Title

Sit to stand activity during stroke rehabilitation

Abstract

Objectives

The sit to stand (STS) movement is key to independence and commonly affected by stroke. Repetitive practice is likely to improve STS ability during rehabilitation, however current practice levels are unknown. The objective of this study was simply to count the number of STS movements performed during the rehabilitation period of stroke patients using a physical activity monitor (PAM) and test whether being observed altered outcome.

Methods

Participants were medically stable patients referred for rehabilitation following stroke. Participants were randomly allocated to either wear or not wear the PAM for 14 days. STS ability and general mobility were recorded before and after.

Results

61 patients was recruited; aged 68.4± 13.15 years, weight 77.12±22.73Kg, Height 1.67±0.1m, within 9±9 days of their stroke and an NIHSS score of 6.4±3.3. The monitored group (n=38) performed 25.00 ± 17.24 daily STS movements. Those requiring assistance achieved 14.29 ± 16.10 per day while those independent in the movement achieved 34.10 ± 12.44. There was an overall improvement in mobility (p=0.002) but not STS performance

(p=0.053) neither outcome was affected by group allocation (p=0.158). Cognition and mobility at baseline explained around 50% of daily STS variability.

Discussion

Low levels of STS activity recorded during rehabilitation questions whether a training effect is achievable. The mean daily STS activity is lower than reports for frail older people receiving rehabilitation, and substantially below levels for community living older adults. STS repetitions may represent general physical activity and these low levels support previous reports of sedentary behaviour during rehabilitation.

Keywords

Sit-to-stand, Physical activity monitor, stroke, rehabilitation

Introduction

Standing up from a chair, toilet or bed (sit to stand [STS]) is a frequently performed everyday movement (1) that is key to independent living (2) but one of the most physically demanding (3). The capacity to perform this movement safely and independently can be affected by a range of impairments such as muscle weakness (4) impaired balance and sensation (5) as well as psychological factors such as anxiety(5). Stroke affects more than 1 million people in the UK (6) with the majority affected by impairments that compromise the STS movement as well as other functional movements(7).

Recovering independence in functional tasks is the broad aim of rehabilitation strategies with interventions typically structured around the repetitive practice of functional movement with guidance, motivation, feedback and assistance provided by rehabilitation professionals and carers (8, 9). The number of daily STS movements and ability (rising speed) are known to improve during the first 3 months after stroke but with great variance (e.g. a 91.8% coefficient of variance (CV) for STS repetitions)(10). There is evidence that increased practice improves recovery of functional movements generally (11, 12) and even modest increases in daily STS practice (~four additional daily repetitions) have produced beneficial effects over standard care for achieving movement independence in acute stroke patients (13).

Setting realistic targets for daily STS movements, for clinical practice and clinical trials, is predicated on knowing current levels. Evidence from acute stroke populations is limited with studies collecting data over very short periods, for example a single 8hour period (10) or using measurement systems that depend on human observation, for example asking staff and family members to press a counting device each time they observe a movement (13).

Achieving high levels of practice, by necessity, means practicing the movement outside of the structured therapy sessions. Practice in everyday environments is also likely to improve ability through greater variation in practice parameters (e.g. seat height, armrests and different floor surfaces) (14) and may well result in greater independence than if practice only occurs under controlled, supervised conditions. There is, therefore, a need to collect objective activity data over an extended period during rehabilitation to account for variation between and within days and to capture both formal practice during therapy sessions and "informal" everyday movements including those performed at home, if discharged.

Accelerometers are now well-established tools to measure physical activity, including the STS movement. These physical activity monitors (PAM) can automatically categorise postures (lying, sitting, standing) and movements (walking, STS and stand to sit) over long time periods and do not require patient interaction (15). They therefore seem an ideal tool to assist with observational and interventional studies where STS activity is the intervention or outcome, however, the possibility exists that knowledge of being measured may influence activity, a phenomenon known as reactivity or the Hawthorne effect (16).

The study, therefore, had three objectives. Firstly, to count the total number of daily STS movements performed by stroke patients during their active rehabilitation period. Secondly, to test the possibility that wearing a PAM affects outcome. Finally, to explore relationships between the number of daily STS movements and potential explanatory factors such as change in function (including STS ability), cognition and weight.

Methods

Design

This was a randomised study (PAM or no PAM) measuring STS activity in acute stroke patients actively engaged in ward-based rehabilitation at the time of recruitment. The study was approved by the West of Scotland Research Ethics committee (14/WS/0097).

