Trunk performance after stroke: an eye catching predictor of functional outcome

Geert Verheyden, Alice Nieuwboer, Liesbet De Wit, Hilde Feys, Birgit Schuback, Ilse Baert, Walter Jenni, Wilfried Schupp, Vincent Thijs, Willy De Weerd

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See end of article for authors' affiliations

Correspondence to:
Dr Geert Verheyden,
University of Southampton,
School of Health Professions
and Rehabilitation Sciences,
Southampton General
Hospital, Mailpoint 886,
Tremona Rd, Southampton
SO16 6YD, UK;
G.Verheyden@soton.ac.uk

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Background and aim: Trunk performance is an important predictor of functional outcome after stroke. However, the percentage of explained variance varies considerably between studies. This may be explained by the stroke population examined, the different scales used to assess trunk performance and the time points used to measure outcome. The aim of this multicentre study was to examine the predictive validity of the Trunk Impairment Scale (TIS) and its subscales when predicting the Barthel Index score at 6 months after stroke.

Methods: A total of 102 subjects were recruited in three European rehabilitation centres. Participants were assessed on admission (median time since stroke onset 20 days) and 6 months after stroke. Correlation analysis and forward stepwise multiple regression analysis were used to model outcome.

Results: The best predictors of the Barthel Index scores at 6 months after stroke were total TIS score (partial $R^2 = 0.52$, $p < .0001$) and static sitting balance subscale score (partial $R^2 = 0.50$, $p < .0001$) on admission. The TIS score on admission and its static sitting balance subscale were stronger predictors of the Barthel Index score at 6 months than the Barthel Index score itself on admission.

Conclusions: This study emphasises the importance of trunk performance, especially static sitting balance, when predicting functional outcome after stroke. The TIS is recommended as a prediction instrument in the rehabilitation setting when considering the prognosis of stroke patients. Future studies should address the evolution of trunk performance over time and the evaluation of treatment interventions to improve trunk performance.

Although the age specific incidence of major stroke has fallen over the past few years,¹ it is still the main cause of long term disability in adults, with a growing number of survivors being dependent for activities of daily living (ADL).^{2–3} Frequently identified variables predicting ADL after stroke are age and initial severity of motor and functional deficits.⁴ Trunk performance has also been identified as an important independent predictor of ADL after stroke.^{5–9} However, based on multiple regression analyses, the reported variance of functional outcome after stroke explained by trunk performance ranges from 9% to 71%.^{5–9} Differences in reported variance could be explained by the stroke population included, the various scales used to measure trunk performance and the time points used to measure outcome.

Previous studies evaluating the predictive validity of trunk performance after stroke were performed in a single rehabilitation setting, warranting caution when generalising results.^{5–10} Clinical tools used to assess trunk performance are the Trunk Control Test,^{5–6–10} trunk control items of the Postural Assessment Scale for Stroke patients^{7–8} and trunk assessment of Fujiwara *et al.*⁹ A limitation of the first two tests is that they both have a ceiling effect, which makes their use less suitable in long term outcome studies.^{5–11–13} Furthermore, the trunk control items of the Trunk Control Test and Postural Assessment Scale for Stroke patients are largely comparable with the items of the trunk measure of Fujiwara *et al.*⁹ All previously mentioned clinical tools include items in the supine position which involve rolling as well as only basic balance movements in sitting. Finally, with the exception of the trunk control items of the Postural Assessment Scale for Stroke patients,⁸ no study has evaluated the prognostic value of trunk performance when predicting functional outcome at 6 months after stroke.

The Trunk Impairment Scale (TIS) for patients after stroke was designed to measure ADL related selective trunk movements

rather than participation of the trunk in gross transfer movements.¹⁴ The TIS assesses static and dynamic sitting balance and trunk coordination. Reliability, validity, measurement error, internal consistency and discriminant ability of the TIS have been reported elsewhere.^{14–15} The TIS has no ceiling effect in subacute and chronic stroke patients and already appeared to be strongly related to measures of gait, balance and functional ability in a cross sectional study.¹² To the best of our knowledge, the predictive value of the TIS and its subscales has not been evaluated. Including age and other measures of motor and functional performance could provide a useful combination of variables predicting outcome after stroke. The Barthel Index score is a widely accepted measure in stroke rehabilitation research and assesses functional milestones in stroke recovery. Predicting Barthel Index scores at 6 months after stroke based on measurements taken on admission to a rehabilitation centre would further establish the importance of trunk performance when predicting long term outcome after stroke. Experts in the field of neurological rehabilitation have addressed the trunk as the central key point of the body.¹⁶ Proximal stability of the trunk is a prerequisite for distal head and limb movement and therefore expected to be related to functional ADL.

