ORIGINAL ARTICLE

ABILOCO: A Rasch-Built 13-Item Questionnaire to Assess Locomotion Ability in Stroke Patients

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ABSTRACT. Caty GD, Arnould C, Stoquart GG, Thonnard J-L, Lejeune TM. ABILOCO: a Rasch-built 13-item questionnaire to assess locomotion ability in stroke patients. Arch Phys Med Rehabil 2008;89:284-90.

Objective: To develop a questionnaire (ABILOCO), based on the Rasch measurement model, that can assess locomotion ability in adult stroke patients (*International Classification of Functioning, Disability and Health* activity domain).

Design: Prospective study and questionnaire development.

Setting: A faculty hospital.

Participants: Adult stroke patients (N=100) (age, 64±15y). The time since stroke ranged from 1 to 260 weeks.

Intervention: A preliminary questionnaire included 43 items representing a large sample of locomotion activities. This questionnaire was tested on the 100 stroke patients, and their responses were analyzed using the Rasch model (RUMM 2020 software) to select items that had an ordered rating scale and fitted a unidimensional model.

Main Outcome Measure: The ABILOCO questionnaire.

Results: The retained items resulted in a 13-item questionnaire, which includes a wide range of locomotion abilities well targeted to the sample population, leading to good reliability (R=.93). The item calibration was independent of age, sex, time since stroke, and affected side. The concurrent validity of ABILOCO was also investigated by comparing it with well-known, criterion standard scales (Functional Walking Category, Functional Ambulation Categories, item 12 of the FIM instrument evaluating walking ability) and the walking speed measured with the 10-meter walk test.

Conclusions: The ABILOCO questionnaire presents good psychometric qualities to measure locomotion ability in adult stroke patients. Its range and measurement precision make it attractive for clinical use throughout the rehabilitation process and for clinical research.

Key Words: Locomotion; Questionnaires; Rehabilitation; Stroke.

POSTSTROKE NEUROLOGIC impairment is a major cause of permanent disability among adults. This impairment frequently limits walking ability, which is an activity essential for daily life activities and social participation. Walking is also considered to be the most important activity of daily living by stroke patients.[1] The assessment of locomotion ability is therefore fundamental in neurologic rehabilitation to follow the patient's improvement in clinical practice and to analyze the therapeutic's efficacy in clinical research. The World Health Organization *International Classification of Functioning, Disability and Health* (ICF)[2] is recommended as the framework to assess rehabilitation. The ICF defines locomotion or mobility as the individual's ability to move about effectively in his/her environment[2] and classifies locomotion in the activity domain.

The functional assessment of a stroke patient can concern several aspects of mobility. In the first ICF domain (body structures and functions), neurologic impairment secondary to stroke can be assessed by using the National Institutes of Health Stroke Scale,[3] the Stroke Impairment Assessment Set,[4] or the Fugl-Meyer Assessment.[5] The gait pattern can be assessed by visual assessment with the Physician Rating Scale,[6] the Observational Gait Scale,[7] the Observation-Based Clinical Gait Assessment Tool,[8] or the Rivermead Visual Gait Assessment.[9] The gait pattern can also be quantitatively analyzed in a gait laboratory, which provides detailed quantification of kinematic, kinetic, energetic, and electromyographic data during walking. These data are useful for treatment planning and clinical research but might not be related to the patient's walking ability during daily life in his/her environment.

In the second ICF domain (activity), locomotion ability can be assessed by several scales including the Functional Walking Category (FWC),[10] the Functional Ambulation Categories (FAC),[11] item 12 of the FIM instrument[12] evaluating walking ability, the Rivermead Mobility Index,[13] the Mobility Milestones,[14] the Modified Emory Functional Ambulation Profile (mEFAP),[15] or the New Mobility Scale.[16] Unfortunately, these scales have certain limitations in measuring walking ability. Indeed, these tools (with the exception of the mEFAP) are ordinal scales that permit only limited computation and low-powered nonparametric statistics.[17,18] Some of these tools may not have the capacity to assess patients throughout their rehabilitation. For instance, the FWC was developed to assess the patient during outpatient rehabilitation, whereas FIM walking ability and FAC seem more appropriate during inpatient rehabilitation. Tests that measure walking speed (10-meter walk test [10MWT], 6-minute walk test[19]) are useful (simple, quick, inexpensive) and well validated. However, these tests describe a subject's performance in an artificial and motivating environment that might not be related to the patient's walking capacity during daily life.

