Archives of Physical Medicine and Rehabilitation
journal homepage: www.archives-pmr.org
Archives of Physical Medicine and Rehabilitation 2024;000: 1−6

ORIGINAL RESEARCH

Modifying the Mobility Scale for Acute Stroke (MSAS) for All Stroke Phases (MSA^{ll}S): Measurement Properties and Clinical Application

Shamala Thilarajah, PhD,[a,b] Ai Ying Low, MSc,[a] Amanda Lee, MSc,[a] Sherie Ng, BSc,[a] Hui Chueng Seow, MSc,[a] Silvana Choo, PhD,[c] Chek Wai Bok, MBBS,[d] Deidre De Silva, FRCP,[e,f,g] Eleanor Shuxian Chew, MSc,[a] Tse Lert Chua, BSc,[h] Li Khim Kwah, PhD,[b] Yong Hao Pua, PhD[a]

From the [a]Department of Physiotherapy, Singapore General Hospital, Singapore; [b]Health and Social Sciences Cluster, Singapore Institute of Technology, Singapore; [c]Department of Occupational Therapy, Singapore General Hospital, Singapore; [d]Department of Rehabilitation Medicine, Singapore General Hospital, Singapore; [e]Department of Neurology, Singapore General Hospital, Singapore; [f]National Neuroscience Institute, Singapore; [g]DukeNUS Medical School, Singapore; and [h]Applied Analytics, Singapore General Hospital, Singapore.

Abstract

Objective: To develop and examine the measurement properties and interpretability of the Mobility Scale for "All" Stroke Phases (MSA^{ll}S) as a potential single outcome measure to capture improvements in physical function throughout the stroke continuum.

Design: Retrospective cross-sectional study.

Setting: Inpatient rehabilitation unit.

Participants: People after stroke at discharge from rehabilitation (N=309).

Intervention: Not applicable.

Main Outcome Measure(s): We developed MSA^{ll}S by extending the highest MSAS level (walk 10 m independently) with 4 gait speed levels. To establish a clinical anchor, we extracted a 4-level discharge outcome. To assess the distributional properties and internal consistency of MSA^{ll}S, we evaluated its ceiling effects and calculated the Cronbach alpha, respectively. To assess structural validity, we performed a confirmatory factor analysis. To assess (i) its convergent validity with the FIM and (ii) its predictive validity with the clinical anchor, we used Spearman's rank correlations. To evaluate the clinical interpretability of MSA^{ll}S, we used an item-response theory-based method to estimate MSA^{ll}S thresholds associated with the clinical anchor.

Results: The MSA^{ll}S had lower ceiling effects compared with MSAS (0% vs 25%). Internal consistency of MSA^{ll}S was excellent (α=0.94). Structural validity of MSA^{ll}S demonstrated a good fit (Comparative Fit Index=0.95; Tucker−Lewis Index=0.92; Root Means Square Error of Approximation=0.17). MSA^{ll}S demonstrated a moderate correlation (rho=0.66) with FIM score and with the clinical anchor (rho=0.75). MSA^{ll}S thresholds for increasing levels of the clinical anchor were 22 (20.8 to 23.6) − at least moderate assistance with walking/transfers, 28 (27.5 to 29.4) - at most supervision with walking, and 33 (32.5 to 33.4) - able to walk unassisted.

Conclusion: The MSA^{ll}S showed adequate measurement properties and clinical interpretability. MSA^{ll}S has the potential to be a single universal measure to evaluate physical function after stroke but further evaluation of clinical interpretability is required.

Archives of Physical Medicine and Rehabilitation 2024;000:1−6

Stroke is a leading cause of disability and disease burden worldwide.[1] Stroke impairments, such as loss of strength, lead to activity limitations and reduced participation in society. Rehabilitation services are essential in promoting recovery after stroke. However, there are huge variabilities in rehabilitation care standards due to a

This abstract was presented as an oral presentation at the SGH Annual Scientific Meeting 2023 in Singapore.

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Disclosures: The authors declare no conflict of interests.

