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Clinical tools to measure trunk performance after stroke: a systematic review of the literature

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Objective: To give a systematic review of clinical measurement scales used to assess trunk performance after stroke.
Data sources: The databases CINAHL, Cochrane, Pedro and PubMed were searched with the terms 'sitting balance' plus 'stroke' and 'trunk' plus 'stroke' mentioned in the title or abstract. Databases were searched from inception to January 2006.
Review methods: All articles were selected which reported or included a clinical measure of trunk performance used in an adult stroke population. Reference lists were searched as secondary sources of articles.
Results: A total of 458 articles resulted from the database search. Thirty-two articles were eligible for inclusion. Earlier studies mentioned ordinal single items or a combination of items which are part of a larger scale used to assess sitting balance as a derived measure of trunk performance. Three clinical tools were available which specifically evaluated trunk performance after stroke; the Trunk Control Test and two Trunk Impairment Scales.
Conclusion: Ordinal single items or subscales of existing larger scales lack a systematic evaluation of psychometric characteristics. Both Trunk Impairment Scales have been extensively examined. A comparative study assessing psychometric properties of the Trunk Control Test and two Trunk Impairment Scales could determine which should be the measure of choice when assessing trunk performance after stroke.

Introduction

Since only a quarter of all patients surviving a stroke make a full recovery,[1] rehabilitation should be targeted to treating the remaining impairments that have a negative impact on everyday activities of daily living. Most studies reporting treatment of performance after stroke are concerned with the lower or upper extremity.[2,3] In comparison with limb rehabilitation, trunk recovery is a rather neglected area of stroke rehabilitation research. Nevertheless, Davies clearly associates a loss of selective trunk control with limitations in breathing, speech, balance, gait, arm and hand function.[4] Furthermore sitting balance has been repeatedly identified as an important predictor of motor and functional recovery after stroke.[5–8]

Trunk performance after stroke has been evaluated in various ways. Methodological approaches used in previous studies included isokinetic muscle testing,[9–11] manual dynamometry,[12–14] electromyographic analysis,[15–19] transcranial magnetic stimulation,[20] computed tomography,[21] and movement

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analysis.[22] These studies are not included in this review since they are not within the scope of this study. This paper provides an overview of clinical scales that have been used to evaluate trunk performance.

Standardized clinical assessment tools are a prerequisite for scientific research and clinical practice. Clinical tools used to evaluate trunk performance have evolved over time. Where originally single, one-dimensional items on an ordinal scale were reported in the literature, today researchers can choose from a variety of tools to measure trunk performance with acceptable psychometric properties. To the best of our knowledge, there has been no critical overview of these tools to see how they compare.

Therefore, based on the fact that measuring trunk performance after stroke is important because of its high predictive value, that there are several clinical measures available for assessing trunk performance, and that there has been no systematic comparison of these measures, it was the aim of this study to give a systematic review of clinical tools designed to evaluate trunk performance after stroke.

Methods

The biomedical databases CINAHL, Cochrane, Pedro and PubMed were searched. Each database was searched from its starting date until January 2006.

The four databases were searched with the terms 'sitting balance' plus 'stroke' and 'trunk' plus 'stroke' mentioned in the title or abstract. The search strategy included all studies in humans with original data from adults after stroke. All articles were selected for this review which reported or included a clinical measure of trunk performance. Only articles that were published in English were included.

One reviewer (GV) independently assessed each title and abstract located through the search engines of the different databases. All predetermined criteria as described above were applied and full-text articles that met inclusion criteria were retrieved. Reference lists from included articles were hand-searched to detect further relevant papers.

Data were extracted from the collected articles by one reviewer (GV) and included information on examined population, number of patients and psychometric characteristics presented.

Results

The search of the CINAHL database resulted in 93 articles, 15 of which reported a clinical tool to measure trunk performance. Searching the Cochrane database gave 31 articles; two included a clinical measure of trunk performance. The Pedro database displayed 14 articles. None, however, reported a clinical tool to measure trunk performance. Finally, the PubMed database listed 320 publications, 15 of which mentioned a clinical scale to evaluate trunk performance after stroke.