In summary, there is still a lack of clarity regarding the importance of trunk performance in functional outcome after stroke. Scales which have been used in previous studies have important statistical limitations and are likely to be a comprehensive measure of motor performance of the trunk. Therefore, the aim of this multicentre study was to examine the predictive validity of the TIS and its subcomponents, together with other known predictors, in predicting functional outcome measured as a Barthel Index score at 6 months after stroke.

Abbreviations: ADL, activities of daily living; TIS, Trunk Impairment Scale

Figure 1 Overview of the number of subjects, evaluated in each of the three European rehabilitation centres, on admission and at 6 months after stroke.

METHODS

Subjects

The study was conducted in three European rehabilitation centres (University Hospital, Pellenberg, Belgium; RehaClinic, Zuzach, Switzerland; and Fachklinik, Herzogenaurach, Germany). In each centre, all consecutive stroke patients were considered for inclusion in the study. Inclusion criteria were first ever stroke, as defined by the World Health Organisation,¹⁷ at age 40–85 years and a score on the gross motor function subscale of the Rivermead Motor Assessment ≤ 11 , or on the leg and trunk function subscale ≤ 8 , or on the arm function subscale ≤ 12 , on admission to the rehabilitation centre.¹⁸ Exclusion criteria were other neurological impairments with permanent damage, stroke-like symptoms attributable to subdural haematoma, tumour, encephalitis or trauma, pre-stroke Barthel Index score < 85 ,¹⁹ a hip prosthesis at the non-hemiplegic side, being admitted to the rehabilitation centre more than 6 weeks after stroke and lack of informed consent. This study was approved by the ethics committee of each centre.

An overview of the number of subjects included in this study on admission and at 6 months after stroke is presented in fig 1. A total of 102 subjects were evaluated at 6 months after stroke. Participants had a mean (SD) age of 70 (10) years on admission. Forty-seven women and 55 men were included in the study. Thirty-eight subjects suffered a left-sided, 55 a right-sided and nine a bilateral lesion. Seventeen participants had a

haemorrhagic accident and 84 an ischaemic accident. The diagnosis of one subject was based on clinical assessment alone.

Procedure

On admission to the rehabilitation centre, participants' age, sex, days post stroke, side of lesion, type of stroke, pre-stroke Rankin Scale score,²⁰ comorbidity, presence of urinary incontinence and swallowing disorder, National Institute of Health Stroke Scale score^{21, 22} and pre-stroke Barthel Index score¹⁹ were recorded. On admission and at the 6 month follow-up, subjects were assessed with the gross motor, leg and trunk, and arm function subscale of the Rivermead Motor Assessment,¹⁸ Barthel Index¹⁹ and TIS.¹⁴ The TIS is a reliable and valid measurement of trunk performance, containing 17 items with a minimum score of 0 and a maximum score of 23 points, a higher score indicating a better trunk performance. Static sitting balance evaluates if a patient can keep a seated position with both feet on the floor and with the legs crossed passively by the therapist and actively by the patient (evaluating compensations of the trunk). Dynamic sitting balance assesses selective lateral flexion, initiated from the shoulder and pelvic girdle. Finally, coordination evaluates selective rotation of the upper and lower part of the trunk, against time.

In every rehabilitation centre, one or two researchers carried out all of the assessments on admission and at the 6 month follow-up. The group of researchers were trained together during a 5 day workshop and a supervisor visited every centre afterwards to provide additional feedback and perform quality control. A manual with clear guidelines was given to each researcher. A total of five researchers participated in the study.

Table 1 Scores of motor and functional performance of 102 consecutive stroke patients on admission and at the 6 month follow-up

Measure (min-max)*	Admission	%	6 months	%
RMA GMF (0–13)	4.88 (3.63)	37	9.03 (3.73)	69
RMA L&T (0–10)	5.39 (2.98)	54	7.51 (3.20)	75
RMA arm (0–15)	5.96 (5.26)	40	8.91 (5.36)	60
BI (0–100)	54.07 (29.25)	54	77.84 (28.22)	78
TIS (0–23)	13.56 (6.18)	59	17.34 (5.63)	75
SSB (0–7)	5.44 (2.25)	78	6.07 (1.65)	87
DSB (0–10)	5.75 (3.17)	58	7.70 (2.92)	77
COO (0–6)	2.37 (1.55)	40	3.57 (1.88)	60

*Measures presented are Rivermead Motor Assessment gross motor function (RMA GMF), leg and trunk (RMA L&T) and arm subscale score (RMA arm), Barthel Index score (BI), Trunk Impairment Scale score (TIS) and TIS static sitting balance (SSB), dynamic sitting balance (DSB) and coordination subscale score (COO).