0003-9993/$36 - see front matter © 2024 by the American Congress of Rehabilitation Medicine.
https://doi.org/10.1016/j.apmr.2024.02.722

lack of quality indicators.[2,3] The functional recovery after a stroke is heterogenous and time dependent.[4,5] Longitudinal studies have found that in the acute phase of stroke, more than half the cohort are unable to walk independently. Even at the end of rehabilitation, approximately a quarter of the cohort is still not able to achieve independent walking.[6] Stroke rehabilitation is also long term as stroke survivors live with permanent disabilities or develop secondary impairments. Given the long trajectory, outcome measures in stroke rehabilitation need to possess adequate psychometric properties across the stroke continuum, feasible to conduct in any setting where rehabilitation can take place (hospital to home), good interpretability, and capture improvements for varying levels of physical ability.[7,8] However, it is difficult to select a single universal measure, for mobility after stroke, that adequately meets clinicians' and patients' needs for evaluation.[9] This may mean that recovery may not be fully captured with any one outcome measure.[10] Specifically, the use of different outcomes at different times may affect clinical goal setting on a patient level and the transparent reporting of the quality of rehabilitation outcomes on national and international platforms.

Expert consensus recommend gait speed as a measure for minimum datasets for stroke rehabilitation,[9,11] but the test requires patients to be able to walk with no assistance which excludes a (sizeable) proportion of patients in every setting.[9,12] Any improvements in other important areas of mobility such as the ability to sit or stand are also not captured. Similarly, the Mobility Scale for Acute Stroke (MSAS) was originally developed to measure improvements specifically among people after an acute stroke where the population may not yet have achieved walking.[13] The MSAS is valid, reliable and provides more specific information on functional mobility as compared with the motor subscale of the FIM. The FIM is not designed specifically for stroke, thus it does not consider the limitations of a hemiparetic arm on self-care items in the motor subsections of the FIM.[14] The patient may make gains with functional mobility but a hemiparetic arm can affect self-care such as dressing, eating, and grooming, which affects the overall score. FIM scores are used on the wards for measuring progress and discharge destination thus it's important that we have specific information on patient progress. The highest level on the MSAS is the ability to walk 10 m independently, with and without the use of a gait aid. By necessity, MSAS does not require the assessment of complex walking tasks. However, this leads to assumptions that are clinically unrealistic. For example, a patient with hemiplegia who relies on a quad stick to walk independently but slowly, will be scored the same as another who has made a full neurological recovery. Crucially, this loss of information means that the use of MSAS in the sub-acute or chronic phase of stroke rehabilitation is severely limited as a proportion of stroke survivors would already have achieved the highest score despite still working toward higher mobility goals.

In addition, an important criterion for the selection of outcome measures, clinical interpretability, has been overlooked.[15] Clinical interpretability is defined as the degree to which one can assign qualitative meaning to an outcome measure's quantitative scores or change in scores.[16] A clear interpretability of the outcome score, to aid in clinical decision-making, will improve the uptake of the measure in clinic. While the clinical interpretability of gait speed is well established,[17,18] this aspect has not been explored for MSAS.

Against this background, we propose a novel and simple approach to modifying the MSAS by extending its highest functional level (independent walking with and without a gait aid) with additional levels derived from gait speed values (termed Mobility Scale for "All" Stroke Phases (MSA^{ll}S) henceforth). Accordingly, our study aimed to comprehensively examine the measurement properties of MSA^{ll}S − namely, reliability, structural, and predictive validity in stroke survivors at discharge from the inpatient rehabilitation unit. In addition, to facilitate a proper interpretation of MSA^{ll}S, we assessed its clinical interpretability by estimating thresholds associated with clinically meaningful discharge outcomes.