The Rasch model was developed in the 1960s in educational and psychologic measurement[20] and thereafter extended to measurement in health sciences[21] to overcome the limitation of the traditional psychometrics method.[22] The Rasch model

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Table 1: Sample Characteristics (N=100)

Characteristics	Values
Age (y)	64±15 (30–89)
Sex	
Male	60
Female	40
Site of lesion[34]	
Right cerebral lesion with hemineglect	15
Right cerebral lesion without hemineglect	25
Left cerebral lesion with aphasia	26
Left cerebral lesion without aphasia	13
Cerebral trunk lesion	8
Cerebellar lesion	5
Many-sided lesions	8
Delay since stroke (wk)	30±42 (1–260)

NOTE. Values are mean ± standard deviation (range) or n.

allows for the measurement of a latent variable that cannot be quantified by a measuring device. For instance, dexterity can be quantified by a tool like the Purdue pegboard or the Box and Block Test. But the measure of manual ability, a latent variable defined as "the capacity to manage daily life activities requiring the use of the upper limbs, whatever the strategies involved,"[23(p1627)] required the development of the ABILHAND questionnaire,[23] a Rasch-built interval scale. The process of establishing a new measure starts with the definition of the variable to be measured. Next, a large bank of items concerning this variable is created to build a preliminary questionnaire to be submitted to a representative population. Rasch analysis is then applied to the subject's responses to select the items fitting the model, respecting the principles of linearity, unidimensionality, and invariance. None of the existing scales available to assess locomotion ability were developed following the Rasch model.

The purpose of this study was to develop a new questionnaire (ABILOCO[a]) that assesses the walking ability of adult stroke patients by focusing on the activity domain of the ICF. The psychometric qualities of the ABILOCO were assessed by using the Rasch probabilistic model.[24,25] This scale would be able to assess the locomotion ability of the stroke patient throughout his/her rehabilitation process (in a hospital setting, at home, in the community) and be suitable for clinical practice and research.

METHODS

Participants

A 100 sample of convenience of adult stroke patients (60 men, 40 women) were recruited from our inpatient and outpatient rehabilitation departments. Sample population characteristics are shown in table 1. Patients had a stroke[26] that occurred at least 1 week before the study with no major cognitive deficit that would prevent them from completing the questionnaire. Their neurologic impairments induced gait disturbances and walking disability noticeable by visual observation. Patients unable to perform any walking rehabilitation because of neurologic impairments or other medical conditions were excluded. Patients confined to a bed or wheelchair or patients who recovered a normal gait without any noticeable disturbances were also excluded. Patients participated freely in the study, which was approved by the local ethics committee.

Questionnaire Development

The preliminary questionnaire included a large sample of activities corresponding to the ICF definition of locomotion[2]: the person's ability to move about effectively in his/her environment classified in the activity domain. Item selection was also based on a review of existing scales (FWC, FAC, FIM walking ability, and the Gillette Functional Assessment Questionnaire[27]) and on the clinical experience of our rehabilitation team (physical therapists, physical medicine and rehabilitation specialists). The first version of ABILOCO included a pool of 43 items.

Procedures

The 43-item questionnaire was completed by the 100 stroke patients by using an interview technique.[23] The ability of patients to participate in the study was established by the rehabilitation team taking care of the patient on a daily basis. These rehabilitation professionals were familiar with the ability of the patient to understand and fill out the questionnaire. The assessors always checked the consistency of the answers. For each question, patients were asked to estimate, using a 3-level rating scale (0, impossible; 1, difficult; 2, easy), their perceived difficulty in performing that locomotion activity. Activities not attempted since the stroke were not scored and were encoded as missing responses. However, when an activity was never attempted because it was impossible, it was scored as impossible. The activities in the questionnaire were presented in a random order to avoid any systematic effect. Ten different random orders of presentation were used.

Data Analysis

Patients' responses were analyzed by using the RUMM computer program.[b] The Rasch model[24] allows the raw total scores to be converted into linear measures. This model requires that only item difficulty and patient ability determine the probabilities of endorsing any given category. Measurement units are expressed in logits (log-odds units), a probability unit that expresses the natural logarithm of the odds of success. At any given ability level, 1 logit difference between 2 patients indicates that their odds of successfully achieving any activity are 2.7:1 (e^1:1). The logit metric provides a linear unit, representing a fixed increment along the entire scale of the explored variable.

Item Selection

Results from successive analyses were used to select the 13 items that constituted the final ABILOCO scale. Items that did not meet any of the following criteria were eliminated.

