Tools for Observational Gait Analysis in Patients With Stroke: A Systematic Review

Francesco Ferrarello, Valeria Anna Maria Bianchi, Marco Baccini, Gaia Rubbieri, Enrico Mossello, Maria Chiara Cavallini, Niccolò Marchionni and Mauro Di Bari

PHYS THER. 2013; 93:1673-1685.
Originally published online June 27, 2013
doi: 10.2522/ptj.20120344

Tools for Observational Gait Analysis in Patients With Stroke: A Systematic Review

Francesco Ferrarello, Valeria Anna Maria Bianchi, Marco Baccini, Gaia Rubbieri, Enrico Mossello, Maria Chiara Cavallini, Niccolò Marchionni, Mauro Di Bari

Background. Stroke severely affects walking ability, and assessment of gait kinematics is important in defining diagnosis, planning treatment, and evaluating interventions in stroke rehabilitation. Although observational gait analysis is the most common approach to evaluate gait kinematics, tools useful for this purpose have received little attention in the scientific literature and have not been thoroughly reviewed.

Objectives. The aims of this systematic review were to identify tools proposed to conduct observational gait analysis in adults with a stroke, to summarize evidence concerning their quality, and to assess their implementation in rehabilitation research and clinical practice.

Methods. An extensive search was performed of original articles reporting on visual/observational tools developed to investigate gait kinematics in adults with a stroke. Two reviewers independently selected studies, extracted data, assessed quality of the included studies, and scored the metric properties and clinical utility of each tool. Rigor in reporting metric properties and dissemination of the tools also was evaluated.

Results. Five tools were identified, not all of which had been tested adequately for their metric properties. Evaluation of content validity was partially satisfactory. Reliability was poorly investigated in all but one tool. Concurrent validity and sensitivity to change were shown for 3 and 2 tools, respectively. Overall, adequate levels of quality were rarely reached. The dissemination of the tools was poor.

Conclusions. Based on critical appraisal, the Gait Assessment and Intervention Tool shows a good level of quality, and its use in stroke rehabilitation is recommended. Rigorous studies are needed for the other tools in order to establish their usefulness.

F. Ferrarello, PT, Functional Rehabilitation Unit, Azienda USL 4 Prato, Piazza dell'Ospedale 5, 59100 Prato, Italy. Address all correspondence to Mr Ferrarello at: francescoferrarello@tiscali.it.

V.A.M. Bianchi, PT, Functional Rehabilitation Unit, Azienda USL 4 Prato.

M. Baccini, PT, Functional Rehabilitation Unit and Motion Analysis Laboratory, Piero Palagi Hospital, Azienda Sanitaria di Firenze, Florence, Italy.

G. Rubbieri, MD, Research Unit of Medicine of Aging, Department of Experimental and Clinical Medicine, University of Florence, and Azienda Ospedaliero–Universitaria Careggi, Florence, Italy.

E. Mossello, MD, PhD, Research Unit of Medicine of Aging, Department of Experimental and Clinical Medicine, University of Florence, and Azienda Ospedaliero–Universitaria Careggi.

M.C. Cavallini, MD, PhD, Research Unit of Medicine of Aging, Department of Experimental and Clinical Medicine, University of Florence, and Azienda Ospedaliero–Universitaria Careggi.

N. Marchionni, MD, Research Unit of Medicine of Aging, Department of Experimental and Clinical Medicine, University of Florence, and Azienda Ospedaliero–Universitaria Careggi.

M. Di Bari, MD, PhD, Research Unit of Medicine of Aging, Department of Experimental and Clinical Medicine, University of Florence, and Azienda Ospedaliero–Universitaria Careggi.

[Ferrarello F, Bianchi VAM, Baccini M, et al. Tools for observational gait analysis in patients with stroke: a systematic review. *Phys Ther.* 2013;93:1673–1685.]

Published Ahead of Print: June 27, 2013
Accepted: June 23, 2013
Submitted: September 6, 2012

Impairment of walking ability is one of the most important determinants of disability in adults with stroke.[1] After a stroke, gait speed and cadence decrease, whereas gait cycle duration and double-limb support time increase; the paretic limb, compared with the contralateral limb, has a longer swing phase and a shorter stance phase.[2] Consequences of these changes on global walking performance are remarkable. A previous study showed that the proportion of patients who need assistance in indoor ambulation was 40% 3 weeks after stroke and 15% at 6 months.[3] In another study, the authors observed that 82% of patients did not fully recover community ambulation 3 months or more after stroke.[4] Energy expenditure during walking is higher in patients with hemiparesis than in people who are healthy,[5] and variability in oxygen consumption after a stroke reflects gait deviations.[6] Moreover, gait pattern alterations contribute to worsening self-image perception,[7] lowering self-esteem and, in turn, restricting participation.[8] Finally, gait deficit contributes to increased risk of fractures.[9] Therefore, gait recovery may improve overall functioning and well-being, and it represents a key goal in stroke rehabilitation.[10]

Physical therapists usually consider gait kinematics as a major target of their assessment of patients with stroke.[11,12] Computerized three-dimensional (3D) gait analysis allows objective, quantitative hemiparetic gait assessment and represents the gold standard for this aim.[12] This technology is not commonly available in clinical practice, its application is complex and time-demanding, and clinicians are often unfamiliar with its results and terminology.[13] Thus, observational gait analysis remains the most common approach to provide an estimation of gait kinematics.[13–15] This approach is based on visual assessment of joint displacement and spatiotemporal components,[15] and it may be supported by video recording, which allows slow motion and freeze-frame analysis.

Accurate assessment of gait kinematics may help predict degree of improvement and future functional conditions,[16] plan appropriately targeted treatments,[17] and monitor efficacy of interventions.[14,18] Tools for observational gait analysis are used in physical therapist education programs to facilitate learning of gait kinematics and its deviations.[19,20]

In visual gait assessment, standardized procedures are not commonly used.[14] Professionals tend to identify their own "core set" of gait descriptors, which often are not exhaustive and have a wide variability, whereas the use of assessment tools improves the analyses and helps avoid omissions of important gait issues.[21] Several tools have been proposed for use by therapists when performing observational gait analysis in various disorders, although they are criticized because of heterogeneity of content[13] or inadequate metric properties.[12,13,22] Evaluation forms vary from a datasheet for text annotations,[19] to checklists,[20] to scales that give a score.[11] Availability of numeric scores facilitates reporting of gait characteristics and understanding of which gait attributes most influence walking ability and relate to other mobility measures.[18]

The aims of this systematic review were: (1) to identify tools proposed for the observational assessment of hemiparetic gait after stroke, (2) to summarize evidence concerning their quality, and (3) to assess their implementation in rehabilitation research and clinical practice.