Values are presented as mean (SD) and percentage of the maximum score of the measure (%).

Data analysis

Only subjects who were assessed on admission to the rehabilitation centre and at 6 months after stroke were included in the statistical analysis. Descriptive statistics, either mean and standard deviation (SD) or median, interquartile range (IQR Q1–Q3) and range were calculated to report motor and functional outcomes. The prognostic value of trunk performance and other predictive factors was first tested in a univariate analysis by calculating correlation coefficients between all explanatory variables and the Barthel Index at 6 months after stroke. Point biserial and Pearson correlation coefficients were used for dichotomous and continuous variables, respectively. Variables with a correlation coefficient of $p > 0.10$ were not retained for further multivariate regression analysis. To examine the possible effect of recruiting patients

Table 2 Point biserial (r_{pb}) or Pearson correlation coefficients (r_p) and p value of variables and scores of measures of motor and functional performance

Variable*		Admission–6 months	
		R	p Value
Age	r_p	–0.33	0.0007
Days on admission	r_p	–0.36	0.0002
MI	r_{pb}	–0.18	0.0720
AF	r_{pb}	–0.18	0.0724
UI	r_{pb}	–0.33	0.0006
PSR	r_p	–0.32	0.0011
Swallowing problems	r_{pb}	–0.23	0.0186
Pre-stroke BI	r_p	0.25	0.0107
NIHSS	r_p	–0.66	<0.0001
RMA GMF	r_p	0.63	<0.0001
RMA L&T	r_p	0.63	<0.0001
RMA Arm	r_p	0.44	<0.0001
BI	r_p	0.70	<0.0001
TIS	r_p	0.72	<0.0001
SSB	r_p	0.71	<0.0001
DSB	r_p	0.62	<0.0001
COO	r_p	0.57	<0.0001

*Variables presented are age at time of stroke (Age), days after stroke on admission to the rehabilitation centre (Days on admission), history of myocardial infarction pre-stroke (MI), presence of atrial fibrillation (AF), presence of urinary incontinence (UI), pre-stroke Rankin Scale score (PSR), pre-stroke Barthel Index score (Pre-stroke BI), National Institute of Health Stroke Scale score (NIHSS), Rivermead Motor Assessment gross motor function (RMA GMF), leg and trunk (RMA L&T) and arm subscale score (RMA Arm), Barthel Index score (BI), Trunk Impairment Scale score (TIS) and static sitting balance (SSB), dynamic sitting balance (DSB) and coordination subscale score (COO) of the TIS. Coefficients are shown between factors on admission and Barthel Index score at 6 months after stroke.

from three different rehabilitation centres, the interaction between each retained variable and centre was evaluated by the PROC GLM procedure, including variable and variable $\times$ centre in the model statement. The variables were further cross tabulated to assess multicollinearity. If the correlation coefficient between two variables was >0.90 , only one of the variables was selected for further analysis. The gross motor function and leg and trunk subscales of the Rivermead Motor Assessment were not included because of multicollinearity with the Barthel Index score. The pre-stroke Barthel Index score was not used because of its association with the pre-stroke Rankin Scale score. Based on the retained explanatory variables, a forward stepwise multiple linear regression analysis was performed. Variables on admission were used to predict

Barthel Index score at 6 months after stroke. Two prediction models were evaluated: (1) a model with the TIS total score and (2) a model with the TIS subscale scores. The assumptions underlying multivariate regression analysis were tested by inspecting the distribution of error terms and outliers. The p value for retaining variables in the multivariate regression model was set at $p < 0.05$.

Statistical analyses were performed using the statistical software program SAS 8.2 and SAS Enterprise Guide 2.0.

RESULTS

Median pre-stroke Barthel Index score for the 102 participants was 100 (IQR 100–100, range 85–100). Median pre-stroke Rankin Scale score was 0 (IQR 0–1, range 0–3). Median time between stroke onset and admission to the centre was 20 days (IQR 15–28, range 9–42). The number of subjects with a history of myocardial infarction and atrial fibrillation was 8 and 21, respectively. On admission, a total of 33 (32%) and 17 (17%) participants had urinary incontinence or swallowing problems and the mean (SD) score on the National Institute of Health Stroke Scale was 6.02 (4.94). Scores for motor and functional performance on admission and at 6 months after stroke are presented in table 1.

