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The ABILHAND Questionnaire as a Measure of Manual Ability in Chronic Stroke Patients

Rasch-Based Validation and Relationship to Upper Limb Impairment

Massimo Penta, Ing; Luigi Tesio, MD; Carlyne Arnould, PT;
Arturo Zancan, MD; Jean-Louis Thonnard, PhD

Background and Purpose—Chronic hemiparetic patients often retain the ability to manage activities requiring both hands, either through the use of the affected arm or compensation with the unaffected limb. A measure of this overall ability was developed by adapting and validating the ABILHAND questionnaire through the Rasch measurement model. ABILHAND measures the patient's perceived difficulty in performing everyday manual activities.

Methods—One hundred three chronic (>6 months) stroke outpatients (62% men; mean age, 63 years) were assessed (74 in Belgium, 29 in Italy). They lived at home and walked independently and were screened for the absence of major cognitive deficits (dementia, aphasia, hemineglect). The patients were administered the ABILHAND questionnaire, the Brunnström upper limb motricity test, the box-and-block manual dexterity test, the Semmes-Weinstein tactile sensation test, and the Geriatric Depression Scale. The brain lesion type and site were recorded. ABILHAND results were analyzed with the use of Winsteps Rasch software.

Results—The Rasch refinement of ABILHAND led to a change from the original unimanual and bimanual 56-item, 4-level scale to a bimanual 23-item, 3-level scale. The resulting ability scale had sufficient sensitivity to be clinically useful. Rasch reliability was 0.90, and the item-difficulty hierarchy was stable across demographic and clinical subgroups. Grip strength, motricity, dexterity, and depression were significantly correlated with the ABILHAND measures.

Conclusions—The ABILHAND questionnaire results in a valid person-centered measure of manual ability in everyday activities. The stability of the item-difficulty hierarchy across different patient classes further supports the clinical application of the scale. (*Stroke*. 2001;32:1627-1634.)

Key Words: arm ■ disability evaluation ■ rehabilitation ■ stroke

Poststroke hemiplegia is one of the most prevalent forms of motor disability, affecting approximately 1% of the population.¹ Although most current stroke survivors achieve an autonomous form of gait, a satisfactory recovery (if any) of the affected upper limb function is much more rare.

Although several tests are available²⁻⁴ for measuring upper limb function in terms of grip strength, dexterity, sensation, and performance in standardized manipulative tasks, the measurements are all made at the focal impairment level.⁵ The actual disability, however, is far from linearly related to the underlying impairments.⁶ It depends on complex interactions between upper limb function and compensatory behaviors of the person, such as using the unaffected limb or dividing complex movements into simpler ones. Moreover, the learning of new motor processes is influenced by the subject's motivational and emotional status, which is likely to be impaired by stroke.⁷

Manual ability may be defined as the capacity to manage daily activities requiring the use of the upper limbs, whatever the strategies involved. Therefore, it should be measured *per se* and not simply inferred from focal impairments. Since it is a behavior, manual ability belongs to the domain of latent variables concealed within the person, such as pain, depression, and intelligence. The "amount" of manual ability can be inferred from observed activities and/or a patient's perceived difficulty⁸ in performing activities, as determined by questionnaires. A linear measure of manual ability, however, can only be properly estimated from raw scores according to measurement models,⁹ the most promising being the Rasch model.¹⁰ Provided that the behavioral data fit the model requirements, the manual ability measure for each patient is estimated via the Rasch model on a measurement "ruler" defined by the difficulty of the manual activities. Once the scale is established, it is necessary to verify that the hierarchy

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From the Rehabilitation and Physical Medicine Unit, Université catholique de Louvain, Brussels, Belgium (M.P., C.A., J-L.T.); and the Salvatore Maugeri Foundation, IRCCS, the Unità di Ricerca, Valutazione Funzionale e Verifica di Qualità in Riabilitazione (L.T.), and Divisione di Recupero e Rieducazione Funzionale (L.T., A.Z.), Pavia, Italy.

Reprint requests to Professor J-L. Thonnard, Université catholique de Louvain, Unité de réadaptation, Tour Pasteur (5375), Avenue Mounier 53, 1200 Bruxelles, Belgium. E-mail: Thonnard@read.ucl.ac.be

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of activity difficulties is the same for patients with different impairments.

The primary objective in this study was to adapt and validate the ABILHAND¹¹ scale for chronic stroke patients. The stability of item difficulty across relevant clinical subgroups was also tested. A secondary objective was the clarification of the relation between the neuromotor deficits and the resulting ABILHAND measures.

Subjects and Methods

Study Design

Five main steps were followed to achieve the study goals. First, patients were asked to answer the original ABILHAND items on a scale of 4 levels. Second, internal validity was established with the Rasch model through selection of items and response levels; this procedure also allowed the perceived difficulty of the items to be determined on a linear scale. Third, stability of item difficulty was verified by comparing 12 different groupings of the sample pool, such as male versus female and right versus left stroke. Fourth, the ranking of item difficulty was compared with expert opinions about the involvement of the affected hand in each activity. Fifth, traditional clinical assessments were used to validate the ABILHAND manual ability measurements.