Available With This Article at ptjournal.apta.org

- eAppendix 1: Tools Excluded, With Reason for Exclusion
- eAppendix 2: Experts' Item Relevance and Tool Comprehensive Assessment

Method

The reporting of this study conforms to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement.[23]

Search

Two independent investigators (F.F., V.A.M.B.) conducted an extensive search for complete original studies, published in English, reporting on tools or scales developed to investigate gait kinematics in adults with a stroke. To be selected, tools had to be based on a strictly visual/observational approach, in terms of joint displacement or spatiotemporal components, and designed for use in stroke rehabilitation. Publications were included in methodological assessment if aimed at development or clinimetric evaluation of a measurement tool as described above. Studies were searched in MEDLINE, PEDro, Cochrane Central Register of Controlled Trials, Cochrane Database of Systematic Reviews, DARE, PsycINFO, CINAHL, ISI Web of Science, EMBASE, and RehabDATA. To ensure retrieval of all potentially relevant publications, we scanned reference lists of related articles and performed a hand search of major journals and books concerning assessment and rehabilitation of people with stroke sequelae, neurological rehabilitation, or movement analysis. Reference lists of articles retrieved were evaluated for relevant publications. Other sources consulted were the American Physical Therapy Association's *Interactive Guide to Physical Therapist Practice: Catalogue of Tests and Measures*,[24] StrokEngine,[25] the

Evidence-Based Review of Stroke Rehabilitation,[26] and the Chartered Society of Physiotherapy searchable database.[27]

The search had no temporal limits and was performed until February 2012 using the following combination of key words: (walk OR walking OR gait OR deambulation OR ambulation) AND (assessment OR measure OR outcome OR evaluation OR scale OR tool) AND (visual OR observational OR qualitative OR quality) AND (stroke OR hemiplegia OR hemiparesis OR cerebrovascular accident) AND (metric properties OR reliability OR validity OR responsiveness). The word "stroke" and combinations of words contained in the name of any potentially relevant tool were entered in Google Scholar to conduct further search.

Full texts of all articles judged to be of possible interest on the basis of title and abstract were retrieved. Two reviewers (F.F., V.A.M.B.) independently evaluated the studies selected for final inclusion; disagreement was resolved by consensus. Reasons for exclusion were declared for any assessment tool identified and eventually excluded.

The 2 reviewers extracted relevant data using a standard data recording spreadsheet, including metric properties of the tool, thoroughness and rigor with which these had been reported,[26] tool implementation in rehabilitation research and practice, and other useful assessment features. They also independently evaluated the metric properties of the tools retrieved, as well as aspects of their clinical utility,[28] and the literature on the metric properties of each tool.

Assessment of a Tool's Metric Properties

Tools were examined in a random sequence. The relevance of each item and the comprehensiveness of the tool as a whole were taken into account as the key characteristics of content validity. Assessment of item relevance was conducted independently by 2 physical therapists (F.F., V.A.M.B.) with more than 25 years of clinical experience in neurological rehabilitation. They initially agreed upon theoretical[29–31] and operational[20] definitions of normal gait, characteristics and patterns of hemiparetic gait,[32] and appropriate set and clothing for tool administration[22] and then, after a first round of familiarization with the assessment procedure, completed their evaluations. Each item was scored on a 4-point (1–4) ordinal scale, where a value of 1 indicated that the characteristic was not present and a value of 4 indicated that the characteristic was fully represented (Appendix 1). Agreement between the 2 raters on the score assigned was evaluated with the intraclass correlation coefficient (ICC). The comprehensiveness of each tool was subsequently assessed by examining whether the tool included at least evaluation of pelvis, hip, knee, and ankle-foot behavior across the gait cycle, in both coronal and sagittal planes.[33] Agreement between the 2 raters on this dichotomous characteristic was analyzed with kappa statistics. Content validity of a tool was eventually judged as satisfactory when all items had received at least a score of 2 for relevance and the tool as a whole had been considered as comprehensive (Tab. 1, Appendix 1).

Scoring criteria, preferred statistical tests, and cutoff points to assess the tools' reliability, concurrent criterion validity, and responsiveness to change were chosen in agreement with previous studies.[26,34] Criteria were graded on a 4-level ordinal scale: a score of 0 was assigned to items that had not been reported, a score of 1 was assigned when the statistical test used was not the recommended test or a poor outcome was evident, a score of 2 was assigned when the property achieved a sufficient outcome, and a score of 3 points was assigned when the property achieved a good outcome (Tab. 1).

When the same tool was considered in several studies, as well as when reliability was assessed by single items and not for the scale as a whole, the quality score was assigned by taking into account the median value of the different test results reported. A summary score was calculated for metric properties assessment, and the maximum score achievable was 13 points (Tab. 1). Analyses were performed using IBM SPSS for Windows, version 20.0 (IBM Corp, Armonk, New York).

Assessment of a Tool's Clinical Utility

For each tool, ability to provide a summary score, availability of objective scoring criteria, mandatory videotaping, and administration time were assessed. The first 2 criteria were rated as dichotomous and received 1 point in case of fulfillment. Mandatory videotaping was chosen as an index of portability and cost, and 1 point was assigned in case of a negative result. Administration time was graded on a 4-level ordinal scale, according to a previous study.[28] A summary score, with a maximum of 6 points, was calculated for clinical utility (Tab. 1).

Assessment of Literature on the Metric Properties

Methodological rigor of individual studies reporting on development and testing of each of the tools was assessed according to 10 criteria. Among these, 8 (representativeness of the sample, definition of selection criteria, reasonable time lag between comparison and index tests, clear description of index tool application, clear description of comparison tool application, blinding of index

Table 1.
Tool Metric Properties and Clinical Utility Scoring Criteria Checklist[a]

Tools	Points			
	0	1	2	3
Metric properties				
Intrarater reliability (ICC, kappa statistics)*	NA	Recommended test not used or ≤.40	.41–.74	≥.75
Interrater reliability (ICC, kappa statistics)*	NA	Recommended test not used or ≤.40	.41–.74	≥.75
Content validity (relevance and comprehensiveness)†	Not adequate	Adequate		
Concurrent criterion validity (correlation coefficient)*	NA	Recommended test not used or ≤.30	.31–.59	≥.60
Responsiveness to change (effect size)*	NA	Recommended test not used or <.50	.50–.80	>.80
Score				
Clinical utility				
Does it provide a score?	No	Yes		
Scoring criteria objectively based	No	Yes		
Mandatory videotaping	Yes	No		
Administration time	NA or >1 h	30–60 min	10–30 min	<10 min
Score				

[a] ICC=intraclass correlation coefficient, NA=not available. *Recommended statistical tests are shown in parentheses. †Operational definitions are given in Appendix 1.

tool assessors, blinding of comparison tool assessors, and report of uninterpretable/uncompleted tests) were derived from the Quality Assessment of Studies of Diagnostic Accuracy included in Systematic reviews (QUADAS) list,[35] one was use of appropriate statistical tests, and the last one was reporting of statistical comparisons for key outcomes. Items were phrased as dichotomous questions, where 1 point was assigned to each "Yes" answer and a rating of 0 was assigned to each "No" or "Unclear" answer. The full text of questions is shown in Appendix 2. Items that relate to a comparison tool were not applied in the case of reliability studies, whereas those items relating to blinding and to a comparison tool were not applied when assessing responsiveness studies. A summary score was calculated as a percentage of the maximum score achievable (6, 8, or 10 points, depending on study type) to express the quality of each study.