Participants

Participants were recruited from the stroke unit of two hospitals within the same health board area. Participants with a clinical diagnosis of stroke, between 3 and 42 days' post ictus, aged over 18 and medically stable enough to begin active rehabilitation were approached to participate. Rehabilitation consisted of daily physiotherapy and occupational therapy that followed practice guidelines (9). Patients with the following criteria were excluded; 1) coexisting physical impairments (in addition to stroke related impairments) which prevent the practice of STS e.g. bilateral lower limb amputee or substantial loss of joint range due to arthritis, 2) patients not expected to survive past the study duration, 3) active medical conditions that may limit prescribed mobility e.g. unstable angina, 4) active dermatological problems that may preclude use of adhesive monitors e.g. severe psoriasis and 5) inability to provide informed consent.

Assessments

Following informed consent and before randomisation a trained clinical trials nurse carried out the following primary outcome measures; 1) Modified Rivermead Mobility Index (MRMI) (17) and 2) the sit to stand time (FTSTS) (18).

Additional assessments of cognition (The Montreal Cognitive Assessment (MoCA) (19)) and delirium, (Confusion Assessment Method (CAM)(20)) were carried out as potential explanatory variables for STS activity. For the same reason the following information was recorded from the medical notes 1) weight, 2) height, 3) type and anatomical location of stroke, 4) hemiplegic side, 5) STS independence (required assistance from one or more persons = dependent, able to carry out on own with/without aids), 6) date of stroke and 7) severity of stroke using the National Institutes of Health Stroke Scale (NIHSS)(21).

Participants were then randomly allocated to wear or not wear a physical activity monitor (PAM) by an independent researcher opening an opaque envelope containing a pre-allocated group allocation code. Randomisation was weighted 2:1 in favour of the PAM to generate a large enough sample for objective 1. The PAM is a small, (45 mm, 25 mm, 5 mm) lightweight (<15 g) tri-axial accelerometer (activPAL3, PAL Technologies Ltd, Glasgow, UK) attached to the anterior aspect of the participant's thigh, the unaffected side was chosen to avoid issues with sensory loss, using Tegaderm™ (3 M, Neuss, Germany), see figure 1. The PAM has been extensively validated in a range of populations including stroke (22, 23) with a 100% agreement for STS movement count when compared with direct observation in unimpaired (15) and impaired samples, including stroke (23). Locating the monitor on the anterior thigh allows a proprietal algorithm to differentiate between standing and sitting using the orientation of the thigh with respect to the gravitational vector, this would be problematic for other sensor locations (e.g. hip or wrist) (24). After fourteen days of continuous wear, the clinical trials nurse removed the monitor and the two primary outcome measures were repeated.

Sit to stand time

The five times sit to stand test (FTSTST) (18) is an established clinical tool that simply records the time to complete five STS movements with a hand held stopwatch. The test excludes participants unable to do less than five repetitions, therefore to enable participation from a wider ability group we decided to time each attempt using the lap timer function of a stopwatch. This adaptation allowed us to include participants from a broader range of physical abilities. The data used for analysis was therefore the mean STS time i.e. the summed time of N repetitions (up to 5) divided by N and not the overall FTSTST result.

Figure 1: Physical Activity Monitor (PAM) attached to the thigh with water resistant material

Data analysis

To address objective 1 the mean (±2 SD) number of daily (24 hours) STS movements was calculated for the whole PAM group (n=38) and two sub groups based on their need for assistance at baseline. These were an independent group (n=18) able to perform the movement on their own, (i.e. scoring 4 or 5 on the STS item of the MRMI) and an assistance group (n=20) who required the supervision or assistance of at least one other person to perform the movement (i.e. scoring 3 or less on the MRMI STS item).The first and final days were excluded from analysis to ensure whole 24 hour periods were used and to avoid days influenced by the assessment procedure. Statistical differences between the two sub groups for number of daily STS movements was tested with an independent t-test.

To address objective 2 the primary outcome measures (MRMI and the STS time) were described for the whole group and the PAM/no PAM groups using mean and SD. A two factor ANOVA was used to test for statistical differences between the two groups and between the time points (day 1 and day 14).

