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ORIGINAL REPORT

# THE ASSISTING HAND ASSESSMENT FOR CHILDREN AND YOUTH WITH BRACHIAL PLEXUS BIRTH INJURY: A STUDY OF VALIDITY AND ITEM HIERARCHY OF AHA-PLEX

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***Objective:*** **Functional assessments that focus on activity performance and that produce valid outcome measures for people with brachial plexus birth injury are lacking. The primary aim of this study was to re-evaluate the internal scale validity of the Assisting Hand Assessment specifically for children and adolescents with brachial plexus birth injury. Two further aims were investigating whether the scale could be shortened for this group while maintaining psychometric quality, and exploring and presenting its item difficulty hierarchy.**
***Design:*** **A cross-sectional psychometric study.**
***Subjects:*** **A convenience sample of 105 children and adolescents (aged 18 months to 18 years, mean 6 years, 7 months, standard deviation (SD) 4 years, 4 months) from Sweden, Norway, and the Netherlands with brachial plexus birth injury.**
***Methods:*** **Participants were assessed with the Assisting Hand Assessment. Data were analysed with Rasch measurement analysis.**
***Results:*** **The 20 Assisting Hand Assessment items together measured a unidimensional construct with high reliability (0.97) and the 4-level rating scale functioned well. Item reduction resulted in 15 items with good item fit, unidimensionality, reliability and acceptable targeting.**
***Conclusion:*** **Assisting Hand Assessment for people with brachial plexus birth injury, called AHA-Plex, has 15 items and good internal scale validity. A unique item hierarchy for people with brachial plexus birth injury is presented.**

*Key words:* assessment; hand function; brachial plexus birth injury; Rasch analysis; validity; AHA-Plex.

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## LAY ABSTRACT

The Assisting Hand Assessment measures how well children and youth with disability on one side of the body use their affected hand in bimanual activities. This test is used in research and by occupational therapists worldwide to plan and evaluate treatment. Previous research has shown that the latest version of Assisting Hand Assessment is well suited for people with unilateral cerebral palsy up to age 18 years, but it needs to be evaluated for people with brachial plexus birth injury. Assisting Hand Assessment was administered to 105 children and youths with brachial plexus birth injury and analysed with Rasch analysis. The results demonstrated excellent validity of the outcomes and that the test worked better with 15 items than the original 20, which reduces the time it takes to score the test. The analysis also revealed a specific difficulty order of the items, which is useful when planning treatment.

Assisting Hand Assessment (AHA) was developed for children with brachial plexus birth injury (BPBI) or unilateral cerebral palsy (unilateral CP) together (1–4), since people in both diagnostic groups commonly have one affected and one well-functioning hand/arm, influencing how they carry out bimanual activities in daily life (5). In both groups, the non-affected hand usually becomes the individual's dominant hand, and the affected hand will be an assisting hand that typically has a stabilizing and holding role. AHA has been shown useful for evaluating change over time as well as for guiding and evaluating treatment (1, 2, 4). Various outcome measures are used to evaluate hand function in children with BPBI (3). Several of these evaluate best capacity to use the affected hand/arm, while AHA aims to evaluate how effectively the affected hand/arm is used during bimanual age-relevant activities (performance). The latter is probably the most important aspect of hand use, since most activities in daily life require collaborative use of both hands. Furthermore, the AHA outcome also enables evaluation of changes over time, and it can guide and evaluate treatment (1, 2, 4).