Further methodological evaluation was conducted using items present in boxes B, D, H, and I (related to reliability, content validity, criterion validity, and responsiveness, respectively) of the 4-point Consensus-based Standards for the selection of health status Measurement Instruments (COSMIN) checklist,[36] recently developed to assess the methodological quality of studies on measurement properties. Any item of the checklist allows 4 response options, representing excellent, good, fair, and poor quality; a methodological quality score per box is obtained by taking the lowest rating of any item in a box ("worse score counts").[36]

Results

Selection of the Studies

Of 209 titles, 127 were retrieved in full text. After complete evaluation, 8 articles fulfilling the selection criteria and describing 5 tools were considered for the review (Figure). These 5 tools were: the adapted New York Medical School Orthotic Gait Analysis (NYMSOGA) work sheet,[37] the Hemiplegic Gait Analysis Form (HGAF),[11] the Wisconsin Gait Scale (WGS),[38] the Gait Assessment and Intervention Tool (GAIT),[22] and the Rivermead Visual Gait Assessment (RVGA).[39] For this last tool, only one interrater reliability study, enrolling a sample mostly composed of patients who had a stroke, was considered suitable for analysis.[39]

Tools were excluded mainly because they targeted patients with conditions other than stroke (children with cerebral palsy, elderly people, and patients with orthopedic diseases, traumatic brain injury, or chronic pain) or they had not been formerly investigated in patients with stroke (eg, the Brunnström walking assessment datasheet,[19] the Rancho Observational Gait Analysis form,[20] and others). Tools excluded and reasons for exclusion are detailed in eAppendix 1 (available at ptjournal.apta.org).

General Characteristics and Clinical Utility of the Tools Selected

All of the tools selected described gait characteristics mainly in terms of joint displacement. Abnormal gait components involving head,[11,37] upper limbs,[11,22,37,39] trunk,[11,22,37,39] and pelvis and lower limbs[11,22,37–39] were investigated in varying degrees. Some tools included analysis of spatiotemporal variables[11,37,38] or identified the need for walking aids or orthoses.[22,38,39]

The format of the tools was diverse. The degree of movement abnormalities was graded on 4 levels in the RVGA and on 3 levels in the NYMSOGA, HGAF, and WGS. In the GAIT, items were scored on 2 to 4 levels, and some items were associated with checklists used to complete the description of specific movement abnormalities (Tab. 2).

Four tools provided a summary score.[11,22,38,39] Regarding clinical utility, detailed objective scoring criteria, based on cutoffs of joint displacement and on specified joint behaviors, were available for the WGS and GAIT, whereas verbal descriptors were used to assess gait pattern in the NYMSOGA, HGAF, and RVGA. The RVGA tool is accompanied by an appendix describing the components of normal gait pattern. The HGAF depicts possible deviations in head and trunk posture and in spatiotemporal factors by using diagrams. Usual time of administration, in a range from 10 to 25 minutes, was reported for the RVGA, GAIT, and WGS. Although videotaping was frequently used to evaluate the tools,[11,22,38,40,41] tape recording was mandatory only in the GAIT (which detailed the procedure for image acquisition) and in the HGAF. The GAIT form allotted space for additional comments, whereas the RVGA allowed scoring of other deviations not covered by the tool (Tab. 2).

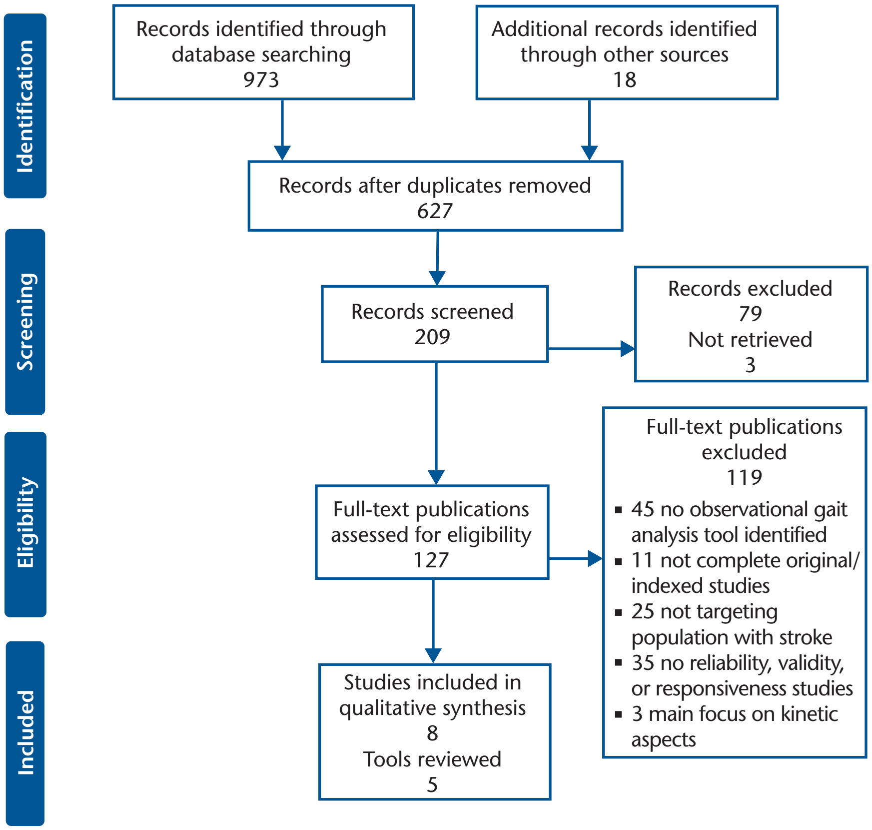

Figure.
PRISMA review flow diagram.

Metric Properties of the Tools

The tools had been formally investigated in participants with poststroke hemiparesis[11,22,37,38,40–42] and other neurological conditions (head injury and multiple sclerosis)[39] in studies in which the sample sizes ranged from 6 to 56. The number of assessors in reliability studies ranged from 1 to 7 (Tab. 3).