To address objective 3 relationships between daily STS activity and the clinical measures of mobility (MRMI and STS time) were explored using correlations (Pearson correlation coefficient) and analysis of variance. Finally a multivariate regression analysis (backward elimination) was conducted using the candidate factors of age, weight, severity (NIHSS score), cognition (MOCA) and mobility at baseline (MRMI).

Results

Sixty-one participants were recruited across two stroke units, 40 were randomised to wear the PAM. Physical activity data were not available from two participants in the PAM group due to the sensor being lost (n=1) and damaged (n=1). A mean of 279.19 hours (SD 58.67) of physical activity monitoring out of a target of 336 hours (i.e. 14 days) was recorded from the PAM group. Appointment time scheduling and the sensors becoming detached before the 14 days had elapsed explains the difference. Of the 38 participants with completed the physical activity monitoring 29 remained in hospital for the whole observation period and nine were monitored for an average of 5.4 ± 3.16 days in hospital and 7.8 ± 3.45 days in the community. There were no differences in daily STS movement between hospital (40.58 ± 13.9) and community (39.78 ± 12.52) observational periods. Four participants from the no PAM group were not assessed at outcome due to withdrawal from the study. Details of the participants are provided in table 1.

Table 1: Participant demographic details

	Age (years)	Body Mass index (Kg/m^2)	Time since stroke (days)	Sex
Whole group (n=61)	68.41 (13.15)	27.69 (8.44)	9.03 (8.98)	M = 36
PAM group (n=40)	66.89 (13.40)	28.42 (9.93)	8.74 (7.53)	M = 23
No PAM group (n=21)	71.50 (12.58)	26.81 (5.51)	9.33 (11.47)	M = 12

<u>Objective 1: Daily STS movement movements</u>

Mean (SD) daily STS movements for the whole PAM group and the two sub-groups (independent and assistance) are presented for the whole data collection period along with the second and penultimate recording days, see table 2.

Table 2: Mean (SD) daily STS movements for PAM group separated by baseline STS ability

	Daily STS movements Whole period	Daily STS movements Day 2	Daily STS movements Penultimate day
Whole group (n=38)	25.00 (17.24)	26.33 (23.18)	26.27 (18.60)
Independent (n=18)	34.10 (12.44)	37.94 (23.37)	35.56 (12.89)
Assistance (n=20)	14.29 (16.10)	12.40 (13.54)	15.13 (18.57)

There was a statistically significant difference in daily STS movements between the two ability sub-groups (T = 4.13, P = 0.000) with the independent participants performing an average of 20 more daily STS movements. Daily STS movements stayed largely the same between the second and penultimate days, irrespective of ability group.

<u>Objective 2: Differences between the PAM and no PAM groups</u>

The two factor (group allocation and time) analysis of variance showed no statistically significant effect of group allocation on either of the primary outcome measures, MRMI (F=0.02, P=0.89) and STS time (F=0.57, P=0.45), however there was an effect of time on

MRMI (F=9.95, P=0.002) but not on STS time (F=3.84, P=0.053). There was no interaction effect (F=0.43, P=0.52) for either MRMI or STS time, see table 3 for details of the primary outcome measures and additional clinical data for whole group and divided into the PAM and no PAM groups.

Table 3: Mobility and stroke related data at baseline (day 1) and end of study (day 14)