List of abbreviations:

CFI	**Comparative Fit Index**
MSAS	**Mobility Scale for Acute Stroke**
MSA^{ll}S	**Mobility Scale for "All" Stroke Phases**
NIHSS	**National Institute of Health Stroke Scale**
RMSEA	**Root Means Square Error of Approximation**
TLI	**Tucker-Lewis Index**

Methods

Participants and procedures

Our study comprised all patients diagnosed with stroke (n=309), admitted to the rehabilitation ward at a large tertiary hospital in Singapore from January 2018 to December 2020. As part of usual care, stroke details and physical function data are assessed and entered into the electronic health records at discharge from the ward. The SingHealth Centralised Institutional Research Board determined that formal ethics review was not required as the project met the criteria for operational service improvement. The data extracted were anonymised by the hospital's data analytics team and only de-identified data were transferred to the study team for analysis. This paper is reported as per the COSMIN Risk of Bias tool to assess the quality of studies on reliability and measurement error.[19]

Measurements

Clinical and demographics details

Age, sex, and the stroke severity score (National Institute of Health Stroke Scale [NIHSS]) were selected for extraction as these are factors known to be predictive of stroke recovery.[12] The NIHSS is a valid and reliable measure of stroke severity.[20-22] The scale quantifies the severity of the symptoms resulting from cerebral infarcts and the extent of neurologic deficits across different domains. The Stroke Recovery and Rehabilitation Roundtable recommendations state that NIHSS scores should be collected at entry into a study and where possible NIHSS scores should be reported at stroke onset (±3 days).[12]

Gait speed and MSAS

All patients diagnosed with stroke at the rehabilitation unit are assessed for comfortable gait speed and MSAS at discharge from the rehabilitation unit. Gait speed is measured over a 14 m walkway at a comfortable speed.[23] The middle 10 meters was timed using a hand-held stopwatch. The average of 2 trials was used for the analysis. The outcome variable was comfortable gait speed in m/s.[24] The discharge assessment is measured within 72 hours prior

Comparison between MSAS and MSA^{ll}S

Mobility Scale for Acute Stroke (MSAS)	Mobility Scale for All Strokes (MSA^{ll}S)
1. Bridging from supine	1. Bridging from supine
2. Sitting from supine, return to supine	2. Sitting from supine, return to supine
3. Balanced sitting for 3 mins	3. Balanced sitting for 3 mins
4. Sit to stand from chair no arms	4. Sit to stand from chair no arms
5. Balanced standing for 1 min	5. Balanced standing 1 min
6. Ability to walk 10m with or without gait aid	6. Ability to walk 10m with or without gait aid
	7. Gait speed (4 levels)
Full score: 36	Full score: 40

Rating scale (Items 1-6):
1. Unable to do activity; patient makes no contribution to activity/unable to complete activity.
2. Maximum assistance of one to two people; patient makes minimal contribution to the activity.
3. Moderate assistance of one person, hands on for most of the activity. Patient is able to perform a part of the activity independently.
4. Minimal assistance, hands on for part of the activity.
5. Supervised (verbal input, no hands on, physiotherapist prepared to give assistance).
6. Unassisted and safe, no verbal input.

Rating scale (Item 7):
If gait speed < 0.70m/s or patient uses a walking aid, no additional point is given.
1. 0.71-1.00m/s
2. >1.00-1.20m/s
3. >1.20-1.40m/s
4. >1.40m/s

Fig 1 Comparison between MSAS and MSA^{ll}S.

to discharge from the rehabilitation unit. The comfortable gait speed is a well-established measure of mobility function and quality[18] as well as different levels of community ambulation.[25] MSAS is a unidimensional instrument that produces a single aggregate score from 6 functional mobility activities (fig 1).[13] The items are typical of an initial physiotherapy assessment, so it doesn't require any extra time, training, or equipment. Comfortable gait speed is a mandatory outcome measure for all settings in our national stroke database but MSAS is not.[26]

MSA^{ll}S

We created MSA^{ll}S by extending the highest MSAS level (Item 6: walk 10 m independently) to Item 7 with gait speed levels. Item 7 consists of 4 ordinal levels based on well-established gait speed ranges; 0.7 to 1.0 m/s, >1.0 to 1.2 m/s, >1.2 to 1.4 m/s, and >1.4 m/s (fig 1).[24,27] If a patient walks at a gait speed of less than 0.7 m/s or uses a walking aid, then the patient does not score a point for Item 7: Gait Speed of the MSA^{ll}S. Thus, their total MSA^{ll}S score remains at 36/40. A gait speed of less than 0.4 m/s have been found to be predictive of household ambulators but we did not include this in our ordinal scale as this function would be captured in other items of the MSA^{ll}S.[18] The most frequently cited gait speed cut-off to differentiate between limited community ambulators and community ambulators in the stroke population is 0.8 m/s.[27] However, based on the wider gait speed literature in young stroke survivors and older adults, we expanded the range to 0.7-1.0 m/s.[27-29] A gait speed of more than 1.0-1.2 m/s is associated with community ambulation with associated with greater levels of physical activity[30] and lower risk of adverse events.[31] A gait speed of 1.4 m/s and above would enable one to cross roads safely[32] and is regarded as a normal speed for younger adults[33] and as fast gait speed for chronic stroke survivors.[34] With a wider gait speed range and higher gait speed threshold, we envision that MSA^{ll}S would be more broadly applicable to young stroke survivors as well as older stroke survivors (with co-morbidities) who have made or are working toward a full recovery.

