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A new scale for the assessment of performance and capacity of hand function in children with hemiplegic cerebral palsy: reliability and validity studies

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***Background*. In hemiplegic children, the recognition of the activity limitation pattern and the possibility of grading its severity are relevant for clinicians while planning interventions, monitoring results, predicting outcomes.**

***Objective*. Aim of the study is to examine the reliabil-**

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ity and validity of Besta Scale, an instrument used to measure in hemiplegic children from 18 months to 12 years of age both grasp on request (capacity) and spontaneous use of upper limb (performance) in bimanual play activities and in ADL.

***Design*. Psychometric analysis of reliability and of validity of the Besta scale was performed.**

***Setting*. Outpatient study sample**

***Methods*. Reliability study: A sample of 39 patients was enrolled. The administration of Besta scale was video-recorded in a standardized manner. All videos were scored by 20 independent raters on subsequent viewing. 3 raters randomly selected from the 20-raters group rescored the same video two years later for intra-rater reliability. Intra and inter-rater reliability were calculated using Intraclass Correlation Coefficient (ICC) and Kendall's coefficient (K), respectively. Internal consistency reliability was assessed using Alpha's Chronbach coefficient. Validity study: a sample of 105 children was assessed 5 times (at t_0 and 2, 3, 6 and 12 months later) by 20 independent raters. Each patient underwent at the same time to QUEST and Besta scale administration and assessment. Criterion validity was calculated using rho-Pearson coefficient.**

***Results*. Reliability study: The inter-rater reliability calculated with Kendall's coefficient resulted moderate K=0.47. The intra-rater (or test-retest) reliability for 3 raters was excellent (ICC=0.927). The Cronbach's alpha for internal consistency was 0.972. Validity study: Besta scale showed a good criterion validity compared to QUEST increasing by age and severity of impairment. Rho Pearson's correlation coefficient r was 0.81 (P<0.0001).**

***Limitations*. Besta scales in infants finds hard to distinguish between mild to moderately impaired hand function.**

***Conclusions*. Besta scale scoring system is a valid and reliable tool, utilizable in a clinical setting to monitor evolution of unimanual and bimanual manipulation and to distinguish hand's capacity from performance.**

KEY WORDS: upper limb function; hemiplegic cerebral palsy; validity; reliability; Besta scale.

Hemiplegic cerebral palsy represents one of the causes of disability in children due to a neurologic motor and sensory impairment. It is caused mostly by an early brain damage occurred both in prenatal and perinatal period, and it results in an upper and lower limb dysfunction.[1] The recognition of the pattern of activity limitation and the possibility of grading its severity are relevant for the clinician while planning rehabilitative interventions, monitoring the results of treatment, and predicting outcomes.

An assessment scale specifically designed for hand impairment in paediatric populations is crucial. This scale should take into account and measure impairment severity, and also the impact of the disability on child development and functioning, aspects that are highly age-specific and relevant to all types of cerebral palsy.

Several instruments and rating scales are currently used to assess arm functioning in children and have been recently reviewed and compared.[2-4] In fact, some of the mostly used assessment tools such as the Melbourne unilateral upper limb (MUUL) assessment,[5, 6] the QUEST [7] and the Jebsen-Taylor [8] require the execution, in a standardized condition, of specific unimanual tasks and actions by the child (for example grasp a cube, hold a pencil, draw a circle), as requested by the therapist. These instruments are therefore measure of unimanual capacity.[2]

Furthermore, QUEST [6] scale and MUUL [4] are built to assess each hand separately. This characteristic is useful while studying the motor performance of the affected hand, but does not measure its real use in bimanual activity.[9]

Recently, a new tool for hand function assessment, the Assisting Hand Assessment (AHA) [10] (and more recently its infant version Mini-AHA [11, 12]), was developed to measure how effectively the involved hand is used for bimanual activity. It is based on observations of actions performed in relevant activities and is meant to reflect the child's usual performance. The rating scale categories are graded in a scale of effectiveness (4=effective, 3=somewhat effective, 2=ineffective, 1=does not do). The activities proposed deal with play session actions in order to assess paretic hand use in bimanual activities, and therefore the AHA is a performance based measure.[2]

To our knowledge, none of the assessment tools currently available evaluates the spontaneous use of the impaired hand in the child's common activities of daily living (ADL). The hand use in ADL is generally assessed by using questionnaires filled in by the parents,[13] such as the Pediatric-Motor Activity Log (P-MAL) [14] and the ABILHAND-kids.[15] However, the parents' judgment of their child's hand use could be influenced by several variables and could not always express an objective measure of hand function.

Another major reason of complaint is that most of the hand function measures are mainly designed for children older than 5 years, being very difficult to apply in populations of preschool children.

Finally, from a clinical point of view, the assessment of hand function in hemiplegic children consists in evaluating the presence and the amount of developmental disregard. According to Taub,[16] this means the difference between a measure of what a person can do when asked to do the best (capacity) and a measure of what a person actually does spontaneously in a real-world situation (performance). Not considering such evaluation, the clinicians may risk to draw a distortion of the child's abilities looking only at what he/she does on request in a standardized setting and not at what he/she is actually able to do spontaneously. In fact, as demonstrated in a prospective study on 31 children with hemiplegic cerebral palsy carried out in our Developmental Neurology Unit [17] in 2003, grasp assessment on request resulted insufficient to evaluate the real disability of the affected hand, and, for meaningful clinical assessment of hand function and disability, the authors underlined the usefulness of an instrument assessing spontaneous hand use in bilateral manipulation during play and ADL. This study employed a pilot version of a new assessment tool, the Besta scale, which was composed by two sections: one assessing the grasp function on request (capacity) and one the spontaneous hand use in bimanual activities (performance). In fact, in each follow-up assessment session from the age of 4 to the age of 12, the hemiplegic children showed better scores in grasp function on request than in spontaneous hand use, and that was attributed to the developmental disregard.