Raters' scoring for content validity is available in the eAppendix 2 (available at ptjournal.apta.org). To varying degrees, all of the items were deemed relevant, with an acceptable interrater agreement (ICC=.66). The kinematic features of gait were found to be comprehensively analyzed in the GAIT (possibly in greater detail), RVGA, and HGAF, which also included information on pattern symmetry. The kinematic analysis proposed for the stance phase in the WGS seemed to lack some content related to pelvis, knee, and ankle behavior. The NYMSOGA was found to be not comprehensive and poorly organized, observations were not linked to the gait cycle, and major weaknesses were evident, such as lack of information on hip and ankle kinematics in the sagittal plane. When assessing comprehensiveness, raters showed excellent agreement

Table 2.
General Characteristics and Clinical Utility Assessment of the Tools[a]

Tool	No. of Items	Tool Format	Type of Gait Variables Considered	Information on Aids or AFO	Training to Use	Summary Score Available (CU Score)	Objective Scoring Criteria (CU Score)	Mandatory Videotaping (CU Score)	Time to Administer, Analyze, and Interpret (CU Score)	CU Summary Score
GAIT[22,41]	31	2- to 4-level ordinal scale	Kinematic	Yes	Inexperienced clinician: 4.5 h, experienced clinician: 2 h	0 (normal) to 62 (worst) (1)	Yes (1)	Yes (0)	20 min (not including videotaping) (1)	3/6
HGAF[11]	18	3-level ordinal scale	Kinematic, spatiotemporal	No	One practice session to assess films of 2 patients	0 (normal) to 88 (worst) (1)	No (0)	Yes (0)	Not reported (0)	1/6
NYMSOGA[37]	17	3-level ordinal scale	Kinematic, spatiotemporal	No	Not reported	None (0)	No (0)	No (1)	Not reported (0)	1/6
RVGA[39]	20 (+2)	4-level ordinal scale	Kinematic	Yes	Assessors trained 5–10 min before using	0 (normal) to 59 (worst) (1)	No (0)	No (1)	Between 10 and 15 min (2)	4/6
WGS[38,40,42]	14	3-level ordinal scale (weighting of items 1 and 4)	Kinematic, spatiotemporal	Yes	Not reported	13.35 (normal) to 42 (worst) (1)	Yes (1)	No (1)	20–25 min for video-recording + 15–20 min for offline analysis (1)	4/6

[a] Scores in this table are assigned in accordance with the criteria listed in Table 1. AFO=ankle-foot orthosis, CU=clinical utility, GAIT=Gait Assessment and Intervention Tool, HGAF=Hemiplegic Gait Analysis Form, NYMSOGA=New York Medical School Orthotic Gait Analysis, RVGA=Rivermead Visual Gait Assessment, WGS=Wisconsin Gait Scale.

(kappa=1). Content validity was ultimately deemed adequate for the GAIT, HGAF, and RVGA scales (Tab. 4).

Reliability had been evaluated with suboptimal statistical tests, such as percentage of agreement[37,39] or correlation coefficient,[11,38,39] in almost all tools; therefore, this property was judged to be poorly investigated. In agreement with the selection criteria, 2 abstracts reporting on reliability assessment of the WGS were ignored; a thorough bibliographic search could not identify any full-text article related to these abstracts. The GAIT scale was the only exception and had good intrarater and interrater reliability, according to the above defined cutoff points (Tab. 1).

Approaches to assess concurrent criterion validity were diverse. The WGS was compared with walking speed, perceived health, and psychological well-being[43] and with Brunnström motor recovery level.[19] One tool (HGAF) was validated against kinematic parameters, measured using an instrumented walkway.[11] The GAIT scale was correlated with gait speed.[41] Further validity assessment was limited to 2 items, which showed good agreement with data obtained from a computerized motion analysis system.[22] Because the full score was not tested, however, this result was not taken into account. Results of validity assessment were sufficient (again in agreement with the cutoff points given in Tab. 1) in 1 scale (WGS) and good in 2 other scales (GAIT, HGAF) (Tab. 3).

Sensitivity to change was investigated by comparing pretreatment and posttreatment values for the WGS, with favorable results.[40,42] The GAIT scale was able to discriminate a significant difference between treatment groups, which paralleled differences in other outcome mea-

Table 3.
Summary of Metric Properties of Tools[a]

Tool, Study, Year	No./Type of Observers/ Observation	No. of Participants/ Clinical Condition	Intrarater Reliability (Statistical Test and Results)	Interrater Reliability (Statistical Test and Results)	Concurrent Criterion Validity (Statistical Test, Reference Measure, and Results)	Responsiveness (Statistical Test and Results)
GAIT, Daly et al,[22] 2009	2 clinicians, video	10–29, stroke	ICC=.98*	ICC=.83,* .99*	SCC, 3D computerized movement excursion data; item 26: r=.65,* item 27: r=.76*	PLUM ordinal regression, parameter estimate=1.72†
GAIT, Zimbelman et al,[41] 2012	Unclear/PTs, video	44, stroke			SCC, unspecified gait analysis → gait speed: r=−.73*	Wilcoxon rank sum test, P=.0004–.036
HGAF, Hughes and Bell,[11] 1994	3 PTs, video	6, stroke	Kendall tau coefficient, range=.40–.95†,‡	Kendall tau coefficient, range=.94†–.95†,‡	SCC, computerized mat data → gait speed: r=.60, step length symmetry: r=−.09, single-support symmetry: r=.94*	
NYMSOGA, Goodkin and Diller,[37] 1973	7 senior PTs, live	10, stroke		Agreement among therapists: 83%‡		
RVGA, Lord et al,[39] 1998	Unclear, up to 7 PTs, live	2, MS 1, HI 7, stroke		Agreement among therapists: 63.8%‡ Kendall tau coefficient: .84*,‡		
WGS, Rodriquez et al,[38] 1996	2 physiatrists, video	18, stroke		Kendall tau coefficient, single items, range=.44–.85‡	SCC, physical functioning score (HSQ subscale): r=.65†	
WGS, Turani et al,[42] 2004	2 physiatrists, live	35, stroke			PCC, unspecified gait analysis → gait speed: r=.45† SCC, Brunnström recovery stages, r=.43†	Wilcoxon rank sum test, P=.007
WGS, Pizzi et al,[40] 2007	1 physiatrist, 1 neurologist, video	56, stroke				Wilcoxon rank sum test, P<.005

[a] ICC=intraclass correlation coefficient, 3D=three-dimensional, GAIT=Gait Assessment and Intervention Tool, HGAF=Hemiplegic Gait Analysis Form, HSQ=Health Status Questionnaire, HI=head injury, MS=multiple sclerosis, NYMSOGA=New York Medical School Orthotic Gait Analysis, PCC=Pearson correlation coefficient, PLUM=Polytomous Universal Model, PT=physical therapist, RVGA=Rivermead Visual Gait Assessment, SCC=Spearman correlation coefficient, WGS=Wisconsin Gait Scale. *P≤.01. †P≤.05. ‡Statistical test not in accordance with the preferred one (Tab. 1).

Table 4.
Summary Scores of Tool Metric Properties Assessment[a]

Metric Property	GAIT[22]	HGAF[11]	NYMSOGA[37]	RVGA[39]	WGS[38]
Intrarater reliability	3	1	0	0	0
Interrater reliability	3	1	1	1	1
Content validity	1	1	0	1	0
Concurrent criterion validity	3	3	0	0	2
Responsiveness	3	0	0	0	1
Score	13/13	6/13	1/13	2/13	4/13

[a] Scores in this table are assigned in accordance with the criteria listed in Table 1 and the data given in Table 3. GAIT=Gait Assessment and Intervention Tool, HGAF=Hemiplegic Gait Analysis Form, NYMSOGA=New York Medical School Orthotic Gait Analysis, RVGA=Rivermead Visual Gait Assessment, WGS=Wisconsin Gait Scale.

sures,[22,44] such as the gait section of the Tinetti Performance-Oriented Mobility Assessment[45] and the knee flexion items (lower extremity motor subsection) of the Fugl-Meyer Assessment Scale.[46] No information on the presence of ceiling or floor effects was available. The GAIT scale achieved the top score in metric properties evaluation (Tab. 4).