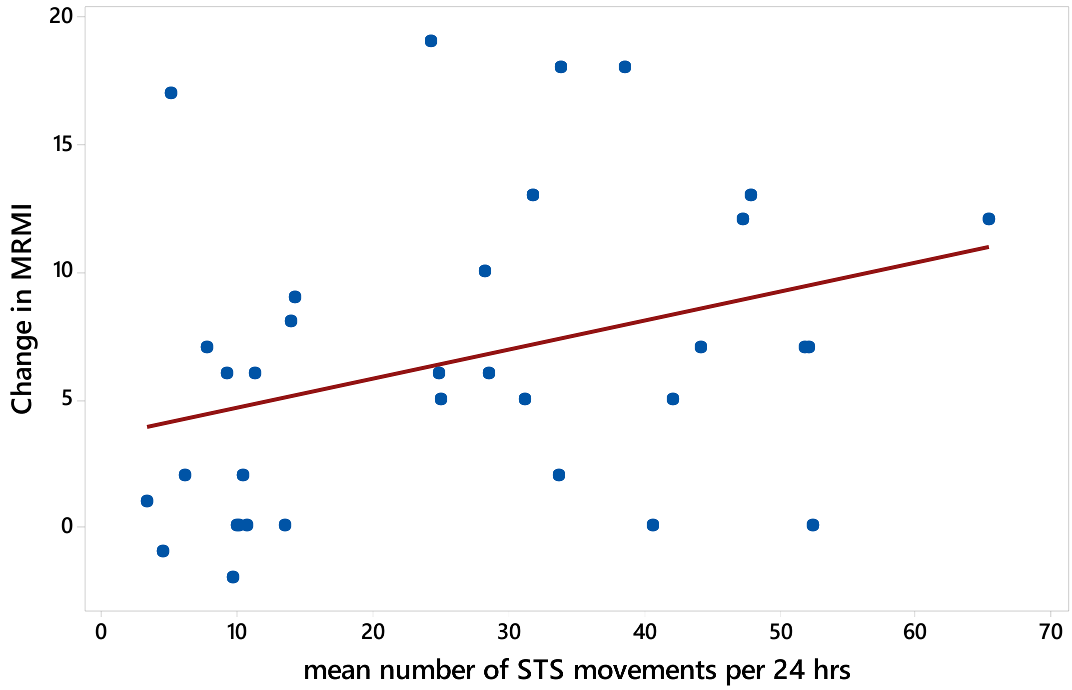
	NIHSS	**Stroke type**	**Hemi side**	MoCA (n=58)	MRMI (day1)	MRMI (day14)	STS time (s) (day1)	STS time (s) (day14)
Whole group (N=61)	6.41 (3.25)	I = 51	L= 31	18.48 (8.82)	19.85 (10.79)	26.70* (11.90)	5.42 (3.90)	4.07 (2.89)
PAM group (n=40)	6.79 (3.47)	I=32	L=19	16.44 (9.48)	19.82 (10.54)	26.63 (12.26)	5.11 (3.37)	4.16 (3.22)
No PAM group (n=21)	5.68 (2.84)	I=19	L=11	21.90 (6.67)	19.50 (11.51)	26.52 (11.80)	6.16 (4.84)	3.96 (2.52)

<u>Objective 3: Relationships between daily STS movements and clinical measures</u>

There was a modest positive correlation between mean daily STS movements and change in MRMI (Pearson's correlation coefficient = 0.373, p= 0.03, see figure 1), but not between mean daily STS movements and change in STS time (r=-0.132).

The multi variate regression analysis using factors; age, weight, NIHSS, mobility (MRMI) and cognition (MoCa) resulted in a regression equation that included cognition (MOCA, T=2.27, p= 0.030) and mobility (MRMI, T=4.19, P< 0.000) which explained 54.14% (r-square) (or 49.39% (adjusted r-square)) of the variance in the mean daily STS movements. Age, weight and NIHSS were discounted at subsequent steps.

Figure 2: Scatterplot of change in MRMI and mean number of STS movements



Discussion

This was an observational study of stroke patient's STS activity during a 14-day period of rehabilitation with randomisation of participant observation. A low number of daily STS movements was found for acute stroke survivors during their rehabilitation period. The mean for the whole group (25, SD 17.24) is lower than reports for frail older people receiving rehabilitation, (36±16)(25) and substantially below values recorded by community living older adults (71±25) (25), which could be considered a real world target for rehabilitation. The sub group of individuals independent in the movement, fared better, carrying out more daily movements (34.10, SD 12.44), with values approaching levels reported previously for chronic stroke survivors using the same PAM (41.2, SD 18.1) (26). The lack of difference in daily STS movements between the beginning and end of the observed period does suggests little impact from rehabilitation, although a larger study would be needed to confirm this.

Barreca et al. (13) calculated that a cut off between 11 and 13.5 daily STS movements predicted which stroke patients would move from being dependent in STS to being independent. This value is substantially lower than our findings, perhaps reflecting the different data collection methods, with Barreca relying on intermittent periods of human observation. In our study four participants (PAM group) changed from requiring assistance to being independent, they achieved 31.4 (SD 27.7) daily STS movements, perhaps this is a more valid target for patients than offered by Barreca et al. since it represents objective data collected continuously over a number of days.