The first selection criterion was the frequency of missing values. Only items with a response rate higher than 50%, indicating that they were commonly attempted by the patients in our sample, were retained.

The second criterion was the order of thresholds between response categories (ordered rating scale). If the anticipated order of response categories was correct, subjects with greater locomotion ability should select a higher response for any given item, and subjects selecting a higher response for a given item should have greater locomotion ability. When these conditions were not met, the order of thresholds between successive response categories was skewed, indicating that the rating scale was not being used as anticipated for that particular item.[28] Only items with thresholds in the anticipated order were retained.

The third criterion was the unidimensionality. The subject's responses to each item had to depend only on locomotion

Table 2: ABILOCO Calibration for Adult Stroke Patients

Items	Difficulty (logits)	SE (logits)	Chi-Square	*P*
1. Hopping on the healthy foot.	4.65	0.43	0.88	.64
2. Going up an escalator alone.	2.77	0.41	1.21	.55
3. Walking while holding a fragile object (such as a full glass).	1.65	0.38	1.50	.47
4. Going up stairs putting each foot on the next step.	0.65	0.42	0.39	.82
5. Walking backwards.	0.49	0.48	1.15	.56
6. Walking more than 5m alone, indoors, on flat ground without assistive device.	0.19	0.43	0.97	.62
7. Striding over an object with the paretic foot first.	0.02	0.45	0.58	.75
8. Striding over an object with the healthy foot first.	−0.74	0.46	0.29	.87
9. Walking less than 5m alone without the help or supervision of a person.	−1.03	0.45	0.70	.70
10. Walking with the help of a person who guides but does not support.	−1.13	0.45	0.31	.86
11. Turning and walking in a narrow space.	−1.46	0.45	0.14	.93
12. Walking less than 5m, indoors, holding onto pieces of furniture.	−2.23	0.47	0.93	.63
13. Walking less than 5m with the help of a person to support.	−3.84	0.58	0.50	.78

Abbreviation: SE, standard error.

ability and not on other patient or item characteristics. Based on the estimated ability of the patient and the difficulty of the item, the expected response of a subject to an item can be computed by the model. The similarity between the observed and expected responses to any item is reported by the software through a chi-square fit statistic.[29] The chi-square fit statistic cumulates the deviations from the model's expectations. A test of significance is then applied to determine whether the chi-square is too high to be attributed to random variations. If the *P* value was less than .05, the item did not fit the unidimensionality criterion and was eliminated.[23]

The fourth criterion was the differential item functioning (DIF) test. The lack of variance in the item difficulty hierarchy among patient subgroups was tested. Four DIF tests were performed on the basis of the following criteria: sex (male vs female), age (<60y vs ≥60y), delay since stroke (<3mo vs ≥3mo), and affected side (right hemiparesis vs left hemiparesis).

The fifth selection criterion was the redundancy. If 2 items had the same level of difficulty and were therefore redundant, the activity with the best-fit unidimensionality criterion (lowest item chi-square) was retained.

Reliability

In Rasch theory, error measure variance is directly computed from the measurement error accompanying each patient's ability and item difficulty estimates.[18,30] A person separation reliability coefficient was determined as the ratio between the true measure variance (as expressed by the standard deviation corrected for measurement error) and the observed (true + error) measure variance in the sample.[25] Separation can be used to estimate the number of strata that are significantly distinguished within the range of observed patient abilities.

Concurrent Validity

The ABILOCO measures were validated according to their relationship with raw scores of widely used existing scales (FWC, FAC, FIM walking ability) and the spontaneous walking speed (10MWT). A Spearman correlation coefficient (ρ) was computed for ordinal scales (FWC, FAC, FIM walking ability) and a Pearson correlation coefficient (r) for spontaneous walking speed.

RESULTS

Patients were unable to distinguish 3 levels of difficulty in locomotion activities: difficulty was perceived as either "impossible" or "easy," whereas the intermediate category "difficult" is rarely observed. This indicated that patient perception was dichotomous, leading us to group the categories, difficult and easy, in a new category of "possible." Consequently, the 3 original categories were rescored as 2 categories: possible or impossible with 1 threshold.