FIM

The FIM is a mandatory outcome measure, for a national stroke database, across inpatient rehabilitation units at tertiary hospitals in Singapore.[26] The FIM is an instrument that was developed as a rehabilitation measure for a variety of clinical populations. It is an 18-item, 7-level, ordinal scale that includes measures of independence for self-care, including sphincter control, transfers, locomotion, communication, and social cognition. The FIM uses the level of assistance an individual needs to grade functional status from total independence to total assistance.[35]

The multi-disciplinary team on the ward undergo training and certification in assessing and scoring the FIM. The FIM is scored on a weekly basis to track the patients' progress and is discussed during the weekly multi-disciplinary meetings to aid treatment and discharge planning. The discharge assessment is scored within 72 hours prior to discharge from the rehabilitation unit. Though it is a national mandatory measure, the FIM has significant limitations. The FIM license is costly and additional time is taken for the training as well as to complete the assessment. In comparison, the MSAS is free, the items are part of a usual physiotherapy assessment so no training required. For the purposes of our cross-sectional analysis, we used only the discharge FIM Locomotor scores.

Clinical anchor

A 4-level discharge outcome was collected, and it was used as the clinical anchor for determining the clinical thresholds of MSA^{ll}S. This clinical anchor had 4 ordinal levels: (i) discharged to community hospital or home and needing at least moderate assistance with walking/transfers, (ii) discharged to community hospital or home and needing minimal assistance with walking, (iii) discharged to home and needing supervision in walking, and (iv) discharged to home and having independence in walking. These outcomes were deemed by the study team as important clinical decisions for discharge planning from rehabilitation.

Statistical analysis

The psychometric properties of MSA^{ll}S were evaluated in terms of ceiling effects, internal-consistency reliability, structural validity, convergent validity, predictive validity, and interpretability.

Ceiling effects

Ceiling effects were assessed by computing the proportion of stroke survivors with the highest possible score (36 points) at the time of hospital discharge. A threshold of more than 15% is deemed as a significant ceiling effect.[36]

Internal consistency and structural validity

Internal-consistency reliability was assessed using Cronbach's alpha. An alpha of 0.95 is deemed as desirable.[37] Structural validity was assessed by evaluating MSA^{II}S as a single-dimensional scale of motor function using confirmatory factor analysis, and the following model-of-fit indices were used: Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), and the Root Means Square Error of Approximation (RMSEA). A CFI and TLI more than 0.90 and a RMSEA close to 0 indicates a good model fit.[38]

Convergent and predictive validity

Convergent validity of MSA^{II}S with discharge FIM scores was assessed using Spearman correlation. Only the locomotion sub-section scores were used for the analysis as the other items of the FIM relate to self-care, cognition, and speech and assessed as not congruent with the MSAS. Furthermore, the FIM locomotion sub-section have shown interactions with and other motor FIM subcategories such as upper body dressing, bowel management, and toileting.[39] Given that the locomotion sub-section of the FIM only contains walking and stairs, we deemed a Spearman's rho of 0.3-0.5 as adequate correlation for convergent validity. Predictive validity of the MSA^{II}S with respect to the 4-level ordinal discharge clinical outcomes was assessed using Spearman correlation. For a multi-factorial outcomes such as discharge, a Spearman's rho strength of above 0.25 can be deemed as acceptable.[40]

Interpretability

Interpretability of the MSA^{II}S was assessed by estimating the clinical MSA^{II}S thresholds for different levels of the discharge clinical outcomes. The estimation process was based on the item response theory method.[41] To compute 95% CIs for all thresholds, we used percentile bootstrapping.