Sit to stand activity may be considered a proxy measure of overall physical activity since it implies an individual is breaking up periods of sedentary behaviour (lying and sitting) considered a risk factor for future health problems (27). Achieving only 34.10 (SD 12.44) daily movements suggests the observed group was sedentary (sitting or lying), and the group requiring assistance with the movement were particularly sedentary with only (14.29, SD 16.10) recorded STS movements per 24 hours, this supports previous findings little physical activity during the rehabilitation period (28).

Our finding that baseline measures of cognition and mobility predict future STS activity is consistent with previous work (29, 30), however, other factors such as sensory loss and fear of falling are likely to be important and should be included in future studies.

Using a body worn PAM is a convenient way of recording STS movements without the potential external influence of direct visual observation, however it carries the potential of error through event misidentification. Although this specific PAM (ActivPAL, PALtechnologies, Glasgow, UK) has been shown to be very accurate (100% agreement with direct observation) for counting STS movements in stroke populations (23) the data should, nevertheless, be considered with a degree of uncertainty.

This observational study was designed with the intention of informing future intervention studies and as such has limited general validity due to the moderate sample size and inability to test causal relationships between STS practice and STS ability due to the design. Nevertheless, the study provides values for STS activity during rehabilitation that may be useful for clinicians and planning rehabilitation research.

Conclusion

Using a physical activity monitor placed on the thigh of stroke patients for 14 days during their rehabilitation period, we were able to count the number of daily STS movements (25.00, SD 17.24), which was approximately 65% less than normally achieved by community living older adults. Compared to a control group the use of a monitor to record STS activity did not appear to influence outcomes. This information, along with the identification of the explanatory factors (baseline cognition and mobility) can inform rehabilitation protocols and clinical trials.

References

1. Dall PM, Kerr A. Frequency of the sit to stand task: An observational study of free-living adults. Applied Ergonomics. 2010;41(1):58-61.

2. Janssen WGH, Bussmann HBJ, Stam HJ. Determinants of the sit-to-stand movement: A review. Physical Therapy. 2002;82(9):866-79.

3. Ploutz-Snyder LL, Manini T, Ploutz-Snyder RJ, Wolf DA. Functionally Relevant Thresholds of Quadriceps Femoris Strength. The Journals of Gerontology Series A: Biological Sciences and Medical Sciences. 2002;57(4):B144-B52.

4. Bohannon RW. Knee extension strength and body weight determine sit-to-stand independence after stroke. Physiotherapy Theory and Practice. 2007;23(5):291-7.

5. Lord SR, Murray SM, Chapman K, Munro B, Tiedemann A. Sit-to-Stand Performance Depends on Sensation, Speed, Balance, and Psychological Status in Addition to Strength in Older People. The Journals of Gerontology Series A: Biological Sciences and Medical Sciences. 2002;57(8):M539-M43.

6. Feigin VL, Lawes CMM, Bennett DA, Barker-Collo SL, Parag V. Worldwide stroke incidence and early case fatality reported in 56 population-based studies: a systematic review. The Lancet Neurology. 2009;8(4):355-69.

7. Langhorne P, Bernhardt J, Kwakkel G. Stroke rehabilitation. The Lancet. 2011;377(9778):1693-702.

8. Peppen RPV, Kwakkel G, Wood-Dauphinee S, Hendriks HJ, Wees PJVd, Dekker J. The impact of physical therapy on functional outcomes after stroke: what's the evidence? Clinical Rehabilitation. 2004;18(8):833-62.

9. SIGN. Management of patients with stroke: rehabilitation, prevention and management of complications, and discharge planning. In: Scotland NQI, editor. Edinburgh: SIGN; 2010.

10. Janssen W, Bussmann J, Selles R, Koudstaal P, Ribbers G, Stam H. Recovery of the Sit-to-Stand Movement After Stroke: A Longitudinal Cohort Study. Neurorehabilitation and Neural Repair. 2010;24(8):763-9.

11. French B, Thomas LH, Coupe J, McMahon NE, Connell L, Harrison J, et al. Repetitive task training for improving functional ability after stroke. Cochrane Database of Systematic Reviews. 2016(11).

12. Lohse KR, Lang CE, Boyd LA. Is More Better? Using Metadata to Explore Dose–Response Relationships in Stroke Rehabilitation. Stroke. 2014;45(7):2053-8.

13. Barreca S, Sigouin CS, Lambert C, Ansley B. Effects of Extra Training on the Ability of Stroke Survivors to Perform an Independent Sit-to-Stand: A Randomized Controlled Trial. Journal of Geriatric Physical Therapy. 2004;27(2):59-64.