Subjects: Chronic Stroke Patients

The study was authorized by the ethics committees of the Université catholique de Louvain, Faculty of Medicine in Brussels, Belgium, and the Salvatore Maugeri Foundation in Pavia, Italy. The World Health Organization definition¹² was adopted for selecting patients. This definition includes subarachnoid hemorrhage but excludes transient ischemic attacks with symptoms lasting <24 hours, subdural hemorrhage, and hemorrhage or infarction caused by infection or tumor.

Given that the data come from patients' perceptions, the study was restricted to patients who performed the listed manual activities in a domestic environment and were able to report their perceived difficulty. Patients had to meet the following criteria: have unilateral hemiplegia/paresis subsequent to a stroke that had occurred at least 6 months earlier; live at home and be independent in a domestic environment (≥ 5 of 7 on the toilet transfer and locomotion items of the Functional Independence Measure¹³); show no major visual acuity deficit (≥ 4 of 5 on the visual item of the Incapacity Status Scale¹⁴); show no major visual neglect (≥ 26 of 35 on the Bell Test¹⁵); show no major cognitive deficit (≥ 24 of 30 on the Mini-Mental State Examination¹⁶); show no major sign of aphasia (6 of 6 on the Breviario di patologia della comunicazione test¹⁷); have no upper limb sensorimotor deficits other than those related to the stroke; and be a native French or Italian speaker.

Two hundred patients from Belgium and 100 patients from Italy fulfilling the inclusion criteria were mailed a standard letter presenting the research and were contacted by telephone a few days later to verify their eligibility and agreement to participate in the study. Of the 300 potential patients, 170 were not evaluated because they had either died ($n=27$), could not be contacted by telephone ($n=88$), were noted to be ineligible for clinical reasons after the telephone interview ($n=35$), or refused to participate ($n=20$).

Testing Procedures

The 130 remaining patients were tested by one of the investigators in a clinical laboratory or at home. Functional tests were performed in 1 session lasting 60 to 90 minutes. After the evaluation, 27 patients were excluded because they failed to meet the eligibility criteria, providing a final sample of 103 patients (74 in Belgium and 29 in Italy). A summary of the final sample is provided in Table 1.

Clinical Assessment

Cerebral lesion territories were determined on the basis of a review of medical charts and neuroimaging (when available) according to

TABLE 1. Sample Description (n=103)

Sex	
Male	64
Female	39
Age, y*	63 (24–84)
Laterality before stroke	
Right	96
Left	7
Delay since stroke, mo*	38 (6–253)
Cerebral lesion territory	
Anterior cerebral artery	2
MCA	61
Large MCA territory	7
Multiple MCA territories	15
Deep MCA infarct	29
Partial superficial MCA infarct	10
Posterior cerebral artery	5
Brain stem	12
Recurrent or combined	5
CVA side	
Right brain	48
Left brain	55
Depression*	11 (0–30)
Physiotherapy	
Ongoing	49
Time since finish, mo*	22.4 (1–180)

MCA indicates middle cerebral artery.

*Mean (range).

Damasio.¹⁸ Middle cerebral artery infarcts were subclassified according to Moulin et al.¹⁹

Handedness

The patient's prestroke handedness was assessed through the Edinburgh Inventory.²⁰

Depression

Depression was assessed with the Geriatric Depression Scale²¹ (GDS). The GDS score was compensated for missing values by forcing each missing score to the average score computed on the answered items.

Manual Ability

Manual ability was assessed with ABILHAND.¹¹ ABILHAND is an inventory of 56 manual activities that the patient was originally asked to judge on a 4-level scale: 0 (impossible), 1 (very difficult), 2 (difficult), and 3 (easy). The test explores both unimanual and bimanual activities done without other human or technical help. For each question the patient provided his/her feeling of difficulty irrespective of the limb(s) actually used to do the activity. Activities not attempted in the last 3 months were not scored and were encoded as missing responses.

Upper Limb Assessment

Upper limb motricity was assessed with the upper limb subscale of the Brunström motor assessment.²² Grip strength was measured with a Jamar dynamometer according to the procedure described by Mathiowetz et al.² Tactile sensitivity on the pulp of the second finger was determined with the Semmes-Weinstein aesthesiometer accord-

ing to the procedure described by Bell-Krotoski.⁴ Manual dexterity was evaluated with the box-and-block test.³ Grip strength, tactile sensitivity, and manual dexterity were evaluated on both hands, starting with the unaffected one.

Data Analysis

Measuring Manual Ability Through the Rasch Model

The ABILHAND questionnaire was analyzed with the Winsteps Rasch analysis computer program.²³ For all items, the response categories were analyzed according to the rating scale model.²⁴ The model requires, within a probabilistic framework, that the patient's response to an item depends solely on the ability of the patient and the difficulty of the response categories (computed as the sum of the item difficulty and the threshold difficulties that separate each pair of successive responses). On the basis of the estimated ability of the patient and 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 2 fit mean-square statistics: (1) the outlier-sensitive fit statistic (OUTFIT) and (2) the information-weighted fit statistic (INFIT).²⁴ The point-measure correlation coefficient (RPM) indicates the coherence of each item within the whole questionnaire. It is computed as the correlation coefficient between all patients' responses to an item and their measures on the overall questionnaire. These indicators were used to refine the original ABILHAND scale specifically for chronic stroke patients.