Assessments should be evaluated for the diagnostic groups they are aimed at (6). Although hand function in children with BPBI and unilateral CP can be measured with the same AHA items (7), there are differences between the groups in aetiology and impairment. While children with unilateral CP have a central nervous lesion with a unilateral brain injury and increased tone in half the body (8), children with BPBI have a peripheral nerve injury to the brachial plexus (9, 10). The degrees of weakness or paralysis of the upper

limb in children with BPBI depend on the site and type of the nerve injury. Upper (middle) plexus injuries (C5–C6 (C7)) affect movements of the shoulder and elbow, and (wrist) extension, whereas global plexus injuries (C5–C8 (Th1)) additionally affect movements of the forearm, wrist, and hand (11). Most children recover from BPBI during the first year of life, while approximately 20% have remaining sequelae with movement restrictions. The rate of spontaneous recovery is unclear, and maybe even inaccurate, due to poor study designs (12, 13). Nevertheless, it is possible that bimanual performance in children with BPBI can be measured accurately with fewer AHA items, as some items relate to issues most typically seen in children with unilateral CP. The aim of this study was therefore to re-evaluate the internal scale validity of the AHA 5.0 specifically for children and adolescents with BPBI. A further aim was to investigate whether the scale could be shortened for this group while maintaining psychometric quality, and to explore and present its item difficulty hierarchy.

## METHODS

This is a multicentre study with a cross-sectional design including participants between 18 months and 18 years of age with a diagnosis of BPBI with remaining sequelae.

### *Participants*

A clinical convenience sample was recruited in Sweden, Norway, and the Netherlands. In Sweden, 36 participants had an AHA session video-recorded for a previous research study (7). Other participants in Sweden ($n$ = 9) were recruited for this study by their local occupational therapists (OTs). In Norway, the AHA had previously been administered and scored for 1 group of participants ($n$ = 16) through a follow-up study (2) and for the other participants ($n$ = 6), through regular clinical follow-up at St Olav's University Hospital, Trondheim, between 2016 and 2018. In the Netherlands, all participants ($n$ = 38) were assessed during regular clinical follow-ups.

### *Assessment tool*

An AHA-assessment is done in 2 steps: (*i*) a video-recorded age-appropriate standardized bimanual activity session is followed by (*ii*) scoring of effective hand use from the video on a 4-point rating scale for the 20 items described in AHA 18-18 (version 5.0) (14). Items are scored on quality and frequency of use of the affected arm/hand as well as quality of grip stability and variation (e.g. stabilizes with grip, varies type of grasp) and on actions and movements (e.g. variations of upper arm, forearm and finger movements). The 4 rating scale categories have general meanings: 4 = effective, 3 = somewhat effective, 2 = ineffective and 1 = not performed. Each category is thoroughly described for each item and the summed raw scores render an interval level measure in the unit logit. The activity sessions are designed to be fun and engaging for children and relevant for teenagers, to enable observation and grading of spontaneous and effective use of the affected hand in bimanual performance (5). The standardized activities in AHA test sessions differ depending on the participant's age. Children aged 18 months to 5 years explore and play freely with specifically selected toys in the AHA test kit. Children aged 6–12 years play 1 of 2 different board games, providing a different context for handling the toys in the AHA test kit (7). Adolescents aged 13–18 years either play the game "Go with the Floe", a board game designed for teenagers and adults, or they do a present task (opening and wrapping a present) or a sandwich task (preparing 2 sandwiches with spread, slices of cheese, turkey, tomatoes and cucumber) (15).

### *Data collection*

All participants were assessed once with AHA. All AHA sessions were scored from video-recordings according to the 20 items in AHA 5.0 (14). The scoring was done by highly-experienced raters in the country where the data were collected. Assessments collected for research studies were scored by researchers and research assistants and assessments collected in clinical follow-ups were scored by local occupational therapists. Data on the participants' ages at assessment, test activity, sex and affected side were collected.

The study was approved by the Swedish Ethical Review Authority (Dnr: 2019-00444). Families in Sweden recruited for this study were informed about the study orally and in writing and signed a written consent before data collection. In Norway, permission to transfer and use anonymized AHA score forms was approved by the Research Department at St Olav's Hospital, Trondheim. The study was not required to be approved by the Regional Ethical Committee for Medical and Health Research, Central Norway (Registered request REC Central: 421516) since the aim of this study is to investigate psychometric properties, not to investigate characteristics of the persons or to produce new knowledge about people or diseases. In the Netherlands, permission to transfer and use anonymized data were granted by the Team Privacy Protection & Information Security of Amsterdam University Medical Centre. Before data were transferred a "letter of objection" was sent to all potential participants

describing the project and giving the opportunity to decline participation.

