrees, control: 1.0 ± 0.6 degrees. There was a significant negative correlation between sagittal plane absolute repositioning error and the Berg Balance Scale score ($r = -0.49$, $P = 0.03$), transverse plane absolute repositioning error and Berg Balance Scale score ($r = -0.48$, $P = 0.03$), and transverse plane repositioning error and the Postural Assessment Scale for Stroke score ($r = -0.52$, $P = 0.02$)

Conclusions: Subjects with poststroke hemiparesis exhibit greater trunk repositioning error than age-matched controls. Trunk position sense retraining, emphasizing sagittal and transverse movements, should be further investigated as a potential poststroke intervention strategy to improve trunk balance and control.

Keywords: balance, repositioning error, stroke, trunk

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INTRODUCTION

Trunk stability is often overlooked as an essential core component of balance and coordinated extremity use for daily functional activities, the performance of higher level motor tasks, and participation in sports activities. Trunk stability requires appropriate muscle strength and neural control as well as adequate position sense to provide a stable foundation for movement.[1,2] While trunk musculature provides some spinal stabilization, without adequate position sense, the trunk cannot be stable.[2,3]

The emphasis of poststroke rehabilitation has been to restore independence in gait and arm function.[4,5] To some extent, this focus may unintentionally bypass the development of good trunk stability in preparation for the performance of daily life skills. In addition, early hospital discharge can result in the use of atypical or compensatory strategies to compensate for trunk instability. Later in recovery, these compensatory patterns may be learned and difficult to reverse.

Studies have identified poststroke deficits of trunk muscle strength on both the contralesional side and, to a lesser extent, on the lesional side.[6–13] A few studies reported poststroke trunk postural control deficits in standing,[14–16] and Dickstein et al[17] recently reported for the first time a deficit of trunk postural control in sitting. Theoretical modeling suggests that position sense is a component of proprioception and is one of the essential elements of postural control.[18–20] However, it is not clear whether a person post-stroke has adequate trunk position sense to provide a stable foundation for the recovery of balance and skilled extremity use. To our knowledge, no studies to date confirm or deny the presence of a trunk position sense impairment in people who have had a stroke. This study attempts to close this gap in knowledge by

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objectively documenting errors of trunk position sense in people poststroke.

Researchers assess trunk position sense by measuring trunk repositioning error (TRE). TRE represents the difference between a target trunk position and the trunk position that a subject assumes when attempting to reproduce that initial position. TRE has been identified as a reliable and valid way of measuring trunk position sense.[21,22] Researchers have studied the relationship between impaired postural control and altered trunk position sense in healthy young and older people, balance-impaired older adults, and people with orthopedic spine disease.[23–27] Goldberg et al[24] reported that older balance-impaired adults have two times the TRE of older adults without balance impairments. In addition, the results of their study indicated that TRE in standing was correlated with clinical balance measures and lower extremity muscle strength. Increased TRE in subjects with orthopedic spinal conditions was associated with altered postural sway, changes in the center of pressure, and asymmetrical weight distribution.[28–30]

As mentioned above, as far as we can determine, there have been no investigations of trunk position sense in people post-stroke. Therefore, the goal of this study was to determine whether there was greater sitting TRE in people in the chronic phase of recovery post-stroke compared to nonneurologically impaired people. In addition, the study explored the relationship between TRE and clinical measures of balance and extremity motor impairment. If there are impairments in trunk position sense, there may be support for expanding the focus of intervention strategies post-stroke to include trunk position sense retraining. Improved trunk stability may lead to improved abilities to coordinate movement sequences of the trunk and limbs and, ultimately, improved performance of daily activities and increased participation in life for people post-stroke.

FIGURE 1. Subject performing forward flexion trunk repositioning sense task. A Flock of Birds sensor is attached over the T1 vertebra, the electromagnetic source is mounted on a wooden bracket in the middle of the seat, and the Flock of Birds system is on the right side of the work shelf.