Determining the Stability of the Scale Through Differential Item Functioning Tests

Once satisfactory metric properties were achieved, the invariance in the item difficulty hierarchy among patient subgroups (eg, men versus women) was tested.^{23,25} Twelve differential item functioning (DIF) subgroups were formed on the basis of the following criteria: (1) sex (male versus female); (2) country (Belgium versus Italy); (3) age (<60 versus ≥60 years); (4) affected side (dominant versus nondominant); (5) delay since cerebrovascular accident (CVA) (<2 versus ≥2 years); (6) level of depression (<10 versus ≥10, where 10 is the upper limit of the normal range according to Brink et al²¹); (7) dexterity of the unaffected upper limb (less versus more dexterity, split on the median score); (8) manual ability (less versus more able, split on the median manual ability measure); (9, 10, 11) grip strength, dexterity, sensitivity of the affected upper limb (less versus more deficit, computed as the difference between affected and unaffected side, split on the median difference); and (12) motricity of the affected upper limb (less versus more motricity, split on the median motricity score).

Content Validation

To validate the difficulty hierarchy of the bimanual activities, 4 occupational therapists were independently asked to classify each item according to the involvement of the affected hand in the activity. All bimanual activities were classified as either (1) not requiring the affected limb, if broken down into several unimanual sequences (A); (2) requiring the affected limb to stabilize an object, but not involving any finger on the affected side (B); or (3) requiring precision grip, grip strength, dexterity, or any digital activity from the affected side (C).

Standardizing Measures of Upper Limb Impairment

Grip strength, manual dexterity, and tactile sensitivity scores were z-transformed with respect to normative data available in the literature^{3,26} or unpublished norms established in our laboratory (for sensitivity). This procedure accounts for sex, age, and handedness and allows the results of all tests, on either limb, to be expressed on a common scale. A z score range between -2 and 2 was considered not significantly different from normal.

Construct Validation: Comparison of ABILHAND Measures Across Demographic and Clinical Subgroups

The relationship between ABILHAND and demographic and clinical indicators was tested with either univariate ANOVA (for nominal

predictors) or correlation coefficients (for continuous predictors). The number of records available precluded a formal multivariate approach, although an exploratory classification was attempted by relating ABILHAND measures to combinations of impairments on the affected side. Patients with z scores <-1 on the affected side were classified as poor performers for grip strength, manual dexterity, or tactile sensitivity. Patients with Brunnström test scores <75% of full scale (ie, 67 of 90) were classified as poor performers for upper limb motricity. The effects of combinations of impairments were tested with ANOVA.

Results

ABILHAND Refinements Made Specifically for Chronic Stroke Patients

Patients were unable to discriminate 4 levels of difficulty in manual activities. Although the 4 possible answers (impossible, very difficult, difficult, and easy) were shown to define increasing levels of difficulty, the second answer was too rarely observed for patients presenting the ability to select this category. This indicated that the 2 intermediate categories were not distinct enough to be differentiated by the patients.²⁷ Consequently, the 4 original categories were rescored as follows: 0 (impossible), 1 (any difficulty), and 2 (easy).

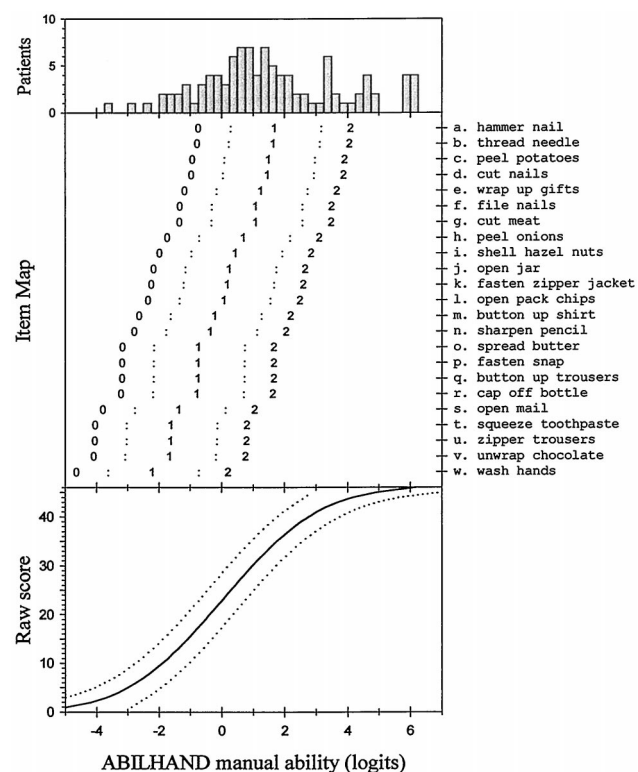


Figure 1. The structure of the ABILHAND variable is shown via the ABILHAND measure distribution (top), the relationship (bottom) between raw scores and manual ability measures (solid line) and its 95% CI (dotted lines), and the item map (middle), which provides a patient's expected score to each item (0, impossible; 1, any difficulty; 2, easy). The threshold measures between consecutive response categories are located -1.26 and 1.26 logits from the difficulty of each item. For each item, the placement of the numeric labels indicates the manual ability required for a given expected score; the colons indicate expected half-score points. A manual ability measure of zero is by convention set at the average item difficulty.