### *Statistical analysis*

The Rasch measurement model for polytomous data (16) was implemented to evaluate the validity of AHA 18-18 version 5.0 for children and adolescents with BPBI. Initially, the properties of the 20 AHA test items were examined for acceptable rating scale functioning and the rating scale model was selected for further analyses. The partial credit model could not be used because there were fewer than 10 observations of scores 1 and/or 2 for some items, in which case the rating scale model gives a more stable item hierarchy (17). Rasch calculations were conducted with the Winsteps Rasch measurement computer program (version 4.7.1.0, John M Linacre 2019).

Internal scale validity of the 20 AHA items was evaluated in 6 steps. (*i*) The point-measure correlation was calculated to ensure that all correlations were positive indicating adequate response-level scorings (18). (*ii*) The rating scale was evaluated according to the criteria that category measures are to advance by category, that the Andrich thresholds are to advance by no less than 1.4 and no more than 5 logits, and that the outfit mean square (MnSq) should not exceed 2.0 for any category (17). (*iii*) The unidimensionality of the scale was investigated in 2 ways, namely by principal components analysis of the residuals (PCA), which is sensitive to detecting 2 or more dimensions, and by investigating item goodness-of-fit, which is more sensitive to threats to unidimensionality by single items. In PCA, there should not be a large second dimension when inspecting variance of residuals. The criteria for the PCA-analyses were that overall the raw variance was to be explained by the measure, with no more than 3% unexplained variance by any additional contrasts (19). The criteria for item fit were an infit MnSq of $< 1.3$ in combination with z-value between –2 and 2 (20). (*iv*) Local independence is an important trait of a scale, meaning that the response to 1 item should not be directly derived from the response to another item (21). Local dependency may inflate reliability estimates. Thus, analyses were repeated with testlets (correlating items pooled together) if inter-item residual correlations exceeded 0.2 and reliability estimates were recalculated (22). (*v*) Targeting of item difficulty to person ability is important to avoid ceiling and floor effects and for the items to be sensitive to change. The targeting of AHA items was investigated by comparing item and person means and inspecting an item-person map. (*vi*) Reliability was assessed both for items and for persons, and both reliability coefficients should be $> 0.94$ to be excellent (19). The item reliability coefficient in Winsteps is comparable to Cronbach's alpha. The person reliability coefficient can be used to calculate the number of distinguishable levels of ability (strata) using the formula (4G+1)/3 (G = person reliability index, derived from the person reliability coefficient). At least 2 strata are needed for the scale to separate between high and low ability, and $>5$ is considered to be excellent (19).

To investigate whether the number of items could be reduced, items were scrutinized with regards to misfit, local dependency, content similarity, unused categories, and targeting. Items deemed redundant were deleted and steps 1–6 were repeated for the remaining items. When the lowest number of items was reached without degradation of measurement properties, deletion stopped. To evaluate the equivalence of person measures between the 20 AHA items and the reduced number of items, the person measures obtained from the 2 item sets were plotted against each other. When the optimal number of items was reached, a conversion table for transforming AHA raw sum scores to AHA units (range 0–100) was produced. To investigate the relationship between age and AHA units, Pearson's correlation coefficient was calculated.

## RESULTS

A total of 105 children and adolescents, with ages ranging from 18 months to 18 years (most in the younger ages), were included in the study (see Table I for demographic characteristics). Fig. 1 shows that 10 individuals (who scored $< -3$ AHA logits) did not use their affected hand for holding or grasping (score 1 in hand grip related items), which may indicate that these children had a total plexus injury.