All analyses were done in R software.[a]

Results

The characteristics of the participants are described in table 1. The median age of the stroke survivors in the cohort was 65 years with a median NIHSS score of 6.0 indicating moderate stroke severity.

Ceiling effects

At discharge, 78 stroke survivors (25%) had the highest MSAS score, while none (0%) had the highest MSA^{II}S score (fig 2).

Internal consistency and structural validity

We found that the internal consistency of MSA^{II}S was excellent with Cronbach's alpha (α) of 0.94. The structural validity demonstrated a good model fit with CFI of 0.95, TLI of 0.92, and RMSEA of 0.17 (table 2).

Convergent and predictive validity

We examined the convergent validity of MSA^{II}S with discharge FIM score and found a moderate to good correlation ρ=0.66 (0.58 to 0.73, P<.001). We also found a moderate to good correlation between MSA^{II}S and 4-level discharge clinical outcome ρ=0.75 (0.69 to 0.81, P<.001) which demonstrates adequate predictive validity.

Table 1 Demographics and clinical characteristics of participants (*n*=309)

Characteristics	
Age, y	64±12 (57, **65**, 73)
Sex (men), n (%)	190 (61%)
Length of stay, weeks	5.1±2.6 (3.4, **4.4**, 6.0)
Stroke severity, NIHSS	7.6±6.6 (3.0, **6.0**, 10.0)
Comfortable gait speed, m/s	0.74±0.32) (0.52, **0.78,** 0.95)
FIM discharge (Transfers and Locomotion)	10.4±3.8 (7.0, **10.0**, 13.0)
MSAS discharge	30.6±6.7 (28.0, **33.0**, 36.0)
Discharged home with at least moderate assistance with transfers	11% (34)
Discharged home with no more than supervision with walking	74% (228)

*Values are mean ± SD (25th, 50th, 75th percentile) unless otherwise indicated. Categorical variables are summarized as percentages and frequencies (N).

†Gait speed values of patients who could walk independently at the point of discharge (n=87).

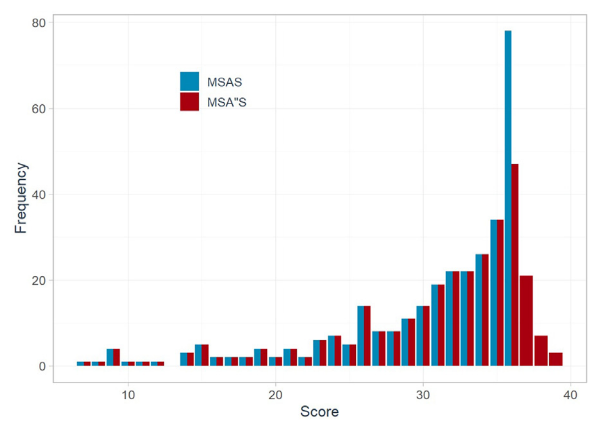

Fig 2 Distribution of ceiling effect of MSAS and MSA^{II}S.

Interpretability

Based on the item response theory method (table 2), the MSA^{II}S threshold for predicting a discharge destination to community hospital or home and needing at least moderate assistance with walking/transfers was 22 points (20.8 to 23.6) (threshold separating levels 1 and 2 of the clinical anchor). A score of 28 (27.5 to 29.4) was associated with a clinical outcome of discharge to home and needing at most supervision with walking (threshold separating levels 2 and 3 of the clinical anchor). Whereas a score of 33 (32.5 to 33.4) and above further discriminated those who can walk unassisted (threshold separating levels 3 and 4 of the clinical anchor).

Discussion

We modified the MSAS by extending its highest functional level to create the MSA^{II}S with additional gait speed levels. We found that the MSA^{II}S possessed adequate distributional and measurement properties. In addition, we estimated MSA^{II}S thresholds associated with clinically meaningful discharge outcomes to facilitate its interpretation and application in stroke rehabilitation.