The item's selection procedure excluded 30 items. Four items were excluded because they had not been attempted since the stroke by more than 50% of the patients (cycling with a

Table 3: The ABILOCO Questionnaire

	Could You Estimate Your Ability to Realize the Following Activities?	Impossible	Possible	?
1	Walking while holding a fragile object (such as a full glass).			
2	Walking with the help of a person who guides but does not support.			
3	Striding over an object with the paretic foot first.			
4	Walking more than 5m alone, indoors, on flat ground without assistive device.			
5	Turning and walking in a narrow space.			
6	Striding over an object with the healthy foot first.			
7	Walking less than 5m with the help of a person to support.			
8	Walking backwards.			
9	Walking less than 5m alone without the help or supervision of a person.			
10	Going up stairs putting each foot on the next step.			
11	Walking less than 5m, indoors, holding onto pieces of furniture.			
12	Going up an escalator alone.			
13	Hopping on the healthy foot.			

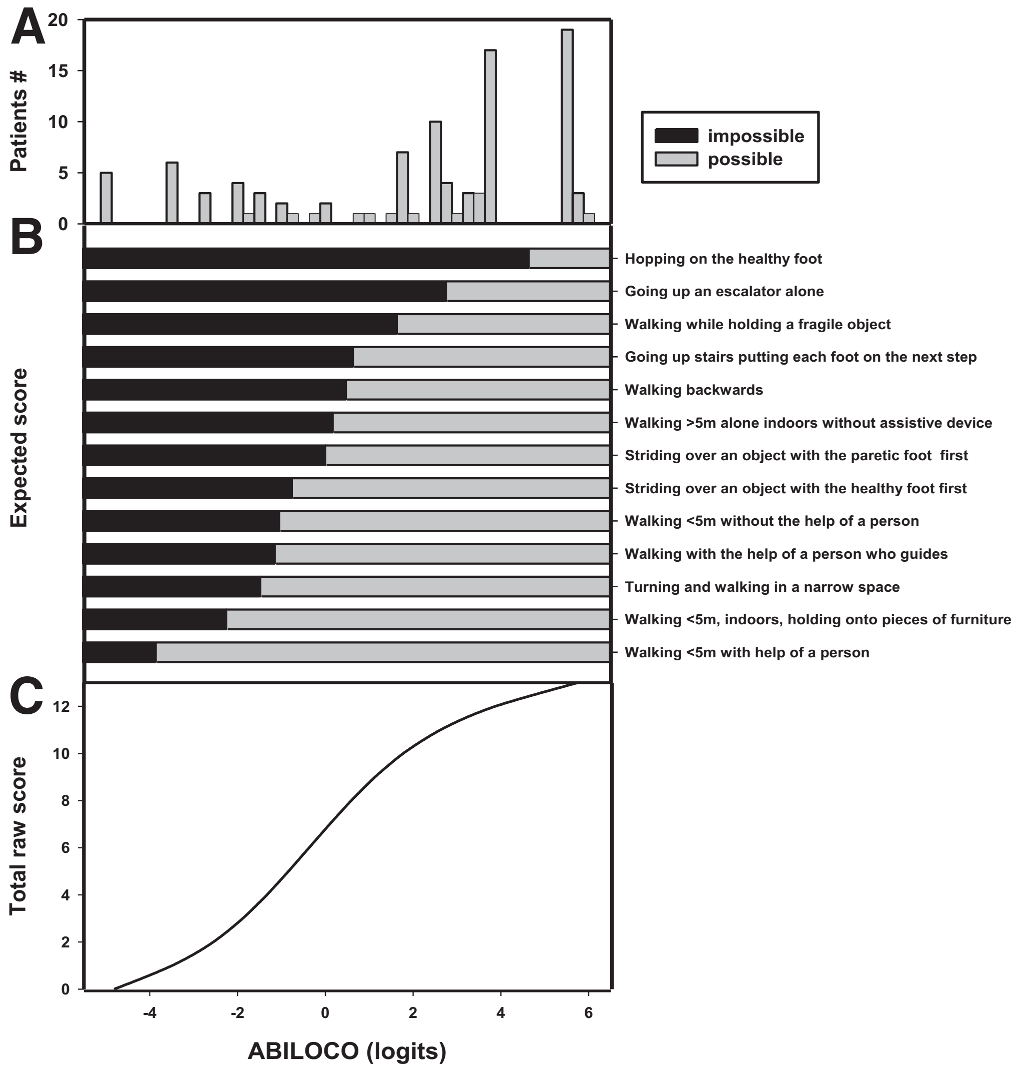


Fig 1. (A) The distribution of patient's perceived locomotion ability as assessed by ABILOCO. (B) The items by decreasing difficulty are shown from top to bottom; this figure shows the patient's expected responses to each item as a function of the underlying measure of locomotion ability. (C) The ogival relationship between the ABILOCO total raw score and the score expressed in logits on the linear scale.