The thoroughness with which the metric properties were reported was poor. Only the WGS was investigated in studies[40,42,47,48] other than those conducted by its proponents, with limited additional information.

Methodological Assessment of Individual Studies

The selected studies had a quality score ranging from 38% to 85% (mean=66%). The sample was representative in 7 studies,[11,22,37,38,40–42] and selection criteria were described in 5 of them.[11,22,39–41] With one exception,[22] time lag between index and comparison test was judged adequate, whereas a clear description of tool application was available in more than half of the cases (Tab. 5). One study reported uncompleted tests[39]; almost all reliability studies did not use the recommended statistical tests[11,37–39] or did not provide statistical comparisons[37,38] (Tabs. 3 and 5).

In most cases, studies received a "poor" rating for methodology according to the COSMIN checklist. The exceptions were 1 GAIT[41] and 2 WGS[40,42] responsiveness studies, which received a "fair" rating. A small sample size was the main factor contributing to the poor methodology ratings (Tab. 5).

Dissemination

Dissemination of these tools in research was modest. None of the tools identified was reported among the most frequently used outcome measures in clinical trials of stroke rehabilitation.[49] We found the GAIT scale utilized as an outcome measure in 1 clinical trial[50] and a randomized controlled trial (RCT),[51] the RVGA was chosen in an ongoing RCT[52] and 5 articles published between 2006 and 2011 (3 clinical trials[53–55] and 2 RCT[56,57]), and the WGS was used in 3 RCTs published between 2009 and 2011.[58–60]

We could not identify any specific investigation addressing the issue of dissemination in clinical practice of observational hemiparetic gait assessment tools. To our knowledge, none of the tools retrieved in this study has been recommended in clinical practice guidelines for stroke rehabilitation.

Discussion

Summary of Evidence

Our extensive search led to the identification of a small number of tools that allowed recognition and qualitative description of the hemiparetic gait pattern after a stroke, purely based on visual observation. The format of these tools consisted of ordinal scales, where the severity of gait abnormalities was scored on a qualitative or a semiquantitative basis. Some variations were observed in the content and the level of detail of the tools, as well as in practical aspects of their use, such as need for videotaping.

The latter is the factor that most influences tool clinical utility, affecting portability and cost, and time of administration. In several pathological conditions, both live and video-based observational gait analysis showed moderate to poor reliability.[21] In our study, in the presence of roughly equivalent scores of clinical utility (Tab. 2), we found that the most reliable and discriminating tool used videotaping and a detailed observation protocol.[22] This finding suggests that, other factors being the same, video recording and a rigorous protocol for data acquisition greatly improve observational analysis of gait and, therefore, should be highly recommended.

Table 5.
Methodological Rigor Assessment of Studies on Metric Properties of the Tools[a]

Tool	GAIT	GAIT	HGAF	NYMSOGA	RVGA	WGS	WGS	WGS
Study, Year	**Daly et al,[22] 2009**	**Zimbelman et al,[41] 2012**	**Hughes and Bell,[11] 1994**	**Goodkin and Diller,[37] 1973**	**Lord et al,[39] 1998**	**Rodriquez et al,[38] 1996**	**Turani et al,[42] 2004**	**Pizzi et al,[40] 2007**
Question 1. Representativeness of the sample	■	■	■	■	○	■	■	■
Question 2. Selection criteria	■	■	■	○	■	○	○	■
Question 3. Reasonable time lag between comparison and index test	■/○	■	■	■	■	■	■	NA*
Question 4. Clear description of index tool application	■	■	■	○	○	○	■	■
Question 5. Clear description of comparison tool application	■	○	■	NA*	NA*	■	○	NA*
Question 6. Blinding of index tool assessors	○	○	■	■	■	■	■	NA*
Question 7. Blinding of comparison tool assessors	○	○	■	NA*	NA*	■	■	NA*
Question 8. Reporting of uninterpretable/ uncompleted tests	○	○	○	○	■	○	○	○
Question 9. Statistical tests in accordance with evaluation standards	■	■	○/■	○	○	○/■	■	■
Question 10. Reporting of statistical comparisons for key outcomes	■	■	■	○	■	○/■	■	■
Q ■	6.5	6	8.5	3	5	6	7	5
Q Score	65%	60%	85%	38%	63%	60%	70%	83%
COSMIN box B	Poor†	NA*	Poor†	Poor†	Poor†	Poor†	NA*	NA*
COSMIN box D	Poor‡	NA*	Poor‡	Poor‡	Poor‡	Poor‡	NA*	NA*
COSMIN box H	Poor†	Poor§	Poor†	NA*	NA*	Poor†	Poor§	NA*
COSMIN box I	Poor†	Fair‖	NA*	NA*	NA*	NA*	Fair‖	Fair‖

[a] Scores in the table are assigned in accordance with the criteria listed in Appendix 2 and the COSMIN checklist scoring system.[36] ■ item scored as "yes," ○ item scored as "no" or "unclear," box B=reliability, box D=content validity, box H=criterion validity, box I=responsiveness, GAIT=Gait Assessment and Intervention Tool, HGAF=Hemiplegic Gait Analysis Form, NYMSOGA=New York Medical School Orthotic Gait Analysis, RVGA=Rivermead Visual Gait Assessment, WGS=Wisconsin Gait Scale. *NA=not applicable. †Small sample size. ‡Not assessed if all items were relevant for the study population or target population not involved. §Criterion not considerable as an adequate gold standard. ‖Unclear how missing items were handled.

Problems are evident when other metric properties of the tools are considered, as they had been rarely tested completely and accurately. According to our assessments, only the GAIT scale could be considered reliable. Sensitivity to change was reported to be adequate for 2 tools, but only in 1 tool (GAIT) were results quantified as an effect size. Finally, validity of the GAIT, HGAF, and WGS was documented, at least in part, in individuals who have had a stroke. However, because reliability is a prerequisite for other metric properties, findings on validity and responsiveness of some tools might be questioned. Limitations in metric properties are particularly crucial when outcomes of intervention studies are compared. Furthermore, low quality or lack of subsequent research may adversely affect dissemination. Nevertheless, the tools have been used in RCTs to evaluate the effects of interventions.

Assessment of criterion validity of tools for observational gait analysis is particularly challenging. Some authors[11,39,41,42] performed this analysis by comparison with walking speed, which is a key element to predict gait effects on health status and outcome, especially among older people,[61] but can hardly be considered as the gold standard to assess gait kinematics. Besides speed, alterations in gait pattern may affect oxygen consumption[5] and self-image,[7] ultimately restricting participation after a stroke.[8] Thus, gait speed should be considered useful to assess construct, rather than criterion, validity.