The problem to quantify the developmental disregard has been taken into consideration very recently. Sutcliffe [18] introduced a quantification criteria by calculating the differences between the baseline score of QUEST and the Pediatric Motor Activity Log score, which represents the amount of typical use of the hemiplegic hand. However the two assessment tools of hand function are very different, the first measuring the hand function directly, the second assessing the hand use using a questionnaire filled out by parents: therefore the difference among the two scores is quite questionable. Aarts *et al.*[19] assessed developmental disregard with a Video Observations tool (VOAA) and the VOAA-Revised,[20, 21] measuring the duration and frequency of the spontaneous use of the affected hand during two selected activities, one demanding the use of both hands (beads task) and the other stimulating, but not demanding, the use of both hands (muffin task). The difference in the duration of upper-limb use between the two tasks represents the developmental disregard. This approach is very interesting, although presents some limitations: in fact, both tasks are subdivided in other subtasks and this makes the test complex and difficult to accomplish for younger, severely impaired or children with mental retardation.

Considering the need of a hand function measure tool, suitable for children affected by hemiplegia aged from 18 months to 12 years and able to assess both capacity and performance, the Besta scale was further developed and improved and recently employed in a multisite clinical trial assessing the role of intensive training on hand function.[15]

The aim of this paper was to present two studies analyzing the reliability and the validity of Besta Scale using two samples of children with hemiplegic cerebral palsy aged between 18 months and 12 years.

Materials and methods

Development of the scale

The Besta Scale is an instrument that was developed in 1985 at the Developmental Neurology Division of the Istituto Neurologico Nazionale (Italian National Neurological Institute) "Carlo Besta" in Milan, to assess in children affected by Hemiplegic cerebral Palsy the quality of grasp (hand function on request) and the spontaneous hand use (bilateral manipulation), and their changes in relation to age and degree of impairment. The first version of this assessment protocol, composed by two sections one assessing the grasp function on request and the other the hand spontaneous use in play, was described in 1986, in a study in which clinical characteristics were analyzed in relation to etiological factors and computed tomography findings in 30 children with congenital hemiplegia.[22] After modification regarding the score system of hand spontaneous use, which has been based on the Touwen concept of stereotypy and variability of movement, the instrument was used in a prospective study to evaluate changes in hand impairment and bilateral manipulation skills over time.[23] To assess the inter-rater reliability of these instruments a pilot study [15] was conducted in 2003 on 15 children with congeni-

tal hemiplegia younger than 7 years and 15 children with congenital hemiplegia older than 7 years. The videotapes of grasp assessment and bilateral manipulation activity assessment for each child were scored by three observers (an occupational therapist, a paediatric neurologist, and a medical student), and the K statistic was calculated. Interobserver agreement of grasp scores was excellent (K=0.95). For bilateral manipulation scores the agreement was also good to excellent, with K ranging from 0.75 to 0.89 for the assessment of younger children and from 0.69 to 0.90 for children over 7 years of age.

The final version of the Besta Scale has been further on modified. The play proposal for the assessment of the hand spontaneous use during bilateral manipulation have been standardized in relation to age range (4 tasks for each age class) and to play material (that necessarily involved both hands use). Moreover, a new section assessing the spontaneous hand use in ADL, as self-care activities where the use of both hands is needed, were added and standardized by age.

The Besta scale is reported in Annex 1 and it is articulated in two sections: grasp (A) and spontaneous use in play (B) and in ADL (C)].

Section A: grasp assessment

It is performed in a standardized setting asking the child to pick up different sized cubes and a marble on request. The child sits in a chair at a table adjusted to his or her height. The three cubes of different sizes (side measurements 4, 2.5, and 1 cm) and the marble are placed on the table and the child is asked to pick up the objects first with the unaffected hand and then with the impaired hand. There is no time limit.

The quality of grasp is scored in a hierarchical way (from 0 to 3). The scoring system is defined as follows:

— Score 0: grasp absent
— Score 1: palmar grasp
— Score 2: whole-hand, radial or three-finger grasp
— Score 3: pincer grasp

Examples are shown in Figure 1.

Section B: spontaneous use

It is assessed during structured activities requiring both hands and the equipment is standardized by age, as shown in Appendix 1. For example, for children aged 25-36 months the tasks are to throw a large ball, to tear a sheet of paper into many pieces, to uncork a bottle closed with a pop-up plug. Children over the age of 7 years are asked to open a packet tied up with string in a single knot, to wrap an object in paper forming a parcel, to cut out geometrical figures and stick them onto a sheet of paper, and to fold a piece of paper and place it in an envelope. The scoring system for the quality of manipulation is based on variability and stereotypy of movement pattern,[24] and is scored in a hierarchical way (from 0 to 3):

— score 0: no use of impaired limb;
— score 1: use of impaired limb (not hand) in a stereotyped pattern (wrist support) for holding;
— score 2: cooperation of the impaired hand by holding with a restricted number of stereotyped patterns;

Figure 1.—Palmar grasp (A), whole-hand, radial or three-finger grasp (B) and pincer grasp (C).

— score 3: cooperation of the impaired hand by holding and manipulation, using a varied repertoire of patterns.

The item score is assigned when the child has involved the impaired hand in the task performance at least two or three times (usual performance) and it is not assigned when the hand is involved only once (best performance).