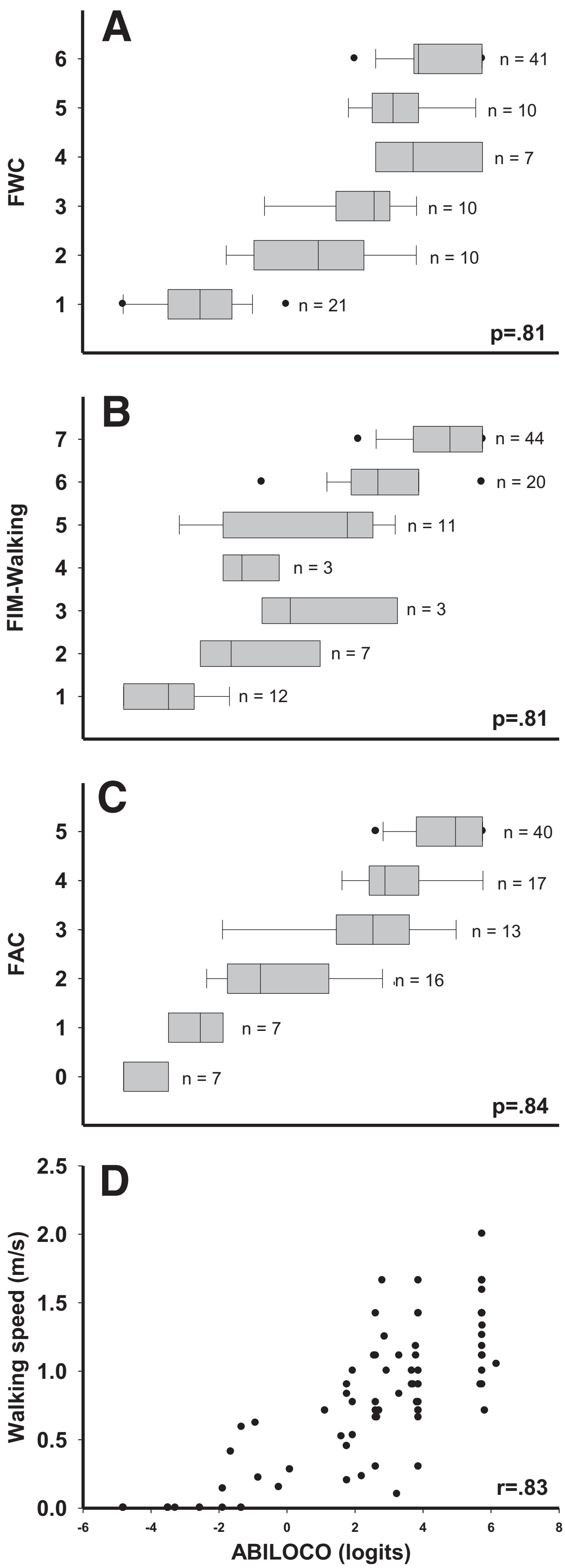
2-wheel bicycle or a tricycle); no item was eliminated for the second selection criterion (the 3 original categories were rescored in 2 categories with only 1 threshold); 7 items did not fit a unidimensional scale (eg, getting the bus up and down, taking the train, running irrespective of the terrain); 17 items had a DIF (eg, running correctly even if you have to turn, stepping up a curb, walking between parallel bars); and 1 item was redundant (going down stairs putting each foot on the next step, .61 logits). Furthermore, 1 item (running on flat and even ground) was eliminated because 74% of the patients rated it as impossible; this item was thus not relevant. The ABILOCO therefore became a 13-item questionnaire.

The perceived difficulties for the 13 activities are presented in table 2. The items are listed in order of decreasing difficulty (range, 4.65 to –3.84 logits) from top to bottom, with higher logit values representing more difficult activities. This table also shows the standard error associated with each item difficulty (range, .38–.58 logits) and the fit statistic computed as a chi-square. A P value greater than .05 indicates that all 13 items contributed to the definition of a unidimensional measure of locomotion ability in our sample.

Table 3 shows the ABILOCO scale presented as a questionnaire. Patients were asked to estimate their ability to perform each activity as impossible or possible. Activities not attempted in the last 3 months were not scored and were entered as not applicable (marked as a "?").