METHODS

Subjects

Twenty subjects more than six months post-stroke were recruited from the outpatient clinical services division of the National Rehabilitation Hospital (NRH) and from local stroke support groups. Twenty-one age-matched, nonneurologically impaired subjects were recruited from residents of the metropolitan area. The principal investigator conducted the medical history and dementia rating (Mini-Mental Status Examination), balance assessments (Berg Balance Scale [BBS] and Postural Assessment Scale for Stroke [PASS]), and extremity motor impairment scales (Fugl-Meyer Assessment Scale–Upper and Lower Extremity Motor Portion [FMA]).

The ability to accurately measure trunk position sense after a stroke required a rigid selection process to minimize confounding impairments of trunk position sense with impaired motor control. This separation was accomplished, at least in part, by selecting subjects who had the motor control necessary to assume the target testing position and, in all probability, the control to reassume that same position. The main inclusion criteria for the subjects post-stroke was the ability to perform the motor task of the study: the ability to sit independently on a bench, reach forward and down to the floor, and return to an upright sitting position with arms folded across the chest and eyes closed.

At screening, subjects from each group were excluded if they had previous orthopedic spinal or hip pathology, if they had other neurological disease affecting movement or balance, such as cerebellar or vestibular lesions, or if they had mental scores that impaired their ability to understand the directions of the study. People post-stroke were also excluded if they had multiple, bilateral or brainstem strokes. Institutional human subject review board approval for the study was granted by Medstar Research Institute (governing board of NRH research), and all subjects gave informed consent.

Protocol

TRE was measured using an electromagnetic movement analysis system, the Flock of Birds (Ascension Technology Corporation, Burlington, VT). The Flock of Birds has been found to be an accurate, reliable, and valid measure of angular position in a reconstructed mechanical model of the spine.[21,22] Within-day and day-to-day reliability in subjects with low back pain and ankylosing spondylitis is good with intraclass correlation coefficients ranging from 0.88 to 0.91.[21,22] This system, the gold standard in TRE testing with an accuracy to 0.1 degree, measures the simultaneous three-dimensional angular orientation of a sensor in space relative to an electromagnetic source.[31] The protocol for measuring TRE in this study replicated those used in previously published studies.[25–27,32–34] The principal investigator conducted the TRE testing, but was blinded to the scores until the conclusion of the study.

Subjects sat on a wooden bench, adjusted to standardize individual sitting positions (hips at 90 degrees), with shoes on and feet flat on the floor. In order to minimize sensory clues from clothing, subjects wore shorts or pants with a loose fitting waistband, men were bare chested, and women wore halter tops.

Subjects were instructed not to shift their seat position during the study in order to maintain the distance between the electromagnetic source and the sensor during the trials.

A two-centimeter magnetic sensor was placed on the skin over the spinous process of the first thoracic vertebra (T1) and secured with double-sided tape. Information from the T1 sensor is thought to be representative of one's perception of spinal position sense.[34] The vertebra was located with manual palpation by the principal investigator[35] and confirmed by a second experienced physical therapist. The sensor was applied while the subject was in a semiflexed position to minimize pulling between the adhesive and skin during the testing movement.

TRE Testing proceeded as follows:

1. Before actual testing began, the maximal range of active forward flexion was measured from a computerized graphic representation. Determining the full range of motion allowed the examiner to establish target points, representative of a percentage of the full range of motion, which subjects were instructed to match during the testing.
2. Subjects performed one practice trial. The examiner asked subjects to flex forward until reaching approximately 25% of full range. Once at this position, subjects were told that this was the practice target position. The subjects returned to the upright sitting position and were asked to find this exact same target position. The examiner told the subjects a new target position would be used for the experimental trials. After a five-minute rest period, the subjects were blindfolded and the actual trials began.
3. The examiner selected a new target position by having the subjects move their trunks into forward flexion at a comfortable pace. When they reached a point approximately 50% of full range, the examiner instructed the subjects to stop and told them this was the target position that they should try to reproduce exactly. The 50% point was selected as the target position since TRE tends to be most stable at the midpoint of spinal range in healthy subjects.[32,34] Subjects then returned to the upright starting position.
4. The examiner instructed the subjects to perform the movement again and stop when they thought they were at the same point (the target position), hold the target position for three seconds, and then return to upright sitting.
5. Each subject performed six trials. Research findings indicate TRE accuracy stabilizes at six trials.[32] Data were collected continuously (streamed) across all trials.