Clinical scales to assess trunk performance after stroke have evolved over time. We present an overview of these tools in the next paragraphs. Originally single items on an ordinal scale were used. Later, more wide-ranging scales such as the sitting balance scale for hemiplegia and various subscales that consist of a combination of items from a larger scale were developed. Finally, three measures are discussed in more detail which assess trunk performance in a more comprehensive way.

Single items on an ordinal scale

Single items on an ordinal scale have been used extensively in the earlier literature concerning functional outcome after stroke.[5,12,23] Wade *et al.* presented a 3-point ordinal item, a lower score indicated a better performance.[5] Sandin and Smith[23] and Bohannon[12] further developed this into a 4- and 5-point ordinal item, respectively. They reversed the scoring system by assigning a higher score to a better performance. Psychometric characteristics of these items were not reported.

Sitting balance scale for hemiplegia

The sitting balance scale for hemiplegia evaluated normal sitting, sitting with the legs crossed, leaning sideways to both sides and leaning forwards.[24] Two- or 3-point ordinal scales were used to evaluate whether or not the patient can keep balance during different tasks, a higher score indicating a better performance. Quality of posture or movement is also scored for each task. Nieuwboer *et al.* examined the reliability of this instrument in 27 stroke patients at different stages of recovery. Four of the five items evaluating quality of movement had kappa values between 0.20 and 0.36, which were found insufficient to establish reliability.

Trunk performance as part of a total motor assessment

There are several examples of scales where trunk performance is included as part of a total assessment. Lincoln and Leadbitter introduced the Rivermead Motor Assessment which comprises the leg and trunk section, presented as a Guttman scale.[25] Two items of this section are closely related to trunk performance. Test–retest reliability was evaluated by means of the correlation coefficient in 10 stroke patients ($r = 0.93$). Adams *et al.* examined the scalability of the Rivermead Motor Assessment in 51 acute and 291 non-acute stroke patients.[26,27] They concluded that the leg and trunk section in acute and non-acute stroke patients did not meet the criteria for consistency of hierarchy.

The Motor Assessment Scale, presented by Carr *et al.* contains three items assessing trunk performance after stroke.[28] Each item is scored on a 7-point ordinal scale, a higher score indicating a better performance. Inter-rater and test–retest reliability were evaluated by means of correlation coefficients (mean $r = 0.95$ and 0.98 for the total scale, respectively) and percentage of raters agreement (between 74% and 99% for the individual trunk performance items) with 5 and 14 patients at various stages of recovery included in the study. The balanced sitting item of the Motor Assessment Scale appeared a significant predictor of stroke outcome.[29] Inter-rater reliability and concurrent validity were further examined by Poole and Whitney in 30 non-acute stroke patients.[30] A low correlation coefficient ($r = 0.28$) was found between the balanced sitting item of the Motor Assessment Scale and total Fugl-Meyer Assessment.

The postural control part of the Chedoke-McMaster Stroke Assessment is a mixture of items, which have to be performed in lying, sitting and standing.[31] Adequate inter-rater ($r = 0.92$, 95% CI 0.84–0.96) and intra-rater reliability ($r = 0.96$, 95% CI 0.93–0.98) by means of intraclass correlation coefficients (ICCs) as well as construct ($r = 0.69$ with total Fugl-Meyer Assessment) and concurrent validity ($r = 0.73$ with total Functional Independence Measure) was reported in a sample of 32 stroke patients admitted to a rehabilitation unit, but only for the total postural control subscale.[32]

Benaim *et al.* introduced lying and sitting items as part of the Postural Assessment Scale for Stroke patients.[33] Each item is scored on a 4-point ordinal scale, a higher score indicating a better performance. Kappa coefficients for inter-rater and intra-rater agreement for the different lying and sitting items ranged between 0.45 and 1. Pearson correlation coefficients were reported for the total score but not for the subscore of the lying and sitting items. The reliability study was performed on 12 stroke patients. Additionally, construct and predictive validity as well as internal consistency were reported for the total scale. Despite the fact that the lying and sitting items of the Postural Assessment Scale for Stroke patients appeared to be an early predictor of comprehensive activities of daily living after stroke,[8] recent literature shows a ceiling effect at various stages after stroke and a limited responsiveness over the first six months.[34]