Other authors evaluated criterion validity of their tool by comparison with 3D computerized gait analysis. Despite its conceptual soundness, this approach presents serious drawbacks. Computerized techniques, indeed, provide an extremely detailed, quantitative description of gait patterns, which cannot be summarized and compared with the summary scale score. Thus, when observational gait analysis tools have been tested against 3D computerized systems, the comparison could not encompass the entire instrumented assessment but was restricted to the few items in a scale offering a semiquantitative assessment of selected joint displacements.[22] An alternative approach is comparison with tools such as the Gillette Gait Index,[62] the Gait Deviation Index,[63] or the Gait Profile Score,[64] which have been previously proposed to summarize the results of 3D computerized gait analysis. However, no such comparison was proposed in the studies retrieved.

Rigor in reporting metric properties was poor. Subsequent studies on these tools were rarely, if ever, available and often only as abstracts.[47,48,65] This paucity of published research might be due to a publication bias, as studies conducted with tools of insufficient reliability and validity are more difficult to be accepted for publication.

The quality of the studies selected was fair, as judged from a mean score of 66%. Overall, study design was adequate, whereas statistical testing was sometimes inappropriate, or statistical comparisons were not reported for the summary score. When tools where evaluated with the COSMIN checklist items,[36] the results were more disappointing.

A proper assessment of the walking pattern is of paramount importance in stroke rehabilitation. The GAIT is the only scale that proved to be reliable,[22] comprehensive,[22] valid,[41] and sensitive to change.[22,41] Administered by expert raters, the level of detail of the GAIT was such to allow identifying impaired gait components and demonstrating their change over time.[41,51] These characteristics justify recommendation of this tool for use in research and education. However, its clinical routine use is hampered by the burden for its administration; moreover, the level of expertise or the specific training required for its best application have not been clearly established. The HGAF, RVGA, and WGS showed poor reliability,[11,38,39] and the WGS has an unsatisfactory comprehensiveness.[38] Therefore, these tools cannot be recommended for routine use until their weaknesses are addressed. The NYMSOGA is to be considered as a historic landmark in the field because it was probably the first observational gait analysis tool to undergo a reliability study,[37] but it is poorly organized and largely incomplete.

Limitations

In the absence of recognized standards, the quality assessment presented in this research was based on self-defined criteria. The challenge was how to assess the quality of the studies from which relevant data were extracted in order to detect the potential for bias (internal validity) and to assess widespread applicability of the results (external validity). Because the COSMIN checklist was not yet available when we developed the study protocol and it was considered only afterward, we selected key elements and domains necessary for rating the quality of individual studies from a comprehensive description proposed by the Agency for Healthcare Research and Quality (AHRQ).[66] Eight out of 10 criteria were found to be accurately covered in QUADAS[35] and, therefore, were adopted, with slight modifications. Two further criteria were added to take into account crucial statistical issues not included in QUADAS but highly valued in the AHRQ document.[66] Thus, we believe that our evaluation process, although never used before, ultimately relies upon solid and commonly shared views on quality requirements for studies on measurement instruments and produced an accurate and objective judgment.

It should be pointed out that our evaluation approach highlighted differences across studies that, conversely, remained almost undetected when the COSMIN checklist boxes were used. Our scoring system did not appear to suffer from a floor effect as the COSMIN checklist did, probably due to the "worse score counts" rating assumption. Although the COSMIN checklist has the potential to become the standard reference to assess the methodological quality of studies on measurement properties, the 10-criteria list developed in this study had a lower administration and examiner burden and was simpler to interpret: these advantages should be adequately valued for future review processes and might make our list appropriate for clinical and educational purposes.

The assessment of content validity also was limited by a lack of accepted standards. Content validity evaluation should not be solely based on information provided by the proponents of a tool, but rather on a thorough analysis of the instrument itself through systematic experts' assessment. However, experts' feedback is subjective, and results may be affected from bias existing among raters.[67] To limit the subjectivity inherent to this process, our evaluation was blinded and preceded by preliminary agreement on the criteria to be applied.

Difficulties in retrieval of published studies may bias systematic reviews. In the present study, only 1 full article and 2 abstracts were not found; we are confident that our search was comprehensive and included almost all of the studies and tools proposed to assess the quality of gait after stroke.

Conclusions

In our view, the toolbox of every physical therapist must include reliable, low-cost, and portable tools to assess gait. Walking abnormalities strongly affect quality of life in patients with stroke.[68] Observational analysis might represent the basic approach to reach this goal[69] and, in contrast to instrumented techniques, offers the specific advantage of an ecological assessment of the patient in any environment. An optimal, thoroughly validated tool for observational gait analysis also might contribute to the integration of research and clinical practice.[70] We identified 5 observational tools for hemiparetic gait assessment. Our findings show that the GAIT scale has good measurement properties, adequate to contemporary standards, and it can be considered the current benchmark in observational gait analysis of patients with a stroke. More research is needed to establish the usefulness of the other tools, which are promising but have not been completely investigated.

Mr Ferrarello, Mr Baccini, Dr Cavallini, and Dr Di Bari provided concept/idea/research design. Mr Ferrarello, Ms Bianchi, and Dr Di Bari provided writing. Mr Ferrarello, Ms Bianchi, and Dr Rubbieri provided data collection. Mr Ferrarello, Dr Rubbieri, and Dr Di Bari provided data analysis. Mr Ferrarello and Ms Bianchi provided project management. Dr Marchionni and Dr Di Bari provided institutional liaisons. Mr Ferrarello, Mr Baccini, Dr Rubbieri, Dr Mossello, Dr Cavallini, and Dr Marchionni provided consultation (including review of manuscript before submission). The authors thank Mrs Stefanini for her technical assistance.

An abstract of preliminary findings of the study was displayed as a poster at the World Confederation for Physical Therapy Congress; June 20–23, 2011; Amsterdam, the Netherlands.

DOI: 10.2522/ptj.20120344

References

1 Chiou II, Burnett CN. Values of activities of daily living: a survey of stroke patients and their home therapists. *Phys Ther.* 1985;65:901–906.

2 von Schroeder HP, Coutts RD, Lyden PD, et al. Gait parameters following stroke: a practical assessment. *J Rehabil Res Dev.* 1995;32:25–31.

3 Wade DT, Hewer RL. Functional abilities after stroke: measurement, natural history and prognosis. *J Neurol Neurosurg Psychiatry.* 1987;50:177–182.

4 Perry J, Garrett M, Gronley JK, Mulroy SJ. Classification of walking handicap in the stroke population. *Stroke.* 1995;34:982–989.

5 Danielsson A, Willen C, Sunnerhagen KS. Measurement of energy cost by the physiological cost index in walking after stroke. *Arch Phys Med Rehabil.* 2007;88:1298–1303.

6 Cunha-Filho IT, Henson H, Wankadia S, Protas EJ. Reliability of measures of gait performance and oxygen consumption with stroke survivors. *J Rehabil Res Dev.* 2003;40:19–25.

7 Pound P, Gompertz P, Ebrahim S. A patient-centred study of the consequences of stroke. *Clin Rehabil.* 1998;12:338–347.

8 Chau JP, Thompson DR, Twinn S, et al. Determinants of participation restriction among community dwelling stroke survivors: a path analysis. *BMC Neurol.* 2009;9:49.