**Table I.** Demographic characteristics of participants ($n$ = 105) and Assisting Hand Assessment (AHA) test activities

| Characteristics | |
|---|---|
| Age at assessment, years, mean (SD) | 6 years 7 months (4 years 4 months) |
| Number per age group | |
| 18 months – 5 years, *n* (%) | 56 (53) |
| 6–12 years, *n* (%) | 39 (37) |
| 13–18 years, *n* (%) | 10 (10) |
| Sex | |
| Female, *n* (%) | 53 (50) |
| Male, *n* (%) | 52 (50) |
| Hand affected | |
| Right, *n* (%) | 66 (63) |
| Left, *n* (%) | 39 (37) |
| AHA test activity | |
| Play, *n* (%) | 68 (65) |
| School-kids' game, *n* (%) | 28 (27) |
| Present or Go with the Floe,* *n* (%) | 9 (9) |
| AHA measure (logits) | |
| Mean (SD) | 1.83 (3.12) |
| Min; max | –7.63; 6.74 |

*No participant performed the sandwich task.
SD: standard deviation; yr: years; mo: months; min: minimum; max: maximum.

| MEASURE LINE | PERSON ABILITY | ITEM CATEGORY DIFFICULTY CATEGORY | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|---|
| | <more able> | <more difficult> | | | | |
| | | | | | | Moves forearm,4 |
| 7 | | | | | | |
| | X | | | | | |
| | | | | | | Moves upper arm,4 |
| 6 | | | | | | Reaches,4 |
| | XXXXXXX | | | | | Chooses,4 |
| | | | | | | Manipulates,4 |
| | XXXXXXXXX | | | | | |
| 5 | S | | | | | |
| | XXX | | | | Moves forearm,3 | |
| | XXXXXXX | | | | | |
| | | | | | | Grasps,4 |
| | | | | | | Varies type of grasp,4 |
| 4 | XXXX | T | | | Moves upper arm,3 | Moves fingers,4 |
| | | | | | | Readjusts grasp,4 |
| | XXXXXXXX | | | | Reaches,3 | Grip force regulation,4 |
| | XXX | | | | Chooses,3 | Flow,4 |
| | | | | | | |
| 3 | XXXXX | | | | Manipulates,3 | Initiates use,4 |
| | XXXXX | | | | | |
| | XXX | | | | | |
| | XX | | | | | Orients objeccts,4 |
| 2 | XXXX | S | | | Grasps,3 | |
| | X M | | | Moves forearm,2 | Varies type of grasp,3 | |
| | | | | | Moves fingers,3 | |
| | XX | | | | Readjusts grasp,3 | |
| | | | | | Grip force regulation,3 | |
| | X | | | | Flow,3 | |
| 1 | X | | | Moves upper,2 | | |
| | XXX | | | Reaches,2 | Initiates use,3 | |
| | XX | | | Chooses,2 | | |
| | XX | | | | | Holds,4 |
| 0 | XXXXX | M | | Manipulates,2 | | |
| | XXX | | | | Orients objects,3 | |
| | XX | | | | | Stabilizes by weight,4 |
| | X | | | | | |
| -1 | XXXX | | | | | |
| | XX S | | Moves forearm,1 | Grasps,2 | | |
| | | | | Varies type of grasp,2 | | |
| | | | | Moves fingers,2 | | |
| | XX | | | Readjusts grasp,2 | | |
| | | | | Grip force regulation,2 | | |
| -2 | X | S | Moves upper arm,1 | Flow,2 | Holds,3 | |
| | XX | | Reaches,1 | Initiates use,2 | | |
| | | | Chooses,1 | | | |
| | | | | | Stabilizes by weight,3 | |
| -3 | XX | | Manipulates,1 | | | |
| | X | | | Orients objects,2 | | |
| | X | | | | | |
| | X | | | | | |
| -4 | | T | Grasps,1 | | | |
| | | | Varies grasp,1 | | | |
| | | | Moves fingers,1 | | | |
| | | | Readjusts grasp,1 | | | |
| | X T | | Grip force reg,1 | | | |
| | | | Flow,1 | | | |
| -5 | X | | | | | |
| | | | Initiates use,1 | Holds,2 | | |
| | | | | | | |
| | | | | Stabilizes by weight,2 | | |
| -6 | | | | | | |
| | | | Orients objects,1 | | | |
| | XX | | | | | |
| | | | | | | |
| -7 | | | | | | |
| | | | | | | |
| | | | | | | |
| | X | | | | | |
| -8 | | | Holds,1 | | | |
| | | | | | | |
| | | | | | | |
| | | | Stabilizes by weight,1 | | | |
| -9 | | | | | | |
| | <less able> | <easier items> | | | | |