All correlation coefficients between the explanatory variables and the Barthel Index score at 6 months after stroke with a p value <0.10 are presented in table 2. Higher correlation coefficients were found for the National Institute of Health Stroke Scale score and all scores of motor and functional performance compared with other predictive variables. For each variable presented in table 2, the interaction of variable and centre was examined. No significant interactions were found. p Values for the interaction terms ranged from 0.21 to 0.93.

Results of the forward stepwise multiple regression analysis are given in table 3. The combination of variables on admission explained 64% and 69% of the variance of the Barthel Index score at 6 months after stroke when the TIS or its subscales were used, respectively. Total TIS (partial $R^2 = 0.52$, $p < 0.0001$) and static sitting balance subscale score (partial $R^2 = 0.50$, $p < 0.0001$) were the most important factors when predicting Barthel Index score at 6 months after stroke. Other significant variables were Barthel Index score on admission, age, pre-stroke Rankin Scale score and days after stroke in combination with the total TIS score. The same variables and National Institute of Health Stroke Scale score were significant predictors when the subscale scores of the TIS were included as explanatory variables.

Table 3 Forward stepwise multiple regression analysis for variables on admission predicting Barthel Index score at 6 months after stroke

Model	Model 1 TIS total score			Model 2 TIS subscales SSB/DSB/COO		
	Variable*	R ²	p Value	Variable*	R ²	p Value
Admission–6 months	TIS	0.52	<0.0001	SSB	0.50	<0.0001
	BI	0.06	0.0002	BI	0.12	<0.0001
	Age	0.02	0.0143	Admission	0.02	0.0108
	PSR	0.02	0.0170	Age	0.02	0.0197
	Admission	0.02	0.0336	PSR	0.02	0.0437
Model R ²				NIHSS	0.01	0.0470
					0.69	

*Variables presented are Trunk Impairment Scale score (TIS), Barthel Index score (BI), age at the time of stroke onset (Age), pre-stroke Rankin Scale score (PSR), days post stroke on admission to the rehabilitation centre (Admission), the TIS static sitting balance (SSB), dynamic sitting balance (DSB) and coordination (COO) subscale score and National Institute of Health Stroke Scale score on admission to the rehabilitation centre (NIHSS). Measure of trunk performance for the prediction models was TIS total score (Model 1) or its three subscales (Model 2) in combination with other predictive variables.

DISCUSSION

The aim of this study was to assess the predictive validity of the TIS and its subscales in combination with other variables when predicting the Barthel Index score at 6 months after stroke.

The results emphasise that trunk performance is an important predictor of functional recovery after stroke from the measures taken in this study. The fact that the total TIS and static sitting balance subscale score of the TIS on admission are the most significant predictors of the Barthel Index score at 6 months after stroke is a remarkable result. Both variables explained more of the variance of the Barthel Index score at 6 months than the Barthel Index score itself on admission. Hsieh *et al* used the trunk control items of the Postural Assessment Scale for Stroke patients 14 days after stroke to predict comprehensive ADL at 6 months after stroke.⁸ They also found that trunk control alone explained 45% of the variance, more than the Barthel Index alone. With 52% of the variance of the Barthel Index at 6 months explained by the total TIS score on admission, our result confirms the importance of early trunk performance after stroke.

The fact that on admission the static sitting balance subscale of the TIS, a three item scale, is the most important factor in predicting the Barthel Index score at 6 months after stroke is of particular interest. The static sitting balance subscale evaluates if a patient can maintain an upright sitting position with and without the legs crossed passively by the therapist and actively by the subject. The score ranges from 0 to 7 points, a higher score indicating a better static sitting balance. It is a simple assessment that can be administered to all subjects after stroke. The Barthel Index measures the degree of independence for several ADL, such as feeding, transfer, personal care, toilet use, bathing, walking, climbing stairs, dressing, and bowel and bladder control. Because many of these activities are performed from a seated position, sitting balance could be seen as a prerequisite for these activities. The primary contribution of the trunk muscles is to stabilise the spine and trunk.²³ This stabilisation is conditional for free and selective movements of the head or extremities. This could explain the importance of the trunk in general and static sitting balance in particular. Hence paralysis of trunk muscles leads to important deficits in ADL activities. It has been reported in other studies that sitting balance is important for predicting functional recovery after stroke.²⁴⁻²⁵ However, the statistical properties of the items measured on an ordinal scale used in the latter studies were not always well documented. Acceptable reliability, validity, internal consistency and discriminant ability of the sitting balance subscale of the TIS has been reported.¹⁴⁻¹⁵ Content validity of the TIS and its subscales has been established on the basis of an extensive literature search, observing stroke patients, consulting experts in the field of neurological rehabilitation and personal experience of the team that developed the TIS.¹⁴ In this study, we used the TIS and its subscales as a measure of trunk performance to avoid the ceiling effect reported for other measures of trunk activity. However, psychometric properties are sample dependent and therefore only a comparison between the various trunk performance measures in the same population could determine the optimal measure.