The Stroke Impairment Assessment Set includes two trunk items: verticality and abdominal manual muscle testing, both evaluated on a 4-point ordinal scale, a higher score indicating a better performance.[35] The clinimetric properties of the total Stroke Impairment Assessment Set have been extensively examined.[36] Reliability of the trunk items was evaluated on 12, 20 and 46 non-acute stroke patients. Weighted kappa statistics of 0.63 and 0.93 were found for inter-rater reliability of the trunk items although another study reported kappa statistics of 0.32 and 0.50 for the same items.[36]

Trunk Control Test

The Trunk Control Test was the first specific clinical tool reported in the literature which evaluated motor performance of the trunk.[37] The test consists of four items which are assessed on a 3-point ordinal scale. The items are rolling from supine to the weak and strong side, sitting up from lying down and maintaining balance in the sitting position on the side of the bed. The total score for the Trunk Control Test ranges from minimum 0 to maximum 100 points, a higher score indicating a better performance.

Inter-rater reliability of the Trunk Control Test was examined by means of Spearman rho correlation coefficient ($r = 0.76$) for the total Trunk Control Test score on 20 non-acute stroke patients.[37] Construct validity was evaluated by calculating correlation coefficients between the Trunk Control Test and the gross motor function subscale of the Rivermead Motor Assessment at 6, 12 and 18 weeks post stroke. Coefficients ranged between 0.70 and 0.79.[37] Franchignoni *et al.* examined 49 stroke patients and evaluated internal consistency and predictive validity (see Table 1).[38] Duarte *et al.* evaluated 28 stroke patients and examined predictive validity as well.[39]

Trunk Impairment Scale (1)

Two Trunk Impairment Scales are available today. The first was presented by Verheyden *et al.*[40] This scale comprises 17 items and evaluates static and dynamic sitting balance and trunk co-ordination. The items of the Trunk Impairment Scale are scored on a 2-, 3- or 4-point ordinal scale. The total score ranges from minimum 0 to maximum 23 points, a higher score indicating a better performance.

Item per item test–retest and inter-rater reliability was established by means of kappa and weighted kappa values (between 0.46 and 1) and percentage of agreement (between 82% and 100%) on 28 stroke patients in a rehabilitation setting.[40] ICCs were calculated for test–retest and inter-rater reliability for subscale and total scores (between 0.85 and 0.99).[40] Test–retest and interexaminer measurement error, internal consistency, content, construct and concurrent validity were also established (see Table 1).[40] The discriminant ability of the Trunk Impairment Scale was evaluated by comparing the scores of 40 stroke patients with those of 40 age- and sex-matched healthy individuals (see Table 1).[41] Recently reliability and validity of the Trunk Impairment Scale was also established for people with multiple sclerosis.[42]

Trunk Impairment Scale (2)

The Trunk Impairment Scale by Fujiwara *et al.* is the most recent scale reported in the literature which measures trunk impairment after stroke.[43] This seven-item scale evaluates perception of trunk verticality, trunk rotation muscle strength on the affected and unaffected side, righting reflexes on the affected and unaffected side and the scale includes also both the verticality and abdominal manual muscle testing items of the Stroke Impairment Assessment Set of Tsuji *et al.*[35] Each item is evaluated on a 4-point ordinal scale. The total score ranges between minimum 0 and maximum 21 points, a higher score indicating a better performance.

Fujiwara *et al.* evaluated several psychometric properties on 73 non-acute stroke patients.[43] They assessed inter-rater reliability on 20 subjects and found weighted kappa values between 0.66 and 1. Principal component analysis was used to establish content validity (see Table 1). Concurrent validity was evaluated by calculating Spearman's rank correlation coefficient between the Trunk Impairment Scale and the Trunk Control Test ($r = 0.91$).[43] Predictive validity and responsiveness were examined (see Table 1).[43] A Rasch analysis was performed to examine internal consistency and item difficulty. Mean square fit statistics for three of the seven items of the Trunk Impairment Scale were above the proposed limit, indicating a poor fit of these items to the Rasch model.[43]

Table 1 gives an overview of the psychometric characteristics of the Trunk Control Test and two Trunk Impairment Scales.