M=mean, S= 1 standard deviation, T= 2 standard deviations, X= one person

**Fig. 1.** Person ability and item difficulty distribution on the 15 AHA-Plex items. Left-hand column shows the distribution of person measures ($n$ = 105) along the vertical measure line marked | on the logit scale. Each person = ×. The right-hand column shows the items positioned at the measures where the category (1–4) has its highest probability to be scored.

### *The original 20 AHA items for children with brachial plexus birth injury*

In the Rasch analysis of the 20 AHA items, all items showed positive point measure correlations, indicating that there was no reversed scoring. The rating scale fulfilled all criteria, except for score 2 on the 4-point rating scale where the outfit MnSq was 2.24, meaning that there were too many unexpected responses in that category. Investigation into unexpected responses showed that 2 children had unexpected responses, and when these 2 children's scores were omitted from the analysis, the outfit MnSq for score 2 dropped to 1.19. However, the scores for these 2 children reflected their actual performance, so we decided that the high outfit MnSq, which is sensitive to outliers, had an acceptable deviation from the rating scale criteria.

The unidimensionality analysis showed that the 20 AHA items measured 1 dimension. In the PCA, 79.9% of the variance was explained by measures and there was 3.2% unexplained variance in the first contrast, equivalent to an Eigenvalue of 3.15. No items misfitted the scale and the highest infit MnSq for any item was 1.13. In the local independence investigation, the highest inter-item residual correlation was found for the items *Stabilizes by grasp* and *Regulates grip force* (r = 0.6). Furthermore, additional 5 item pairs had local dependency with correlations between 0.31 and 0.39. The targeting analysis showed that the person mean was 2.35 logits higher than the item mean, indicating that there were too many easy items in relation to the persons' ability (see Fig. 1). There were, however, no children in this sample who had the minimum or maximum AHA scores, thus there were no ceiling or floor effects. The reliability coefficient was excellent, at 0.99 for items and 0.97 for persons, giving a person separation index of 5.29 and 8 ability strata.

Taken together, the 20 AHA item scale was unidimensional and had high reliability for children and adolescents with BPBI, but the targeting was not optimal and there was local dependency between several items.

### *Shortened Assisting Hand Assessment scale for people with brachial plexus birth injury*

The above results were considered when a group of highly experienced occupational therapists discussed how the AHA scale could be shortened without losing clinically important information. First, the issue of local dependency was addressed. The item pair *Stabilizes by grasp* and *Regulates grip force* had high inter-item residual correlation and these 2 items were deemed too similar to retain both. It was decided to keep the item *Regulates grip force* since it had a higher item measure and better item fit, and the item *Stabilizes by grasp* was thus removed. The other item pairs with possible local dependency were kept, since each item was considered important for people with BPBI (23). Next, targeting was addressed. The items *Holds*, *Amount of use* and *Stabilizes by weight or support* had the lowest measures, and the scoring categories 1 and 2 were rarely used for these items, which therefore are less useful for measuring change. Of the 3, *Amount of use* was considered to be the least discriminative (almost always scoring 4) for people with BPBI and was deleted to increase targeting. Other potentially redundant items were those not conceptually representative of the issues related to hand function in people with BPBI (e.g. *Coordinates, Proceeds* and *Releases*). These items were deleted 1 at a time. The remaining 15 items were suggested as the Assisting Hand Assessment for people with brachial plexus birth injury (AHA-Plex) scale and new analyses were run to evaluate its psychometric properties. The targeting improved from a mean of 2.35 to 1.83 logits. The correlation between person measures for the new 15-item AHA scale and the original 20-item AHA scale was 0.994. Table II shows the psychometric properties of the 2 scales.