The ABILOCO scale and patient's locomotion abilities are shown in figure 1. The distribution of the patient's locomotion abilities, as presented in figure 1A, ranges from −4.8 to 6.17 logits. The measures of locomotion ability for the stroke patients are obtained by converting the ordinal total scores into linear scores. Figure 1C shows the ogival relationship between the total raw score ranging from 0 to 13 and the measure of locomotion ability on the linear scale in logits. This relationship is approximately linear between total raw scores of 4 and 8. However, outside this central range, a small increase in the total raw score corresponds to a large increase in locomotion ability on the linear scale. This difference highlights the nonlinearity of the total ordinal score.

Figure 1B shows the expected response to a given item as a function of the underlying locomotion ability. By comparing the locomotion ability of a given patient to the difficulty of each item, it is possible to determine the expected response of the patient to the item. A patient with an ability of 0 logit would be expected to be able to perform the 6 easiest activities and to fail to perform the 7 most difficult activities. According to the



distribution of the subject's locomotion abilities, 23% of the patients in our sample should be able to successfully perform all the activities, and 5% should not be able to perform any of the 13 ABILOCO items. The 13 items explore a wide range of locomotion abilities well targeted to our sample. ABILOCO was elaborated from a representative sample of the stroke population because 80% have a right or left cerebral lesion, with 5% presenting a cerebellar lesion. These 5 patients fit the model, and their locomotion abilities are distributed on our scale from −1.88 logits to 3.31 logits (mean, .98±2.27 logits). The patient reliability equals .93, indicating that 5.2 statistically different levels of ability can be distinguished in this sample.[30]

The relationships between ABILOCO and the FWC, FAC, FIM instrument walking ability, and 10MWT are presented in figure 2. The ABILOCO results correlated highly with the results obtained by using the FWC (ρ=.81, $P\leq$.001), FAC (ρ=.84, $P\leq$.001), and FIM walking ability (ρ=.81, $P\leq$.001). The ABILOCO results also correlated highly with walking speed as measured by the 10MWT (r=.83, $P\leq$.001).

DISCUSSION

According to the ICF, the main objective of rehabilitation after a stroke is to increase activity achievement and to promote the participation of the patient. The locomotion ability of a patient is critical to reach this objective.[1] Stroke rehabilitation specialists have to assess the walking ability at each stage of recovery in clinical practice and in clinical research. Unfortunately, there is a lack of scales presenting good psychometric qualities. Therefore, the purpose of this study was to develop a new scale (ABILOCO) to measure the stroke patient's walking ability in a hospital setting, at home, and in the community. The major interest in this scale is that a Rasch analysis was applied in its developmental stages, showing its unidimensionality, its invariance, and its linearity.

In comparison with the existing scales, the final 13-item ABILOCO presents several advantages. The first is linearity. By adding the score obtained at each question, the total raw score is obtained on an ordinal scale. The Rasch analysis then allows the conversion of this total raw score into a linear score expressed in logits on an interval scale. In contrast to the former, this latter score may be submitted to arithmetical computation and powerful parametric statistical analysis. The second advantage is unidimensionality, meaning that ABILOCO only measures locomotion ability and is not influenced by other patient characteristics. The unidimensionality of existing scales has never been tested. The third advantage is the invariance of ABILOCO across sex, age, delay since stroke, and clinical presentation. Other scales may not be invariant. Indeed, several activities included in the FAC and the FWC scales (eg, walking alone on any grounds or walking between parallel bars) presented a DIF and were disregarded after the Rasch analysis. The invariance of ABILOCO for delay since

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Fig 2. The relationships between the ABILOCO and (A) the FWC, (B) FIM walking ability (item 12), (C) the FAC, and (D) walking speed as measured with the 10MWT. Boxplots (panels A, B, C) show the patient distributions in a given category; the box indicates the 25% and 75% limits, and the vertical line inside the box indicates the median. The vertical bars indicate the 10% and 90% limits, and the solid dots indicate the 5% and 95% outliers. The number of patients (n) in each category is indicated. The ρ values report the results of the Spearman correlation test. In panel D, each point shows the results obtained for 1 patient. The r value reports the results of the Pearson correlation test.

stroke would permit its use to assess the stroke patient's locomotion throughout his/her rehabilitation process. Other scales may not be adapted to the entire rehabilitation process. FIM walking ability, the FAC, and the Mobility Milestones seem more appropriate for patients with low locomotion ability at the inpatient rehabilitation stage. Conversely, the functional walking category and the New Mobility Scale assess the locomotion ability only at home and in the community. Moreover, 40% of our patients obtained the maximum FWC, FIM walking ability, and FAC scores, indicating a ceiling effect, whereas ABILOCO can discriminate between walking abilities from 3 to 6.17 logits among these patients. The invariance of ABILOCO among the different subgroups would confirm that the patients estimated correctly their walking capacity irrespective of their clinical presentation.