Section C: activities of daily living

Several activities of self-care and autonomy requiring both hands are assessed; the activity types are standardized by age according to the Griffiths Mental Development Scales (Appendix 1), with age classes >18 months, >2 years, >3 years, >6 years, >7 years. The scoring system for the assessment of spontaneous hand use in ADL is the same of the previous section B.

The whole scale performance is video-recorded and scored on subsequent viewing.

Population

Reliability study

A sample of 39 patients was recruited and the Besta scale was administered and videorecorded (one video per each patient). The administration videorecording was performed on a standardized protocol basis. For each patient, information was collected on age, sex, side of the hemiplegia, and severity of impairment (Table I).

Each video was scored by 20 independent raters participating to a national multicentre clinical trial on CIMT and intensive bimanual training, belonging to 20 different rehabilitation centers, in order to assess the inter-rater reliability, for a total amount of 780 Besta scales. Raters were tested for systematic differences.

To evaluate the intra-rater (test-retest) reliability, the same videos (39 patients) were re-scored two years later by 3 raters randomly selected from the 20-raters group.

For quality purpose, the video-recording and the tests administration were subsequently randomly reviewed and evaluated by an expert.

Validity study

To assess criterion validity and responsiveness, a sample of 105 children with hemiplegic cerebral palsy aged between 18 months and 12 years, enrolled in a multicentric clinical trial comparing different intensive training protocols (constraint therapy and bimanual training [25]), was utilized. Each of the 20 participating centres provided a trained assessor who was in charge of scoring all videos regarding patients of the centre enrolled.

During the pre, post treatment and follow up phases, the 105 children underwent 5 assessment sessions (at enrolment and after 10, 22, 34 and 62 weeks respectively), performing both QUEST and Besta Scales at each session, for a total amount of 525 Besta Scale and 525 QUEST evaluations. The tests administrations were video-recorded and subsequently randomly reviewed and scored by an expert for quality purpose.

Information on age, sex, side of the hemiplegia, and severity of impairment were collected for each patient (Table I).

Table I.—*Study samples: main characteristics.*

Reliability study	N. *(%)*
Cases	39
Sex: female	18 *(48)*
Age	
< 3	9 *(23)*
3-5	16 *(41)*
6-8	14 *(36)*
Hemiplegia: side (right)	20 *(51)*
Hemiplegia: level of severity*	
1	13 *(33)*
2	18 *(46)*
3	8 *(21)*
Validity study	**N *(%)***
Cases	105
Sex: female	42 *(40)*
Age	
< 3	32 *(30)*
3-5	48 *(46)*
6-8	25 *(24)*
Hemiplegia: side (right)	56 *(53)*
Hemiplegia: level of severity*	
1	26 *(24)*
2	45 *(43)*
3	34 *(32)*

(* for severity classes see Pacchin *et al.*[11]).

Severity classes

For both reliability and validity studies, the samples were classed by levels of severity: the severity

of upper extremity motor impairment was divided into three groups, according to the following criteria. In the first group the paretic hand manipulates without restrictions but with limitations in more advanced fine motor skills (severity 1), in the second, the paretic hand has only holding function during bimanual manipulation (severity 2) and in the third, the paretic hand has no functional ability (severity 3).

Chi squared test was utilized to verify if there was an equal distribution among the age classes and severity classes and the equal distribution was confirmed (P value=0.6622).

Raters training

For both studies, a specific training program was provided to familiarize professionals with testing procedures in order to develop a homogeneous scoring of the Besta Scale.

The assessors were equipped with a training package including: a presentation module illustrating the sections of Besta scale and describing the scoring procedures with practical video-recorded examples, which included the videos of 3 children with different levels of hemiplegia, 2 of which were scored and the third was blind (with the scoring enclosed in a sealed envelope).

During the self-training phase, several meetings with scale experts were organized for the assessors in order to discuss issues related to scoring process.

Statistical analysis

Reliability study

Patients' data were collected in a database and kept up to date using Microsoft Access® software (Microsoft Corp., Redmond, WA, USA). The statistical analysis was performed with the SAS® package, version 9.1 (SAS Institute Inc., Cary, NC, USA). Summary statistics of the overall scores are presented as mean ± SD ratings (Table II).

Inter-rater reliability.—Inter-rater reliability was assessed by Kendall's coefficient of concordance (K). Kappa statistic is used to compute estimates and tests of agreement among multiple raters when ratings are on ordinal scale.[26] Kendall's coefficient of concordance is comprised between 0 (=no agreement) and 1 (=perfect agreement) and indicates the degree of agreement according to this range: "0-0.2"=slight; "0.2-0.4"=fair; "0.4-0.6"=moderate, "0.6-0.8"=substantial, "0.8-1"=almost perfect).[27] SAS "%MAGREE macro" was utilized to compute Kendall's coefficient.[28]

Patients were stratified by age ("2-32", "4-5","6-12") and by severity of impairment ("1" mild impairment, "2" medium impairment, "3" severe impairment).

Besta scale was analyzed both item by item (23 item; range 0-3) and on the 5 global mean scores (1 overall mean score and 4 sub-sections mean scores):

— assessment on the grasp function of the paretic hand on request (4 items);

— qualitative assessment of the spontaneous use of the paretic hand in bimanual manipulatory activities (4 items);

— qualitative assessment of the use of the paretic hand in feeding and clothing ADL in children 18 months-7 years (11 items);

— qualitative assessment of the use of the paretic hand in feeding and clothing ADL in children older than 7 years (4 items).