For the AHA-Plex scale with 15 items, local dependency was indicated for 3 item pairs with correlations between 0.29 and 0.38 (*Grasps – Chooses assisting hand when closer to objects* 0.38, *Moves upper arm – Moves fingers* 0.35, *Varies type of grasp – Manipulates* 0.29). We combined these item pairs into 3

**Table II.** Measurement properties for the original 20 items of Assisting Hand Assessment (AHA) and the 15 items of Assisting Hand Assessment for people with brachial plexus birth injury (AHA-Plex)

| Measurement quality | 20 items | 15 items |
|---|---|---|
| Rating scale functioning, highest outfit MnSq | 2.24 (score 2) | 2.28 (score 2) |
| Item reliability | 0.99 | 0.99 |
| Person reliability | 0.97 | 0.96 |
| Person separation index | 5.29 | 4.69 |
| Strata, *n* | 8 | 7 |
| PCA raw variance explained by measures | 79.9% | 79.7% |
| PCA unexplained variance in 1st contrast | 3.2% | 3.9% |
| Person misfit, *n* | 4 | 5 |
| Targeting, mean person logits compared with item mean = 0 | 2.35 | 1.83 |
| Local independence, highest inter-item residual correlation between an item pair | 0.60 | 0.38 |
| Correlation with 20 item-person measures | | 0.994 |

MnSq: mean square; PCA: principal components analysis.

**Table III.** The 15 items of Assisting Hand Assessment for people with brachial plexus birth injury (AHA-Plex) ranked hierarchically with more difficult items at the top. Both infit and outfit statistics are reported, however only infit statistics are used as criteria

| | | | Infit | | Outfit | |
|---|---|---|---|---|---|---|
| Item name | Measure logits | SE | MnSq | z-std | MnSq | z-std |
| *More difficult items* | | | | | | |
| Moves forearm | 3.14 | 0.19 | 1.00 | 0.04 | 1.87 | 2.53 |
| Moves upper arm | 2.36 | 0.18 | 1.06 | 0.46 | 5.11 | 7.35 |
| Reaches | 2.09 | 0.18 | 1.01 | 0.15 | 1.15 | 0.61 |
| Chooses assisting hand when closer to objects | 1.86 | 0.18 | 1.19 | 1.37 | 1.11 | 0.50 |
| Manipulates | 1.38 | 0.19 | 0.88 | −0.86 | 0.78 | −0.83 |
| Grasps | 0.31 | 0.20 | 0.86 | −0.98 | 0.70 | −1.43 |
| Varies type of grasp | 0.28 | 0.20 | 0.55 | −3.67 | 0.49 | −2.76 |
| Moves fingers | 0.08 | 0.20 | 0.98 | −0.09 | 1.10 | 0.50 |
| Readjusts grasp | −0.04 | 0.20 | 0.84 | −1.11 | 0.75 | −1.10 |
| Regulates grip force | −0.16 | 0.20 | 1.07 | 0.52 | 0.90 | 0.35 |
| Flow in bimanual performance | −0.46 | 0.21 | 0.71 | −2.09 | 0.78 | −0.83 |
| Initiates use | −0.90 | 0.22 | 1.20 | 1.22 | 1.31 | 1.00 |
| Orients objects | −1.86 | 0.23 | 1.04 | 0.28 | 1.03 | 0.23 |
| Holds | −3.68 | 0.28 | 1.28 | 1.32 | 0.51 | −0.47 |
| Stabilizes by weight or support | −4.40 | 0.32 | 0.70 | −1.37 | 0.23 | −1.06 |
| *Easier items* | | | | | | |

SE: standard error; MnSq: mean square; z-std: z-statistics.

testlets and ran new analyses. Doing so reduced the PCA unexplained variance in the first contrast to 2%, while the reliability indices remained unchanged. When cross-plotting the person measures from the analysis including all 15 items against those from the analysis including testlets, there was almost perfect correlation (> 0.99).