Table 2 Measurement properties of MSA^{II}S (n=309)

Measurement Construct	Measurement Properties	Results
Distributional properties	Ceiling effects	0%
Reliability	Internal consistency	Cronbach's α=0.94
Validity	Structural validity	CFI=0.95
		TLI=0.92
		RMSEA=0.17
	Convergent validity with FIM Motor score	Spearman ρ=0.66 (0.58-0.73, P<.001)
	Predictive validity with MSA^{II}S and 4-level Discharge Clinical Outcome	Spearman ρ=0.75 (0.69-0.81, P<.001)
Interpretability	Home/CH discharge destination and needing at least moderate assistance with walking/transfer[†]	22 (20.8-23.6)
	Home discharge and walking with or without supervision	28 (27.5-29.4)
	Home discharge and independence in walking	33 (32.5-33.4)

*Abbreviation: CFI, Comparative Fit Index; TLI, Tucker-Lewis Index; RMSEA, Root Means Square Error of Approximation; D/C, discharge; FIM, Functional Independence Measure; MSA^{II}S, Mobility Scale for All Strokes Phases.
† Clinical thresholds (95% CI) derived from comparing persons needing at least moderate assistance with walking/transfer (level 1) with persons not needing at least moderate assistance with walking/transfer (levels 2, 3, and 4).

With respect to distributional properties, our findings agree with previous studies in demonstrating a significant ceiling effect of the original MSAS.[14] This means that a proportion of stroke survivors would score the maximum score even before entering rehabilitation.[14] In comparison, the MSA^{II}S eliminated the ceiling effect among stroke survivors at discharge from the rehabilitation unit. Hence, the MSA^{II}S, compared with MSAS, has improved capability to characterize progress among stroke survivors, even after discharge from rehabilitation. From our study cohort, we found that only 22.6% of our population were able to achieve walking independently to complete a comfortable gait speed test. Among those who were able to walk independently, the average high (75th percentile) gait speed was 0.95 m/s, and the average low (25th percentile) gait speed was 0.52 m/s. The difference of 0.42 m/s far exceeds the minimal clinically important difference of 0.1 m/s. However, all stroke survivors will be given the same score using the original MSAS[42] - a finding which strengthens the need to extend the capability of MSAS.

With respect to reliability and validity, a previous study found that the internal consistency of the original MSAS was Cronbach's α=0.97 and convergent validity with discharge FIM motor sub-scale score was r=0.88.[14] We found that the MSA^{II}S possessed comparable measurement properties as the original scale.

With respect to clinical interpretability, previous work found a cut-off score of 26, predicted discharge to home from acute stroke unit using a binary clinical anchor.[14] Different from this study, to enhance the interpretability of MSA^{II}S, we sought to estimate its thresholds associated with multiple distinct discharge outcomes.

Study limitations

A limitation to this study is that we were not able to calculate the minimal important change values as we did not have sufficient consistent data from electronic records for change scores. It is also likely that MSA^{II}S may not be able to differentiate between a limited community ambulator and a community ambulator as one would need to achieve a walking speed of at least 0.7 m/s in order to obtain 1 more point. We also did not follow-up with MSAS scores after discharge and thus do not have information on the longitudinal distributional properties of MSA^{II}S.

Conclusions

In this study, we developed MSA^{II}S which possessed adequate measurement properties and showed no ceiling effects compared with the original MSAS. By leveraging the strengths of both MSAS and gait speed measures, the MSA^{II}S represents a potentially feasible measure of stroke rehabilitation outcomes across the recovery continuum. Future studies are needed to investigate the validity of the MSA^{II}S among subacute and chronic stroke survivors as well as across different age groups.

Keywords

Outcome measure; Physical function; Rehabilitation; Stroke

Corresponding author

Shamala Thilarajah, Department of Physiotherapy, SGH Rehabilitation Centre, Outram Community Hospital (OCH), SingHealth Tower Level 4, 10 Hospital Boulevard, Singapore 168582. *E-mail address:* shamala.thilarajah@sgh.com.sg.

Acknowledgments

The authors thank Ms Jennifer Liaw (Head of Department, Physiotherapy), Ms Natalie Chew (Head of Department, Occupational Therapy), and Dr Geoffrey Sithamparapillai (Head of Department, Rehabilitation Medicine) at the Singapore General Hospital for their support and dedication toward improving stroke care.