The computation of the spontaneous walking speed over 10m is an easy and validated test[19] that provides continuous results. However, walking speed describes a subject's performances under a particular set of circumstances and may not reflect locomotion ability under different conditions. On the one hand, patients walking at the same slow speed ($<.5$m/s) present a wide range of locomotion ability from -5 to 3 logits (see fig 2D). On the other hand, patients with the same walking ability (around 4 logits) present a wide range of spontaneous walking speeds from .25 to 1.7m/s (see fig 2D). The ABILOCO and 10MWT are therefore complementary. Both tests can be performed easily in only a few minutes; the ABILOCO can also be self-administered. The mEFAP comprises 5 individually timed tasks performed over different environmental terrains and provides clear functional information without apparent ceiling effect.[15] Nevertheless, this timed tool is a performance, not necessarily reflecting the mobility within the individual's usual environment.

The item hierarchy in ABILOCO corresponds to the experience of rehabilitation professionals and to the patient's goals. The easiest item (13), walking less than 5m with the help of a person to support, is usually the first step in locomotion rehabilitation after stroke. The next item (12), walking less than 5m indoors, holding onto pieces of furniture, allows the patient to walk in his/her bedroom and reach the bathroom. Walking without help or supervision (item 9) is more difficult than walking with help or supervision (item 10) and corresponds to the limit between dependence and independence. Item 3 (walking while holding a fragile object [such a full glass]) requires the ability to perform 2 tasks at the same time[31] and demands considerable concentration. This activity allows the patient to walk while holding an object, a task required in cooking, shopping, or gardening. Items 1 and 2 require good balance and sufficient strength in both legs. These activities allow the patient to walk in the community for social participation. ABILOCO explores a wide range of pedestrian locomotion but does not consider transfers and wheelchairs ambulation.

Study Limitations

ABILOCO has the qualities of a good measure of walking activity. It is reliable, accurate in measuring mobility, clinically practical, and economical.[32] However, all the psychometric properties of a scale cannot be established in a single study.[33] In the future, it will be important to study the responsiveness of ABILOCO in a stroke population as a function of spontaneous recovery or after treatment with botulinum toxin injections. ABILOCO could also be evaluated in other patients suffering from multiple sclerosis, Parkinson's disease, or amputation.

CONCLUSIONS

The ABILOCO is a questionnaire that assesses the walking ability of adult stroke patients focusing on the ICF activity domain. This scale was developed following a Rasch analysis. It presents good psychometric qualities (reliability, linearity, and unidimensionality) and can be used regardless of age, sex, affected side, and time since the stroke.

For practical use of the ABILOCO, a website (*http://www.rehab-scales.org*) will be accessible shortly. The online analyses taking into account the missing values directly convert total scores into linear measures expressed in logits.