The item hierarchy for the 15-item AHA-Plex test for children and adolescents with BPBI is shown in Table III and a conversion table from raw scores to a more user-friendly logit-based measure 0–100 AHA-Plex units is shown in Table IV. The correlation between age and AHA units was r = 0.03.

## DISCUSSION

This study demonstrates that spontaneous and effective use of the affected hand in bimanual activities can be validly and reliably measured with the 15 AHA-Plex items in children and adolescents between 18 months and 18 years of age with BPBI. AHA-Plex has good internal scale validity and provides a unique item hierarchy that indicates the next difficulty level in bimanual performance for people with BPBI. This information may be useful in the planning of intervention. We therefore propose that this 15-item AHA-Plex should be used for young people with BPBI when the aim is to measure functional use of the hands together.

**Table IV.** Conversion of raw scores (15–60) to Assisting Hand Assessment for people with brachial plexus birth injury (AHA-Plex) units (0–100)

| Raw scores | AHA-Plex units | Raw scores | AHA-Plex units | Raw scores | AHA-Plex units |
|---|---|---|---|---|---|
| 15 | 0 | 31 | 45 | 47 | 66 |
| 16 | 9 | 32 | 47 | 48 | 68 |
| 17 | 16 | 33 | 48 | 49 | 69 |
| 18 | 20 | 34 | 49 | 50 | 70 |
| 19 | 24 | 35 | 51 | 51 | 72 |
| 20 | 27 | 36 | 52 | 52 | 73 |
| 21 | 29 | 37 | 53 | 53 | 75 |
| 22 | 31 | 38 | 55 | 54 | 77 |
| 23 | 33 | 39 | 56 | 55 | 79 |
| 24 | 35 | 40 | 57 | 56 | 81 |
| 25 | 36 | 41 | 58 | 57 | 84 |
| 26 | 38 | 42 | 60 | 58 | 87 |
| 27 | 40 | 43 | 61 | 59 | 92 |
| 28 | 41 | 44 | 62 | 60 | 100 |
| 29 | 42 | 45 | 64 | | |
| 30 | 44 | 46 | 65 | | |

The new item difficulty hierarchy based on these 15 items is worth discussing, as the item hierarchy in AHA-Plex is clearly different from AHA 18-18 for people with unilateral CP. Research and clinical experience both show that upper arm movements, in particular the external rotation of the shoulder, is the most common sequelae for people with upper BPBI (C5–C7), while hand function is not directly affected. Items that measure arm movements, such as *Moves forearm, Moves upper arm* and *Reaches* are subsequently the most difficult items for people with BPBI, whereas the most difficult items for persons with unilateral CP, such as *Manipulates* and *Grasps,* were comparatively easier for persons with BPBI. These differences were anticipated and were in fact a strong motivation for us to explore a separate item hierarchy for people with BPBI. This new hierarchy will make the AHA-Plex more useful for establishing the functional ability level and the next difficulty level in bimanual performance for persons with BPBI. This information is valuable in the planning of intervention and training for children with BPBI.

These results also confirm the reliability of AHA-Plex by indicating trustworthiness in its internal consistency, the reproducibility of the item hierarchy, and the distribution of person abilities. Some items displayed local dependency. However, the person reliability remained unchanged when using testlets to absorb the

effect of local dependency. The item pairs with local dependence appear to share some similar traits, i.e. both *Grasps* and *Chooses assisting hand when closer to objects* assess whether and from where, and/or to what extent, the affected hand is used to approach and grasp objects. However, the item *Grasps* differentiates between the ability to actively grasp an item from the table or from the other hand, to the use of a more passive grasp where objects are placed in the hand. In contrast, the item *Chooses assisting hand when closer to objects* measures whether the affected or the preferred hand is used to grasp and handle objects located on the assisting hand side. Thus, these 2 items provide important and somewhat different clinical information. Furthermore, the items *Moves fingers* and *Moves upper arm* measure aspects of movements, but still have obvious differences that evaluate different body parts, not focusing only on range, but also ease and frequency of movements. Therefore, combining the above-mentioned items would mean losing important information regarding the person's bimanual performance. The content of the items is crucial to consider when handling local dependency (21, 23).