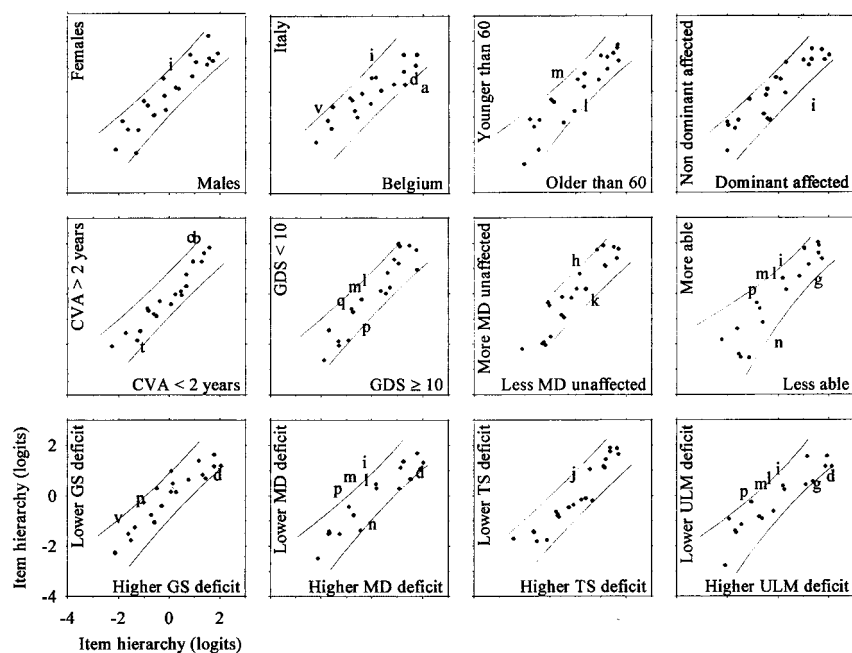


Figure 2. DIF plots of 12 different patient groupings and 95% CI (solid lines) of the ideal invariance. More difficult items are plotted in the top/right part of each plot. In each plot, items (dots) lying within the control lines have the same difficulty for both subgroups. Outliers are identified by their labels. Upper limb impairment measures include grip strength (GS), manual dexterity (MD), tactile sensitivity (TS), and upper limb motricity (ULM).

Analysis of the original 56 ABILHAND items showed that they could be divided into 2 groups: those usually realized with 1 hand (30 items) and those usually realized with 2 (26 items). Not only were unimanual activities the easiest for chronic stroke patients, but they were also the least related ($RPM < 0.50$) to the common manual ability construct (see Discussion). Therefore, only the bimanual activities were retained in the ABILHAND calibration proposed specifically for chronic stroke patients. Two “alternate unimanual” activities, cutting and filing nails, were also kept because they require the skillful use of the affected hand. Three additional items were excluded because they were not commonly practiced across the calibrating sample. All together, the calibration proposed for chronic stroke patients was established on 23 usually bimanual items.

The Final Measure of Manual Ability

Description of ABILHAND

The definition and use of the linear ABILHAND scale is shown in Figure 1. The distribution of patient measures is presented in the top panel of the figure, ranging approximately from -3.5 to 6 logits. This range indicates that the odds of success (the pass/fail ratio) of the most able patient for any given item are 13 360 times ($e^{9.5/1}$) greater than for the least able patient; this clearly illustrates the wide variety of manual ability levels encountered in this study. This measure of manual ability was obtained by converting the raw score on the 23 questionnaire items into linear logit units, as shown by the relationship presented in the bottom of the figure. The nonlinear relation between the raw score and ABILHAND measures results in greater ability discrimination in the central scoring range. At any given ability level, a 1-logit difference between 2 patients indicates that their odds of successful achievement of any activity are 2.7:1 ($e^{1/1}$), 2 logits results in 7.4:1 odds, and 3 logits results in $>20:1$ odds.

As shown in the item map (Figure 1, middle panel), the greater the difference between a patient’s ability and the average difficulty for any given item, the more likely is a higher score. For instance, being able to easily spread butter on a slice of bread requires a measure of at least 0.73 logits, while any patient less able than -2.16 logits would be expected to report this activity as impossible. As measured by ABILHAND, chronic stroke patients report a relatively high manual ability. Patients with measures >0.28 logits (75 of 103) report that they can successfully perform all the listed activities, although with some difficulty on the most difficult ones. Furthermore, patients with measures >3.17 logits (26 of 103) report that they can perform all the listed activities easily. This suggests that the scale has the potential to measure more severely disabled patients.

Differential Item Functioning

The difficulty hierarchy of ABILHAND appears to be uniformly perceived by chronic stroke patients. The patients were divided into 2 groups on the basis of 12 different criteria such as sex or age, and the 2 groups’ perceptions of each item’s difficulty are plotted one against the other in the 12 panels of Figure 2. Since the majority of items lie within the 95% CI of the identity line, the perceptions appear to be group independent. There are exceptions; for instance, “shelling hazel nuts” appears to be more difficult for women than for men, while “tearing open a pack of chips” appears to be more difficult for patients older than 60 years than for younger patients.