Discussion

This study was performed to provide a systematic review of clinical tools to assess trunk performance after stroke. Based on four biomedical databases, articles were selected which included the development or use of a clinical scale.

With the evolution in (neuro)rehabilitation research, the further use of the term 'sitting balance' seems less appropriate. Trunk function implies more than just sitting balance. Stabilization and selective movements of the trunk in flexion, extension, lateral flexion and rotation are important aspects as well. For the purpose of rehabilitation, physiotherapists and occupational therapists make a distinction between the upper and lower part of the trunk. To allow efficient walking, counter rotation between the shoulder and pelvic girdle is needed. This need for proximal stabilization to allow distal movements on the one hand and the ability to selectively initiate trunk movements on the other hand has led to the abandoning of the term 'sitting balance'. Instead the terms 'trunk control', 'trunk impairment' and 'trunk performance' were introduced.

Clinical measures to evaluate trunk performance after stroke have evolved especially during the past three decades. In 1909 Beevor drew attention to the paralysis of the movements of the trunk,[44] but it was not until the early 1980s that single items on an ordinal scale were used in studies predicting stoke outcome. However there is a consistent lack of any statistical quality for these types of assessments. Basic psychometric properties such as reliability or validity were not reported. Despite the fact that these tools were significant predictors for outcome after

Table 1 Overview of the psychometric characteristics of the Trunk Control Test,[37] Trunk Impairment Scale[40] and Trunk Impairment Scale[43]

Psychometric characteristic	Trunk Control Test	Trunk Impairment Scale (Verheyden)	Trunk Impairment Scale (Fujiwara)
Number of items	4	17	7
Score of each item	0, 12 or 25	0–1, 0–2 or 0–3	0–3
Total score range	0–100	0–23	0–21
Test–retest reliability	Not available	Kappa and weighted kappa values, percentage of agreement, ICC (kappa between 0.46 and 1, % of agreement between 82% and 100%, ICC between 0.87 and 0.96)	Not available
Inter-rater reliability	Spearman rho correlation coefficient ($r = 0.76$)	Kappa and weighted kappa values, percentage of agreement, ICC (kappa between 0.7 and 1, % of agreement between 82% and 100%, ICC between 0.85 and 0.99)	Weighted kappa values (between 0.66 and 1)
Measurement error	Not available	Inter- and test–retest examiner measurement error (inter: −1.84 to 1.84, test–retest: −2.90 to 3.68)	Not available
Responsiveness	Not available	Not available	Standardized response mean value (0.94)
Internal consistency	Cronbach's α (0.83 and 0.86)	Cronbach's α (between 0.65 and 0.89)	Rasch analysis (All but three items showed mean square fit statistic within 1.3)
Content validity	Not available	Literature review, observing stroke patients, clinical experience and discussion with specialists in stroke rehabilitation	Principal component analysis (three factors identified)
Construct validity	Correlation with gross motor function subscale of the Rivermead Motor Assessment (between 0.70 and 0.79)	Correlation with Barthel Index ($r = 0.86$)	Not available
Concurrent validity	Not available	Correlation with Trunk Control Test ($r = 0.83$)	Correlation with Trunk Control Test ($r = 0.91$)
Predictive validity	Significant predictor on admission of (motor part of the) FIM at discharge ($R^2 = 0.54$ when predicting FIM, $R^2 = 0.71$ when predicting motor FIM)	Significant predictor on admission of Barthel Index score at six months post stroke (unpublished data)	Significant predictor on admission of motor part of the FIM at discharge (added $R^2 = 0.09$)
Discriminant ability	Not available	Significant differences between stroke patients and healthy individuals ($P < 0.0001$)	Not available

stroke,[5,12,23] the lack of established reliability does not warrant further use in scientific studies.