Functional assessments that focus on activity performance and that produce valid outcome measures for people with BPBI are rare. Previous research on BPBI has used a variety of evaluation instruments, which makes comparison of results problematic. In a systematic review, Chang et al. (2013) reported that in 307 reviewed articles 126 evaluation methods were used. A clear majority were used to measure active and passive movement range, all variables at the "Body function/structure" level in the International Classification of Functioning Disability and Health (ICF) (24). Furthermore, out of the 126 assessments, only 5 (the Active movement scale, Toronto scale score, Mallet scale, Assisting Hand Assessment and Pediatric Outcome Data collection instruments) have shown evidence of producing valid and reliable measures when used in individuals with BPBI. An ambitious attempt to reach international consensus on what tests to use for individuals with BPBI was the iPluto (international PLexus oUtcome sTudy grOup) project (13); however, consensus was only reached on items from the Body Function and Structure domain, i.e. for range of active and passive motion in degrees, and for the Mallet score. iPluto concluded that assessments in additional ICF domains should be addressed in future research, and we therefore propose the use of the revised and diagnosis-specific AHA-Plex as a measure of functional performance in the ICF Activity and Participation domain.

There are some limitations to this study that should be considered when interpreting the results. The participants constituted a convenience sample recruited from occupational therapy departments at hospitals and habilitation services, and may not be representative for the entire population of children and adolescents with BPBI. However, this sample is thought to be quite representative of the clinical population seen by occupational therapists and other professionals for whom the AHA-Plex will be useful. Another potential limitation is that our sample includes relatively few teenagers; however, this study and other versions of AHA have not found any correlation between age and the produced outcome measure (AHA-Plex unit), therefore, we do not consider the skewed age distribution as a threat to the validity of our results. Moreover, the wide age range covered, from 18 months to 18 years, is unique and provides the opportunity to study development over time with the same measure. In addition, there were no ceiling or floor effects, but the outcomes cover almost the full raw score range and thus is well matched to the persons' diverse abilities. AHA-Plex can produce a valid measure of hand use in both people with very low ability who cannot use the hand to grasp or hold, and for people with high ability of arm use and hand use.

Another limitation concerns lack of information describing the extent and level of plexus injury for the participants. Unfortunately, these data could not be found in the medical records of several of the participants. To compensate, we used the AHA results to show that the severity of the BPBI varied among participants. The ability profile from AHA-Plex can be used to show to what extent the hand and/or the arm is/are more or less affected. One important conclusion of our study is therefore that, despite these differences in ability within persons with BPBI, the 15-item AHA-Plex shows excellent measurement properties for the BPBI group as a whole.

### *Clinical implications*

The new AHA-Plex scale provides new opportunities for occupational therapists who see children and adolescents with BPBI. AHA-Plex uses the same activity sessions for various ages as are utilized in the original AHA 18-18. Due to the reduced scale with only 15 items, the time needed to score AHA is lessened. To facilitate the scoring process, a new score sheet containing the 15 AHA-Plex items has been developed, along with an automatically generated results sheet in which items are ordered according to their hierarchical difficulty level. This results sheet shows an individual's response profile and enables therapists to plan intervention and training. It should be noted that the Rasch analysis provides person measures (AHA-Plex units, 0–100 scale) that are considered to be interval-level data, which makes it possible to compare results bet-

ween or within individuals and to investigate changes over time. The AHA-Plex units are obtained when using the special AHA-Plex score form or by inserting the raw sum scores into the conversion table (Table IV). Person measures (units) are preferable in any situation where AHA-Plex results are reported and used.

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