References

1. Feigin VL, Brainin M, Norrving B, et al. World Stroke Organization (WSO): Global Stroke Fact Sheet 2022. Int J Stroke 2022;17:18–29.
2. Langhorne P, Bernhardt J, Kwakkel G. Stroke rehabilitation. Lancet 2011;377:1693–702.
3. Grube MM, Dohle C, Djouchadar D, et al. Evidence-based quality indicators for stroke rehabilitation. Stroke 2012;43:142–6.
4. Jørgensen HS, Nakayama H, Raaschou HO, Vive-Larsen J, Støier M, Olsen TS. Outcome and time course of recovery in stroke. Part I:

outcome. The Copenhagen Stroke Study. Arch Phys Med Rehabil 1995;76:399–405.
5. Kwakkel G, Kollen B, Twisk J. Impact of time on improvement of outcome after stroke. Stroke 2006;37:2348–53.
6. Jørgensen HS, Nakayama H, Raaschou HO, Olsen TS. Recovery of walking function in stroke patients: the Copenhagen Stroke Study. Arch Phys Med Rehabil 1995;76:27–32.
7. Sullivan JE, Crowner BE, Kluding PM, et al. Outcome measures for individuals with stroke: process and recommendations from the American Physical Therapy Association neurology section task force. Phys Ther 2013;93:1383–96.
8. Moore JL, Potter K, Blankshain K, Kaplan SL, O'Dwyer LC, Sullivan JE. A core set of outcome measures for adults with neurologic conditions undergoing rehabilitation: a clinical practice guideline. J Neurol Phys Ther 2018: 42.
9. Pohl J, Held JPO, Verheyden G, et al. Consensus-based core set of outcome measures for clinical motor rehabilitation after stroke - a Delphi study. Front Neurol 2020;11:875.
10. Burton L-J, Tyson S, McGovern A. Staff perceptions of using outcome measures in stroke rehabilitation. Disabil Rehabil 2013;35:828–34.
11. Bernhardt J, Hayward KS, Kwakkel G, et al. Agreed definitions and a shared vision for new standards in stroke recovery research: the Stroke Recovery and Rehabilitation Roundtable taskforce. Int J Stroke 2017;12:444–50.
12. Kwakkel G, Lannin NA, Borschmann K, et al. Standardized measurement of sensorimotor recovery in stroke trials: consensus-based core recommendations from the stroke recovery and rehabilitation roundtable. Neurorehabil Neural Repair 2017;31:784–92.
13. Simondson J, Goldie P, Brock K, Nosworthy J. The Mobility Scale for acute stroke patients: intra-rater and inter-rater reliability. Clin Rehabil 1996;10:295–300.
14. Tinl ML, Kale MK, Doshi S, Guarino AJ, Beninato M. The Mobility Scale for acute stroke predicts discharge destination after acute hospitalization. J Rehabil Med 2014;46:219–24.
15. Wade DM, Hankins M, Smyth DA, et al. Detecting acute distress and risk of future psychological morbidity in critically ill patients: validation of the intensive care psychological assessment tool. Crit Care 2014;18:519.
16. Mokkink LB, Terwee CB, Patrick DL, et al. The COSMIN study reached international consensus on taxonomy, terminology, and definitions of measurement properties for health-related patient-reported outcomes. J Clin Epidemiol 2010;63:737–45.
17. Studenski S, Perera S, Patel K, et al. Gait speed and survival in older adults. JAMA 2011;305:50–8.
18. Perry J, Garrett M, Gronley JK, Mulroy SJ. Classification of walking handicap in the stroke population. Stroke 1995;26(6):982–9.
19. Mokkink LB, Boers M, Van Der Vleuten C, et al. COSMIN Risk of Bias tool to assess the quality of studies on reliability or measurement error of outcome measurement instruments: a Delphi study. BMC Med Res Methodol 2020;20:1–13.
20. Adams H, Davis P, Leira E, et al. Baseline NIH Stroke Scale score strongly predicts outcome after stroke: a report of the Trial of Org 10172 in Acute Stroke Treatment (TOAST). Neurology 1999;53:126–31.