Intra-rater (test-retest) reliability.—Intra-rater (or test-retest) reliability was used to understand how stable a rater answers was over time. Test-retest reliability was measured by the intraclass correlation coefficient (ICC). The ICC is the proportion of the total variance explained by the between-person variance. In other words, if the between-person variance is much greater than the within-person variance over the two administrations then the instrument is considered reliable over the test-retest period.[29] The ICC theoretically ranges from 0 to 1. An ICC ≥ 0.70 is considered an acceptable level of test-retest reliability.[30]

The data set included two records per patient: one record for each patient with the score at the "test" time and one record with the score at "retest" time. The ICC was calculated using a macro available from SAS support,[31] using a 95% confidence interval (CI).

Internal consistency.—Internal consistency reliability evaluates the extent to which related items measure the same concept. It is measured using Cronbach's alpha which represents the degree to which items within a scale are inter-correlated with one another. Statistically, it is based on the sum of the variances of the items divided by the variance of the scale. Cronbach's alpha typically ranges from 0 to 1. Internal-consistency reliability is usually

TABLE II.—*Besta Scale: mean raw scores and standard deviation (SD).*

	TOTAL		SEVERITY						AGE					
			1		2		3		2-3		4-5		6-12	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
*Assessment on the **grasp function** of the paretic hand on request*														
Grasp a bilia	1.99	0.8	2.54	0.5	2.08	0.4	0.95	0.9	1.74	0.8	2.04	1.0	2.06	0.6
Grasp a cube 1.5 cm	2.01	0.8	2.56	0.5	2.09	0.4	1.00	0.9	1.77	0.8	2.07	1.0	2.08	0.6
Grasp a cube 2.5 cm	1.99	0.8	2.52	0.5	2.08	0.4	0.99	0.9	1.77	0.8	2.06	1.0	2.04	0.6
Grasp a cube 4 cm	1.96	0.9	2.56	0.5	2.04	0.5	0.86	0.9	1.78	0.9	2.01	1.0	2.01	0.7
Mean score	*1.99*	*0.8*	*2.55*	*0.5*	*2.07*	*0.4*	*0.95*	*0.9*	*1.78*	*0.8*	*2.05*	*1.0*	*2.05*	*0.6*
*Qualitative assessment of the spontaneous use of the paretic hand in **bimanual manipulatory activities***														
Hold/throw a big/small ball; Unwrap a packet	1.93	0.9	2.64	0.5	1.84	0.6	0.99	0.8	1.72	0.7	1.92	1.0	2.07	0.7
Tear tissue paper; Wrap a packet	2.06	0.7	2.49	0.6	2.04	0.5	1.35	0.7	2.07	0.6	2.07	0.8	2.03	0.7
Grasp/drink from baby's bottle/bottle; uncork/fill in a bottle; Fold a sheet	1.86	0.9	2.50	0.6	1.86	0.6	0.98	0.8	1.61	0.8	1.92	0.9	1.95	0.8
Grasp a doll; unwrap a packet; paste paper shapes on the corresponding outlines	1.98	0.9	2.68	0.5	1.93	0.5	0.96	0.9	1.87	0.8	2.11	0.9	1.91	0.8
Mean score	*1.96*	*0.7*	*2.57*	*0.4*	*1.93*	*0.4*	*1.06*	*0.7*	*1.83*	*0.6*	*2.00*	*0.8*	*2.00*	*0.6*
*Qualitative assessment of the use of the paretic hand in feeding and clothing **ADL***														
Drink from a cup (>18 m)	1.81	1.1	2.66	0.6	1.78	0.9	0.66	0.8	1.53	1.0	1.97	1.1	1.81	1.1
Drink form a big glass (>18 m)	1.10	1.2	1.53	1.4	1.07	1.1	0.56	0.8	1.00	1.2	1.16	1.3	1.09	1.2
Slice the bread (>18 m)	1.95	0.8	2.47	0.5	2.07	0.5	1.07	0.8	1.84	0.6	1.94	0.9	2.19	0.6
Fold a napkin (> 3 yrs)	1.86	1.0	2.62	0.5	1.75	0.8	0.64	0.9	1.66	1.1	1.94	1.0	1.87	1.0
Cut with fork and knife (> 6 yrs)	2.12	0.6	2.79	0.4	1.82	0.4	1.95	0.2	.	.	.	.	2.12	0.6
Wash hands (> 2 yrs)	1.80	1.0	2.55	0.7	1.71	0.8	0.89	0.7	1.41	1.0	1.96	1.0	1.96	0.8
Wash face (> 2 yrs)	1.21	1.3	2.06	1.2	0.75	1.0	0.22	0.5	1.24	1.2	1.31	1.2	0.94	1.3
Take off the shoes (> 2 yrs)	1.10	1.2	2.17	1.1	0.73	1.0	0.25	0.7	1.00	1.2	1.24	1.2	0.89	1.3
Take off the socks (>18 m)	1.21	1.3	2.19	1.1	0.90	1.1	0.21	0.6	1.08	1.2	1.30	1.3	1.16	1.3
Take off the sweater (> 3 yrs)	1.56	1.2	2.62	0.6	1.21	0.9	0.10	0.3	1.40	1.0	1.78	1.2	1.21	1.2
Take off the trousers (> 2 yrs)	1.32	1.2	2.50	0.8	0.94	1.0	0.07	0.4	1.05	1.2	1.49	1.2	1.21	1.3
Mean score	1.49	0.9	2.35	0.5	1.33	0.6	0.52	0.5	1.26	0.8	1.63	0.9	1.45	0.9
Wear a sweater	1.94	1.0	3.00	0.2	1.79	0.7	0.39	0.5	.	.	.	.	1.94	1.0
Wear trousers	2.17	0.8	3.00	0.2	1.96	0.5	0.14	0.4	.	.	.	.	2.17	0.8
Wear socks	2.01	1.0	3.00	0.2	1.99	0.6	0.00	0.0	.	.	.	.	2.01	1.0
Wear shoes	1.75	1.1	3.00	0.2	1.56	0.8	0.00	0.0	.	.	.	.	1.75	1.1
Mean score	*1.93*	*0.9*	*3.00*	*0.2*	*1.83*	*0.5*	*0.13*	*0.2*	.	.	.	.	*1.93*	*0.9*
Global mean score	*5.43*	*2.3*	*7.34*	*1.6*	*5.41*	*1.1*	*2.44*	*1.9*	*4.66*	*1.9*	*5.52*	*2.5*	*5.82*	*2.2*

considered to be acceptable when Cronbach's alpha ≥0.70.[26] Internal consistency is relevant only for multi-item scales. Cronbach's alpha was calculated using SAS macro PROC CORR.