Metric Properties of ABILHAND

The measure of perceived difficulty for the 23 retained bimanual items is presented in Table 2. The items are sorted, from top to bottom, in order of decreasing difficulty (range, 1.72 to -2.18 logits), with higher logit values indicating more difficult activities. The table also gives the standard error of the item difficulty estimates. Overall, the 23 items fit

TABLE 2. ABILHAND Calibration for Chronic Stroke Patients

Items	Difficulty, Logits	SE, Logits	INFIT* Mean Square	OUTFIT*, Mean Square	RPM	Bimanual Involvement
a. Hammering a nail	1.72	0.23	0.92	0.96	0.77	C
b. Threading a needle	1.68	0.24	1.09	1.07	0.75	C
c. Peeling potatoes with a knife	1.53	0.25	1.00	0.99	0.77	C
d. Cutting one's nails	1.49	0.21	0.99	0.96	0.77	C
e. Wrapping up gifts	1.28	0.26	0.86	0.78	0.77	C
f. Filing one's nails	1.12	0.23	1.16	1.22	0.70	C
g. Cutting meat	1.11	0.20	0.69	0.64	0.83	C
h. Peeling onions	0.73	0.26	1.12	1.00	0.71	C
i. Shelling hazel nuts	0.47	0.25	1.33	1.44	0.66	C
j. Opening a screw-topped jar	0.28	0.21	0.91	1.03	0.68	C
k. Fastening the zipper of a jacket	0.22	0.21	0.98	1.09	0.70	B
l. Tearing open a pack of chips	0.11	0.21	1.22	1.07	0.65	C
m. Buttoning up a shirt	−0.18	0.21	1.16	1.64	0.53	A
n. Sharpening a pencil	−0.33	0.28	0.65	0.51	0.74	C
o. Spreading butter on a slice of bread	−0.71	0.24	0.91	0.76	0.59	B
p. Fastening a snap (eg, jacket, bag)	−0.72	0.23	1.10	1.26	0.55	A
q. Buttoning up trousers	−0.72	0.23	0.95	0.75	0.65	B
r. Taking the cap off a bottle	−0.75	0.23	1.01	1.14	0.58	B
s. Opening mail	−1.33	0.25	0.89	0.92	0.59	B
t. Squeezing toothpaste on a toothbrush	−1.58	0.25	0.98	0.74	0.53	A
u. Pulling up the zipper of trousers	−1.59	0.25	1.11	0.90	0.52	A
v. Unwrapping a chocolate bar	−1.63	0.25	1.04	0.75	0.57	A
w. Washing one's hands	−2.18	0.27	0.82	0.73	0.55	A

A indicates breakable into unimanual sequences; B, require stabilization with the affected limb; C, require digital activity from the affected side.

*Acceptable values are 0.80 to 1.20 for INFIT and 0.41 to 1.59 for OUTFIT.

the Rasch model, according to the acceptable range of fit statistics proposed by Smith et al.²⁸ Therefore, the 23 items define a common continuum of manual ability. All RPM are positive, indicating that all items are coherent with the overall questionnaire and contribute to the measurement of manual ability.

The least measurable difference²⁵ (the difference in linear measure obtained by a unit increase in raw score) is equal to 0.13 logits in the center of the scale. This indicates that in the central range, the scale resolution is sufficient to differentiate the ability of 2 subjects if one has 50% probability to pass a given item and the other 47%. The overall scale precision is summarized by a good person separation reliability of 0.90 in

this sample. It appears sufficient to discriminate across patients and, presumably, to capture even subtle functional changes with time.

Content Validation

The opinions of the 4 experts concerning limb involvement in each activity were consistent. The most frequently reported opinion is presented for each item in the last column in Table 2. It appears that the activities that define the more difficult levels of the scale also tend to require a higher involvement of the affected limb (C), while the easier activities can be achieved in a movement sequence that does not require the affected limb (A).

TABLE 3. Upper Limb Impairments

	Unaffected Limb		Affected Limb	
	Median	IQR	Median	IQR
Upper limb motricity (range, 0–90)	...	...	57	31 to 79
Grip strength (z score)	−0.03	−0.59 to 0.72	−1.72*	−3.23 to 0.61
Tactile sensitivity (z score)	−1.04	−1.27 to 0.58	−1.04	−2.00 to 0.58
Manual dexterity (z score)	−1.85	−2.69 to 1.07	−4.19*	−7.02 to −2.92

IQR indicates Interquartile range.

*Significant difference between affected and unaffected limb ($P<0.001$).

TABLE 4. Relationship of Variables to Manual Ability

Variable	Statistic*	P
Country	$U=1069$	0.977
Sex	$U=1213.5$	0.815
Age	$R=-0.188$	0.058
Side affected	$U=1181.5$	0.350
Cerebral lesion territory	$H=9.744, df=7$	0.204
Depression	$\rho=-0.213$	0.030
Delay since CVA	$R=-0.049$	0.626
Delay since end of physiotherapy	$R=0.180$	0.074
Unaffected upper limb		
Grip strength	$R=0.242$	0.014
Tactile sensitivity	$R=0.021$	0.836
Manual dexterity	$R=0.248$	0.012
Paretic upper limb		
Grip strength	$R=0.562$	<0.001
Tactile sensitivity	$R=0.127$	0.201
Manual dexterity	$R=0.598$	<0.001
Upper limb motricity	$\rho=0.730$	<0.001
Impairment combinations on paretic limb	$H=48.221, df=4$	<0.001

*Reported statistics are as follows: U for Mann-Whitney test, H for Kruskal-Wallis tests, ρ for Spearman correlations, and R for Pearson correlations.