References

1. Chiou IL, Burnett CN. Values of activities of daily living: a survey of stroke patients and their home therapists. Arch Phys Med Rehabil 1985;65:901-6.
2. World Health Organization. The international classification of functioning, disability and health: ICF. Geneva: WHO; 2001.
3. Roth EJ, Heinemann AW, Lovell LL, Harvey RL, McGuire JR, Diaz S. Impairment and disability: their relation during stroke rehabilitation. Arch Phys Med Rehabil 1998;79:329-35.
4. Chino N, Sonoda S, Domen K, Saitoh E, Kimura A. Stroke impairment assessment set. In: Chino N, Melvin JL, editors. Functional evaluation of stroke patients. Tokyo: Springer; 1996. p 19-31.
5. Duncan PW, Propst M, Nelson SG. Reliability of the Fugl-Meyer assessment of sensorimotor recovery following cerebrovascular accident. Phys Ther 1983;63:1606-10.
6. Pirpiris M, Ugoni A, Starr R. The "physician rating scale"—validity and reliability [abstract]. Gait Posture 2001;13:293.
7. Mackey AH, Lobb GL, Walt SE, Stott NS. Reliability and validity of the Observational Gait Scale in children with spastic diplegia. Dev Med Child Neurol 2003;45:4-11.
8. Toro B, Nester C, Farren P. The development and validity of the Salford Gait Tool: an observation-based clinical gait assessment tool. Arch Phys Med Rehabil 2007;88:321-7.
9. Lord SE, Halligan PW, Wade DT. Visual gait analysis: the development of a clinical assessment and scale. Clin Rehabil 1998; 12:107-19.
10. Perry J, Garrett M, Gronley J, Mulroy S. Classification of walking handicap in the stroke population. Stroke 1995;26:982-9.
11. Brun V, Mousbeh Z, Jouet-Pastre B, Benaim C. Evaluation clinique de la marche de l'hémiplégique vasculaire: proposition d'une modification de la functional ambulation classification. Ann Readapt Med Phys 2000;43:14-20.
12. Granger CV, Hamilton BB, Linacre JM, Heinemann AW, Wright BD. Performances of the Functional Independence Measure. Arch Phys Med Rehabil 1993;72:84-9.
13. Collen FM, Wade DT, Robb GF. The Rivermead Mobility Index: a further development of the Rivermead Motor Assessment. Int Disabil Stud 1991;13:50-4.
14. Baer GD, Smith MT, Rowe PJ, Masterton L. Establishing the reliability of Mobility Milestones as an outcome measure for stroke. Arch Phys Med Rehabil 2003;84:977-81.
15. Baer HR, Wolf SL. Modified Emory functional ambulation profile: an outcome measure for the rehabilitation of poststroke gait dysfunction. Stroke 2001;32:973-9.
16. Stanko E, Goldie P, Nayler M. Development of a new mobility scale for people living in the community after stroke: content validity. Aust J Physiother 2001;47:201-8.
17. Merbitz C, Morris J, Grip JC. Ordinal scales and foundations of misinference. Arch Phys Med Rehabil 1989;70:308-12.
18. Wright BD, Linacre JM. Observations are always ordinal; measurements, however, must be interval. Arch Phys Med Rehabil 1989;70:857-60.

19. Dobkin BH. Short-distance walking speed and timed walking distance: redundant measures for clinical trials? Neurology 2006; 66:584-6.
20. Andrich D. Controversy and the Rasch model: a characteristic of incompatible paradigms. Med Care 2004;42(1 Suppl):I7-16.
21. Conrad KJ, Smith EVJr. International Conference on Objective Measurement: applications of Rasch analysis in health care. Med Care 2004;42(1 Suppl):I1-6.
22. Hobart J. Measuring disease impact in disabling neurological conditions: are patients' perspectives and scientific rigor compatible? Curr Opin Neurol 2002;15:721-4.
23. Penta M, Tesio L, Arnould C, Zancan A, Thonnard JL. The ABILHAND questionnaire as a measure of manual ability in chronic stroke patients: Rasch-based validation and relationship to upper limb impairment. Stroke 2001;32:1627-34.
24. Rasch G. Probabilistic models for some intelligence and attainment tests. Chicago: Mesa Pr; 1992.
25. Wright BD, Masters GN. Rating scale analysis. Chicago: Mesa Pr; 1982.
26. World Health Organization. Control of stroke in the community: methodological considerations and protocol of WHO Stroke Register. Geneva: WHO; 1973.
27. Novacheck TF, Stout JL, Tervo R. Reliability and validity of the Gillette Functional Assessment Questionnaire as an outcome measure in children with walking disabilities. J Pediatr Orthop 2000;20:75-81.
28. Andrich D. A rating formulation for ordered response categories. Psychometrika 1978;43:561-73.
29. Andrich D, Sheridan BE. Interpreting RUMM 2020: part II, polytomous data. 3rd ed. Perth: RUMM Laboratory; 2005.
30. Fisher WP. Reliability statistics. Rasch Meas Trans 1992;6:238.
31. Bowen A. Dual-task effects of talking while walking on velocity and balance following a stroke. Age Ageing 2001;30:319-23.
32. Pearson OR, Busse ME, van Deursen RW, Wiles CM. Quantification of walking mobility in neurological disorders. QJM 2004; 97:463-75.
33. Hobart JC, Riazi A, Lamping DL, Fitzpatrick R Thompson AJ. Measuring the impact of MS on walking ability: the 12-Item MS Walking Scale (MSWS-12). Neurology 2003;60:31-6.
34. Ring H, Feder M, Schwartz J, Samuels G. Functional measures of first-stroke rehabilitation inpatients: usefulness of the Functional Independence Measure total score with a clinical rationale. Arch Phys Med Rehabil 1997;78:630-5.

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