In order to evaluate the repeatability of the testing, four control subjects returned to the laboratory within three days of initial testing and repeated the entire protocol. For these subjects, TREs were compared between sessions using the procedures described above.

The difference in degrees between the target and the replicated position was defined as TRE. Signed (+, −) differences in TRE represent overshooting or undershooting of the target, and unsigned differences represent absolute error. The average of the six trials was defined as mean absolute TRE.

Clinical Measures

The PASS, a measure of the ability to maintain and change lying, sitting, and standing postures (12 items scored 0–3, total 36 points), was used as one of the clinical assessments of balance and postural control.[36] This scale was constructed specifically for people post-stroke and has good predictive ($r = 0.78$) and construct validity ($r = 0.73$), high internal consistency (Cronbach alpha coefficient = 0.95), and high interrater and test-retest reliability (mean kappa values of 0.88 and 0.72).[37]

The BBS evaluates one sitting and 13 standing balance tasks. The scoring is based on a five-point scale with the total score ranging from zero to 56. The scale was originally designed for screening frail older adults at risk of falling. Subsequent studies revealed the test to be a reliable and valid measure of balance in people post-stroke.[38,39]

The FMA was used as a measure of extremity motor impairment. This measure was designed to test motor recovery post-stroke and includes categories for movement, reflexes, and coordination. It has good interrater and intrarater reliability and good construct validity.[40] The FMA motor score ranges from zero to 100: upper extremity is scored from zero to 66 and lower extremity is scored zero to 34. A higher score indicates greater motor recovery.

Data Analysis

The Flock of Birds angular data describing the movement path of the T1 sensor were analyzed using custom software written in Matlab version 7 (Mathworks Inc., Natick, MA). For each trial, the start and end positions for all three planes were identified as the point at which the subject's trunk remained in a fixed position for at least three seconds. The target position that the subject was attempting to match was also identified and stored. All position data was exported to Excel (Microsoft XP) and MiniTab (Release12) for statistical analysis.

Descriptive statistics were used to characterize age, gender, and length of time post-stroke. Independent t tests (two tailed) were used to compare the difference in TRE between the poststroke group and the control group. Separate tests were conducted for each of the three planes of movement: sagittal, frontal, and transverse. Thus, a Bonferroni correction factor was used to accommodate multiple t tests (alpha level for t tests set at ≤ 0.016). Spearman correlation analyses were used to examine the relationship between repositioning error and the scores on the PASS, BBS, and the FMA ($P \leq 0.05$).

RESULTS

The mean of absolute TRE value was significantly greater in both the sagittal and transverse planes in subjects post-stroke compared to nonneurologically impaired subjects, as shown in Table 2 ($t = 4.67$, $P = 0.0001$ and $t = 3.63$, $P = 0.0012$, respectively). In the frontal plane, mean absolute TRE value was not statistically different between groups.

For subjects post-stroke, the absolute mean sagittal TRE at T1 expressed as a percentage of full active forward flexion range was 11% (range, 2%–18%) compared to 4%

TABLE 1. Summary of Group Descriptive Characteristics

	Post-Stroke ($n = 20$)	**Controls ($n = 21$)**
Mean age, yr	60.5	62.6
Range	44–83	46–81
Sex		
Male	11	12
Female	9	9
Time post-stroke, yr		
Mean	5.3	
SD	5.5	
Median	2.5	
Range	0.8–16.6	
Lesion side		
Right	9	
Left	12	
Fugl-Meyer score 0-100		
Mean	49	
SD	24	
Range	15–95	
Berg Balance Scale 0-56		
Mean	43	55.4
SD	11	1.1
Range	16–55	53–56
Postural Assessment Scale for Stroke 0–36		
Mean	31	
SD	3	
Range	22–36	

Abbreviation: SD, standard deviation.