Construct Validation

Description of Upper Limb Impairments

Both grip strength and tactile sensitivity were in the normal range on the unaffected limb, although manual dexterity was significantly impaired in 47 of the 103 patients (Table 3). On the affected limb, the patients showed a wide variety of motricity impairment. For all impairments on the affected side, the scores were more spread than on the unaffected side, reinforcing the impairment heterogeneity observed in motricity. A Wilcoxon signed rank test showed a significant difference between the affected and unaffected side in both grip strength and manual dexterity.

Relationship of ABILHAND Measures to Other Clinical Indicators

The effects of demographic and clinical variables on ABILHAND measures are presented in Table 4. Through univariate tests, no significant differences in ABILHAND measures were observed across demographic indexes (country, sex, and age). Tactile sensitivity in either upper limb, the side affected, or the cerebral lesion site was not significantly related to ABILHAND measures. Grip strength and manual dexterity were slightly but significantly related to ABILHAND measures in the unaffected limb. ABILHAND measures were significantly related both to individual motor impairments and to cumulative motor impairments on the affected side. Depression was also significantly related to ABILHAND measures.

Influence of Interacting Impairments on ABILHAND Measures

The effect of combined motor impairments on ABILHAND measures is illustrated in Figure 3. In the entire sample, the 2

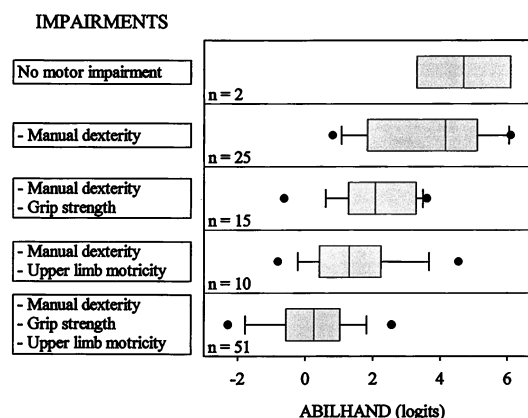


Figure 3. Box plots showing the ABILHAND measures distributions for all 5 different combinations of motor impairments, as noted on the ordinate. Solid dots indicate the 5% and 95% outliers; vertical bars indicate the 10% and 90% limits; the box indicates the 25% and 75% limits; and the vertical line in the box indicates the median of the distribution in the overall sample of 103 patients.

patients without motor impairments on the affected side had the highest manual ability (top row). Twenty-five patients with poor manual dexterity (z score <-1) and normal performance on other upper limb functions presented slightly reduced ABILHAND measures (second row). From top to bottom, more complex observed combinations of impairments on the affected side led to higher disability in manual activities. The 51 patients with poor performance in dexterity, grip strength, and motricity on the affected upper limb (bottom row) had a median ABILHAND measure of approximately 0 logits, corresponding to the average item difficulty. Tactile sensitivity was found to have little interaction with the other motor impairments on the affected side, since if it were included in the groups shown in Figure 3, it had no effect on their hierarchy.

Discussion

Patient's Reported Manual Ability in Chronic Stroke

The primary focus of this study was the validation of ABILHAND as a measure of manual ability in chronic stroke patients. The original questionnaire included both unimanual and bimanual activities of daily life needing manual skills for successful completion.¹¹ Analysis of the original questionnaire showed that the unimanual activities were too easy to be able to discriminate manual ability in chronic stroke patients; the patients reported they could fulfill the activities using the unaffected limb, whether dominant or nondominant. In contrast, the bimanual (or alternate unimanual) activities were shown to be more demanding and capable of discriminating the patients' manual ability. These observations were reinforced by the low coherence between the scores for the unimanual activities and the other responses in the questionnaire (RPM ranging from 0.10 to 0.49). Moreover, a significant difference in INFIT ($P<0.001$, t test) revealed a subtle but systematic difference in the patients' perceived difficulty in unimanual versus bimanual activities. ABILHAND was clearly able to measure a patient's adaptation, several months

after stroke, to managing bimanual activities that by definition require the use of the affected hand.

According to the aforementioned considerations, only the bimanual activities were retained for the validation of ABILHAND in chronic stroke. The fit statistics reported in the final analysis indicate that, overall, bimanual activities are tightly focused on the recovery of manual ability in chronic stroke. This coherence of ABILHAND was obtained by asking the patient's perception of an activity's difficulty, independent of the limb used or strategy adopted. Only the items "shelling hazel nuts" (item i), "tearing open a pack of chips" (item l), and "buttoning up a shirt" (item m) showed inflated fit statistics, indicating a minor inconsistency in the difficulty experienced by patients of different ability. This inconsistency may be because these activities can be done either bimanually or unimanually. Nevertheless, the observed item hierarchy in our sample makes clinical sense because activities requiring a higher bimanual involvement were estimated to be more difficult. This hierarchy appears to match the learning-based pattern of motor recovery after stroke and suggests that rehabilitation in chronic stages should focus on learning adaptive processes either through the more difficult bimanual activities or through the forced use of the affected limb.²⁹

The observed stability in the item hierarchy across the different groups of patients supports the clinical application of the ABILHAND scale as a measure of manual ability in chronic stroke patients. However, since this validation study investigated a highly selected sample of stroke patients, further research is needed to verify that the item hierarchy remains stable both among a more general population of stroke patients and along the process of rehabilitation.