9 Weerdesteyn V, de Niet M, van Duijnhoven HJ, Geurts AC. Falls in individuals with stroke. *J Rehabil Res Dev.* 2008;45:1195–1213.

10 Lord SE, McPherson K, McNaughton HK, et al. Community ambulation after stroke: how important and obtainable is it and what measures appear predictive? *Arch Phys Med Rehabil.* 2004;85:234–239.

11 Hughes KA, Bell F. Visual assessment of hemiplegic gait following stroke: pilot study. *Arch Phys Med Rehabil.* 1994;75:1100–1107.

12 Toro B, Nester C, Farren P. A review of observational gait assessment in clinical practice. *Physiother Theory Pract.* 2003;19:137–149.

13 Coutts F. Gait analysis in the therapeutic environment. *Man Ther.* 1999;4:2–10.

14 Toro B, Nester CJ, Farren PC. The status of gait assessment among physiotherapists in the United Kingdom. *Arch Phys Med Rehabil.* 2003;84:1878–1884.

15 Eastlack ME, Arvidson J, Snyder-Mackler L, et al. Interrater reliability of videotaped observational gait-analysis assessments. *Phys Ther.* 1991;71:465–472.

16 Kaczmarczyk K, Wit A, Krawczyk M, et al. Associations between gait patterns, brain lesion factors and functional recovery in stroke patients. *Gait Posture.* 2012;35:214–217.

17 Kaczmarczyk K, Wit A, Krawczyk M, Zaborski J. Gait classification in post-stroke patients using artificial neural networks. *Gait Posture.* 2009;30:207–210.

18 Harvey A, Gorter JW. Video gait analysis for ambulatory children with cerebral palsy: why, when, where and how! *Gait Posture.* 2011;33:501–503.

19 Brunnström S. *Movement Therapy in Hemiplegia*. New York, NY: Harper & Row; 1970.

20 Perry J. *Gait Analysis: Normal and Pathological Function*. Thorofare, NJ: Slack Inc; 1992.

21 Watelain E, Froger J, Rousseaux M, et al. Variability of video-based clinical gait analysis in hemiplegia as performed by practitioners in diverse specialties. *J Rehabil Med.* 2005;37:317–324.

22 Daly JJ, Nethery J, McCabe JP, et al. Development and testing of the Gait Assessment and Intervention Tool (G.A.I.T.): a measure of coordinated gait components. *J Neurosci Methods.* 2009;178:334–339.

23 Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *BMJ.* 2009;339:332–336.

24 Interactive Guide to Physical Therapist Practice. Available at: http://guidetoptpractice.apta.org. Accessed April 12, 2012.

25 StrokEngine. Available at: http://www.medicine.mcgill.ca/strokengine-assess/. Accessed April 12, 2012.

26 Salters K, Jutai J, Zettler L, et al. Outcome Measures in Stroke Rehabilitation. Available at: http://www.ebrsr.com/uploads/Chapter-21-outcome-assessment-SREBR-15_1.pdf. Accessed April 12, 2012.

27 The Chartered Society of Physiotherapy. Searchable database. Available at: http://corporate.csp.midev.rroom.net/director/effectivepractice/outcomemeasures/database.cfm. Accessed November 19, 2011.

28 Tyson S, Connell L. The psychometric properties and clinical utility of measures of walking and mobility in neurological conditions: a systematic review. *Clin Rehabil.* 2009;23:1018–1033.

29 Saunders JB, Inman VT, Eberhart HD. The major determinants in normal and pathological gait. *J Bone Joint Surg Am.* 1953;35:543–558.

30 Kuo AD. The six determinants of gait and the inverted pendulum analogy: a dynamic walking perspective. *Hum Mov Sci.* 2007;34:617–656.

31 Kuo AD, Donelan JM. Dynamic principles of gait and their clinical implications. *Phys Ther.* 2010;90:157–174.

32 Woolley SM. Characteristics of gait in hemiplegia. *Top Stroke Rehabil.* 2001;7:1–18.

33 Saleh M, Murdoch G. In defence of gait analysis: observation and measurement in gait assessment. *J Bone Joint Surg Br.* 1985;67:237–241.

34 Andresen EM. Criteria for assessing the tools of disability outcomes research. *Arch Phys Med Rehabil.* 2000;81:S15–S20.

35 Whiting P, Rutjes AW, Reitsma JB, et al. The development of QUADAS: a tool for the quality assessment of studies of diagnostic accuracy included in systematic reviews. *BMC Med Res Methodol.* 2003;3:25.

36 Terwee CB, Mokkink LB, Knol DL, et al. Rating the methodological quality in systematic reviews of studies on measurement properties: a scoring system for the COSMIN checklist. *Qual Life Res.* 2012;21:651–657.

37 Goodkin R, Diller L. Reliability among physical therapists in diagnosis and treatment of gait deviations in hemiplegics. *Percept Mot Skills.* 1973;37:727–734.

38 Rodriquez AA, Black PO, Kile KA, et al. Gait training efficacy using a home-based practice model in chronic hemiplegia. *Arch Phys Med Rehabil.* 1996;77:801–805.

39 Lord SE, Halligan PW, Wade DT. Visual gait analysis: the development of a clinical assessment and scale. *Clin Rehabil.* 1998;12:107–119.

40 Pizzi A, Carlucci G, Falsini C, et al. Gait in hemiplegia: evaluation of clinical features with the Wisconsin Gait Scale. *J Rehabil Med.* 2007;39:170–174.

41 Zimbelman J, Daly JJ, Roenigk KL, et al. Capability of 2 gait measures for detecting response to gait training in stroke survivors: Gait Assessment and Intervention Tool and the Tinetti Gait Scale. *Arch Phys Med Rehabil.* 2012;93:129–136.

42 Turani N, Kemiksizoglu A, Karatas M, Ozker R. Assessment of hemiplegic gait using the Wisconsin Gait Scale. *Scand J Caring Sci.* 2004;18:103–108.

43 *Health Status Questionnaire (HSQ) 2.0 User Guide*. Bloomington, MN: Health Outcomes Institute; 1993.

44 Daly JJ, Roenigk K, Holcomb J, et al. A randomized controlled trial of functional neuromuscular stimulation in chronic stroke subjects. *Stroke.* 2006;37:172–178.

45 Tinetti ME. Performance-oriented assessment of mobility problems in the elderly. *J Am Geriatr Soc.* 1986;34:119–134.

46 Fugl-Meyer AR, Jääskö L, Leyman I, et al. The post-stroke hemiplegic patient, 1: a method for evaluation of physical performance. *Scand J Rehabil Med.* 1975;7:13–31.

47 Rubertone JA, Baldwin K, Bucknam J, et al. Reliability analysis of the Wisconsin Gait Scale for novice evaluators [abstract]. *Phys Ther.* 2000;80:S19.

48 Wellmon R, Campbell SL, Rubertone JA, et al. The interrater and intrarater reliability of the Wisconsin Gait Scale when administered by physical therapists to individual post-stroke. *Neurol Rep.* 2002;34:197–198.