21. Brott T, Adams HP, Olinger CP, et al. Measurements of acute cerebral infarction: a clinical examination scale. Stroke 1989;20:864–70.
22. Lyden P, Brott T, Tilley B, et al. Improved reliability of the NIH Stroke Scale using video training. NINDS TPA Stroke Study Group. Stroke 1994;25:2220–6.
23. Fulk GD, Echternach JL. Test-retest reliability and minimal detectable change of gait speed in individuals undergoing rehabilitation after stroke. J Neurol Phys Ther 2008;32:8–13.
24. Middleton A, Fritz SL, Lusardi M. Walking speed: the functional vital sign. J Aging Phys Act 2015;23:314–22.
25. Lord SE, McPherson K, McNaughton HK, Rochester L, Weatherall M. Community ambulation after stroke: how important and obtainable is it and what measures appear predictive? Arch Phys Med Rehabil 2004;85:234–9.
26. Kwah LK, Ong PH, Lim V, et al. Towards harmonised practice: the why, what and how of collecting standardised outcome measures. Singapore: Singapore Institute of Technology and Ministry of Health, Singapore; 2021.
27. Fritz S, Lusardi M. White paper: "Walking speed: the sixth vital sign". J Geriatr Phys Ther 2009;32:2–5.
28. Jarvis HL, Brown SJ, Price M, et al. Return to employment after stroke in young adults: how important is the speed and energy cost of walking? Stroke 2019;50:3198–204.
29. Chen L-K, Woo J, Assantachai P, et al. Asian Working Group for Sarcopenia: 2019 Consensus Update on sarcopenia diagnosis and treatment. J Am Med Dir Assoc 2020;21:300–7. e2.
30. Bowden MG, Balasubramanian CK, Behrman AL, Kautz SA. Validation of a speed-based classification system using quantitative measures of walking performance poststroke. Neurorehabil Neural Repair 2008;22:672–5.
31. Montero-Odasso M, Schapira M, Soriano ER, et al. Gait velocity as a single predictor of adverse events in healthy seniors aged 75 years and older. J Gerontol A Biol Sci Med Sci 2005;60:1304–9.
32. Braden HJ, Hilgenberg S, Bohannon RW, Ko M-S, Hasson S. Gait speed is limited but improves over the course of acute care physical therapy. J Geriatr Phys Ther 2012;35:140–4.
33. Jarvis HL, Brown SJ, Butterworth C, et al. The gait profile score characterises walking performance impairments in young stroke survivors. Gait Posture 2022;91:229–34.
34. Vive S, Elam C, Bunketorp-Käll L. Comfortable and maximum gait speed in individuals with chronic stroke and community-dwelling controls. J Stroke Cerebrovasc Dis 2021;30:106023.
35. Linacre JM, Heinemann AW, Wright BD, Granger CV, Hamilton BB. The structure and stability of the Functional Independence Measure. Arch Phys Med Rehabil 1994;75:127–32.
36. Terwee CB, Bot SD, de Boer MR, et al. Quality criteria were proposed for measurement properties of health status questionnaires. J Clin Epidemiol 2007;60:34–42.
37. Bland JM, Altman DG. Statistics notes: Cronbach's alpha. BMJ 1997;314:572.
38. Hu Lt, Bentler PM. Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. Struct Equ Modeling 1999;6:1–55.
39. Kimura T. Interaction between locomotion and three subcategories for patients with stroke demonstrating fewer than 37 points on the total functional independence measure upon admission to the recovery ward. J Phys Ther Sci 2020;32:516–23.
40. Portney L, Watkins M. Foundations of clinical research: applications to practice. 3rd ed. New York, NY, USA: Pearson; 2009.
41. Terluin B, Griffiths P, van der Wouden JC, Ingelsrud LH, Terwee CB. Unlike ROC analysis, a new IRT method identified clinical thresholds unbiased by disease prevalence. J Clin Epidemiol 2020;124:118–25.
42. Perera S, Mody SH, Woodman RC, Studenski SA. Meaningful change and responsiveness in common physical performance measures in older adults. J Am Geriatr Soc 2006;54:743–9.