TABLE 2. Summary of Between-Group Trunk Repositioning Error Differences

	Mean (deg)	**SD**	***t***	***P***
Sagittal plane				
Stroke	6.9	3.1	4.67	0.0001
Control	3.2	1.8		
Transverse plane				
Stroke	2.1	1.3	3.63	0.0012
Controls	1.0	0.6		
Frontal plane				
Stroke	2.1	1.6	1.48	0.15
Controls	1.4	1.4		

Abbreviations: deg, degrees; SD, standard deviation

(range, 2%–9%) for the control group. To ensure that spine height did not affect TRE, a covariate analysis of spine height on TRE was performed. The results indicated that spine height did not play a role in differences in TRE ($P = 0.992$).

The sagittal plane signed repositioning error was examined to assess trends in the magnitude and direction of undershooting and overshooting across the six trials. In the sagittal plane, 11 subjects in the poststroke group undershot the target by an average of 6.4 degrees and nine subjects overshot the target by an average of 7.4 degrees (Table 3). Ten subjects in the control group undershot the target by an average of 2.5 degrees and 11 subjects overshot by an average of 4.2 degrees. This difference in error scores between the control and poststroke subjects was not significant.

Within three days of initial testing, four control subjects returned for test-retest measurements. Variability in TRE across days ranged from 0.2 degrees to 2.3 degrees. Intraclass correlation coefficients (3.2) revealed strong test-retest reliability for sagittal (0.941) and frontal (0.882) plane error and good reliability for transverse (0.727) plane error.

In the sagittal plane, the absolute TRE in the poststroke group demonstrated a significantly negative correlation with BBS scores ($P = 0.03$), yet was not correlated with either the PASS or FMA. Transverse plane absolute TRE in the poststroke group was negatively correlated with both BBS ($P = 0.03$) and the PASS ($P = 0.02$) scores, but was not related to the FMA score. There were no significant correlations between frontal plane TRE and any of the three clinical measures (Table 4).

A post hoc analysis of the relationship between TRE and extremity motor impairment was performed to further evaluate potential relationships. Pearson correlation analyses between lower extremity and upper extremity FMA scores and TRE revealed no significant relationships ($P = 0.39$ and $P = 0.38$).

DISCUSSION

Between-Group Differences

The findings of this study suggest that trunk position sense, as defined by TRE, is impaired in individuals in the chronic phase of recovery post-stroke compared to nonneurologically impaired people. The median length of time post-stroke in this study was 2.5 years, which indicates that

TABLE 3. Post-Stroke Group Signed Mean Sagittal Plane Trunk Repositioning Error (TRE) (Undershoot −/Overshoot +)

Subject	**Mean Sagittal TRE**
1	−12.5
2	−11.6
3	−9.3
4	−8.8
5	−8.5
6	−7.8
7	−5.5
8	−5.2
9	−4.2
10	−3.3
11	−0.4
12	2.0
13	3.6
14	4.5
15	4.5
16	6.1
17	6.8
18	8.1
19	8.6
20	12.7

TABLE 4. Correlations Between Trunk Repositioning Error

	Saggital Plane	Transverse Plane	Frontal Plane
Berg Balance Scale	$r = 0.11$ $P =$ (NS)	$r = -0.49$ ($P = 0.03$)	$r = -0.48$ ($P = 0.03$)
Postural Assessment Scale for Stroke	$r = -0.09$ $P =$ (NS)	$r = -0.30$ $P =$ (NS)	$r = -0.52$ ($P = 0.02$)
Fugl-Meyer Assessment Motor Score	$r = 0.31$ $P =$ (NS)	$r = -0.42$ $P =$ (NS)	$r = -0.37$ $P =$ (NS)

Abbreviation: NS, nonsignificant.

this is not a transient impairment that repairs itself with healing. In the sagittal and transverse planes, people post-stroke exhibited twice the TRE as control subjects. The difference in accuracy in the frontal plane followed a similar trend, but was not as great and did not reach statistical significance. Double TRE in the sagittal plane was consistent with the findings of Goldberg et al,[24] who looked specifically at neurologically intact, but balance impaired older adults. While the neuromuscular impairments underlying balance problems may differ in people with stroke and balance-impaired older individuals without stroke, the relationship between impaired balance and altered trunk control as measured by TRE was similar.