VALIDITY STUDY

Patients' data were collected in a database and kept up to date using Microsoft Access® software (Microsoft Corp., Redmond, WA, USA). The statistical analysis was performed with the SAS® package, version 9.1 (SAS Institute Inc., Cary, NC, USA).

Content validity.—The first version of the Besta Scale used from 1986 up to 2000 was elaborated by a paediatric neurologist and two occupational therapists for assessing the hand function on request and the spontaneous hand use in bilateral manipulation in children aged between 2 and 7 years. The grasp assessment was performed asking the child to pick up three cubes of different size and the spontaneous hand use was assessed asking the child to accomplish four simple tasks (to throw a ball, to tear a sheet of paper, to unscrew/screw up a bottle with cap, to open a packet) which required bilateral ma-

nipulation. Some years later, other four tasks suitable for children over the age of 7 years were added. The scoring system both for grasp and for spontaneous use was defined at that time in a hierarchical way as previously described.

A modification of the first version of the Scale was carried out since the year 2000. To evaluate in a specific way the pincer grasp, the grasp assessment was integrated with a new item, asking the child to pick up a marble with the impaired hand. Moreover, the setting and the equipment for the assessment of spontaneous use in bilateral manipulation have been standardized by age, defining four structured tasks every range of age from 6 months to 12 years, as shown in Annex 1. Finally, a set of item assessing the spontaneous use of the impaired hand in several ADL requiring both hands were added: the tasks have been selected and standardized by age according to the Griffiths Mental Development Scales.

Criterion validity.—The BESTA and QUEST total scores and grasp subscores (section A of Besta Scale and section B of QUEST scale) were compared. Correlation analysis was carried out using Rho Pearson's correlation analysis.

Results

Reliability study

Raw scores

The mean raw scores were calculated and are shown in Table II. These results are expressed item per item and are stratified by age and severity.

The raw mean score tends to increase with age from 2-3 years to 6-12 years and tends to decrease with the severity of hand impairment. The standard deviation (SD) is low for items of section A (grasp on request) and B (spontaneous use in bimanual activities in play), while it is higher in section C (spontaneous use in ADL).

Inter-rater reliability

Kendall's coefficient K was calculated for 20 raters for 39 patients and it resulted moderate K=0.47 (Table III). The agreement among observers was slight in grasp on request for mild impairment and for spontaneous use in bimanual activities for moderate impairment (K<0.2), while it was almost perfect in ADL for older children with mild impairment (K=0.82).

Intra-rater (test-retest) reliability

The ICC demonstrated an excellent level of intra-rater reliability with a mean value of 0.927 and a range varying from 0.971 (drink form a big glass or wash face) to 0.813 (cut with fork and knife) (Table IV).

Internal consistency

The Cronbach's alpha coefficient was 0.966 (raw) and 0.972 (standardized), demonstrating an almost perfect consistency. The coefficient range varied from a minimum of 0.969 to a maximum of 0.972.

Validity study

Criterion validity

The analyses of the study sample (105 children, 20 raters, 5 assessment sessions, 1050 evaluations) demonstrated that the Besta scale has a good criterion validity in comparison to QUEST (Figure 2). Both scales tend to a similar increase on the raw mean score by age and severity of impairment (Figures 2A, B). The interval among severity classes (1-2 and 2-3) is more regular in QUEST than in Besta Scale, where the distance between class of impairment severity 3 and 2 is greater than the one between 1 and 2 severity classes.

The Rho Pearson's correlation coefficient R was 0.81 (P<0.0001) for the global score while it was 0.71 (P<0.0001) for grasp on request (Figures 2C, D).

Discussion

This paper describes the scale development process and the reliability and validity studies of the Besta scale, an assessment tool designed to measure hand function in hemiplegic children, both on request (capacity) and in spontaneous use during play and ADL (performance).

The systematic review on upper limb activity measures for children with congenital hemiplegia recently published [1-3] underlines the need that the outcome measures address the multidimensional nature of the ICF not only by body structure and func-

TABLE III.—*Inter-rate reliability: K for Besta Scale (N.=39 patients; 20 raters).*