Measuring sitting balance by means of several items offered more variety compared with the single items on an ordinal scale. Nieuwboer *et al.* evaluated the inter-rater reliability of the sitting balance scale for hemiplegia.[24] However several items showed low kappa values. Furthermore the ability to lean maximally to either side or forward is apparently not strongly related to function,[45] indicating that the items of the sitting balance scale for hemiplegia would need reconstruction.

Several subscales, as part of a larger scale, were reported in the literature for assessing trunk performance. A great variety of items ranging from part of transfer movements to specific trunk muscle activity are included. Mostly there is no clear rationale behind the choice made and neither is there a content validity study. Although some of these tools showed a moderate to good reliability and predictive validity could be presented, a consistent lack of critical appraisal of all the other psychometric properties warrants caution for the use of these measures when evaluating trunk performance.

Currently available tests that specifically evaluate trunk performance after stroke are the Trunk Control Test and two Trunk Impairment Scales. The Trunk Control Test became a well-established assessment tool, but at the same time several shortcomings were reported in the literature. The Trunk Control Test does not take quality of movement into account.[37] Furthermore Bohannon found low correlation coefficients from 0.23 to 0.50 between Trunk Control Test scores and trunk musculature measurements by means of a hand dynamometer.[14] However, the weak correlations may just point out the fact that for completing the Trunk Control Test, full trunk muscle force is not required. Probably the most limiting aspect of the Trunk Control Test is its ceiling effect. Several studies have pointed out that during rehabilitation a high percentage of stroke patients obtained the maximal score. The scale probably works best around or below the floor of measures of functional performance.[39,46,47]

Most of the tools described start with tasks in the supine position. The first described Trunk Impairment Scale has a different approach.[40] A standardized sitting position is used throughout the assessment. Movements are performed in the sagittal, frontal and horizontal plane. Quality of movement is taken into account by observing whether or not the task is performed with compensations. The different items are related to treatment and function.[40] Furthermore this Trunk Impairment Scale has no ceiling effect.[47] Responsiveness, Rasch analysis and predictive validity have not been reported so far. However data are available that show that the static sitting balance subscale and total Trunk Impairment Scale score on admission to the rehabilitation centre are significant predictors of Barthel Index score at six months after stroke, and are even more important than Barthel Index score on admission itself (unpublished data).

While extensive testing of essential psychometric properties was carried out for both Trunk Impairment Scales, this is lacking for the Trunk Control Test. The Trunk Impairment Scale of Verheyden *et al.* has no ceiling effect. The presence of a ceiling effect has not yet been evaluated for the Trunk Impairment Scale of Fujiwara *et al.* The Trunk Impairment Scale of Fujiwara *et al.* has been evaluated with Rasch analysis. Rasch analysis remains to be carried out for the Trunk Impairment Scale of Verheyden *et al.* Future research will therefore determine which of these scales should be the measure of choice.

There are important limitations with regard to this study that must be considered. Search strategies used in systematic reviews inevitably miss measures. High-quality measures (or subcomponents of measures) used in different pathological conditions were not included in this study. This study was conducted by only one reviewer. Adding a second reviewer who independently performs the search and data collection as well would be a suggestion for further research. Furthermore, studies discussing psychometric characteristics of measurement tools assess different stroke populations at different points in time after stroke. In this review, the results of these studies are brought together with the purpose of comparing clinical tools. This must be kept in mind when discussing the results of this study. Finally, to the best of our knowledge, no study has compared different measures of trunk performance on the same population of stroke patients. No study has been performed on several types of stroke patients and at different points in time after stroke, so comparison of measurement scales should be performed with caution.

Clinical messages

- Single items on an ordinal scale and a compilation of items or subscales of larger scales should not be used when assessing trunk performance because of lack of proven statistical quality.
- Standardized clinical measures available today are the Trunk Control Test and two Trunk Impairment Scales.

Competing interest
None declared.

Contributors

GV searched the databases, selected the articles and wrote the paper. AN, AVdW and WDW assisted on interpretation of the data found in the various studies, made essential contributions to the manuscript and approved the final version.

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