49 Salter KL, Teasell RW, Foley NC, Jutai JW. Outcome assessment in randomized controlled trials of stroke rehabilitation. *Am J Phys Med Rehabil.* 2007;86:1007–1012.

50 McCabe JP, Dohring ME, Marsolais EB, et al. Feasibility of combining gait robot and multichannel functional electrical stimulation with intramuscular electrodes. *J Rehabil Res Dev.* 2008;45:997–1006.

51 Daly JJ, Zimbelman J, Roenigk KL, et al. Recovery of coordinated gait: randomized controlled stroke trial of functional electrical stimulation (FES) versus no FES, with weight-supported treadmill and over-ground training. *Neurorehabil Neural Repair.* 2011;25:588–596.

52 Waldner A. Robot Assisted Therapy for Acute Stroke Patients: A Comparative Study of GangTrainer GT I, Lokomat System and Conventional Physiotherapy. Available at: http://clinicaltrialsfeeds.org/clinical-trials/show/NCT01146587. Accessed April 12, 2012.

53 Chon SC, Oh DW, Shim JH. Watsu approach for improving spasticity and ambulatory function in hemiparetic patients with stroke. *Physiother Res Int.* 2009;14:128–136.

54 Kofler M, Quirbach E, Schauer R, et al. Limitations of intrathecal baclofen for spastic hemiparesis following stroke. *Neurorehabil Neural Repair.* 2009;23:26–31.

55 Mehrholz J, Rutte K, Pohl M. Jump training is feasible for nearly ambulatory patients after stroke. *Clin Rehabil.* 2006;20:406–412.

56 Kuys SS, Brauer SG, Ada L, Russell TG. Increasing intensity during treadmill walking does not adversely affect walking pattern or quality in newly-ambulating stroke patients: an experimental study. *Aust J Physiother.* 2008;54:49–54.

57 Verma R, Arya KN, Garg RK, Singh T. Task-oriented circuit class training program with motor imagery for gait rehabilitation in poststroke patients: a randomized controlled trial. *Top Stroke Rehabil.* 2011;18(suppl 1):620–632.

58 Onigbinde AT, Awotidebe T, Awosika H. Effect of 6 weeks wobble board exercises on static and dynamic balance of stroke survivors. *Technol Health Care.* 2009;17:387–392.

59 Park IM, Oh DW, Kim SY, Choi JD. Clinical feasibility of integrating fast-tempo auditory stimulation with self-adopted walking training for improving walking function in post-stroke patients: a randomized, controlled pilot trial. *J Phys Ther Sci.* 2010;22:295–300.

60 Patil P, Rao S. Effects of Thera-Band® elastic resistance-assisted gait training in stroke patients: a pilot study. *Eur J Phys Rehabil Med.* 2011;47:427–433.

61 Abellan van Kan G, Rolland Y, Andrieu S, et al; an International Academy on Nutrition and Aging (IANA) Task Force. Gait speed at usual pace as a predictor of adverse outcomes in community-dwelling older people. *J Nutr Health Aging.* 2009;13:881–889.

62 Cretual A, Bervet K, Ballaz L. Gillette Gait Index in adults. *Gait Posture.* 2010;32:307–310.

63 Schwartz MH, Rozumalski A. The Gait Deviation Index: a new comprehensive index of gait pathology. *Gait Posture.* 2008;28:351–357.

64 Baker R, McGinley JL, Schwartz MH, et al. The Gait Profile Score and Movement Analysis Profile. *Gait Posture.* 2009;30:345–349.

65 Lord S. Further validation of the Rivermead Visual Gait Assessment. *Neurorehabil Neural Repair.* 1999;13:27.

66 West S, King V, Carey TS, et al. *Systems to Rate the Strength of Scientific Evidence*. AHRQ Publication No. 02- E016. Rockville, MD: Agency for HealthCare Research and Quality; 2002. Available at: http://www.thecre.com/pdf/ahrq-system-strength.pdf. Accessed November 19, 2011.

67 Rubio DM, Berg-Weger M, Tebb SS, et al. Objectifying content validity: conducting a content validity study in social work research. *Soc Work Res.* 2003;27:94–104.

68 Alguren B, Fridlund B, Cieza A, et al. Factors associated with health-related quality of life after stroke: a 1-year prospective cohort study. *Neurorehabil Neural Repair.* 2012;26:266–274.

69 Gronley JK, Perry J. Gait analysis techniques: Rancho Los Amigos Hospital gait laboratory. *Phys Ther.* 1984;64:1831–1838.

70 Manns PJ, Darrah J. Linking research and clinical practice in physical therapy: strategies for integration. *Physiotherapy.* 2006;92:88–94.

Appendix 1.

Content Validity Assessment Definitions

Relevance: the item is relevant in providing an estimation of gait kinematics in a patient with stroke, through description of body segment or joint placement/displacement and/or other features strictly connected with gait pattern such as spatiotemporal components (parameters), or the use of orthoses or assistive devices (present/absent, impact).

1	2	3	4
Not relevant	Somewhat relevant	Quite relevant	Highly relevant

Comprehensiveness: instrument adequately covers the content it is meant to represent. Minimum requirements include evaluation of pelvis, hip, knee, and ankle-foot behavior across gait cycle, in both the coronal and the sagittal planes.[33]

Appendix 2.

Criteria to Assess Methodological Rigor of Individual Studies on Metric Properties of the Tools[a]

Question 1. Was the spectrum of patients representative of the patients who will receive the test in practice?

Question 2. Were selection criteria clearly described?

Question 3. Is the time period between comparison tool and index tool applications (or between assessors' evaluations) short enough to be reasonably sure that the target condition did not change between the 2 tests?

Question 4. Was the application of the index tool described in sufficient detail to permit its replication?

Question 5. Was the application of the comparison tool described in sufficient detail to permit its replication?

Question 6. Were the index tool results interpreted without knowledge of the results of the comparison tool (or other assessors' results)?

Question 7. Were the comparison tool results interpreted without knowledge of the results of the index tool?

Question 8. Were uninterpretable/uncompleted tests reported?

Question 9. Were statistical analysis tests in accordance with evaluation standards?

Question 10. Were statistical comparisons for key outcomes reported?

[a] *Index tool* refers to the outcome measure object of the study. *Comparison tool* refers to the outcome measure with which the index tool is compared. Items that relate to a comparison tool (questions 5 and 7) were not applied in the studies assessing only reliability. Items relating to blinding and to a comparison tool (questions 3, 5, 6, and 7) were not applied in the studies assessing only responsiveness.

Physical Therapy
Journal of the American Physical Therapy Association

Tools for Observational Gait Analysis in Patients With Stroke: A Systematic Review

Francesco Ferrarello, Valeria Anna Maria Bianchi, Marco Baccini, Gaia Rubbieri, Enrico Mossello, Maria Chiara Cavallini, Niccolò Marchionni and Mauro Di Bari

PHYS THER. 2013; 93:1673-1685.
Originally published online June 27, 2013
doi: 10.2522/ptj.20120344