Relationship with Clinical Measures

We found that sagittal and transverse TREs were negatively correlated with BBS scores. Since upright trunk control allows safe walking, one might reasonably expect that performance on the BBS, a predictor of safe independent walking, would have a relationship with trunk position sense impairments.[38,39] The validity of the BBS has been established in elderly people through correlations with walking ability, gross motor function, and the Timed-Up-And-Go test.[38,41] While the reliability of the BBS for people post-stroke has been established, there are very few studies reporting a correlation between the BBS and poststroke characteristics. Stevenson and colleagues[42] reported an association between the BBS score and anticipatory postural responses. The present study, which found a significant relationship between BBS scores and TRE in the sagittal and transverse planes, adds to the body of literature on the use of the BBS as an appropriate clinical measure of balance post-stroke.

The significant correlation between transverse plane error and PASS score may relate to the fact that the PASS includes transitional items such as rolling and sitting up from side lying, movements that may use transverse plane (rotational) strategies.[36] Initial investigation of the PASS suggests that it is more sensitive to people in the earlier recovery period post-stroke.[37] This study provides the first evidence that impairments captured by the PASS may continue into the later recovery period. While the test name implies a clinical measure of postural control, the scale does not demand movements of the extremities during tasks in which the trunk must remain stable and adaptable and may be more reflective of trunk movement control. A more precise and specific examination tool such as a computerized balance platform would provide a more sensitive and responsive measure for a study of the relationship between TRE and postural control.

Goldberg et al,[24] studying TRE in balance impaired and healthy older adults, analyzed the relationship between TRE and trunk extensor strength and reported no significant correlation. The researchers suggested that there were other factors that might be related to TRE and encouraged investigations of TRE and lower extremity strength and coordination. TRE was measured while standing in the Goldberg et al study, a position in which lower extremity control may influence trunk position sense. Our investigation of the relationship between sitting TRE and extremity impairment (FMA) revealed no significant correlation. However, since the correlation analysis findings approached significance in the sagittal plane, a post hoc analysis separating the FMA scores into their upper and lower extremity components was performed. Again, no significant relationship was found between TRE and either upper or lower extremity FMA score.

Lin,[43] in a recent study of ankle and knee position sense in people with chronic stroke, demonstrated a significant correlation between ankle joint position sense and gait speed and stride length. Lin's findings suggest that the relevant relationship may be between position sense and function rather than position sense and extremity motor impairment.

Reliability and Validity

We were unable to compare our TREs with other values in the literature because this is the first reported study conducted on people post-stroke. However, our mean absolute TRE value of 3.2 degrees for the control group was similar to previously published reports.[24–27] In addition, we reported control group sagittal TRE mean values being approximately 4% of full active trunk forward flexion range, which agrees with the findings of Swinkles and Dolan.[34] While Swinkles and Dolan reported a tendency for overshooting in subjects with orthopedic spinal pathology, in this study, both groups demonstrated a relatively equal number of subjects overshooting and undershooting.[34]

Intraclass correlation coefficient values for within-day and day-to-day test-retest reliability in each plane of movement (ranging from 0.73 to 0.94) agree with previously published reliability values for electromagnetic RE testing.[21,22] The strong reliability values along with the high degree of accuracy of the Flock of Birds adds strength to the technique used in this study.