14. George Hornby T, Straube DS, Kinnaird CR, Holleran CL, Echauz AJ, Rodriguez KS, et al. Importance of Specificity, Amount, and Intensity of Locomotor Training to Improve Ambulatory Function in Patients Poststroke. Topics in Stroke Rehabilitation. 2011;18(4):293-307.

15. Grant PM, Ryan CG, Tigbe WW, Granat MH. The validation of a novel activity monitor in the measurement of posture and motion during everyday activities. British Journal of Sports Medicine. 2006;40(12):992-7.

16. Sanne WTF, Willem EHH, Noël LWK. Variation and achievement of ambulatory activity among patients with chronic stroke. Journal of Rehabilitation Medicine. 2013;45:5.

17. Collen FM, Wade DT, Robb GF, Bradshaw CM. The Rivermead Mobility Index: A further development of the Rivermead Motor Assessment. Disability and Rehabilitation. 1991;13(2):50-4.

18. Whitney SL, Wrisley DM, Marchetti GF, Gee MA, Redfern MS, Furman JM. Clinical Measurement of Sit-to-Stand Performance in People With Balance Disorders: Validity of Data for the Five-Times-Sit-to-Stand Test. Physical Therapy. 2005;85(10):1034-45.

19. Nasreddine ZS, Phillips NA, Bedirian V, Charbonneau S, Whitehead V, Collin I, et al. The Montreal Cognitive Assessment MoCA a brief screening tool for mild cognitive impairment. . J Am Geriatric Soc 2005;53:695-9.

20. Inouye SK, van Dyck CH, Alessi CA, Balkin S, Siegal AP, Horwitz R. Clarifying confusion: The Confusion Assessment Method. Annals of internal medicine. 1990;113:941-8

21. Meyer BC, Hemmen TM, Jackson CM, Lyden PD. Modified National Institutes of Health Stroke Scale for Use in Stroke Clinical Trials: Prospective Reliability and Validity. Stroke. 2002;33(5):1261-6.

22. Taraldsen K, Chastin SFM, Riphagen II, Vereijken B, Helbostad JL. Physical activity monitoring by use of accelerometer-based body-worn sensors in older adults: A systematic literature review of current knowledge and applications. Maturitas. 2012;71(1):13-9.

23. Taraldsen K, Askim T, Sletvold O, Einarsen EK, Grüner Bjåstad K, Indredavik B, et al. Evaluation of a Body-Worn Sensor System to Measure Physical Activity in Older People With Impaired Function. Physical Therapy. 2011;91(2):277-85.

24. Yang C-C, Hsu Y-L. A Review of Accelerometry-Based Wearable Motion Detectors for Physical Activity Monitoring. Sensors. 2010;10(8).

25. Grant PM, Dall PM, Kerr A. Daily and hourly frequency of the sit to stand movement in older adults: a comparison of day hospital, rehabilitation ward and community living groups. Aging Clinical and Experimental Research. 2011;23(5-6):437-44.

26. English C, Healy GN, Coates A, Lewis L, Olds T, Bernhardt J. Sitting and Activity Time in People With Stroke. Physical Therapy. 2016;96(2):193-201.

27. Biswas A, Oh PI, Faulkner GE, Bajaj RR, Silver MA, Mitchell MS, et al. Sedentary time and its association with risk for disease incidence, mortality, and hospitalization in adultsa systematic

review and meta-analysissedentary time and disease incidence, mortality, and hospitalization. Annals of internal medicine. 2015;162(2):123-32.

28. Bernhardt J, Chan J, Nicola I, Collier JM. Little therapy, little physical activity: Rehabilitation within the first 14 days of organized stroke unit care. Journal of Rehabilitation Medicine. 2007;39(1):43-8.

29. Toglia J, Fitzgerald KA, O'Dell MW, Mastrogiovanni AR, Lin CD. The Mini-Mental State Examination and Montreal Cognitive Assessment in Persons With Mild Subacute Stroke: Relationship to Functional Outcome. Archives of Physical Medicine and Rehabilitation. 2011;92(5):792-8.

30. Mehrholz J, Wagner K, Rutte K, Meiβner D, Pohl M. Predictive Validity and Responsiveness of the Functional Ambulation Category in Hemiparetic Patients After Stroke. Archives of Physical Medicine and Rehabilitation. 2007;88(10):1314-9.