A potential limitation of the ABILHAND scale lies in the subjective nature of patients' reports, which restricts its application to patients without severe cognitive deficits. In addition, self-reported scores are prone to overestimation or underestimation of actual performances, depending on either motivation and/or cognitive skills. Nevertheless, self-estimated measures of disability have many advantages. First, they explore activities that are very meaningful to the patient in real-life contexts yet very hard to reproduce in a laboratory environment. Second, the self-estimated measures can capture a sort of weighted average of the performance across long time periods, which is not the case for most observational tests. This "average" has more chance of representing the overall impact of the disability on the burden of care required and the patient's quality of life.³⁰

Relationship Between ABILHAND and Clinical Presentation

The analysis of the relationship between neuromotor performance and the resulting ABILHAND measure appears not only as a form of validation of ABILHAND but also as a clinical end point in itself. The upper limb impairments measured in this study confirm previous reports of functional deficits in chronic stroke patients on both the unaffected^{31,32} and the affected sides.³³ This study confirms that grip strength and manual dexterity were significantly impaired on the affected side. On the unaffected side, only manual dexterity

appeared to be significantly impaired (z score < -2) in 47 of 103 patients. However, both dexterity and grip strength were significantly correlated to manual ability on the unaffected side. The impact of mild motor impairments of the unaffected limb on manual ability, anticipated in other studies,^{31,32,34} fits very well with the required bimanual involvement of the ABILHAND activities.

The lack of a significant relationship between the side (dominant/nondominant) affected and manual ability also confirms previous reports.^{31,35} No significant changes in ABILHAND measures were found as a function of the lesion location, width, and depth. This finding can be explained by (1) the chronicity of the lesion, allowing time for neural repair, either intrinsic or adaptive; (2) the exclusion of subjects with major cognitive deficits³⁶; and (3) the small number of cases representing each different type of brain damage, resulting in a low power to detect any difference. Nevertheless, the lack of a strong relationship between manual disability and specific brain lesions argues in favor of ABILHAND being focused on the behavioral learning of new motor processes through compensatory strategies, irrespective of the underlying impairments. Further evidence can be found in the insignificant impact of the delay since the CVA or the end of physiotherapy. This may also be explained by the selection criteria restricting participation in this study to chronic stroke survivors living at home. Hence, the patients investigated here had experience performing most of the listed activities and had already developed, at least to some degree, new motor strategies to independently cope with their domestic environment; this would not be the situation in acute cases.

The most influential determinants of ABILHAND measures in this study are depression and motor deficits (particularly on the affected side). While manual ability can profit from any compensation strategy, it will suffer from any failure in the underlying neuromotor functions and/or in the patient's motivation to compensate for the failure itself. Moreover, depression might affect the reported ABILHAND measure either through a patient's motivation or self-judgment of the reported difficulty. The relationship between manual ability and brain lesions, motor impairments, cognitive impairments, and age certainly needs further investigation. Because of the limited number of cases involved in this study, a multivariate analysis could not be validly attempted, yet a clear tendency toward a cumulative impact of motor impairments on ABILHAND measures was detected. Some recent studies have reported a weak relationship between sensory motor impairment and manual activities of daily life.^{31,37,38}

ABILHAND was not tested for sensitivity to a change in patients' status, such as before and after rehabilitation. The stability in item hierarchy across different patient subgroups suggests that the hierarchy very well may also be maintained across time and treatment. If the hierarchy is also maintained along time, this scale will provide both a valid outcome measure and a detailed guideline for goal setting in treatment planning, complementary to the available measures of focal impairments.