The multifaceted nature of trunk position sense testing post-stroke requires care to minimize potentially confounding motor impairments. Since a motor control deficit could partially mask itself as position sense impairments, we cannot definitively say that the TRE demonstrated in this study represents trunk position sense. However, we used several methods to decrease the likelihood that measure of TRE reflected motor system deficits. First, we required the subjects to have the motor skill to actively and independently perform the target movement and hold a midway point in this movement for the required three seconds. The target point was a midway point in their active forward flexion movement path. We did not ask them to move to a position that they had difficulty controlling. Second, subjects with a history of neurological disorders that could affect the neuromotor control system (cerebellar or vestibular disorders, for example) were excluded from the study. Third, there was an attempt to eliminate input from the visual system (blindfolding) and to decrease tactile input (limiting clothing, positioning the arms to avoid touching other body parts). If we assume that we controlled for vision and tactile information and that the motor system control was adequate to allow the subjects to move into the target position, the primary inputs available to the subjects to judge trunk position sense were somatosensory and vestibular. We acknowledge that there is a possibility that this population of individuals post-stroke controlled their sitting posture by limiting mediolateral movements and that TRE might reflect a need to help maintain stability rather than being related to position sense. However, since the movement was a self-selected pattern and the target was not at the limits of their functional ability, we believe that this is not a major confound of this study.

Limitations

The results of this study represent TRE in sitting in a group of people in the chronic recovery stage post-stroke. The inclusion requirements established to avoid confounding trunk position sense with trunk motor control (ie, the ability to perform the task) excluded individuals in the more acute phase of recovery with deficits of sitting balance. In addition, this study measured TRE only during a sagittal plane (forward bending) movement.

The study made no attempt to differentiate between the central nervous system integration and processing of the trunk position sense input and the detection of position sense from spinal muscles and joints during the active target movement. Indeed, the assumption was made that if an impairment in trunk position sense existed, it was most likely a result of the pathology in the central nervous system. However, it is possible that decreased input from position sense receptors as a result of trunk muscle weakness could have been a contributing factor.

A limitation of electromagnetic testing is the possibility of slight skin movement under the sensor. However, research findings demonstrate that spinal movement can be measured by surface sensors with good validity.[44] All subjects were asked to bend slightly forward while the sensor was applied to decrease the possibility of skin stretching or pinching under the tape during testing.

The spine is a multisegmental structure with multiple sensory receptors, all of which may contribute to trunk position sense. Locating the sensor at T1 was not an attempt to measure position sense at T1, but was selected because research indicates that measures at T1 most closely represent an individuals' perception of the total range of sagittal spinal flexion.[34]

Issues of sensitivity of TRE and the responsiveness of TRE to change were not part of the scope of the study. Although subjects post-stroke demonstrated greater TRE than controls, the clinical relevance of the group differences is unclear.

Clinical Implications

The findings of this study represent an important first step in understanding the nature of trunk position sense impairments in people post-stroke. The identification of this impairment is clinically important for several reasons: it adds to the body of knowledge of trunk impairments, adds information about possible underlying factors for altered balance, and suggests direction for future clinical studies of trunk position sense. The relationship between TRE and clinical measures of balance suggest that individuals with balance impairments from stroke are more likely to have deficits in trunk position sense. Trunk position sense retraining is not typically addressed with rehabilitation interventions. However, there is some evidence that position sense may be enhanced through specific retraining programs such as tai chi.[45–47] Trunk position sense retraining with an emphasis on sagittal and transverse movements may prove to be an important intervention strategy to improve trunk stability for balance and for coordinated functional extremity movements.

Future Research

This study measured TRE only during a forward bending movement. To build on the findings of this study, target movements in the frontal and transverse planes should also be examined. Furthermore, since theoretical modeling proposes an essential link between postural control and position sense, research that investigates the relationship between trunk position sense errors and altered trunk postural control might lead to new intervention strategies. Additional research may also show that, just as ankle joint position sense is related to gait performance,[48] trunk position sense may be related to functional activities such as sitting to standing or walking. Whether other sensory or perceptual deficits are related to trunk position sense may also be determined by future research.

CONCLUSION

For the first time, an impairment in trunk position sense as measured by TRE has been identified in people in the chronic phase of recovery post-stroke. This impairment in trunk position sense appears to be related to clinical measures of balance and posture. The findings of this study provide a platform for continuing research in TRE and its relationship to balance and functional performance. In clinical practice, therapists should keep in mind that trunk position sense training may become an important intervention strategy to improve trunk stability as a precursor to balance and functional activities for patients post-stroke.

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