		SEVERITY			AGE		
ITEMS	TOTAL	1	2	3	2-3	4-5	6-12
*Assessment on the **grasp function** of the paretic hand on request*							
Grasp a marble	0.35	0.15	0.29	0.34	0.34	0.35	0.28
Grasp a cube 1.5 cm	0.43	0.11	0.44	0.49	0.26	0.49	0.34
Grasp a cube 2.5 cm	0.46	0.12	0.50	0.52	0.32	0.52	0.36
Grasp a cube 4 cm	0.45	0.11	0.51	0.53	0.35	0.49	0.33
Mean score	*0.42*	*0.12*	*0.43*	*0.47*	*0.32*	*0.46*	*0.33*
*Qualitative assessment of the spontaneous use of the paretic hand in **bimanual manipulatory activities***							
Hold/throw a big/small ball; Unwrap a packet	0.43	0.22	0.17	0.60	0.36	0.40	0.45
Tear tissue paper; Wrap a packet	0.40	0.37	0.09	0.42	0.27	0.43	0.43
Grasp/drink from baby's bottle/bottle; uncork/fill in a bottle; Fold a sheet	0.37	0.36	0.14	0.35	0.26	0.31	0.48
Grasp a doll; unwrap a packet; Paste paper shapes on the corresponding outlines	0.43	0.34	0.12	0.47	0.48	0.38	0.39
Mean score	*0.41*	*0.32*	*0.13*	*0.46*	*0.35*	*0.38*	*0.44*
*Qualitative assessment of the use of the paretic hand in feeding and clothing **ADL 18m-7yrs***							
Drink from a cup (>18 m)	0.49	0.36	0.41	0.52	0.28	0.47	0.65
Drink form a big glass (>18 m)	0.42	0.37	0.28	0.51	0.36	0.44	0.38
Slice the bread (>18 m)	0.49	0.37	0.46	0.51	0.40	0.43	0.57
Take off the socks (>18 m)	0.42	0.34	0.34	0.22	0.33	0.42	0.41
Wash hands (> 2 yrs)	0.44	0.38	0.37	0.28	0.32	0.42	0.50
Wash face (> 2 yrs)	0.46	0.38	0.44	0.29	0.47	0.46	0.34
Take off the shoes (> 2 yrs)	0.41	0.41	0.25	0.38	0.26	0.43	0.45
Take off the trousers (> 2 yrs)	0.42	0.31	0.32	0.01*	0.37	0.40	0.35
Fold a napkin (> 3 yrs)	0.53	0.40	0.50	0.71	0.52	0.49	0.57
Take off the sweater (> 3 yrs)	0.35	0.23	0.23	0.09*	0.28	0.31	0.34
Cut with fork and knife (> 6 yrs)	0.57	0.34	0.52	0.82	-	-	0.57
Mean score	*0.45*	*0.35*	*0.37*	*0.47*	*0.36*	*0.43*	*0.47*
*Qualitative assessment of the use of the paretic hand in feeding and clothing **ADL >7 yrs***							
Wear a sweater	0.52	0.79	0.28	- *	-	-	0.52
Wear trousers	0.64	0.82	0.42	- *	-	-	0.64
Wear socks	0.60	0.82	0.37	- *	-	-	0.60
Wear shoes	0.63	0.82	0.39	- *	-	-	0.63
Mean score	*0.60*	*0.82*	*0.37*	- *	-	-	*0.60*
Global mean score	*0.47*	*0.39*	*0.34*	*0.47*	*0.35*	*0.42*	*0.46*

tion, but also by activity and participation.[2] Hoare *et al.*[32] analysing the link of scored items from Melbourne Assessment, QUEST and Assisting Hand Assessment, reported that the Melbourne Assessment evaluated concept in the body function domain, the QUEST measured concepts mainly in the body function except for grasp where concept were coded in both the body function and activity domain. The only measure where the majority of items assess concepts in the activity domains was the Assisting Hand Assessment. Anyway, to obtain a complete evaluation of the body function and of the activity domain in the assessment of hand function, there is the need to administer to the child almost two or three assessment tools. The Besta Scale assessment may represents an appropriate answer to this suggestion: in fact the items concerning the grasp (section A) measure mainly the body function, while the items concerning the spontaneous use in play and in ADL (section B and C) regard the activity domain.

Besta scale is a tool which is not based on the "best performance" criterion, but on the acquired use of a certain movement pattern that has become of common use for that child, *i.e.*, not only being able to unwrap a package covered with paper once, but being commonly able to do it two or three times during test administration.

We demonstrated that Besta scale has a moderate inter-rater reliability. This result differs from the one reported in the pilot study of the scale (K=0.47

TABLE IV.—*Intra-rater (test-retest) reliability: ICC (N.=39 patients; 3 raters).*

ITEMS	TOTAL	CI 95%
*Assessment on the **grasp function** of the paretic hand on request*		
Grasp a marble	0.950	0.909 - 0.972
Grasp a cube 1.5 cm	0.944	0.896 - 0.968
Grasp a cube 2.5 cm	0.952	0.916 - 0.974
Grasp a cube 4 cm	0.916	0.842 - 0.951
*Qualitative assessment of the spontaneous use of the paretic hand in **bimanual manipulatory activities***		
Hold/throw a big/small ball; Unwrap a packet	0.939	0.886 - 0.966
Tear tissue paper; Wrap a packet	0.911	0.846 - 0.952
Grasp/drink from baby's bottle/bottle; uncork/fill in a bottle; Fold a sheet	0.850	0.723 - 0.918
Grasp a doll; unwrap a packet; Paste paper shapes on the corresponding outlines	0.946	0.904 - 0.971
*Qualitative assessment of the use of the paretic hand in feeding and clothing **ADL***		
Drink from a cup (>18 m)	0.963	0.931 - 0.982
Drink form a big glass (>18 m)	0.971	0.941 - 0.987
Slice the bread (>18 m)	0.914	0.827 - 0.958
Take off the socks (>18 m)	0.963	0.919 - 0.980
Wash hands (>2 yrs)	0.910	0.793 - 0.963
Wash face (>2 yrs)	0.971	0.927 - 0.985
Take off the shoes (>2 yrs)	0.963	0.921 - 0.980
Take off the trousers (>2 yrs)	0.969	0.924 - 0.981
Fold a napkin (>3 yrs)	0.964	0.925 - 0.984
Take off the sweater (>3 yrs)	0.900	0.787 - 0.947
Cut with fork and knife (>6 yrs)	0.813	0.302 - 0.965
Wear a sweater (>7 yrs)	0.906	0.703 - 0.973
Wear trousers (>7 yrs)	0.874	0.642 - 0.967
Wear socks (>7 yrs)	0.906	0.673 - 0.979
Wear shoes (>7 yrs)	0.917	0.719 - 0.974

vs. 0.95) and it seems to be influenced by the high number of raters (20 assessors), located in 20 separate and independent rehabilitation services, while the pilot study involved only 3 assessors working together in the same rehabilitation centre.