Because of the relative high proportion of the explained variance by the static sitting balance subscale of the TIS, one could question the predictive validity of the total TIS. The small difference of explained variance between the static sitting balance subscale score ($R^2 = 0.50$) and total TIS score ($R^2 = 0.52$) suggests that the outcome of Barthel Index at 6 months after stroke is mainly determined by static sitting balance. That would make the total TIS score redundant when determining the long term prognosis of the degree of independence after stroke. However, univariate correlation

coefficients revealed a significant relation between all TIS subscales and the Barthel Index score at 6 months ($p < 0.0001$). Furthermore, there was no multicollinearity between the subscales of the TIS. With regard to the current results, the static sitting balance subscale could be favoured over the total TIS. However, it is our opinion that the dynamic sitting balance and coordination subscales, which evaluate more selective movements of the trunk such as lateral flexion and rotation, will be of great importance during the rehabilitation phase when patients have control over static sitting balance and receive treatment for more selective and functional movement. A recent study undertaken on 40 non-acute stroke patients revealed a clear hierarchy, from static sitting balance over dynamic sitting balance over coordination, when examining trunk performance with the TIS.¹⁵ It could be concluded that the importance of the static sitting balance subscale of the TIS is in the early prediction of functional outcome after stroke. The total TIS with its subscales may be of importance when assessing non-acute trunk impairment, documenting trunk performance in longitudinal studies and evaluating treatment interventions in randomised studies. This needs to be confirmed in future studies.

With the evolution in (neuro)rehabilitation research, the further use of the term "sitting balance" seems less appropriate. Trunk performance implies more than just keeping an upright sitting posture. Stabilisation and selective movements of the trunk towards flexion, extension, lateral flexion and rotation are also important aspects. Physiotherapists and occupational therapists make a clinical distinction between the upper and lower part of the trunk. To allow efficient walking, counter rotation between the shoulder and pelvic girdle is needed. Proximal stabilisation of the trunk to allow distal movements of the extremities on the one hand and the ability to selectively initiate trunk movements on the other hand has led to abandoning of the term "sitting balance". Instead, the more relevant terms "trunk control", "trunk impairment" and "trunk performance" were introduced.

A known limitation of prediction studies based on data from admission to rehabilitation centres is the preselected group of participants. For this study, a rehabilitation population was chosen with a clear motor impairment after stroke. That was the reason why cut-off scores for the gross motor function, leg and trunk and arm function subscales of the Rivermead Motor Assessment were used in this study. Pooling the data from three different rehabilitation centres with inevitable differences in services seemed justified because no significant interaction was found between the retained variables and centre. Furthermore, recent studies by De Wit *et al* showed that there was no significant difference in the amount or content of therapy in the three rehabilitation centres.²⁶⁻²⁷ The advantage of pooling data from three rehabilitation centres is that we brought together a larger and more diverse group of subjects and therefore the conclusions are probably more widely applicable. Future studies should include a wide range of people after stroke, such as subjects in the acute phase, who were not part of the present cohort. Finally, this study used only standardised clinical tools to predict functional outcome after stroke. Future research should combine combinations of clinical and laboratory measurements of various types to further optimise prediction of stroke outcome.

SUMMARY

This study emphasises the importance of assessing trunk performance in the prediction of functional recovery after stroke. On admission to the rehabilitation centre, total TIS and static sitting balance subscale score appeared to be the most important predictors of the Barthel Index score at 6 months

after stroke. With established psychometric properties, the TIS and its subscales could be considered as a measure of trunk performance in further studies. Future studies should assess the long term evolution of trunk performance after stroke and evaluate the additional effect of rehabilitation of trunk performance on functional outcome after stroke.

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Authors' affiliations

Geert Verheyden, Alice Nieuwboer, Liesbet De Wit, Hilde Feys, Ilse Baert, Willy De Weerd, Department of Rehabilitation Sciences, Faculty of Kinesiology and Rehabilitation Sciences, Katholieke Universiteit Leuven, Leuven, Belgium

Birgit Schuback, Walter Jenni, Rehaclinic Zurzach, Quellenstrasse, Zurzach, Switzerland

Wilfried Schupp, Fachklinik Herzogenaurach, In der Reuth 1, Herzogenaurach, Germany

Vincent Thijs, Department of Neurology, UZ Gasthuisberg, Katholieke Universiteit Leuven, Leuven, Belgium

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