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References

- Hankey GJ. Stroke: how large a public health problem, and how can the neurologist help? *Arch Neurol*. 1999;56:748–754.
- Mathiowetz V, Weber K, Volland G, Kashman N. Reliability and validity of pinch and grip strength evaluations. *J Hand Surg*. 1984;9A:222–226.
- Mathiowetz V, Volland G, Kashman N, Weber K. Adult norms for the box and block test of manual dexterity. *Am J Occup Ther*. 1985;39:386–391.
- Bell-Krotoski JA. Light touch–deep pressure testing using Semmes-Weinstein monofilaments. In: Hunter JM, Schneider LH, Mackin EJ, Callahan AD, eds. *Rehabilitation of the Hand: Surgery and Therapy*. St Louis, Mo: Mosby Co; 1990:585–593.
- World Health Organization. *International Classification of Impairments, Disabilities, and Handicaps*. Geneva, Switzerland: WHO; 1980.
- 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;79:329–335.
- Wade DT. Epidemiology of disabling neurological disease: how and why does disability occur? *J Neurol Neurosurg Psychiatry*. 1997;63:S11–S18.
- Grimby G, Andren E, Daving Y, Wright B. Dependence and perceived difficulty in daily activities in community-living stroke survivors 2 years after stroke: a study of instrumental structures. *Stroke*. 1998;29:1843–1849.
- Wright BD, Linacre JM. Observations are always ordinal; measurement, however, must be interval. *Arch Phys Med Rehabil*. 1989;70:857–860.
- Rasch G. *Probabilistic Models for Some Intelligence and Attainment Tests*. Chicago, Ill: Mesa Press; 1980.
- Penta M, Thonnard J-L, Tesio L. ABILHAND: a Rasch-built measure of manual ability. *Arch Phys Med Rehabil*. 1998;79:1038–1042.
- World Health Organization. *Control of Stroke in the Community: Methodological Considerations and Protocol of WHO Stroke Register*. Geneva, Switzerland: WHO; 1973.
- Guide for the Uniform Data Set for Medical Rehabilitation (Including the FIM™ Instrument)*, version 5.1. Buffalo, NY: University of Buffalo; 1997.
- Kurtzke JF. Disability rating scales in multiple sclerosis. *Ann NY Acad Sci*. 1984;436:347–360.
- Gauthier L, Dehaut F, Joannette Y. The Bells test: a quantitative and qualitative test for visual neglect. *Int J Clin Neuropsychol*. 1989;11:49–54.
- Folstein MF, Folstein SE, McHugh PR. Mini-Mental State: a practical method for grading the cognitive state of patients for the clinician. *J Psychiatr Res*. 1975;12:189–198.
- Schindler O. *Breviario di patologia della comunicazione (Handbook of Communication Disorders)*. Turin, Italy: Omega Edizioni; 1998.
- Damasio H. A computed tomographic guide to the identification of cerebral vascular territories. *Arch Neurol*. 1983;40:138–142.
- Moulin T, Cattin F, Crépin-Leblond T, Tatu L, Chavot D, Piotin M, Viel JF, Rumbach L, Bonneville JF. Early CT signs in acute middle cerebral artery infarction: predictive value for subsequent infarct locations and outcome. *Neurology*. 1996;47:366–375.
- Oldfield RC. The assessment and analysis of handedness: the Edinburgh Inventory. *Neuropsychologia*. 1971;9:97–113.
- Brink TL, Yesavage JA, Lum O, Heersema PH, Adey M, Rose TL. Screening tests for geriatric depression. *Clin Gerontol*. 1982;1:37–43.
- Sultana R. *La méthode de Brunnström: Bilan et techniques dans la rééducation des hémiplegiques et des traumatisés crâniens*. Paris, France: Masson; 1994.
- Linacre JM, Wright BD. *A User's Guide to Winsteps: Rasch-Model Computer Program*. Chicago, Ill: Mesa Press; 1998.
- Wright BD, Masters GN. *Rating Scale Analysis*. Chicago, Ill: Mesa Press; 1982.
- Wright BD, Stone MH. *Best Test Design*. Chicago, Ill: Mesa Press; 1979.
- Mathiowetz V, Kashman N, Volland G, Weber K, Dowe M, Rogers S. Grip and pinch strength: normative data for adults. *Arch Phys Med Rehabil*. 1985;66:69–74.
- Andrich D. Category ordering and their utility. *Rasch Meas Transact*. 1996;9:464–465.
- Smith RM, Schumacker RE, Bush MJ. Using item mean squares to evaluate fit to the Rasch model. *J Outcome Meas*. 1998;2:66–78.
- Van der Lee JH, Wagenaar RC, Lankhorst GJ, Vogelaar TW, Devillé WL, Bouter LM. Forced use of the upper extremity in chronic stroke patients: results from a single-blind randomized clinical trial. *Stroke*. 1999;30:2369–2375.
- Lusardi MM, Smith EV. Development of a scale to assess concern about falling and applications to treatment programs. *J Outcome Meas*. 1997;1:34–55.
- Desrosiers J, Bourbonnais D, Bravo G, Roy P-M, Guay M. Performance of the “unaffected” upper extremity of elderly stroke patients. *Stroke*. 1996;27:1564–1570.
- Sunderland A. Recovery of ipsilateral dexterity after stroke. *Stroke*. 2000;31:430–433.
- Boissy P, Bourbonnais D, Carloti MM, Gravel D, Arseneault BA. Maximal grip force in chronic stroke subjects and its relationship to global upper extremity function. *Clin Rehab*. 1999;13:354–362.
- Yelnik A, Bonan I, Debray M, Lo E, Gelbert F, Bussel B. Changes in the execution of a complex manual task after ipsilateral ischemic cerebral hemispheric stroke. *Arch Phys Med Rehabil*. 1996;77:806–810.
- Bernspang B, Fisher AG. Differences between persons with right or left cerebral vascular accident on the assessment of motor and process skills. *Arch Phys Med Rehabil*. 1995;76:1144–1151.
- Sunderland A, Bowers M, Sluman S-M, Wilcock DJ, Ardron ME. Impaired dexterity of the ipsilateral hand after stroke and the relationship to cognitive deficit. *Stroke*. 1999;30:949–955.
- Sonoda N, Chino N, Domen K, Saitoh E. Changes in impairment and disability from the third to the sixth month after stroke and its relationship evaluated by an artificial neural network. *Am J Phys Med Rehabil*. 1997;76:395–400.
- Kopp B, Kunkel A, Flor H, Platz T, Rose U, Mauritz K-H, Gresser K, McCulloch KL, Taub E. The arm motor ability test: reliability, validity, and sensitivity to change of an instrument for assessing disabilities in activities of daily living. *Arch Phys Med Rehabil*. 1997;78:615–620.