The coefficient trend is coherent with the trend expected and demonstrated by other reliability studies for impairment severity and for age: the K coefficient resulted lower in assessing milder disabilities and increased more and more as the impairment worsened; at the same time it was lower for smaller children and it increased as the child got older.

The intra-rater (test-retest) reliability resulted excellent and the scoring of the same children was very coherent in time 2 years later, with a ICC very close to 1.

Furthermore, when compared with another validated assessment tool for hand function (QUEST), the Besta scale resulted valid and expressed a similar trend in assessing the same children, as demonstrated in the correlation analysis.

This tool has the advantage of assessing also very young children (from 6 months) and it can be useful to demonstrate early impairments in hand function and to describe their evolution over time, with items exploring the same tasks.

Moreover, Besta scale is an objective assessment tool reserved to professionals and not a questionnaire for parents: for this reason it is not affected by under or overestimation of the child's abilities.[33]

Differently from other scales currently available, Besta scale evaluates both Capacity and Performance; in fact in separate sections it assesses what the child can do in a standardized setting (Section A, grasp on request) and what he/she actually does in his/her daily environment (sections B and C, hand spontaneous use in play and ADL). The difference between the score of the section B /C and the section A represents the developmental disregard. In fact according to Taub [14] the difference between a measure of what a person can do when asked to do the best and a measure of what a person actually does spontaneously in a real world situation express the learned non-use or in children the developmental disregard.

In the assessment of the affected limb function in the hemiplegic cerebral palsy, the developmental disregard is fundamental to be taken in consideration since it characterizes the disease's natural his-

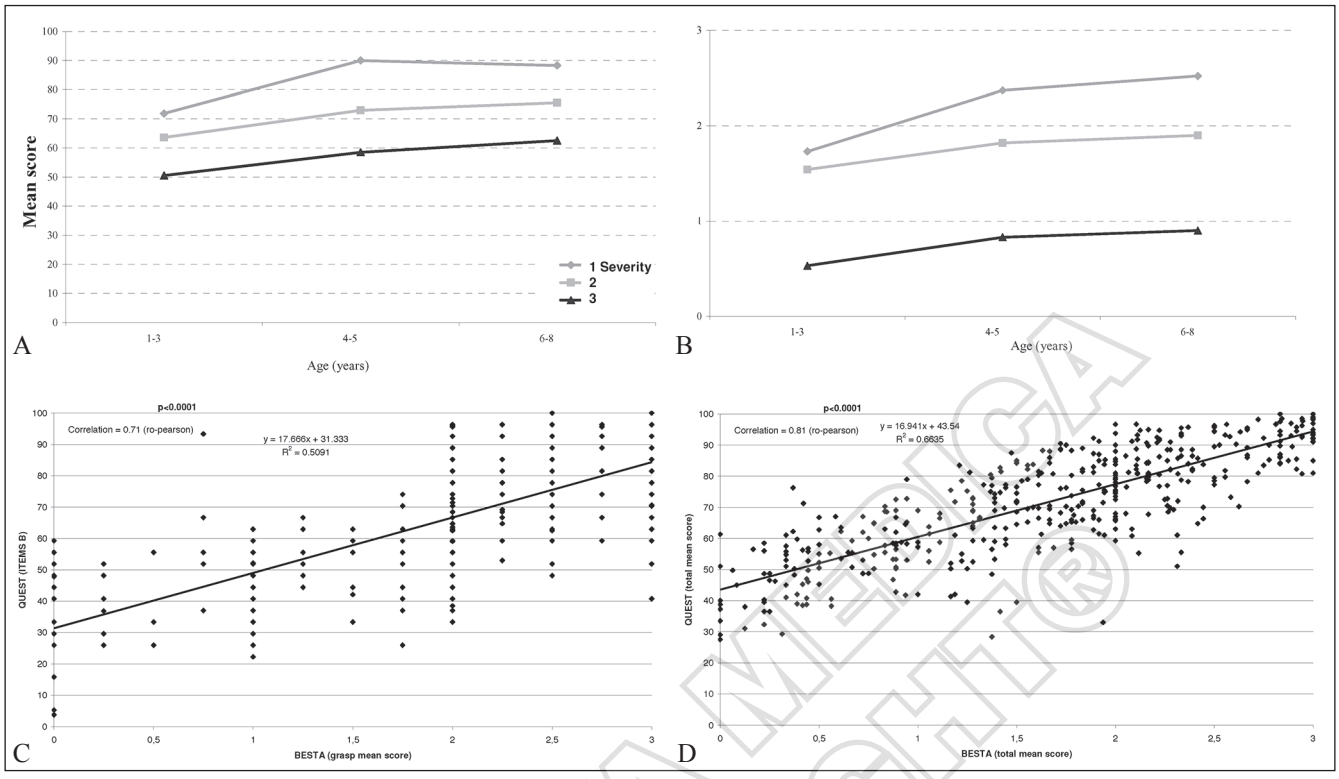

Figure 2.—Criterion validity, comparison among QUEST and Besta Scale results: Mean scores stratified by age and severity (QUEST: A; Besta: B); correlation analysis for total mean score (C) and grasp subscore (D) (N.=105 children; 20 raters).

tory. As these children develop, they tend to acquire even greater skills with the unaffected hand and increasingly neglect the impaired hand. As a consequence, such children show good hand function if required to use the impaired hand during a therapy session or in a standardized setting, but they tend to underuse it in spontaneous bimanual manipulation.

However, the Besta scale still has some weaknesses. For example, in infants it is hard to distinguish between mild to moderately impaired hand function. This problem can be due to the difficulty of assessing hand function in young children with CP. In fact, as suggested by Greaves *et al.*,[3] infancy is a time of rapid physical and psychological changes and instruments should take into account the likely variability of responses, the rapidly changing fine motor and adaptive skill levels and the more limited cognitive understanding of younger children.

In assessing the spontaneous use in bimanual activities, in some items that motivate most the child, for example in new and more challenging proposals, the risk is to assess the best performance instead of the real use, while in usual or less new items such as put on/take off clothes or eat something, the child tends to disregard the affected limb and adopt motor sequences more commonly used in his/her daily life. To avoid this risk, the scale was built as redundant including both usual and unusual activities, in order to distinguish the best performance typical of the learning phase from the common use typical of the stabilized motor sequences.

In conclusion, this study demonstrated that Besta scale scoring system is a reliable and a valid tool that does not only evaluate the effectiveness of movement, but helps in defining the quality of patterns and mostly the variability or the stereotypy in hand function.

In a rehabilitation setting, working with the child, this tool can be a reliable method to follow-up and monitor the clinical evolution of unimanual and bimanual manipulation, to distinguish the capacity from the performance, as suggested by the ICF, and to set the appropriate interventions. The scale needs an accurate training phase for raters to improve the

assessment of the conditions where the prognosis is more unpredictable (*i.e.*, the younger child and the milder hand impairment).

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Appendix 1 Besta Scale

Patient ID_____ Date of birth_____ Sex Assessor_____

A) Assessment on the **grasp function** of the paretic hand on request

Grasp a cube 1.5 cm	0	1	2	3
Grasp a cube 2.5 cm	0	1	2	3
Grasp a cube 4 cm	0	1	2	3
Grasp a marble	0	1	2	3
Total			___/12	

B) Qualitative assessment of the spontaneous use of the paretic hand in **bimanual manipulatory activities** (objects are standardized by age classes)

6 - 12 months

Hold a big ball (Ø 40 cm)	0	1	2	3
Tear tissue paper	0	1	2	3
Grasp a baby's bottle	0	1	2	3
Grasp a doll	0	1	2	3
Total			___/12	

13 - 24 months

Throw a big ball (Ø 40 cm)	0	1	2	3
Tear tissue paper	0	1	2	3
Drink form a bottle or a baby's bottle	0	1	2	3
Unwrap a packet (transparent paper)	0	1	2	3
Total			___/12	

25 - 36 months

Throw a big ball (Ø 40 cm)	0	1	2	3
Tear tissue paper	0	1	2	3
Uncork a bottle (popup plug)	0	1	2	3
Unwrap a packet (rubber band)	0	1	2	3
Total			___/12	

37 - 48 months

Throw a big ball (Ø 40 cm)	0	1	2	3
Tear tissue paper	0	1	2	3
Uncork a bottle (popup plug) and fill it (water)	0	1	2	3
Unwrap a packet (ribbon)	0	1	2	3
Total			___/12	

5 - 6 years

Throw a leather football (Ø 25 cm)	0	1	2	3
Tear paper into small pieces	0	1	2	3
Uncork a bottle (screw plug) and fill it (water)	0	1	2	3
Unwrap a packet (knotted ribbon)	0	1	2	3
Total			___/12	

> 7 years

Unwrap a packet (knotted ribbon)	0	1	2	3
Wrap a packet (knotted ribbon)	0	1	2	3
Fold a sheet and put it into an envelope	0	1	2	3
Paste paper shapes on the corresponding outlines	0	1	2	3
Total			___/12	

C) Qualitative assessment of the use of the paretic hand in feeding and clothing **Activities of Daily Living** (tasks are standardized by age classes)

18 months -7 years

Drink from a cup (>18 m)	0	1	2	3
Drink from a big glass (>18 m)	0	1	2	3
Take off socks (>18 m)	0	1	2	3
Slice bread (>18 m)	0	1	2	3
			___/12	
Take off trousers (> 2 yrs)	0	1	2	3
Wash hands (> 2 yrs)	0	1	2	3
Wash face (> 2 yrs)	0	1	2	3
Take off shoes (> 2 yrs)	0	1	2	3
			___/24	
Fold a napkin (> 3 yrs)	0	1	2	3
Take off sweater (> 3 yrs)	0	1	2	3
			/30	
Cut using knife and fork (> 6 yrs)	0	1	2	3
Total			___/33	

7-12 years

Put on a sweater	0	1	2	3
Put on trousers	0	1	2	3
Put on socks	0	1	2	3
Put on shoes	0	1	2	3
Total			___/12	

GLOBAL SCORE

A = ___/12
B= ___/12
C= ___/12 or ___/24 or ___/30 or ___/33

SCORING SYSTEM

Grasp Assessment (Section A)

0	Grasp absent
1	Palmar grasp
2	Whole-hand, radial or three finger grasp
3	Pincer grasp

Spontaneous Use in play and Activities of Daily Living (Sections B and C) (the scoring system was based on variability and stereotypy of movement patterns)

0	no use of the impaired limb
1	use of the impaired limb (not the hand) in a stereotyped pattern for holding (wrist support)
2	cooperation of the impaired hand with holding functions with a restricted number of stereotyped patterns
3	cooperation of the impaired hand with holding and manipulative functions, using a varied repertoire of patterns